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STUDIES ON THE HOST SPECIFICITY OF *GASTROPHYSA ATROCYANEA* MOT. (COL.: CHRYSOMELIDAE), A POTENTIAL BIOLOGICAL CONTROL AGENT AGAINST *RUMEX OBTUSIFOLIUS* L. (POLYGONACEAE) IN JAPAN

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INTRODUCTION

In the grasslands of Japan, *Rumex obtusifolius* L. is a troublesome weed. This plant of Eurasian origin was first introduced to the northern part of Japan and it has spread recently and rapidly to attain a weed status on account of its strong propagating power. The possibility of the biological control of the weed is being considered because chemical or mechanical methods have certain limitations and difficulties.

Among 40 or more species of insects which are known to feed on *R. obtusifolius* in Japan a chrysomelid, *Gastrophysa atrocyanea* Mot. was chosen as a possible agent, since it is oligophagous and causes considerable damage to the weed in spring. During 1972 and 1973 studies were made to clarify the host specificity and host preference of the beetle. The following discussion concerns the results of the tests on feeding and ovarian development of the adult, larval development and host preference of the adult.

Outline of the life-history of G. atrocyanea

G. atrocyanea is univoltine, hibernating in the soil as adult. In early spring overwintered adults begin to feed on *R. obtusifolius* and certain other Polygonaceous plants, and deposit eggs on the leaves of the host plants. After three moults larvae pupate in the soil from late spring to early summer. Several days later the adults emerge for several days, fall on the ground, enter diapause and hibernate. In the middle part of Japan, the active period of the insect is from late March to early July.

MATERIAL AND METHOD

Adults that hibernated in the laboratory under normal temperatures were used in the tests on the ovarian development and host preference. Before fed on

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any plant host, they were tested just after they became active or were kept under a constant temperature of 5°C. until the tests were started. In the latter case, the beetles were placed under the experimental conditions and were kept there and starved before the tests were started in order to acclimatize them to the conditions.

For the feeding and host preference tests with newly emerged adults, larvae were collected in the field and reared on *R. obtusifolius*. The adults as they emerged were kept under the experimental conditions for one or two days until their bodies became sufficiently strong.

In the test of larval development, larvae that had just hatched were used.

All the experiments were at a constant temperature of 20°C. and under fluorescent light set at a 16-hr photoperiod. Petri-dishes of 85 × 20 mm. with wet filter papers at the bottom were used for all tests.

The experiments were of two types: (a) basic feeding test in which adults or larvae were offered single plant species; and (b) preference tests where the insect was able to choose between two or more possible host plants.

THE FEEDING TESTS

Feeding and ovarian development of the overwintered adult.

These were designed to demonstrate the range of plants that are acceptable to the insect and that are suitable for its ovarian development. Forty plant species belonging to 12 families were offered to the overwintered adults. Usually 10 females were fed individually on each test plant species. Amount of feeding and the number of eggs deposited were recorded every day until all the beetles were dead (Table 1).

It was found that females developed ovaries only on the plants belonging to Polygonaceae. All the females tested fully developed their ovaries when fed on *R. obtusifolius* and had the highest fecundity (average number of eggs deposited being 1440) when fed on *R. obtusifolius*. *R. longifolius* D. C. also proved to be suitable for the ovarian development (giving 502 eggs on an average). On the contrary, small numbers (100) of eggs were deposited on *Rumex acetosa* L. and no ovarian development was observed on *R. acetosella* L.

Polygonum spp. were less suitable than *Rumex* (*Lapathum*) spp. However, considerable numbers of eggs were laid on *P. filiforme* Thunb. (average number of 207), *P. perfoliatum* (183), and *P. sagittatum* L. var. *aestivum* Makino (128). On *P. cuspidatum* Sieb et Zucc. where only light to moderate feeding was observed, only one female laid 201 eggs. *P. thunbergii* Sieb et Zucc. was unsuitable as host, as none of the females tested developed their ovaries.

TABLE 1

Feeding and fecundity of *Gastrophysa atrocyanea* on various plants.
1-1: Fecundity of the over-wintered adult; 1-2: Feeding of the newly emerged adult; 1-3: Larval development.

