Growth, Development, and Morphological Characteristics of *Echinochloa colona*

J. C. Chun* and K. Moody**

*Echinochloa colona*의 生長, 發育 및 形態的 特徵

全 載 哲*·키이스 무디**

ABSTRACT

The growth, development, and morphological characteristics of *Echinochloa colona* (L.) Link were determined through one life cycle. *E. colona* emerged 2 to 3 days after seeding (DAS) and reached the two-leaf stage by 8 DAS. During the early growth stages, root length was greater than plant height, but the relationship was reversed from 4 weeks after seeding (WAS). Tillering started from the third leaf of the main culm as the sixth leaf on the main culm emerged. The unfolding of the leaves and tillering followed a regular pattern during the vegetative growth period. This resulted in the production of 19 tillers (5 primary, 12 secondary, 1 tertiary, and 1 nodal) at the 14-leaf stage. Shoot-root weight ratio was highest just before panicle initiation. The second spike from the top of the panicle was the shortest and produced the fewest seeds. Thereafter, spike length and the number of seeds per spike generally increased, the lower the position of the spike on the panicle. Seeds on the lower spikes weighed less and had lower germination ability than those from the upper spikes. Adventitious roots arose from the leaf sheath bases of a flowering stalk. The ability to produce adventitious roots was greater in a younger stalk than in an older stalk.

Key words; seedling growth, tillering, panicle morphology, adventitious root.

INTRODUCTION

E. colona, an annual grass, is considered the fourth worst weed in the world[3] and is serious in serveral major crops as rice (*Oryza sativa* L.)[5] and maize (*Zea mays* L.)[4]. Holm *et al.*[3] reported that it is associated with 35 crops in more than 60 countries.

It is believed to have originated from Africa or India[1,9] and is confined to the termal tropical area[2].

E. colona has a very short vegetative period, resulting in flowering as early as 5 WAS[7]. Maximum tillering capacity occurred in 4 to 6 weeks[5]. Although the principal means of propagation is by seeds, adventitious roots often emerge at the lower nodes[6]. Ramakrishnan[8] observed that adventitious roots occur whenever nodes come in contact with the soil.

This paper describes experiments with *E. colona* to determine (a) seedling growth and tillering,

* 全北大學校 農科大學, ** 國際米作研究所

* Department of Agricultural Chemistry, Jeonbug National University, Jeonju 520, Korea.

** Department of Agronomy, International Rice Research Institute, Los Banos, Laguna, Philippines.

(b) panicle morphology, and (c) the formation of adventitious roots at the leaf sheath bases of a flowering stalk.

MATERIALS AND METHODS

Seeds were collected from *E. colona* plants growing in a maize field at the International Rice Research Institute, Los Banos, Philippines, and air-dried in a greenhouse. Five seeds were planted on the soil surface in a plastic pot (14 x 14 cm) which contained sieved sandy clay loam. Before the seedling reached the two-leaf stage, the number of seedlings was reduced to one per pot. After removal of the extra seedlings, urea equivalent to 100 kg N/ha was applied. The pots were subirrigated for the first 5 DAS and then the soil was maintained at saturation during the rest of the experimental period by frequent watering. At 1-week intervals four seedlings were selected at random to determine the growth behavior of *E. colona*. After all the panicles were completely formed, they were harvested to determine the panicle morphology.

To determine seed weight and germination ability of seeds on different spikes, 100 mature seeds were selected at random from each spike. After taking 100-seed weight, the seeds were planted on the soil surface in a plastic pot (9 x 9 cm). There were four replications. The number of germinated seeds were recorded 10 DAS.

Formation of adventitious roots of the leaf sheath bases was also examined. A flowering stalk was cut before, during, or after panicle formation to obtain a nodal piece. The flowering stalk cut before panicle formation was younger than that obtained after panicle formation. Each nodal piece was placed on a piece of filter paper in a 250-ml Erlenmeyer flask with 3 ml of distilled water. Adventitious roots were considered formed when they reached a length of 1 cm.

RESULS AND DISCUSSION

Seedling growth and tillering *E. colona* emerged 2 to 3 DAS. The young seedling reached the two-leaf stage by 8 DAS. Unlike rice which produces the first leaf without a leaf blade, the first leaf of *E. colona* had a well-developed leaf blade and grew about 2 cm long. The length of the root at this stage was greater than the plant height but this relationship was reversed from 4 WAS (Fig. 1).

