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# Biology of Perennial Weeds : As A Basis for Their Control

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Many perennial weeds are not easily controlled because of their ability to reproduce and regrow vegetatively. Since the organs in question exist underground and are so diverse among species, they have been paid less attention, and this may often be a reason for unsuccessful control. Therefore, fundamental ecological studies are necessary for their effective control.

With respect to the difficulty of control annual and perennial weeds are basically different in the following points :

1) An annual plant consists of one ramet whereas a perennial consists of multiple ramets ; even the plant emerged from a single tuber has several "potential ramets" on the tuber which can soon replace the existing shoot with a new one.

2) "Potential ramets" of annuals(seeds) are located in the upper several centimeters of soil surface while those of perennials(buds) are distributed as deep as over several dozen centimeters.

These facts indicate the importance of studies on the following topics : 1) How vegetative propagules are arranged in perenating systems, i.e., the architecture of vegetative propagules.

2) How the buds on vegetative propagules form and sprout.

3) To what extent different perennial species depend on vegetative reproduction.

4) How perennial species respond to control measures.

The above-mentioned topics are discussed in this paper. The species reviewed here are mainly the upland perennials commonly distributed in Japan, since upland perennials are generally more agressive than those in rice paddy. Furthermore, a review on rice paddy perennials has already been presented by Kusanagi(1988)[11].

## I. Upland perennial weeds common in Japan

Common and/or serious perennial species are listed in Table 1. Among these, the following species are thought to be most important in upland fields :

*Equisetum arvense* is a most serious perennial in field crops, distributed from Hokkaido to Kyushu. It often invades into crop fields during no-till periods when wheat, barley or forage crops are planted. In the established plants 70-80% of total biomass exists underground. The undergound system consists of both vertical and creeping rhizomes, and tubers are also present on some rhizome nodes. Since the subterranean parts of established plants are distributed so deeply throughout the soil profile, often as deep as 1m in cultivated fields, they are extremely difficult to control.

*Calystegia japonica* and *C. hederacea* are troublesome climbing weeds in cultivated fields and orchards across Honshu and Kyushu, having deep rhizome systems. These species do not set seeds in most cases, but easily reproduce themselves from fragmented rhizomes.

*Cyperus rotundus* and *Imperata cylindrica* are serious weeds mainly in orchards in the southern regions of Japan, having well-developed underground systems. *C. rotundus* reproduces by tubers, while *I. cylindrica* reproduces by seeds and rhizome fragments.

*Oxalis corymbosa* is a very troublesome perennial in field crops in Kyushu and southern islands. This species reproduces only vegetatively by bulbs. New bulbs are produced laterally around a parent bulb and are detached when they become mature.

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**Table 1.** Major perennial weeds in cultivated fields in Japan

| Species | (Family) | Distribution[a] as weeds North 1 | 2 | 3 | South 4 |
|---|---|---|---|---|---|
| Upland fields | | | | | |
| *Equisetum arvense* | (Equisetaceae) | X | X | X | X |
| *Artemisia* spp. | (Compositae) | X | X | X | X |
| *Rumex crispus* & *R. obtusifolius* | (Polygonaceae) | X | X | X | X |
| *Rumex acetosella* | 〃 | X | X | X | |
| *Calystegia* spp. | (Convolvulaceae) | | X | X | X |
| *Oxalis corymbosa* | (Oxalidaceae) | | | X | X |
| *Imperata cylindrica* | (Gramineae) | | X | X | X |
| *Cyperus rotundus* | (Cyperaceae) | | | X | X |
| *Cayratia japonica* | (Vitaceae) | Mainly in orchards | | | |
| *Taraxacum officinale* | (Compositae) | Orchards and turfs in the north | | | |
| *Cirsium arvense* | 〃 | Crop fields in Hokkaido | | | |
| *Rorippa sylvestris* | (Cruciferae) | 〃 | | | |
| *Agropyron repens* | (Gramineae) | Crop fields & pastures in the north | | | |
| *Agrostis alba* | 〃 | 〃 | | | |
| Rice paddy | | | | | |
| *Sagittaria trifolia* | (Alismataceae) | X | X | X | X |
| *Alisma canaliculatum* | 〃 | X | X | | |
| *Sagittaria pygmaea* | 〃 | X | X | X | X |
| *Potamogeton distinctus* | (Potamogetonaceae) | X | X | X | |
| *Oenanthe javanica* | (Umbelliferae) | X | X | X | X |
| *Scirpus juncoides* | (Cyperaceae) | X | X | X | X |
| *Cyperus serotinus* | 〃 | | X | X | X |
| *Eleocharis kuroguwai* | 〃 | | X | X | X |
| *Eleocharis acicularis* var. *longiseta* | 〃 | X | X | X | X |
| *Scirpus planiculmis* | 〃 | Mainly in reclaimed lands | | | |
| *Scirpus nipponicus* | 〃 | In the north | | | |
| *Leersia oryzoides* | (Gramineae) | 〃 | | | |
| *Paspalum distichum* | 〃 | In the south, levee | | | |