	1—1					1—2				1—3			
	Mean no. of eggs deposited					Degree of feeding				Larval development attained to: Instar			Adult
	0	1-100	101-200	201-300	500-1500	−	+	++	+++	I	II	III	
Polygonaceae													
Rumex (Lapathum)					2				4				4
Rumex (Acetosa)		1							1			1	
Rumex (Acetosella)	1						1			1			
Polygonum	1	1	2	1			1	4	5	3			8
Fagopyrum		1						1	1	1		1	
Amaranthaceae	2					1	1			2			
Caryophyllaceae	3						1	1	1	2	1		
Chenopodiaceae	1					2				2			
Compositae	3					3				3			
Convolvulaceae	2					3				3			
Cruciferae	5					2	5			7			
Leguminosae	6					6	1			6			
Malvaceae	2					2				2			
Poaceae						2	1			3			
Solanaceae	2					2				2			
Violaceae	2						1			2			
Vitaceae	2					2				2			

The figures in the table show the number of plant species that fall in each category. Degree of feeding is graded as follows: − : no feeding (0 mm²), + : nibbling or small amount of feeding (less than 50 mm²), ++ : light to moderate feeding (50-200 mm²), +++ : moderate to heavy feeding (more than 200 mm²).

A considerable amount of feeding was observed on *Fagopyrum esculentum* Moench., but ovarian development was poor on this plant; of the 10 females tested only 5 developed their ovaries and only one laid 26 eggs. Remarkably, among the non-Polygonaceous plants tested, some feeding was observed on *Stellaria media* Villars and to a lesser degree on *Malachium aquaticum* Fries both of Caryophyllaceae. However, ovarian development never occurred on these plants. No appreciable feeding occurred on the other plants.

Feeding of the newly emerged adults

At the time when the adults first emerge, many plants begin to grow in the field. For these experiments 55 plant species belonging to 13 families were selected from those available in the field at this season and from those grown in the laboratory. Twenty newly emerged adults were used for the feeding test on each plant. They were tested individually and the amount of leaf consumed was measured after 72 hours' feeding (Table 1).

Again in the newly emerged adult, appreciable feeding was observed almost exclusively on Polygonaceous plants. Heavy feeding occurred on *Rumex* (*Lapathum*) spp. including *R. obtusifolius* (feeding amount averages 527 mm^2), *R. acetosa acetosa* (259), and such species of *Polygonum* as *P. filiforme* (714), *P. persicaria* L. (391), *P. longisetum* De Bruyn (333), *P. lapathifolium* L. (234) and *P. sagittatum* var *aestivum* (267). A considerable amount of feeding was observed on *F. esculentum* (398), whilst on *F. cymosum* Meisn. feeding was not so outstanding (126).

Among the non-Polygonaceous plants *S. media* was consumed to a considerable extent (365); but feeding on *M. aquaticum* was slight (70). Most other plants were not accepted by the beetles at all. Slight feeding of not more than 30 mm^2 on average was observed on some plants belonging to the following genera:— *Amaranthus* (Amaranthaceae); *Dianthus* (Caryophyllaceae); *Brassica*, *Capsella*, *Nasturtium* and *Raphanus* (Cruciferae); *Vicia* (Leguminosae); *Phleum* (Poaceae); *Viola* (Violaceae).

Development of larvae

These tests were aimed at discovering the range of plants on which larvae of *G. atrocyanea* could complete their development. Fifty-six species of plants belonging to 13 families were tested (Tables 1-3). Generally the test for each plant species was conducted in 5 replications of a collective rearing of 10 larvae.

The acceptability of plants for larval feeding and their suitability for larval development are more strongly restricted than in the case of adults. Almost all the non-Polygonaceous plants tested were either unacceptable or unattractive; many of the larvae immediately abandoned such test plants and all the larvae starved

to death within two or three days without attempting to feed. Appreciable feeding was observed only among certain Caryophyllaceous plants; *S. media* was accepted readily and fed on to a remarkable extent, and *M. aquaticum* was also consumed but to a slighter degree. These plants, however, could not support larval development to maturity; on *S. media* the larvae did not attain the 3rd instar, though 23% of them attained the 2nd, and on *M. aquaticum* all the larvae died in the 1st instar.

Of the Polygonaceous plants tested, *Rumex* (*Lapathum*) spp., *R. obtusifolius*, *R. crispus* L. ssp. *japonicus* Kitamura, *R. conglomeratus* Murr. and *R. longifolius*, all of which belong to the subgenus *Lapathum*, fully supported rapid larval development to the adult stage. On *R. acetosa* and *R. acetosella* the larvae died in the 3rd and 1st instar respectively. *P. persicaria* and *P. filiforme* were accepted readily and larvae rapidly developed to adults on these plants. On the contrary, *P. cuspidatum*, *P. nepalense* Meisn. and *P. thunbergii* were fed on little, all the larvae dying in the first instar. Other *Polygonum* spp., including *P. aviculare* L., *P. longisetum*, *P. sagittatum* var. *aestivum* and others, supported some larval development as far as maturity, but the mortality of the larvae was high and the emerging adults were usually rather small in size.