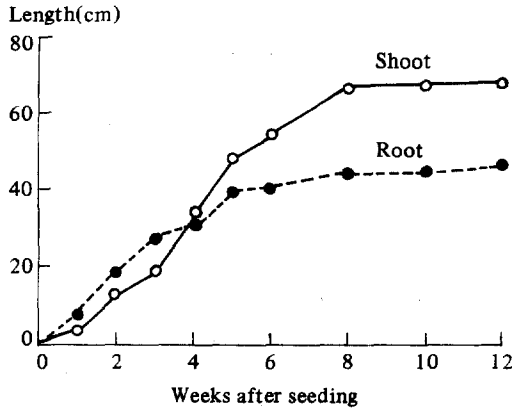

Fig. 1. Shoot and root lengths of *Echinochloa colona* throughout its life cycle.

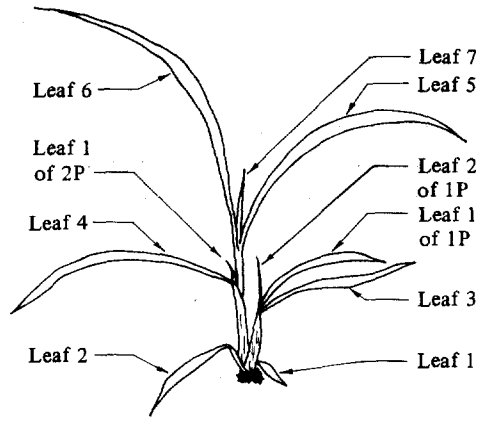

Fig. 2. Six leaf stage of *Echinochloa colona* (1P and 2P denote first- and second-primary tiller, respectively).

There was no tillering until the 5-leaf stage of the main culm.

Tillering started from the third leaf of the main culm. The first and second leaves did not produce tillers. When the sixth leaf of the main culm em-

erged, the first leaf of the primary tiller arose from the axil of the third leaf of the main culm (Fig. 2). The first leaf of the primary tiller was always produced in the same direction as the third leaf of the main culm. As expected, the direction of the second leaf of the primary tiller was opposite that of the first leaf of the same tiller. This was when the seventh leaf of the main culm and the second primary tiller between the fourth and the sixth leaf of the main culm were elongating smultaneously.

The unfolding of the leaves and the tillering of *E. colona* followed a regular order. The leaf stage, the number of tillers, and the position of each tiller are indicated in Table 1. Elongation of the first secondary tiller from the first primary tiller started at the 8-leaf stage of the main culm. Subsequently another secondary tiller was produced from the second primary tiller. When the second primary tiller completely emerged, the main culm had reached the 9-leaf stage and at the same time had started to produce the fourth primary tiller between the sixth and the eighth leaf of the main culm.

Table 1. Number and position of the tillers in relation to the leaf stage.

Leaf stage	Number of tillers*			
	Primary	Secondary	Nodal	Total
6	1	0	0	1
7	2	0	0	2
8	3	1 (1-1P)	0	4
9	4	2 (1-1P, 1-2P)	0	6
10	4	3 (2-1P, 1-2P)	0	7
11	5	6 (3-1P, 2-2P, 1-3P)	0	11
12	5	8 (3-1P, 2-2P, 2-3P, 1-4P)	0	13
13	5	8 (3-1P, 2-2P, 2-3P, 1-4P)	1 (1-MC)	14

* In parentheses, the number of tillers followed by the position of the tillers are indicated. 1P = first primary tiller, 2P = secondary primary tiller, MC = main culm.

The production of primary tillers ceased when the main culm reached the 11-leaf stage, but the production of secondary tillers continued along with the elongation of the internode from the base of the main culm. Internode elongation indicated the start of the reproductive stage. As the first node was detected, the tip of the flag leaf, which was the 14th leaf arising from the main culm, also became visible. A panicle emerged from the axil of the flag leaf with further extension of this leaf. During this time the first nodal tiller was being produced from the first node of the main culm. At the 14-leaf stage, one *E. colona* plant consisted of 5 primary, 12 secondary, 1 tertiary, and 1 nodal tiller (Fig. 3).

