Ecology and Control of *Sagittaria pygmaea* in Paddy Fields

By SUEMA EGUCHI, MINORU TAKABAYASHI, HIDEJIRO SHIBAYAMA* and MASUJI MIYAHARA**

1st Crop Division, Kyushu National Agricultural Experiment Station
(Chikugo, Fukuoka, 833 Japan)

Introduction

The control of annual weeds in paddy fields has become quite easy, owing to recent development of many herbicides that show consistent effectiveness in controlling annual weeds without causing any damage to rice plants. However, perennial weeds have come to offer difficult problems by taking the place of annual weeds. In the Kyushu region, a perennial weed, *Sagittaria pygmaea* infests 57% of the total paddy field area.[1] Although several herbicides recognized as effective against *S. pygmaea* are available, their effectiveness is not consistent, showing insufficient effectiveness some times. The present study was carried out with an aim of establishing a reliable control method against *S. pygmaea*.

Materials and methods

Tubers of *S. pygmaea* were collected from many places. Of them, the tubers collected from paddy fields in Saga Prefecture, Nagasaki Prefecture and Ooita Prefecture were selected for the use in the present study, because they represent wide variations usually observed in characteristics of the tubers of *S. pygmaea* (Table 1).

The experiment was conducted for 5 years, from 1978 to 1982, on 4 different experimental plots of a paddy field in the Kyushu National Agricultural Experiment Station (Chikugo). On the first plot (plot 1) and the second plot (plot 2), the early season rice cultivation (transplanted in late April and harvested in late August) was practiced, and the plot 1 received occasional irrigation during the period from rice harvesting to rice transplanting in the next year to keep the field wet during that cropless period, while the plot 2 was kept drained during that period. On the other hand, on the third plot (plot 3) and the fourth plot (plot 4), the ordinary season rice cultivation (transplanted in mid-June, and harvested in the end of October) was practiced, and the plot 3 received occasional irrigation, while the plot 4 was kept drained during the cropless period.

Tubers of 3 different origins were planted to each plot at the rate of 3 tubers/m^2 at the start of the experiment. Then, the multiplication of the tubers (in term of the number of tubers increased), the number of rice panicles produced, and rice yields as affected by the weed were examined over a period of 5 successive rice crops.

Since it was shown by our previous research that pyrazolate was a herbicide which showed most consistent effectiveness in controlling *S. pygmaea* among many kinds of herbicides tested, pyrazolate (granule) was applied to the weed at the rate of 300 g/a at an early reproductive stage of rice of the second cropping.

Present address:
* Chugoku National Agricultural Experiment Station (Fukuyama, Hiroshima, 721 Japan)
** National Agricultural Research Center (Yatabe, Ibaraki, 305 Japan)

Table 1. Rate of tuber multiplication and mean tuber weight of *S. pygmaea* used for the study

Tuber collected from	Number of multiplied tubers*		Mean tuber weight (mg)	
	Irrigated in autumn	Non-irrigated in autumn	Irrigated in autumn	Non-irrigated in autumn
Saga	490	429	28	52
Nagasaki	459	407	34	67
Ooita	325	264	46	80

* Tubers were multiplied in pots containing paddy field soil, with or without irrigation in autumn. Initial number of tubers was 2/50×25 cm area. The number of multiplied tubers/50×25 cm after 1 year is given.

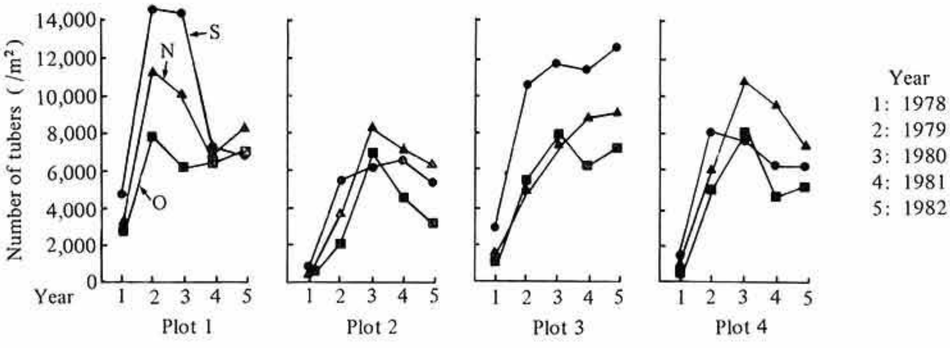

Fig. 1. Changes in the number of tubers observed each year

Results

1) Multiplication pattern of S. pygmaea in paddy fields

Changes in the number of tubers observed each year of 5 successive rice crops are shown in Fig. 1. In the plot 1, the number of tubers increased remarkably from the first year to the second year, and then it turned to decrease after the second year. The remarkable increase in the number of tubers occurred in the plot 1 was caused by high temperature and irrigated field condition which lasted during the period from rice harvesting (late August) to late October. On the contrary, the number of tubers in the plot 2 was apparently less than that of the plot 1 because the field of the plot 2 was kept dry without irrigation after rice harvest, and such dry condition caused withering the top part of the weed.

