Life Cycle of *Cyperus Serotinus* Rottb., A Perennial Weed, and Control Measures

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As a result of various changes in agricultural techniques and in agricultural situation which have occurred in recent years in Japan, various perennial weeds have rapidly increased in paddy fields throughout the country. The infestation of perennial weeds makes it difficult not only to develop labor-saving mechanized cultivation, but also to assure a better labor distribution to other crops than rice. Therefore, it is an urgent task to develop effective control measures for the perennial weeds.

C. serotinus, a perennial weed in paddy fields, is distributed widely in the whole country, and its control is a serious problem especially in areas of "early season rice cultivation" and of "direct-sowing to dry soil."[3,4,5,7,10] The author investigated physiological and ecological characteristics of this weed during its whole life process, together with agronomic and chemical methods of control, and designed an effective integrated control system. This study was carried out at Chiba Agricultural Experiment Station during a period from 1966 to 1976.

Analysis of life cycle of *C. serotinus*

The life cycle is divided into 4 stages, emergence, propagation, tuber formation, and preparation for emergence, as shown in Fig. 1. Reproduction occurs by seeds, tubers, base of shoots, base of new shoot-tubers, and stolon, but mainly by tubers. Propagation occurs by rhizomes, which produce branch shoots successively. Until late-July, the number of plants increases by this manner, but after that until mid-September it continues to increase by the sprouting of new shoot-tubers produced from the above branch shoots: a distinctive feature of this weed.

1) *Characteristics and factors effecting tuber sprouting*

It was found that the tuber has no natural dormancy, and, in general, the sprouting shows apical dominance, which is strong immediately after the tuber formation but weakened gradually toward the early spring of the succeeding year.

The lowest, highest and optimum temperatures for sprouting were ca. 10°C, 42.5°C, and 30—35 °C, respectively. However, in water with oxygen concentration lower than 5 ppm the sprouting was completely inhibited even at the allowable temperatures. In this case, the higher the water temperature, the earlier the death of tubers, as shown in Fig. 2. This result indicates that oxygen supply is the most important factor for the sprouting.

In the fields, soil moisture content determines oxygen supply. The highest emergence rate was observed at 60% of the maximum water-holding capacity of soil. As given in Fig. 3, the emergence rate was reduced markedly at higher soil moisture contents. Tubers buried in soil by field puddling lose their sprouting ability due to the lowering of soil Eh. In this case, the extent of tuber death was greater in continuously flooded fields than in well-drained or water-leaking fields.

Low temperature and dry condition also caused loss of sprouting ability. The latter was more detrimental, and when combined with the former, it caused a great reduction in sprouting.

