Ecological Control of Perennial Weeds in Paddy Fields

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Remarkable increase of perennial weeds in paddy fields has been recognized in various places in recent years, creating serious problems in controlling them. Particularly, the increase in kinds of perennial weeds and the expansion of infested areas are regarded as a characteristic trend never experienced before. According to the 1974 survey, paddy field area infested by major perennial weeds reached about 2.1 million ha, constituting about 78% of the total lowland rice area of Japan. Such an increase of perennial weeds seems to be caused by big changes which have occurred recently in the form of utilization of paddy fields, cultural practices, and weed control measures, etc.

Current weed control measures in this country depend mostly on the chemical method using herbicides. Even for perennial weeds, effective herbicides have been developed, and as a result it becomes relatively easy to minimize weed damage. However, with perennial weeds it is important not only to minimize weed damage, but also to eliminate sources of infestation. In this sense, the dependence on herbicides alone is not enough. It happens sometime that continuous use of specific herbicide causes particular perennial weeds resistant to that herbicide to become dominant. Basically, it is necessary to make clear the ecology of weeds, especially the ecological weak points in the process of their multiplication, and to establish integrated control measures based on the ecological control attacking their weak points.

From this point of view, the author and co-workers have been working to accumulate basic knowledge on physiology and ecology of weeds, and to find out ecological control methods by the use of tillage, winter cropping, etc. In this paper research results obtained so far with representative perennial weeds, *Sagittaria pygmaea* Miq. (arrowhead), *Eleocharis kuroguwai* Ohwi (water chestnut) and *Cyperus serotinus* Rottb, on the formation and characters of vegetative reproductive organs, killing effect of tillage on them, etc. will be briefly presented.

Ecological characteristics of vegetative reproductive organs

Main propagation organ of the above three weeds is tubers produced in soil. Time of tuberization is September–October for water chestnut and cyperus. These two weeds are apparently short day plants, and tubers are not formed until that time (Fig. 1)[3,6]. On the contrary, arrowhead produces tubers after

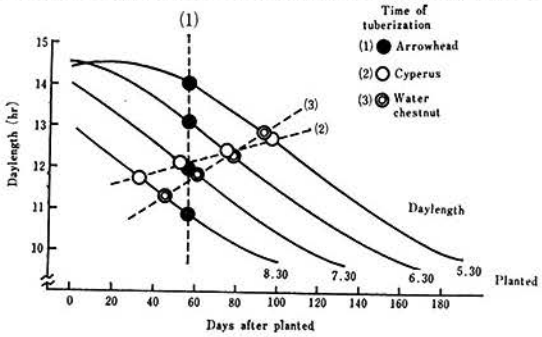
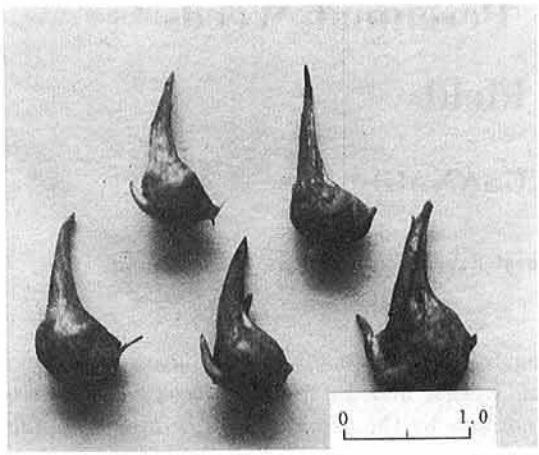
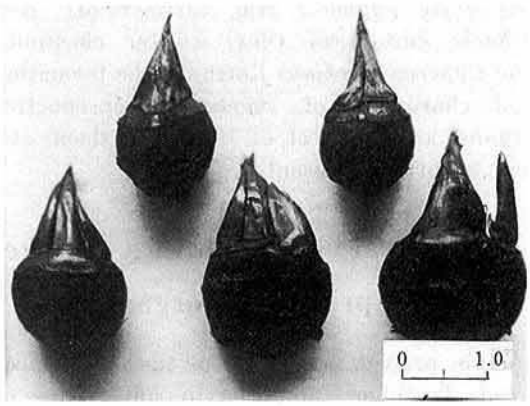


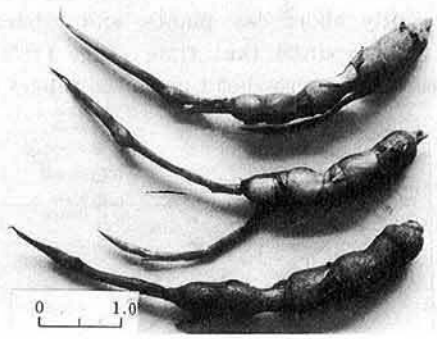
Fig. 1. Relation between number of days from planting to tuberization and daylength (1974)



Sagittaria pygmaea Miq. (cm)



Eleocharis kuroguwai Ohwi.