a ; 1 : Hokkaido, 2 : Northern Honshu, 3 : Southern Honshu, 4 : Shikoku and Kyushu

*Artemisia princeps* and *Solidago altissima* are tall, often taller than 2m, agressive species having shallow rhizome systems. *A. princeps* is one of the most serious weeds in orchards thoroughout the country, and *S. altissima* is the most predominant species in noncrop urban areas except for Hokkaido. *S. altissima* was introduced from North America several dozen years ago and has increased its distribution very rapidly. These species reproduce both by seeds and rhizome fragments. *S. altissima* is estimated to produces 700,000 to 4,200,000 wind-disemminated seeds/$m^2$.

Four *Rumex* species, *R. crispus*, *R. obtusifolius*, *R. acetosa* and *R. acetosella* are common. *R. crispus* L. subsp. *japonicus* (Houtt.) Kitam. is a weed in field crops and orchards, while *R. obtusifolius* is a very serious pasture weed. These two species, although they are mainly seed-producers, have tap roots, and the fragmented roots can sprout into new ramets when the land is cultivated. *R. acetosella* is a weed mainly in pasture and turf. It has a well-developed creeping-root system, and its fragments sprout very easily. (The difference between a rhizome and a creeping-root will be mentioned later). *R. acetosa*, common in both crop and non-crop fields, does not reproduce vegetatively.

## II. Life history

The ideal life history of perennial species includes

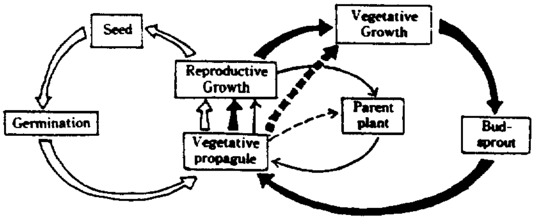



**Fig. 1.** Life cycle of the ideal perennial weed.
⇨ sexual reproduction
➔ vegetative reproduction
→ regrowth

regrowing, seed-propagating and vegetatively propagating cycles(Fig. 1). Degree of dependence on the two propagating cycles are varies among species, for examples :

1) Both vegetative and by seeds : *Artemisia princeps*, *Solidago altissima*, *Sonchus arvensis*, *Agropyron repens*, *Imperata cylindrica*, *Rorippa indica*, etc.
2) Vegetative more than by seeds : *Sagittaria trifolia*, *Cyperus serotinus*, *Sagittaria pygmaea*, etc.
3) Vegetative only : *Calystegia japonica*, *Oxalis corymbosa*, etc.
4) By seeds only : *Scirpus juncoides*, *Alisma canaliculatum* *Rumex acetosa*, *Plantago* spp. *Paspalum dilatatum*, etc.

## III. Propagules and their distribution pattern in soil

Vegetative organs able to become propagules are segments of rhizome, stolon and root, tubers, bulbs, and corms. Fragmented aerial stems can be propagules in some species. Many of the major upland perennials reproduce by rhizomes as well as roots, while most of the important perennials in rice paddy reproduce by tubers(Figs. 2 and 3). Distribution patterns of these organs in the soil are primarily divided into two types according to the spreading pattern as follows :

Creeping(or spreading) type(Fig. 2).