2) *Factors related to propagation*

Effects of temperature, fertilizer elements and

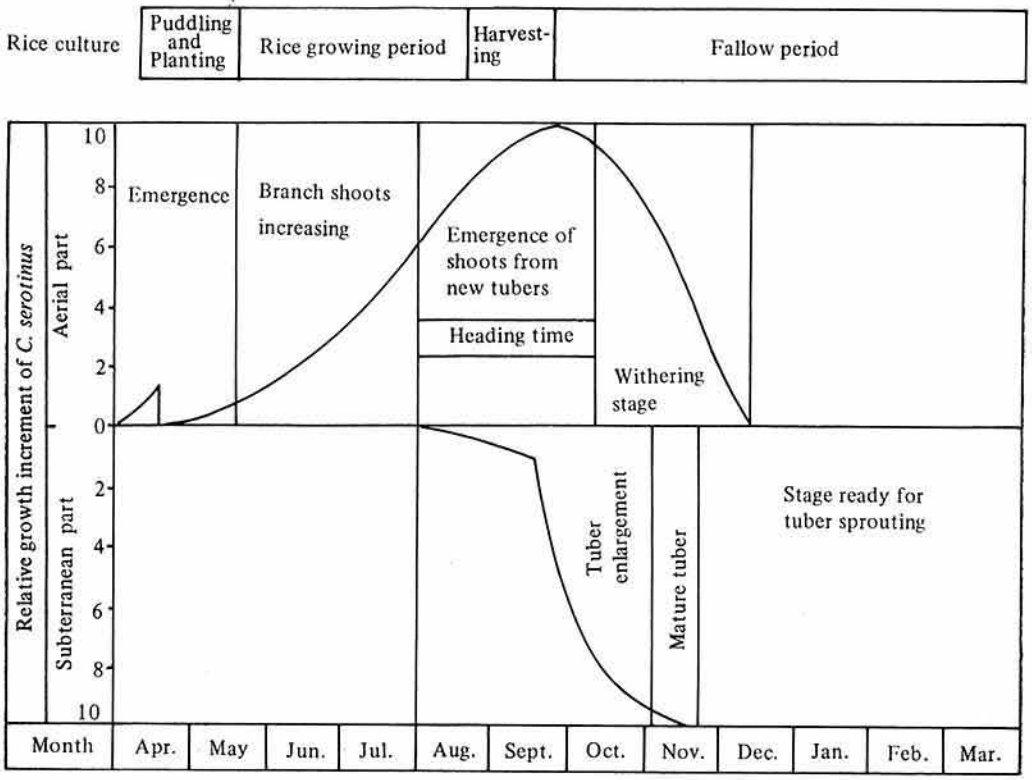

Fig. 1. Life cycle of *C. serotinus*

light on the propagation were examined.

Growth of aerial parts of this plant was rapid at mean temperature above 18°C. The higher the temperature, the faster the rate of leaf emergence and the more branch shoots produced per day.

Effect of the shading treatment is shown in Table 1. The number of shoots observed after a 60 day treatment was reduced to 53% and 27% of the control (natural light) by 25% and 50% shading, respectively, indicating greater inhibition of propagation by enhanced shading.

Of three elements of fertilizer, nitrogen is most needed: in a cropless field, marked propagation occurred at the presence of nitrogen. However, in the field with transplanted rice, the propagation of this weed was more restrained by heavy application of nitrogen than the standard application rate, or by the application emphasized on basal dressing than split application. Futhermore, the propagation was examined by varying the date of emergence of this weed under

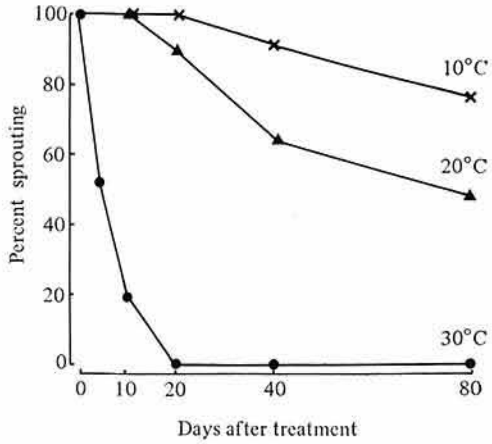

Fig. 2. Effect of water temperature on percent sprouting of tubers in water with oxygen concentration which permits the sprouting

transplanted rice. The result showed that the later the emergence of this weed, the less was the number of its shoots as compared to that of the plants emerged just at the time of rice

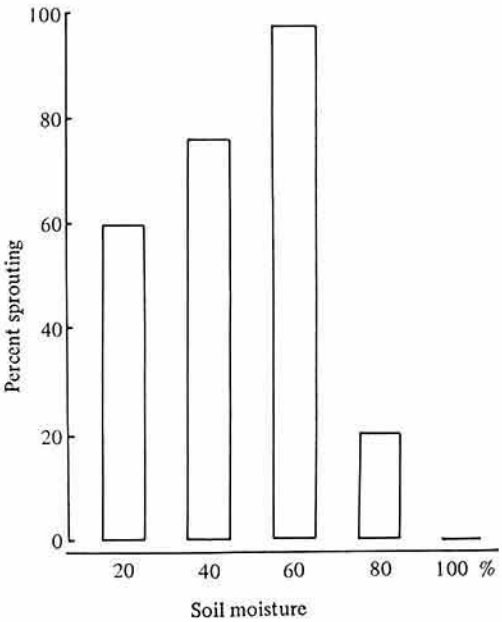

Fig. 3. Effect of soil moisture on percent sprouting of tubers

Note: Soil moisture is expressed as percent of the maximum water-holding capacity of soil. Tubers were buried at 5 cm depth below the soil surface.

transplanting, as shown in Table 2.

Competition for nutrients between rice plants and *C. serotinus* may be one reason for the retarded propagation of the latter in rice fields, but the dominant limiting factor for the propagation of *C. serotinus* is presumed to be light intensity, because in any case mentioned above the propagation was more retarded when growth of rice plant was greater in relation to that of the weed.

