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The Potential of *Gastrophysa viridula* as a Biological Control Agent for *Rumex obtusifolius*

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ABSTRACT: This study was carried out to see whether *Gastrophysa viridula* (Degeer) (Coleoptera: Chrysomelidae) could be used as a biological control agent for *Rumex obtusifolius* L., with human manipulation of the beetle population. The study was consisted of three experimental sets: Wet-Dry experiment (the wet weight Vs dry weight relationship of *Rumex obtusifolius* L.), Greenhouse feeding experiment, and Field experiment. There was a significant correlation between the total wet and dry weight of *Rumex obtusifolius* as follows: Total dry weight = $-0.23542 + (0.17514 \times$ Total wet weight) ($R^2=0.9317$, $p=0.047$, $T=16.927$ ($dF=21$)). In the Greenhouse feeding experiment, the result was very promising. The relationship between the density unit of the beetles and the growth of the plant is given below (20 day): Plant growth $=105.8 + (-34.4 \times$ Density unit) ($R^2=0.76$, $p=0.13$). A repeated introduction of the beetle population into the field vegetation of *R. obtusifolius* from April to October is suggested to see the beetle's grazing ability on the plant. This study shows that the potential grazing power of the beetle on *Rumex obtusifolius* was enough to defoliate the plants, but it was able to recover from its root reserves. The practical question remains as to whether repeated additions (by man) of the beetles to *Rumex obtusifolius* could eliminate them.

Key Words: Broad-leaved dock, Green dock beetle, Herbivory, Phytophage.

INTRODUCTION

A number of authors (Huffaker 1953, Harper 1970, Peschken and Beecher 1973, Harris 1973) showed that relatively minor herbivory by invertebrates can cause profound effects on the abundance and resistance of plant species. But their effects are dependent upon various conditions. First of all, most phytophages can find their host more efficiently when no other plant species are present to interfere. This is especially true for *Gastrophysa viridula* as shown by Smith and Whittaker (1980a, 1980b). Secondly, *G. viridula* is a seasonal specialist, because they are active from April through October. There are periods during this time when grazing by the beetle is not intense. This gives *R. obtusifolius* a chance to recover from the damages caused by the beetle.

Speight and Whittaker (1987) have considered the use of *G. viridula* as a biological control agent for *R. obtusifolius*, but concluded that under normal conditions it would need to be used in conjunction with herbicide.

This study was carried out to see whether *Gastrophysa viridula* (Degeer) (Coleoptera: Chrysomelidae) could be used as a biological control agent for *Rumex obtusifolius* L., with human manipulation of the beetle population.

MATERIALS AND METHODS

Plant

The broad-leaved dock plant, *Rumex obtusifolius* L. is a widespread weed plant in the United Kingdom (Cavers and Harper 1964, Cottam *et al.* 1986). The plant shows considerable resistance to human disturbance, grazing by herbivores as well as to herbicide, mainly due to its extensive root system.

Two hundred and fifty *Rumex obtusifolius* seeds collected in the ground of Lancaster University were sown in John Innes Compost on March 1990 for experimental use, and watered daily. After being grown, the plants were transplanted into 7.5 cm diameter pots on 4 April, and they were transplanted again into the 10.5 cm diameter pots on 28 April.

In order to release sufficient number of beetles into the field, optimum rearing condition of *Gastrophysa viridula* in the laboratory was followed (Kwon 1996).

Insects

The green dock beetle, *Gastrophysa viridula* (Degeer) is an oligophagous herbivore whose main host plant is broad-leaved dock (Smith and Whittaker 1980b). They are commonly seen on the dock leaves from late April to early

October.

Thirty *G. viridula* (17 males and 13 females) were captured from the area around the campus of the University of Lancaster on 17 and 18 April 1990. The beetles were reared in the plastic box of 100 cm × 35 cm × 50 cm with a ventilation window on each side. Abundant amount of *R. obtusifolius* leaves were put into the box every 3 days, and old leaves were removed from the box. Then the offsprings from the box were put into the boxes of 18 cm × 18 cm × 10 cm with a 3 cm^2 ventilation window on each side for experimental use. Temperature in the laboratory was at 17 ~ 23℃, and fresh leaves of *R. obtusifolius* were added every 3 days.