F. esculentum was readily accepted, and yet a greater part of larvae perished in the first instar, and only a few developed to 2nd or 3rd instar and none to the adult stage. On *F. cymosum* all larvae died in the first instar.

HOST PREFERENCE TESTS

The preference tests were of two types: in the first set the insects were offered a choice between two plant species (a couple) and in the second set the choice was between 3—5 plant species.

Coupled plant test

Various plants were offered in couples for the choice of adults of *G. atrocyanea* to determine its host preference. For each of the coupled test plants, two pieces of leaves of a uniform size were prepared and placed alternately along the perimeter of the petri-dish. Ten females and 10 males were used for each couple of plant species. These were reared individually and the feeding amount was recorded 48 hours later.

In the coupled plant test with overwintered adults of *G. atrocyanea*, *R. obtusifolius*, *R. crispus* ssp. *japonicus*, *R. acetosa*, *R. acetosella* and *Spinacia oleracea* L. were used. *Rumex* spp. used in this test are commonly found in the field when the overwintered adults of *G. atrocyanea* appear, they constitute the principal group of plants among which the beetle would choose in the field. The test plants were coupled in all possible combinations.

As is apparent from Fig. 1, preference for *R. obtusifolius* and *R. crispus* ssp. *japonicus* is much stronger than for others. When *R. obtusifolius* and *R. crispus* ssp. *japonicus* were coupled, the latter was preferred.

Another coupled plant test with *R. obtusifolius*, *P. filiforme*, *P. sagittatum* var. *aestivum*, *F. esculentum* and *S. media* also used overwintering adults. These plants were selected because they were the plants on which high feeding had been observed in the feeding test with the newly emerged adults. The results are shown in Fig. 2.

It should be noted that preference for *P. filiforme* was as high as for *R. obtusifolius*. Compared to these plants, *P. sagittatum* var. *aestivum* and *S. media* were not so attractive. Feeding on *F. esculentum* greatly varied from test to test. This variability, considered with the high larval mortality and contrasted with the high larval feeding acceptability suggests the presence of certain toxic substances in the plant. This plant is known to be toxic to *G. cyanea* (Force, 1966).

The other coupled plant test with *R. obtusifolius*, *P. persicaria* and *P. longisetum* was made using on this occasion newly emerged adults. *P. persicaria* and *P. longisetum* are among the plants on which feeding of *G. atrocyanea* has been observed in the field. As these plants are usually still small in the field when the overwintered adult becomes active, the test was undertaken using the newly emerged adult. Though variation was large in the test, it is worth noticing that preference for *P. persicaria* was not lower than for *R. obtusifolius*.

Multiple-choice test

Adults of *G. atrocyanea* were presented with five different species of plants simultaneously to choose from. The following combinations of plants were used.

(1) *R. obtusifolius*, *R. crispus* ssp. *japonicus*, *R. acetosa*, *R. acetosella* and *S. oleracea*.

(2) *R. obtusifolius*, *P. filiforme*, *P. sagittatum* var. *aestivum*, *P. cuspidatum* and *F. esculentum*.

(3) *R. obtusifolius*, *P. persicaria*, *P. longisetum*, *P. sagittatum* var. *aestivum* and *F. esculentum*.

A leaf piece of a uniform size was punched out from each of 5 plants that constituted a group. The 5 leaf pieces were placed around the perimeter of the petri-dish. Two arrangements of leaf pieces were adopted, one with 5 plant species (a-e) arranged clockwise in the order of a-b-c-d-e and in another with the plants arranged a-d-b-e-c. Ten females and 10 males were used in the test for each plant group in