3) *Factors effecting tuber formation*

Tuber formation was promoted by short-day.[6] However, even under the short-day condition, tubers formed at the tip of stolons did not grow, and shoots came out at 30°C, while all the stolons produced tubers at the temperature lower than 20°C, indicating that not only day-length but also temperature is an important factor effecting tuber formation.

The number of tubers is determined by the number of plants, and also by the factors effecting propagation of plants. In the field of "usual season rice cultivation," where *C. serotinus* entered into the tuber formation stage under the growing rice plants, the number of tubers produced was remarkably less and average weight/tuber is also lighter than in the field of "early season rice cultivation," where the tuber formation stage occurred after the rice had already been harvested. The tuber formation seems to be greatly influenced by presence or absence of competition for light between rice and *C. serotinus* (Table 3).

Crop damage caused by *C. serotinus*

To examine effects of *C. serotinus* on growth and yield of rice, *C. serotinus* was planted at different time and different amount in paddy fields under various methods of rice cultivation. The result obtained is given in Table 4. The

Table 1. Effect of shading treatment on the growth of *C. serotinus*

Plot	30 days			40 days			60 days		
	Plant height (cm)	No. of leaves	No. of shoots	Plant height (cm)	No. of leaves	No. of shoots	Plant height (cm)	No. of leaves	No. of shoots
Control	42.4	12.0	11.0	52.8	15.0	19.7	81.7	19.3	60.0
25% shading	46.6**	9.0**	5.2**	57.3**	11.7**	9.3**	84.4	15.0**	32.0**
50% shading	57.2**	8.0**	2.8**	71.1**	10.0**	4.3**	97.3**	12.3**	16.0
LSD(0.05)	1.2	1.0	2.9	1.8	1.7	2.7	7.4	2.0	8.3
(0.01)	2.2	1.5	4.4	2.9	2.9	4.5	10.8	3.4	13.7

*, **: Significant at 5% and 1% level, respectively.
Shading treatment was began just after transplanting of *C. serotinus*.

Table 2. Shoot production of *C. serotinus* as effected by various different conditions

Factors		No. of shoots*/m² Cropless paddy field (A)	No. of shoots*/m² Rice growing paddy field (B)	B/A (%)
Emergence time (days after rice transplanting)	0	1288	120	9.3
	10	1222	49	4.0
	20	1150	22	1.9
	30	1047	15	1.4
Fertilizer application	Standard rate	1288	86	6.7
	Top-dressed		128	9.9
	Heavy rate		15	1.2
Planting density of rice (hills/m²)	13.9	1098	207	18.9
	18.5		168	15.3
	22.2		88	8.0
	27.8		78	7.1

* No of shoots examined at the rice harvesting time.

Table 3. Yield of tubers of *C. serotinus* as effected by different rice cropping season and planting time of *C. serotinus*

Plot		No. of shoots produced in the whole period/m²	Yield of tubers	
Rice cropping season	Planting time of *C. serotinus**		No. of tubers/m²	Total Wt: g/m²
Early season	0	537(159)	742	310.6
	20	204(128)	510	243.8
Usual season	0	456(0)	115	37.1
	10	173(0)	27	5.1
	20	83(0)	104	22.9
	30	25(0)	35	13.8

1) Numerals in parentheses: No. of new shoots emerged after rice harvesting.
2) Early season culture: Transplanted April 30, harvested Aug. 25.
Usual season culture: Transplanted May 26, harvested Sept. 29.
* Planting time of *C. serotinus* in days after rice transplanting.

weed planted immediately after rice transplanting caused a great reduction of rice yield, and the reduction was increased by increased number of the planted weed, but almost no effect on rice was observed when the weed was planted 30 days after rice transplanting at the rate of 1–8 shoots/m². As to fertilizer application, it was recognized that heavy application of nitrogen (50% more than the standard rate) caused less damage on rice, and split application caused more damage than the application emphasized on basal dressing. High planting density of rice alleviated crop damage. Furthermore, transplanting of rice seedlings at 5-leaf stage resulted in less damage by *C. serotinus* than direct-sowing to flooded field, and transplanting of rice seedlings at 2-leaf stage. All these results indicate that the dominancy of rice plants in the competition for light with *C. serotinus* causes less crop damage by the weed.

The yield component which contributed most to the rice yield reduction was a decrease in panicle number, followed by a decrease in grain number per panicle.