Cyperus serotinus Rottb.

Plate 1. Tubers of arrowhead, water chestnut and cyperus

a definite period, about 50 days, from emergence, irrespective of the date of emergence, because it is insensitive to daylength in tuberization.

Location of tubers in soil is different for each weed. It is shallowest for arrowhead: 70–80% of all tubers are located in the surface layer up to 5 cm of depth, and almost no tubers are produced below 10 cm of depth. Tubers of cyperus are located slightly deeper than those of arrowhead: most of them are at 5–10 cm depth. Water chestnut shows a characteristic vertical distribution of tubers, mostly in a deep layer 10–20 cm of depth (Fig. 2)[3]. There is a tendency that the weed with shallower tubers produces larger number of tubers. An example of the survey showed that, when these weeds covered the surface of paddy field with ordinary transplanted rice, the number of tubers per m^2 was 3,000–4,000 for arrowhead, 1,500–2,000 for cyperus, and 1,000–1,500 for water chestnut. As the tubers of water chestnut are large in size, that number of tubers correspond to about 500 kg/10 are.

Depth of emergence (depth of soil from which weeds emerge) corresponds generally to the depth of tuberization. However, conditions required for the emergence differ with different weeds. As tubers of arrowhead and cyperus have no dormancy, their emergence tends to be uniform. But, water chestnut has a dormancy lasting for a long period, 4–5 months, and the dormancy awakening is not uniform, so that its emergence is staggering.

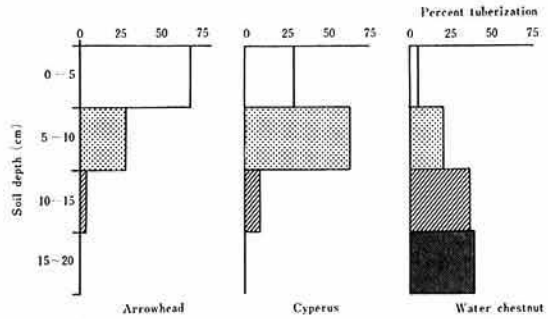


Fig. 2. Distribution of tuberization in soil (1974)

Arrowhead and water chestnut are not possible to emerge under non-flooded condition, but they emerge easily under oxygen-deficient, reductive state of soil of flooded paddy fields. Recently, it was found that ethylene or CO_2 gas promotes emergence of arrowhead[5]. It suggests that not only endogenous ethylene, but also ethylene or CO_2 gas produced in soil by flooding after plowing might be playing an important role in emergence and growth of arrowhead. Quite contrary to these weeds, cyperus shows a high requirement for oxygen in emergence. When tubers of cyperus are buried into soil by the puddling operation, no emergence or extremely delayed emergence takes place. This is the reason why cyperus grow more abundantly in the "direct-sowing to non-flooded field" culture than in transplanting culture.

Life span of tubers of arrowhead and cyperus is only 1–2 years, while that of water chestnut is several years. Critical low temperature lethal to tubers is not yet known. When water content in tubers decreases to about 30%, the tubers lose sprouting ability and die gradually[1]. To reduce water content of tubers to such a level, a spell of 3–4 fine days is enough under outdoor conditions. Thus, the tubers are extremely susceptible to drying.

Effect of tillage on extinction of tubers

It has been known by experiences that tillage in autumn and winter promotes the extinction of vegetative propagation organs such as tubers and tuberous roots. However, it was revealed that the actual effects vary to a considerable extent depending on methods of tillage and water conditions of soil after tillage[2,7].

Although the killing effect on tubers of these weeds is generally greater with the overturning plowing than with the rotary tillage, the actual effect differs markedly depending on the soil water conditions even with the same method of tillage. Namely, when the fields are kept under flooded condition, the effect of tillage is minimized, irrespective of the methods of tillage, plowing or rotary tillage, and almost no tubers are killed, except those placed in surface soil layer within 5 cm of depth including those exposed to the soil surface. Extinction rate (%) of tubers in soil layer within 5 cm of depth as related to methods of tillage and soil water conditions is given in Table 1. At the combination of plowing and dry soil condition, it was 40% with arrowhead, 50% with cyperus and 55% with water chestnut. All the tubers exposed to soil surface were killed under dry or wet conditions of soil, except flooded condition.