Single(or centered) type(Fig 3).

The creeping type may then be further divided into five classes(A to E in Fig. 2). A is a stolon system of species such as clovers, *Oxalis corniculata*, and so forth. B is an underground creeping system without tubers. Creeping parts consist of either rhizomes as in *I. cylindrica* or of roots as in *R. acetosella*. C, D and E are also underground creeping systems but have tubers or bulbs. *E. arvense* represents the C type in which aereal shoots never sprout from tubers while tubers are attached to the rhizome(tubers can sprout when they are detached from rhizome nodes). In contrast, in *C. rotundus*, a D type, aerial shoots emerge only from tubers(and often through basal

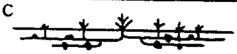
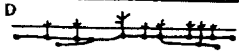
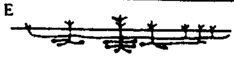
| Underground system | Propagule | Important species Upland | Paddy |
|---|---|---|---|
| A  | STOLON segment | 4 | 2 |
| B  | ROOT segment | 4 | 0 |
| | RHIZOME segment | 18 | 1 |
| C  | RHIZOME & TUBER | 1 | 0 |
| D  | TUBER | 1 | 1 |
| E  | BULB | 0 | 1 |

**Fig. 2.** Distribution patterns of vegetative-reproductive organs, and propagules and number of important species in each pattern.
(1) Creeping type.

| Underground system | Propagule | Important species Upland | Paddy |
|---|---|---|---|
| A  | BULB | 2 | 0 |
| | CORM | 1 | 1 |
| B  | TUBER | 0 | 1 |
| C  | ROOT | 5 | 0 |
| D  | (None) | 7 | 2 |

**Fig. 3.** Distribution patterns of vegetative-reproductive organs, and propagules and number of important species in each pattern.
(2) Single type.

bulbs), its rhizome never being a reproductive organ. E is a system of the species like *Potamogeton* in paddy fields.

The single type in Fig. 3 is sub-divided into four classes (A to D). Among these, most of the upland perennial weeds have either tap-roots (B) or no particular system of vegetative reproduction (D).

## IV. Bud-sprouting characteristics :

Bud-sprouting characteristics are another important biological aspect from the control point of view. There are two different ways of sprouting, adventitious and nonadventitious. Rhizomes, tubers, bulbs and corms develop axillary and apical nonadventitious buds during their growth. On the other hand any sprouts from the root occur adventitiously.

Morphological differences between rhizomes and creeping-roots are as follows :

Externally, rhizomes have lateral buds and often nodes or node-like traces, while creeping-roots do not have either of the above but can develop root-buds. Anatomical features of rhizomes are basically the same as aerial stems except that the rhizome cortex is thicker, while the internal features of creeping-roots are identical to those of other roots, as seen in centripetal arangement of xylems.

Adventitious buds on the root, called root-buds, are known to be initiated from pericycle tissue, similar to lateral root initiation, in many weedy species such as *Cirsium arvense*, *Convolvulus arvensis*, *Euphorbia esula*, *Ascrepias syriaca*[10], etc. On the creeping-roots of *C. arvensis* and *Rorippa sylvestris*[5] many quiecent root-buds are apparent which are not observed on *Solanum calorinense* and *C. arvense* roots. The creeping roots sprout in a few days both from quiecent root-buds already formed and by breaking directly through the epidermis when the roots are cut into segments or the aerial shoots are removed. General patterns of sprouting from root segments are classified and demonstrated in Fig. 4. In most species, sprouts from true roots come laterally regardless whether it is a tap-or creeping-root. In *Taraxacum*[7] species, however, the buds are initiated at the cut end of the roots. In *Rumex obtusifolius* and *R. crispus* only the proximal 5 cm is able to form adventitious buds[13][15], while *Rorippa indica* can sprout from any part of the root[7]. In the tap-root system the root crown portion is actually a very shortened perenated shoot having axillary buds from which the shoots regrow. The vertical portion connecting to the aerial shoot in the creeping system is rhizomatous and has axillary buds. Therefore, these portions can sprout nonadventitiously from axillary buds when they are cut.