Table 4. Percent reduction of rice yields* due to competition with *Cyperus serotinus* under various conditions

Conditions		No. of shoots emerged per m² 1	2	4	8	16
Emergence time (days after rice transplanting)	0	5%	15%	25%	28%	36%
	10	1	3	7	14	20
	20	0	2	3	4	
	30	0	0	0	1	
Fertilizer application	standard rate	5	15	25	28	36
	top-dressed	10	15	35	44	
	heavy rate	1	4	8	12	
Planting density of rice plants (hills/m²)	13.9	10	23	33	37	
	18.5	7	16	23	32	
	22.2	4	12	19	25	
	27.8	2	14	16	18	
Seedlings planted	5-leaf stage	3	9	18	25	
	2-leaf stage	9	18	23	38	
Direct-sowing		8	16	18	41	

* Percent reduction: yield reduction as expressed by percentage to the grain of weed-free plot.

Methods to control *C. serotinus*

1) *Agronomic control methods*

Effect of plowing in winter to kill reproductive organs is shown in Fig. 4. The plowing killed 30–50% of reproductive organs. Turn-over plowing effective in drying soils, and plowing in December-January with low temperature and less rainfall were effective. Puddling was highly effective in killing both overwintered organs and shoots sprouted at the time of puddling, by burying them in the soil. Puddling combined with turn-over plowing in winter killed about 80% of the reproductive organs.

In the fields of early season rice cultivation, the beginning of tuber formation of *C. serotinus* almost coincides with the time of rice harvest. Therefore, plowing immediately after the rice harvest was very effective in preventing tuber formation. In this case, rotary plowing was more effective than turn-over plowing (Fig. 5). The effect to suppress the source of emergence in the following year was higher than the plowing in winter.

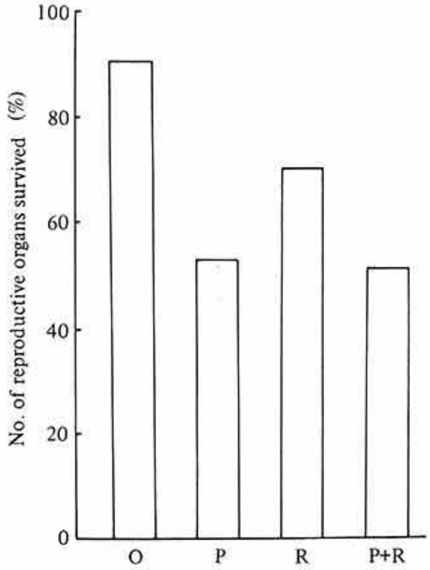

Fig. 4. Effect of plowing in winter on the number of reproductive organs of *C. serotinus*

Note: O: Not plowed
P: Turn-over plowing on January 17
R: Rotary plowing on January 17
P+R: Turn-over plowing January 17, followed by rotary plowing on February 13

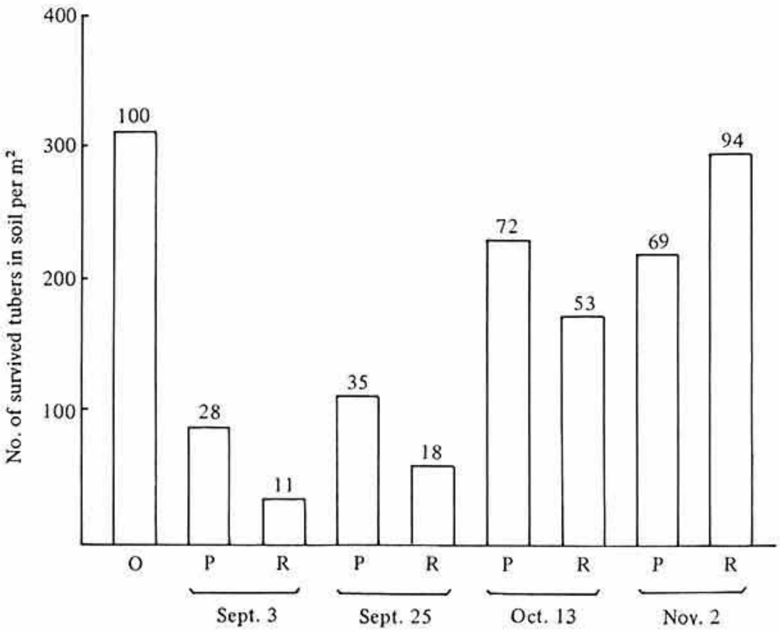

Fig. 5. Effect of date and method of plowing done after the rice harvest on the number of survived tubers in the following spring

Note: Numerals above the columns indicate percentages to the O plot
O, P and R: Same as shown in Fig. 4

2) *Herbicidal control*

For soil treatment after rice transplanting, thiobencarb, butachlor, mixture of molinate, simetryn and MCPB, mixture of piperophos, dimethametryn, and bentazone were effective. These herbicides were most effective, when applied at the 3 to 4 leaf stage prior to emergence of branch shoots. Foliage treatment with paraquat prior to puddling was effective in killing emerged shoots,[10,11] but not so effective in preventing emergence after the puddling in early season rice cultivation.