Table 1. Rate of extinction (%) of tubers in relation to methods of tillage and soil water condition after tillage (1973—75)

Weed species	Plowing			Rotary tillage			Non-tillage		
	Flooded	Wet	Dry	Flooded	Wet	Dry	Flooded	Wet	Dry
Sagittaria pygmaea	2.7	25.0	42.4	6.6	17.3	24.0	3.9	0.4	1.9
Cyperus serotinus	0	42.0	49.5	0	35.1	37.0	0	0	0
Eleocharis kuroguwai	4.2	26.1	55.6	0	19.2	40.0	0	0	13.3

Note: 1) Determined with tubers sampled from 0—5 cm depth of soil layer.
2) Depth of tillage: About 15 cm for overturning plowing and about 10 cm for rotary tillage.
3) Time of tillage: Middle December.

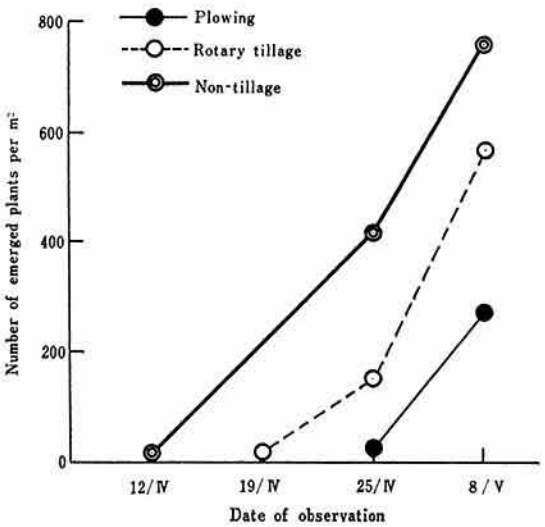


Fig. 3. Relation between different methods of winter tillage and number of plants of *Cyperus serotinus* emerged in the following year (dry field condition, 1974—75)

Although two factors, low temperature and drying, are considered as causes of killing tubers, the above result together with the susceptibility of tubers to drying as stated above seems to suggest that the drying is more influential than low temperature on the extinction of tubers in areas where these weeds generally grow.

Consequently, it can be concluded that in order to reduce the source of multiplication of these weeds it is most effective to adopt the overturning plowing in areas where soil can be dried. By killing most of the tubers in surface soil layer by the tillage, the initial emergence of these weeds can be avoided remarkably (Fig. 3). In actual rice cultivation, it is of great significance that rice plants can grow ahead of weeds and can escape from the weed damage at the atcive tillering stage which is most sensitive in the competition against weeds, exerting strong influences on grain yield.

The above result was that obtained by a single tillage practiced in December. It seems that there is a possibility of minimizing the source of multiplication by studying the time and frequency of tillage. For controlling perennial weeds, it is desirable to establish effective measures by utilizing adequate herbicides and weeding machines based on the ecological control as described above.

References

1) Kusanagi, T. & Hattori, K.: Effect of temperature and water conditions on the extinction of vegetative reproductive organs of perennial weeds. Weed Science Society of Japan. Abstracts of presentation at 11th meeting 16–18 (1972) [In Japanese].
2) Kusanagi, T. & Hattori, K.: Effect of methods of winter plowing and differences in water management on survival of tubers and emergence of water chestnut. Weed Science Society of Japan. Abstracts of presentation at 12 Meeting 41–43 (1973) [In Japanese].
3) Kusanagi, T. & Takamura, T.: Time of formation and numbers of seeds and tubers of perennial weeds in paddy fields, and some environmental factors affecting them. Weed Science Society of Japan. Abstracts of presentation at 14 Meeting 79–81 (1975) [In Japanese].
4) Japan Association for Advancement of Phytoregulators: *Shokucho* 9(4) 15 (1975) [In Japanese].
5) Suge, H. & Kusanagi, T.: Ethylene and carbondioxide: Regulation of growth in two perennial aquatic plants, arrowhead and pondweed. *Plant & Cell Physiol.* **16**: 65–72 (1975).
6) Suge, H. & Kusanagi, T.: Photoperiodic control of flowering and tuberization in *Cyperus serotinus*. I. Tuberization. *Weed Res. Japan*, **20**(1) 8–11 (1975).
7) Yamagishi, A. & Hashizume, A.: Studies on control of some perennial weeds on paddy field. V. Effect of tillage in winter and puddling on the emergence from overwintering reproductive organs of *Cyperus serotinus* Rottb. *Bull. Chiba Agr. Exp. Sta.*, 12, 43–50 (1972).