As the plant aged, there was a corresponding increase in the number of roots and fresh and dry weight of the shoots and roots (Table 2). A great

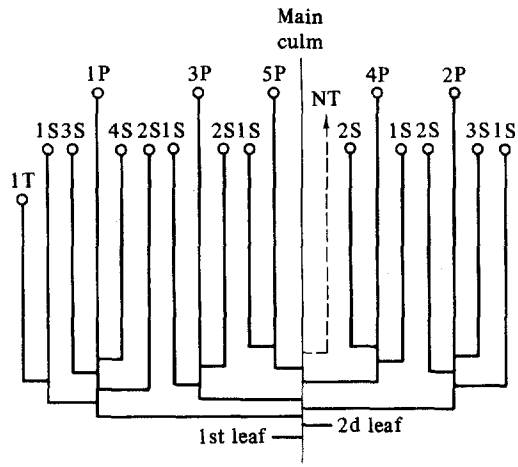

Fig. 3. A schematic diagram of *Echinochloa colona* showing number and position of tillers. Numbers indicate the order of tiller production and P, S, and T denote primary, secondary, and tertiary tiller. The broken line represents a nodal tiller (NT) arising from the axil of the 8th leaf of the main culm.

Table 2. Growth and development of one *Echinochloa colona* plant.*

Weeks after seeding	Leaf stage	Roots (no.)	Fresh weight (g)			Dry weight (g)			Shoot-Root ratio**
			Shoot	Root	Total	Shoot	Root	Total	
1	2.0	1.0	–	–	–	–	–	–	–
2	3.5	2.2	0.09	0.05	0.14	0.01	0.01	0.02	2.2
3	5.0	3.8	0.15	0.16	0.31	0.02	0.02	0.04	1.1
4	6.7	8.1	0.50	0.32	0.82	0.08	0.04	0.12	2.3
5	8.4	11.3	1.30	0.75	2.05	0.33	0.13	0.46	2.5
6	9.9	11.9	3.42	0.91	4.33	0.86	0.16	1.02	5.4
8	–	17.5	7.14	1.47	8.61	1.81	0.36	2.17	5.0
10	–	25.5	9.47	2.15	11.62	3.04	0.62	3.66	4.9
12	–	38.5	11.53	4.81	16.34	3.71	1.19	4.90	3.1

* Average of four replications. – = Not measured.
** Dry weight basis

increase in shoot weight occurred 5 WAS as secondary tillers were being produced. From 6 WAS the number and weight of roots increased greatly. Shoot-root weight ratio was highest at 6 WAS when panicle initiation began.

Panicle morphology The inflorescence of *E. colona* is a panicle. The spikes are alternately arranged on the panicle rachis, except for the uppermost spike. However, two or three spikes sometimes arise from one point on the rachis. The sheath of the flag leaf is usually closed and the leaf blade is almost 90° to the uppermost internode. The specific measurements of the panicle formed in the main culm are given in Table 3. Great variation was found in the number of seeds produced per panicle. The seed weight of *E. colona* was less

Table 3. Morphological characteristics of the panicle of *Echinochloa colona*.

Characteristic	Measurement*
Panicle length (cm)	9.8 ± 1.1
Length from uppermost node to panicle tip (cm)	17.2 ± 2.4
Length of flag leaf (cm)	16.3 ± 6.4
Number of spikes/panicle	8.5 ± 1.0
Number of seeds/panicle	200.3 ± 42.9
100-seed weight (mg)	117.9 ± 3.1

* The data were taken 11 weeks after seeding. Numbers after means indicate standard error.

Table 4. Length of spikes, number of seeds per spike, weight of 100 seeds, and germination ability of seeds as affected by position of the spikes on the panicle.

Spike number (from the top of the panicle)	Length (mm)[a]	No. of seeds/spike[a]	Weight of 100 seeds (mg)[b]	Germination (%)[b]
1	20.6 ± 3.9	34.0 ± 8.5	129.5 a	72.4 a
2	7.0 ± 1.9	12.8 ± 4.7	125.1 ab	68.1 a
3	8.8 ± 2.2	16.1 ± 6.7	125.0 ab	45.4 b
4	10.8 ± 2.7	20.3 ± 6.6	121.1 bc	47.5 b
5	11.1 ± 2.4	22.5 ± 6.1	121.3 bc	37.2 c
6	10.6 ± 3.1	23.0 ± 6.5	118.5 c	32.2 c
7	12.8 ± 2.6	26.8 ± 7.1	117.3 c	15.3 d
8	15.8 ± 3.5	32.6 ± 6.5	111.4 d	3.2 e
9	14.3 ± 2.5	26.6 ± 1.5	108.2 d	6.1 e

a Numbers after means indicate standard error.
b In a column, means followed by a common letter are not significantly different at the 5% level by Duncan's multiple range test.

than that of *Echinochloa crus-galli* (L.) Beauv. Pons[7] reported that *E. crus-galli* seed weighed 1.5 mg.