As foliage treatment after the rice harvest, paraquat, $NaClO_3$, and 2,4-D, all applied at the beginning of tuber formation stage, were highly effective in preventing weed emergence in the following spring, by inhibiting tuber formation. Ammonium sulfamate, a mixture of 2,4-D and ATA, and ATA alone were also effective in inhibiting both tuber formation and emergence in the following spring.

Integrated control system for *C. serotinus*

Based on the above results, an integrated control system to be applied at present to the transplanted early-season rice cultivation was designed as shown in Fig. 6.

1) In areas where transplanting is made from late-April to early-May, turn-over plowing is practiced in winter to kill propagating organs.

2) In areas where transplating is made in mid-May and later, rotary plowing is practiced to induce uniform emergence of the weed, and, then, emerged shoots are killed by foliage treatment with paraquat.

3) In both areas, intensive puddling is made to bury reproductive organs of the weed.

4) For reproductive organs remained on soil surface, soil treatment with effective herbicides is done to prevent the emergence.

5) After the rice harvest, plowing or application of herbicides of contact type or translocation type is made by the time of initial tuber forma-

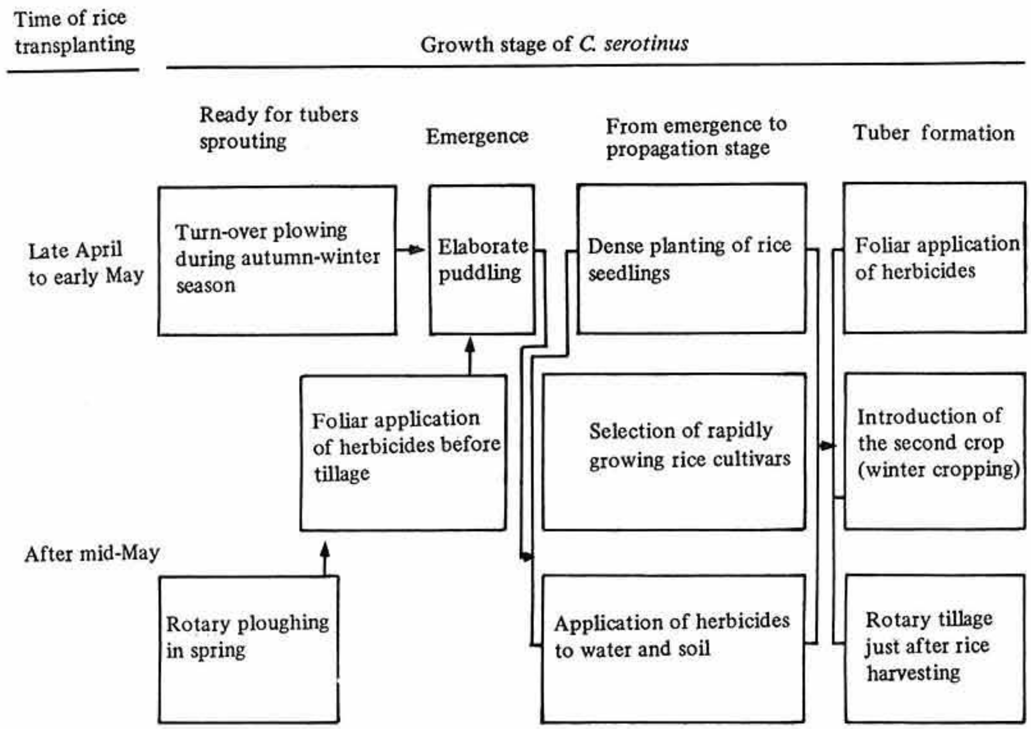

Fig. 6. Integrated control of *C. serotinus*

tion stage to prevent tuber formation.

6) Introduction of a winter crop, followed by usual season rice cultivation is also one of the control measures.

Depending on the extent of weed infestation or different field conditions, the combination of these various control measures will be modified.

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