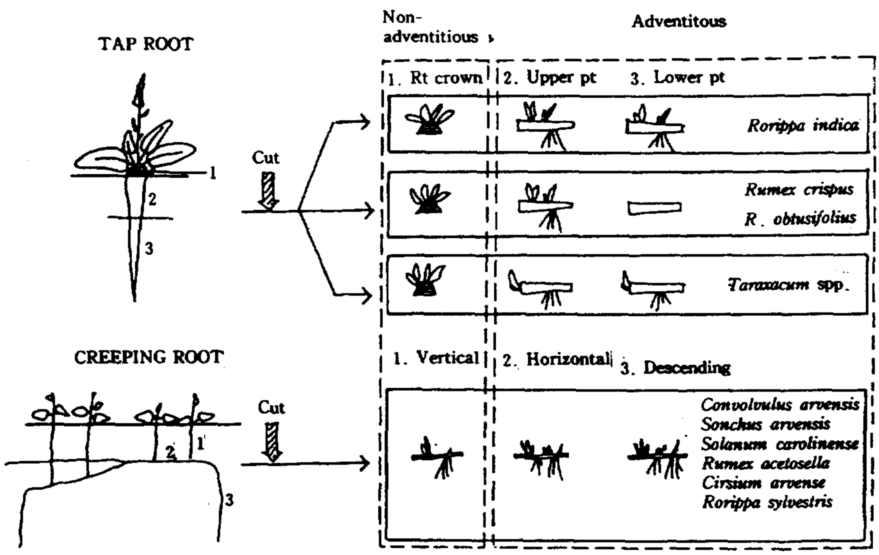



**Fig. 4.** Sprouting patterns from root fragments.

Seasonal change of sprouting ability is also an important point to be noticed. The fragmented or detached organs for vegetative reproduction are able to sprout if they are not in dormant phase. Some of the tubers, bulbs and corms have dormancy, whether it is deep or shallow, such as tubers of *Sagittaria trifolia*, *Eleocharis kuroguwai*[11] and *Cyperus rotundus*[3] and the bulbs of *Oxalis corymbosa*[9]. Rhizomes and roots have the ability to sprout throughout the season in many species such as *Taraxacum* spp.[4], *C. arvensis*[16] and *C. arvense*, if conditions are favorable, although sprouting ability is reduced at blooming in *Rumex obtusifolius*[15].

## V. Response to control measures

The most effective means for controlling upland perennial weeds are tillage and herbicide treatment. Once the plants have established, it is very difficult to eradicate them. Successive control is necessary, and a control practice must be properly timed and implemented, otherwise it may be ineffective or even increase weed populations. Therefore, it is important to understand how tillage and herbicides affect perennial weed growth and reproduction in various cases.

Tillage : Tillage affects perennials in following ways :

1) to cut rhizomes and roots to produce fragmented propagules
2) to help their dispersal by making them bind to the machine.
3) to bury them deeper in soil, if plowed deep.
4) to move them up to the soil surface so that they are able to be killed by low temperature and/or drought, if it is done in a proper time of the season ;
5) to deepen the distribution of originally deep subterranean parts, e.g. the rhizome of *Equisetum arvense*[6,17] ; and/or
6) to force the plant to consume food reserves and thereby be weakened.

Whether the tillage has positive or negative effects on control depends on timing, depth and frequency.

Herbicides : Foliar-applied translocated herbicides may be more effective than soil-applied herbicides in most cases, bacause herbicide layers in soil surface made by soil application are not deep enough to contact with most underground parts of the plant. Herbicidal efficacy is generally attribute to high absorption, high translocation and slow metabolism. In the case of perennials mentioned here, however, direct and precise attack to the buds or to the bud initiating tissues are necessary. This means that the chemicals should be systemically translocated, accumulate in buds and kill them or inhibit their sprouting for several months. A. typical accumulation was reported on asulam-treated bracken fern (*Pteridium aquilinum*)[18,20] (Fig. 5).