The length of the spikes and number of seeds per spike varied with position on the panicle (Table 4.) Except for the topmost spike, the length of the spikes tended to increase, the lower their position on the panicle. A similar trend was observed for the number of seeds per spike. The highest number of seeds per spike was associated with the longest spike. However, seed weight and germination ability were lower with seeds from the lower spikes (Table 4). The higher the position of the spike in the panicle, the heavier was the seed weight and the greater was the germination percentage. The differences in seed weight and germination ability were related to the order of emergence of the spikes. The topmost spikes always preceded the others in emergence and maturation and shattered earlier. According to Yoshioka *et al.*[10], *Echinochloa phyllopogon* (Stapf) Koss. seeds which shattered early were heavier than those which shattered after heading. Mean weight of the shattered seeds decreased as the time of heading was delayed. Differences in germination percentage between seeds from different spikes were probably due to either variability in dormancy or sterilization. More sterile seeds were found in the lower than in the upper spikes.

Formation of adventitious roots A flowering stalk of *E. colona* has four or five nodes along its length. When the flowering stalk was cut into small pieces containing one node each before, during, or after panicle formation, adventitious roots arose from the leaf sheath bases. Depending on the stage of panicle formation and the position of the leaf sheath bases, the formation of adventitious roots varied (Table 5).

The lower nodes (up to the 3d node from the ground) in a flowering stalk before or during panicle formation were always able to produce adventitious roots after excision, whereas the formation of adventitious roots in the upper nodes of a younger stalk and the lower nodes of an older stalk was erratic between the nodal pieces examined. However, the fourth nodal piece of a flowering stalk and the first nodal piece of a nodal tiller originating from the fourth node of the flowering stalk, which were obtained after panicle formation, had the ability to form adventitious roots. The ability to form adventitious roots was greater in a younger stalk than in an older stalk. With one nodal piece of the stalk, an independent plant of *E. colona* could be established (Fig. 4). Adventitious roots are a means of vegetative propagation in *E. colona*.

Table 5. Formation of adventitious roots from nodes of a flowering stalk.

Stage of panicle formation	Position of node (from ground)*				
	1st	2d	3d	4th	5th
Before	+	+	+	±	±
During	+	+	+	±	–
After	±	±	±	+	+**

* + = formed, ± = either formed or not formed, – = not formed.

** The node was the lowest leaf sheath base of a nodal tiller originating from the 4th node of the main culm.

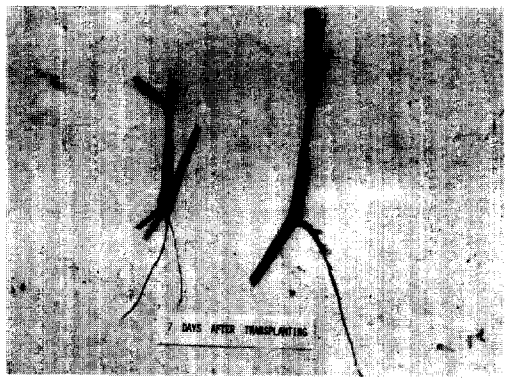

Fig. 4. Establishment of an individual plant of *Echinochloa colona* from a nodal piece of the flowering stalk obtained during panicle formation.

The results revealed that *E. colona* possesses rapid growth through the vegetative phase, discontinuous seed production, and formation of adventitious roots, features which are the bases of its success as a weed.

摘　　要

Echinochloa colona (L.) Link 의 生長, 發育 및 形態的 特徵을 全生活環을 通해서 調査하였다. *E. colona* 는 播種後 2~3日에 發芽하며, 播種後 8日이면 2葉期에 도달한다. 生長의 初期에는 根長이 草長보다 길지만, 播種後 4週가 經過되면서 이 關係는 뒤바뀐다. 分蘖은 主莖의 第6葉이 出現될 때 主莖의 第3葉으로부터 시작된다. 營養生長期 동안의 葉 및 分蘖은 一定한 規則性에 따라 展開되어 14葉期時에는 19個의 分蘖(1次 分蘖 5, 2次 分蘖 12, 3次 分蘖 1 및 節分蘖 1)을 이루었다. 莖葉/根部重量比는 出穗直前에 가장 높았다. 圓錐花序중 가장 짧은 小穗는 上位 2번째의 것으로 가장 적은 數의 種子를 生産한다. 이 小穗로부터 下位의 小穗로 내려갈수록 小穗의 길이와 小穗當 種子生産數는 增加된다. 種子의 무게는 下位小穗의 것이 上位小穗의 것보다 가벼웠으며, 發芽力도 낮았다. 不定根의 伸張은 花梗의 葉鞘基部에서 이루어지며, 그 伸張力은 오래된 花梗에서 보다는 어린 花梗에서 더욱 컸다.

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