METHODS

Wet-Dry experiment

Twenty two *R. obtusifolius* (12 from the field, 10 from the greenhouse culture) were used for the experiment. They were randomly selected on 2 June 1990. The plant from the field was taken with the soil containing the root (30 cm^2 × 50 cm depth). The root of each plant from both the field and the culture was washed carefully with water. The wet weights of the individual plants were recorded. The plants were put in a drying chamber for 7 days and dried to constant weight. The dry weights of the individual plants were recorded. Each plant was measured for total height, root length, shoot height, total wet weight, and total dry weight.

Greenhouse feeding experiment

Sixteen plants from greenhouse culture were randomly selected and used in the experiment, from 9 July to 3 September 1990. A density unit of the beetles was defined in order to measure the effects of the beetle on the plant. One density unit was arbitrarily set as one gravid female and two males. All the beetles were from a laboratory cohort. Cages were made with two metal rings, each measuring 46 cm in diameter, with a fine net fabric to contain the first instar larvae of *G. viridula*. The length of the cages was about 58 cm. Sixteen plants (3 plants for 15-day experiment, 13 cages for 20-day experiment) were put in the greenhouse where temperature varied from 21℃ to 35℃, and photoperiod was adjusted to 16L : 8D. The cages were categorized into three:

Control: a plant without the beetles
(5 cages: 1 for 15-day experiment, 4 for 20-day experiment)
Density unit 1: a plant with 1 gravid female and 2 male beetles
(5 cages: 1 for 15-day experiment, 4 for 20-day experiment)
Density unit 2: a plant with 2 gravid female and 4 male beetles
(6 cages: 1 for 15-day experiment, 5 for 20-day experiment)

All the plants were watered daily.

Field experiment

Strips of land at the University of Lancaster campus (SD 485585), originally ploughed and used as tree nurseries, were chosen for the field experimental site. This site was ploughed in early July 1990, approximately one month before the field experiment. The vegetation in the field consisted of various plants. The dominant species was *Holcus lanatus* L. and also *Ranunculus repens, Polygonum aviculare, Achillea millefolium, Taraxanum officinale* were found. Four experimental plots were chosen randomly in the field site, approximately 10 meters apart. Each plot was 2 m × 2 m in size, divided into 25 small plots of 40 cm × 40 cm in size. Fig. 1 shows the arrangement of each plot. Four plants were put into each plot at positions B2, D2, B4, D4. The ground was excavated to 50 cm depth for planting.

The beetles added to the field plot were from a laboratory cohort, and the plants used were from greenhouse culture. Ten gravid female and forty male beetles were released into each of 2 plots, affecting a total of 8 plants. The other two were control plots. All the plots were visited every other day. In each plot, two of the plants were put in pots sunk to ground level to prevent interspecific competition with surrounding grasses. The other two were transplanted in the ground. Any adults or eggs of *Gastrophysa viridula* which appeared in the control plots from dispersing beetles were removed by hand. The experiment started on 6 August and finished on 3 September 1990. After the experiment, the plants were washed

A	B	C	D	E
	B2		D2	
	B4		D4	

Fig. 1. Experimental plot design of field experiment.

and dried in the same manner as Wet-Dry experiment for data processing.

RESULTS

Wet-Dry experiment

Table 1 shows the results of the Wet-Dry experiment. There was a significant relationship between the wet and dry weight of the total *Rumex obtusifolius* plant. The regression is given below:

Total dry weight
$= -0.23542 + (0.17514 \times \text{Total wet weight})$
$r^2 = 0.9317 \quad p = 0.047$
$T = 16.927 \ (dF = 21)$

Fig. 2 shows the relationship between the wet and dry weight of R. obtusifolius plant with data points obtained from the experiment.