Foliar-applied translocated herbicides capable of controlling upland perennial weeds are glyphosate, gluphosinate, asulam, triclopyr, 2, 4-D, sulfonylureas, etc. Although these chemicals are all highly translocatable, the efficiency of downward trans-

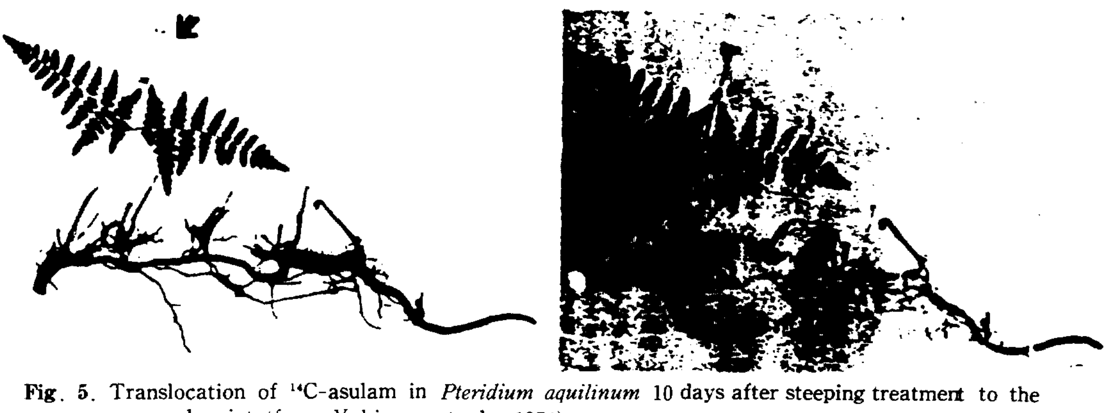


**Fig. 5.** Translocation of $^{14}$C-asulam in *Pteridium aquilinum* 10 days after steeping treatment to the arrowed points(from Yukinaga et al., 1974).
Left : mounted plant, right : autoradiograph.

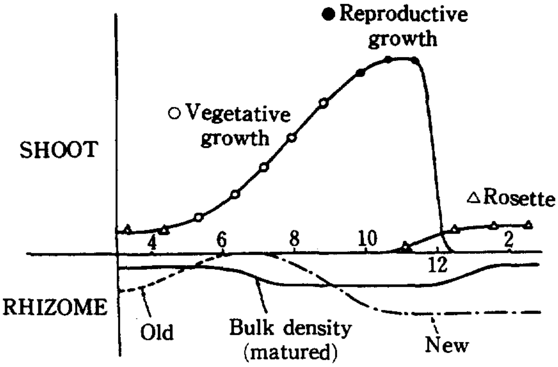



**Fig. 6.** Phenology of *Solidago altissima*. (Modified from Yukinaga, et al., 1975 and Iwaki, et al., 1969.)

location is affected by the timing and the means of application. Adequate application timing means during the stage of active symplastic translocation with enough leaf area for absorbing chemicals. The symlpastic movement of chemicals often synchronizes with photosynthate translocation. Gerenally in the first few months after spring flush the direction is mainly from the underground parts to the shoots consuming food reserves. Thereafter there is a critical period followed by the downward translocation. The trend is also apparent in the phenology of *S. altissima* demonstrated in Fig. 6. Glyphosate which