Changes in the number of tubers observed in the plots 3 and 4 were roughly similar to those in the plots 1 and 2, but the difference between the plots 3 and 4 was not so apparent as in the case between the plots 1 and 2, probably due to low temperature after rice harvest (end of October for the ordinary season rice cultivation).

Thus, it was clearly shown that the temperature and water conditions of paddy fields in the cropless period after rice harvest strongly influenced the rate of multiplication of the weed tubers.

2) Growth and yield of rice crop as affected by the weed

Changes in the number of panicles/m² of rice plants in 5 successive years are shown in Fig. 2. In the first year, no appreciable reduction in the number of panicles of rice plants occurred in most cases in the early season cultivation, whereas slight reduction was observed in the ordinary season cultivation. From the second year onwards, the panicle number was reduced in response to the multiplication of the weed. The degree of reduction was greater in the irrigated plots than in the drained plots.

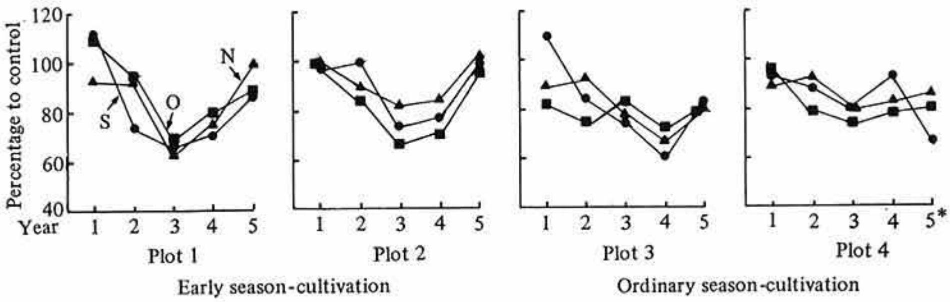

Fig. 2. The number of rice panicles as affected by *S. pygmaea*
* Year 1, 2, 3, 4, 5: See Fig. 1.

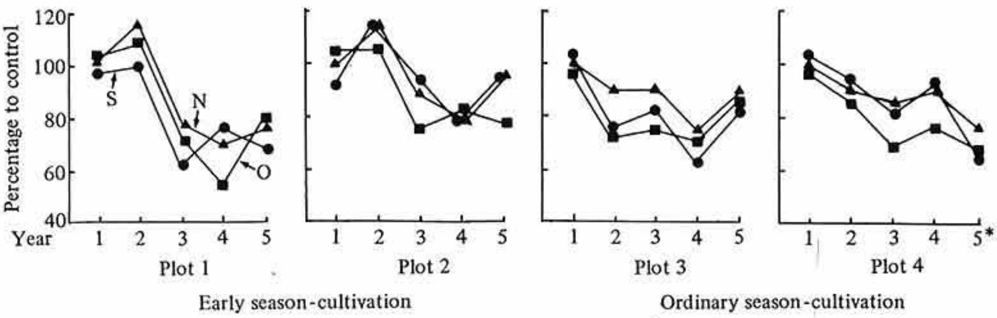

Fig. 3. Grain yield of rice as affected by *S. pygmaea*

Table 2. Appropriate time-range for application of main herbicides to control *S. pygmaea* and their effectiveness as influenced by various factors

Herbicides	MCPA G.	Bentazone G.	ACN G.	Naproanilide G.	Pyrazolate G.
Time-range for application	Post-emergence～ early reproductive stage	Post-emergence～ early reproductive stage	3-4 leaf stage	Pre-emergence～ early reproductive stage	Pre-emergence～ early reproductive stage
Degree of effectiveness as related to transplanting time	E＝O (Effective)	E<O	E<O	E<O	E＝O (Effective)
Degree of effectiveness as related to water leakage of paddy fields	L≠Non-L	L≪Non-L	L<Non-L	—	L<Non-L
Decrease of effectiveness by rainfall	Big	Big	Little	Little	—

E : Early rice-transplanting field
O : Ordinary rice-transplanting field
L : Water leakage condition
Non-L: Non-water leakage condition
—: Not determined

Rice yields are shown in Fig. 3. Due to the multiplication of the weed, yield reduction began to occur in the second year with the ordinary season cultivation, and in the third year with the early season cultivation. The reason for the occurrence of yield reduction in the third year, but not in the second year with the early season cultivation was that the