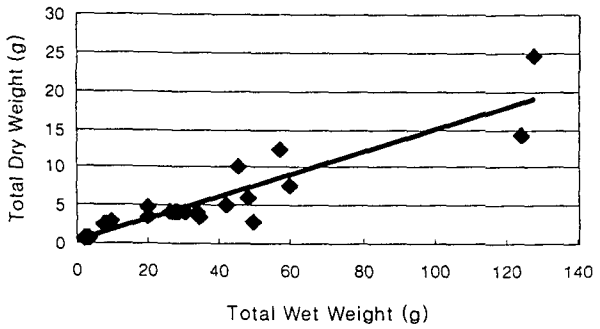

Fig. 2. Relationship between the wet and dry weight of *Rumex obtusifolius* (total plant) with a regression line.

Greenhouse feeding experiment

Table 2 shows the results of the greenhouse feeding experiment. In 15 day exploratory experiment, it was found that the beetles were not having a very marked effect on plant growth. This was probably because the third instar (which has the highest rate of consumption) had not been reached by this time.

In the 20 day experiment, the result was very promising. The relationship between the density unit of the beetles and the growth of the plant is given below (20 day):

Plant growth $= 105.8 + (-34.4 \times \text{Density unit})$
$r^2 = 0.76, \ p = 0.13$

The ratios of mean total root dry weight to mean total shoot dry weight on *R. obtusifolius* were increased as the grazing of *G. viridula* got more intense: Control = 1.93, Density 1 = 2.07, and Density 2 = 2.72. This result confirmed that *R. obtusifolius* responds to grazing with an increase in the root : shoot biomass ratio (Cottam *et al.* 1986).

Field experiment

Table 3 shows the results of the field exper-

Table 1. The data of the individual plants in the experiment for the wet weight vs. dry weight relationship of *Rumex obtusifolius*

Plant No.	Total Height (cm)	Root Length (cm)	Shoot Height (cm)	Total wet weight (g)	Total dry weight (g)
1	67	8	59	56.88	12.26
2	24	7	17	7.55	2.49
3	25	5	20	3.18	0.57
4	23	8	15	9.86	2.80
5	34	10	24	19.77	4.76
6	26	7	19	8.04	2.52
7	20	9	11	2.58	0.71
8	11	3	8	1.92	0.62
9	62	28	34	124.13	14.19
10	61	25	36	19.89	3.60
11	62	17	45	127.68	24.63
12	38	14	24	45.42	10.23
13	51	26	25	27.42	4.07
14	57	26	31	33.60	4.22
15	49	24	25	26.19	4.02
16	52	27	25	28.40	4.16
17	43	21	22	34.48	3.35
18	45	25	20	59.87	7.51
19	57	32	25	48.09	5.89
20	42	20	22	30.10	4.23
21	44	24	20	41.95	5.05
22	47	21	26	49.56	2.72

Table 2. The dry weights of the plants used in the greenhouse feeding experiment and percentage of growth (* = Arcsine transformation)

Duration	Type	Initial Dry Weight		Final Dry Weight		% Growth
15 days	Control		18.63		31.77	70.6
	Density 1		13.93		22.21	59.4
	Density 2		15.48		20.55	32.8
20 days	Control	Mean	19.06	Mean	41.62	121.15
		S.E.	2.05	S.E.	3.48	11.79*
	Density 1	Mean	21.11	Mean	37.32	70.58
		S.E.	1.41	S.E.	3.80	5.66*
	Density 2	Mean	22.07	Mean	32.14	45.54
		S.E.	2.42	S.E.	3.75	2.99*

Table 3. Conditions of the plants used in the field experiment with their initial and final dry weights and percentage growth