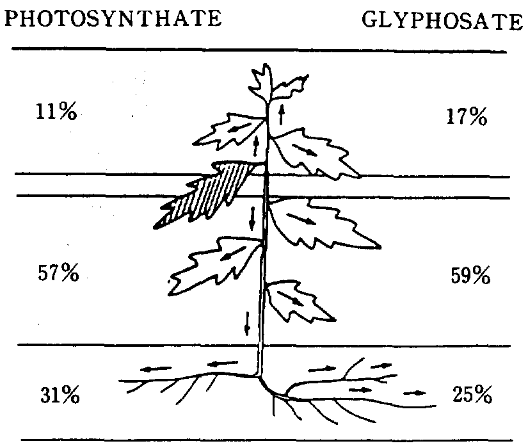



**Fig. 7.** Translocation of $^{14}$C-glyphosate and $^{14}$C-photosynthates in *Cirsium arvense* (Created from the data of McAllister et al., 1985). Figures indicate the percent allocation. Labelled compounds are treated on the leaf shaded and activit was counted 8 days after treatment.

is known to be more effective in late season application showed on allocation pattern very parallel to that of photosynthates in *C. arvense* (Fig. 7).

It is also important to prolong the translocation period, particularly when slow-acting chemicals such as glyphosate, or asulam are applied. Prolonged tissues life for symplastic translocation, mainly in the phloem, causes greater total translocation. There is much evidence that mowing within a week after application, or tank-mix with other fast-acting chemicals or with excess surfactant often results in insufficient control. In addition to these factors, the most effective chemicals may be expected to have a mode of action related to meristematic growth, i.e. they should have the potential to accumulate into the buds on subterranean systems and interfere with some process of bud formation or sprouting. In fact, most of the herbicides recognized effective to control some upland perennials are

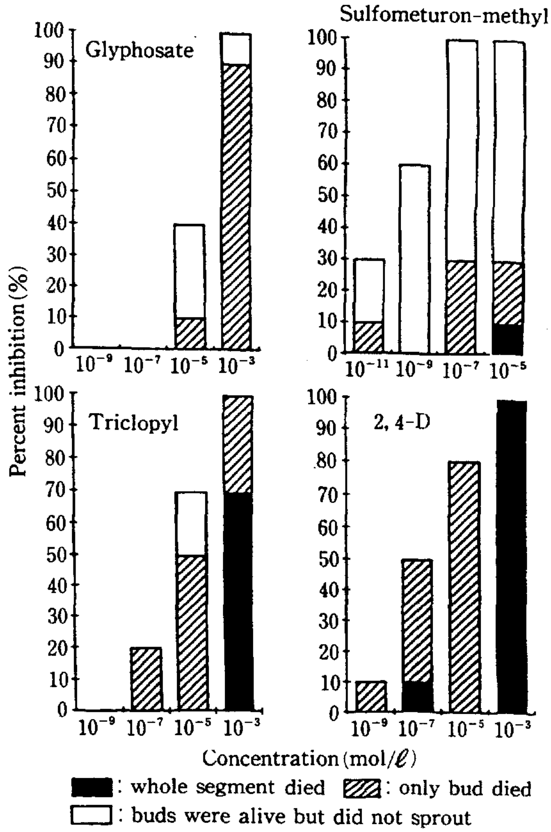



**Fig. 8.** Inhibition of bud-sprout of rhizome segments of *Solidago altissima* by herbicides applied in agar medium.

related either to protein synthesis or morphogenesis ; Glyphosate and sulfonylureas inhibit the aromatic and chain amino acid syntheses, respectively[2], asulam is involved in the inhibition of purine synthesis[14], while 2, 4-D and triclopyl may dusrupt the morphogenetic orientation at the meristematic regions. A study was conducted to confirm the direct effect on the rhizome buds of these chemicals. One-bud segments of *Solidago altissima* and *Calystegia hederacea* rhizomes were treated with several herbicides added in agar medium. The buds did not sprout at all in sulfometuron-methyl applied segments without showing necrosis in any part of the segments. Triclopyr and 2, 4-D, however, inhibited bud sprouting by killing rhizome tissue or the bud itself (Fig. 8). The fact that glyphosate, gluphosinate and asulam did not give good results may indicate the importance of whole plant systems for absorption and translocation of these chemicals. Further research is needed to evaluate chemicals for efficient direct effects on the buds in rhizome and creeping-root systems, as weel as to find additional measures to enhance the systemic downward movement of chemicals.

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