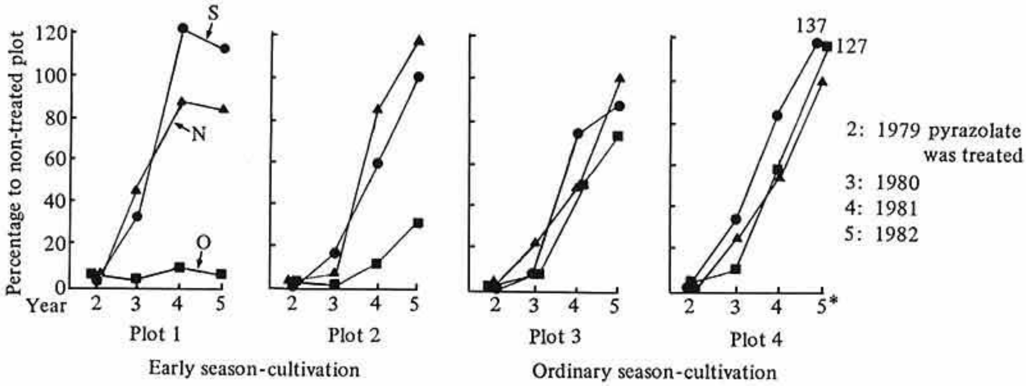

Fig. 4. Yearly trend of the number of tubers after the application of pyrazolate

Tabl 3. Effect of removal (pulling out) of emerged tubers of *S. pygmaea* on the survival of the weed

Plot		Number of emerged tubers of *S.pygmaea* (/pot)					
		Year					
		1st	2nd	3rd	4th	5th	Total
Saga	Plot 1	1,042	35	0.3	0	0	1,077
	2	943	144	2.0	0	0	1,089
	3	1,495	40	0	0	0	1,535
	4	1,398	167	1.3	0	0	1,566
Nagrsaki	Plot 1	1,176	87	0	0	0	1,263
	2	990	238	2.0	0	0	1,230
	3	1,573	47	0.3	0	0	1,620
	4	1,113	121	2.3	0	0	1,236
Ooita	Plot 1	598	104	0.7	0	0	703
	2	389	284	3.0	0	0	676
	3	545	115	0	0	0	660
	4	484	271	15.0	0	0	770

Emerged tubers were removed in the year 1st, 2nd and 3rd from pots simulating the plots 1, 2, 3 and 4 of the field experiment.

yield of the control plots without the weed was decreased by lodging occurred in the second year. Although such variation occurred, it was apparently recognized that the yearly trend of yield reduction in 5 years corresponded to the yearly trend of panicle number reduction.

From these results shown above, it can be estimated that when *S. pygmaea* infests paddy fields to the maximum extent in warm regions, rice yield will be reduced by 20–30%.

3) Methods of control of S. pygmaea

Effect of many kinds of herbicides on *S. pygmaea* was examined by the authors for the past 10 years. Although the effectiveness of these herbicides varied due to many factors such as time of transplanting, water leakage in paddy fields and rainfall, pyrazolate granules showed the most consistent effectiveness among them as shown in Table 2.

Therefore granular pyrazolate was applied in the second year (1979), and yearly trend in the number of tubers was examined in the following years (Fig. 4). The result showed that the application of pyrazolate was very effective in killing the weed, but the number of tubers increased enormously after the next year, indicating clearly that a single application is not able to kill all the tubers in the soil.

In this connection, a simple pot experiment was carried out. Tubers of *S. pygmaea* were multiplied in the pots simulating the field conditions of the plots 1, 2, 3, and 4 of the field experiment. Then, all the tubers which emerged were removed by pulling them out. However, in the next year a certain number of emerged weeds were observed. By removing all of them, almost no emergence was found in the third year (Table 3). This result suggests the need of repeated application of pyrazolate from year to year at least for 2–3 years.

When the weed-infested field is rotary-tilled several times during winter, the tubers in the soil must have been dug up to the soil surface and directly exposed to low air temperature and drought.[2] This agronomic treatment was proved by our experiment to be very effective in controlling the weed. However, as this is a result obtained in only one year, further confirmation experiments are now in progress.

Summary

1) Temperature and water conditions of paddy fields in the cropless period after rice harvest strongly influenced the rate of multiplication of tubers of *Sagittaria pygmaea*.

2) Infestation of *S. pygmaea* in paddy fields reduces the number of rice panicles produced, and causes a substantial yield reduction of rice.

3) Pyrazolate was recognized as a useful herbicide against the weed, because it showed a consistent killing effect under various conditions. However, it was found that pyrazolate must be applied repeatedly for at least 2–3 years in order to get perfect effect of control.

4) Rotary-tilling of paddy fields several times during winter was found a very effective agronomic control method against the weed.

References

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