Plant No.	Plot No.	Status	I.D.W.(g)	F.D.W.(g)			% Growth
				T.S.	T.R.	T.W.	
1 (potted)	A	Con	22.01	8.28	34.13	42.41	92.7
2 (potted)	A	Con	26.74	5.65	26.82	32.47	21.5
3 (potted)	B	Con	23.93	3.33	25.67	29.00	24.5
4 (potted)	B	Con	24.63	2.53	26.47	29.00	21.4
		Mean:	24.33	4.95	28.27	33.22	40.03
		S.E.:	0.98	1.29	1.97	3.17	11.52*
5	C	Con	17.63	4.85	17.15	22.00	21.2
6	C	Con	22.53	4.98	22.38	27.36	17.9
7	D	Con	17.98	2.39	19.92	22.31	24.1
8	D	Con	18.33	9.78	27.94	37.72	105.8
		Mean:	19.12	5.50	21.85	27.35	42.25
		S.E.:	1.15	1.55	2.30	3.67	19.19*
9 (potted)	C	Exp	17.10	3.33	18.80	22.13	29.4
10 (potted)	C	Exp	26.04	5.40	34.05	39.45	51.5
11 (potted)	D	Exp	21.31	7.17	36.23	43.40	26.9
12 (potted)	D	Exp	15.35	8.42	23.26	31.68	37.2
		Mean:	19.95	6.08	28.09	34.17	36.25
		S.E.:	2.38	1.11	4.20	4.69	3.28*
13	C	Exp	25.69	4.64	27.96	32.60	103.7
14	C	Exp	13.78	2.09	16.81	18.90	106.4
15	D	Exp	20.26	5.24	21.46	26.70	31.8
16	D	Exp	19.73	8.02	24.55	32.57	65.1
		Mean:	19.87	5.00	22.70	27.69	76.75
		S.E.:	2.44	1.22	2.37	3.24	17.45*

Con = Control
I.D.W. = Initial Dry Weight
T.S. = Total Shoot Dry Weight
T.W. = Total Dry Weight
Exp = Experimental
F.D.W. = Final Dry Weight
T.R. = Total Root Dry Weight
* = Arcsine transformation

iment. The growth (%) shows no significant differences (p never less than 0.29) among the plants as noted:

Plant 1~4: p = 0.54 Plant 5~8: p = 0.98
Plant 9~12: p = 0.48 Plant 13~16: p = 0.29

Those which grew more than 50% of the original dry weight had new leaves grown in considerable biomass. However, there was no indication of significant defoliation by the beetles on any of the experimental plants (p never less than 0.72). Also, there was no indication of interspecific competition among plants (p never less than 0.55).

DISCUSSION

Two important factors were observed during the period of the *Greenhouse feeding experiment.* First, even though the above-ground part of the plant was defoliated successfully by the beetle, root reserves remained and so it

would be necessary to repeat the addition of the beetles as soon as the new leaves begin to grow. Second, the individual fecundity of the female beetle was a significant factor in the successful defoliation of the plant rather than the simple numerical quantities of the beetles.

The period of 20 days for the *Greenhouse feeding experiment* was appropriate since by that time most of the third instar larvae of *G. viridula* were beginning to pupate. However, in the field a lot of time would be needed to compensate for the lower temperature, predation, and bad weather. Since time was not available, further experiments could not be performed. Repetition of the 20 day experiment on the same plant over a period of time is strongly recommended to give a more complete picture in the relationship between the density of the beetle and the growth rate of the plant.

There were several problems involved in the *Field experiment*. As Bach (1980) stated, insects are less inclined to stay on their host in polyculture than in monoculture. Also, the larval survival of *G. viridula* is reduced in floristically diverse habitats (Smith and Whittaker 1980a). Together with the dispersal of the adult beetles, these factors decreased the effect of *G. viridula* grazing on the experimental plants. But, most of all, there was not sufficient time to allow the beetles to defoliate the plants successfully. When the plants were dug up on 3 September, many egg batches and first instar larvae of the beetle were found on the experimental plants. Therefore, a repeated introduction of the beetle population into the field vegetation of *R. obtusifolius* for the period of April to October is suggested to see the beetle's grazing ability on the plant.

The study showed that the potential grazing power of the beetle on *R. obtusifolius* was enough to defoliate the plants, but it was able to recover from its root reserves. The practical question remains as to whether repeated additions (by man) of the beetles to *R. obtusifolius* could eliminate them.

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