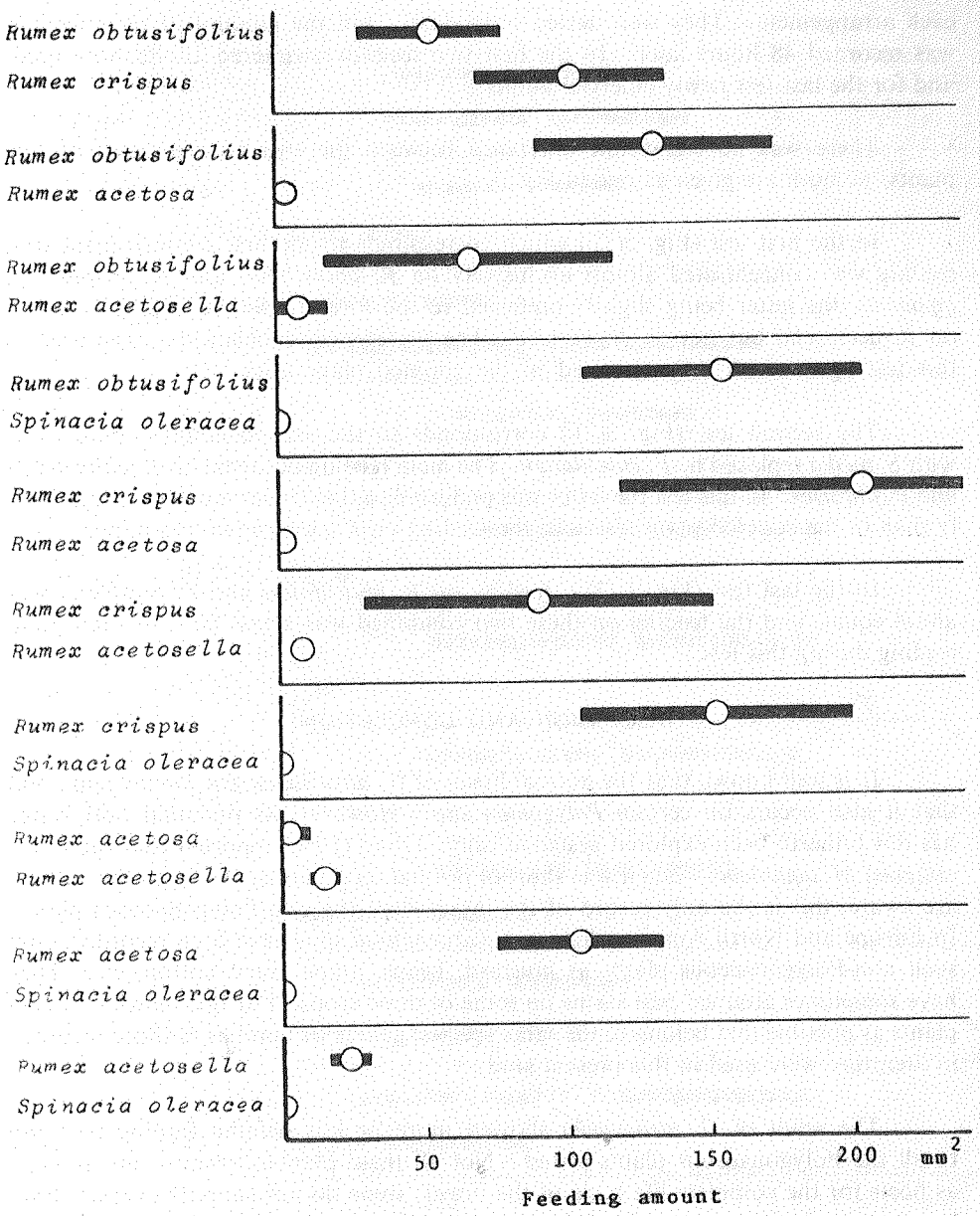

Fig. 1. Coupled plant test with adults of *Gastrophysa atrocyanea* on every combination between *Rumex obtusifolius*, *R. crispus* ssp. *japonicus*, *R. acetosa*, *R. acetosella* and *Spinacia oleracea*. Open circle in the figure indicates the mean amount of feeding, black bar the standard deviation. Results for females are given.

each arrangement. They were tested individually and the amount of their feeding was recorded 48 hours later. In the first two tests overwintered adults were used, and for the last test newly emerged adults.

There was no significant difference between the two arrangements of test plants, so both are given as one in Fig. 3.

In the first test (Fig. 3(1)) which corresponds to the first coupled plant test, feeding was concentrated almost exclusively on *R. obtusifolius* and *R. crispus* ssp. *japonicus*, the latter being slightly preferred to the former. Slight feeding occurred on *R. acetosella* but not on *R. acetosa*. The preference tendency that appeared in this test agrees with that observed in the coupled plant tests.

The second test (Fig. 3(2)) corresponds to the second coupled plant test, with *S. media* replaced by *P. cuspidatum*. The main feeding occurred on *R. obtusifolius* and *P. filiforme*. In this test the latter was preferred to the former much more markedly than in the coupled plant test, and the feeding on *F. esculentum* was minor.

In the last test (Fig. 3 (3)), feeding on *R. obtusifolius* and *P. persicaria* was about equal, and the feeding on these two combined was about 80% of total plant feeding during this test.

DISCUSSION AND CONCLUSION

It is well known that the normal hosts of *G. atrocyanea* are *Rumex* spp., and that it also occurs on certain *Polygonum* spp. However, its potential host range has not hitherto been explored systematically. Ohno (1956) reported that the insect attacked *M. aquaticum* when it was short of normal food plants. As far as the authors are aware, this is the only record of the insect from the non-Polygonaceous plants. In Europe and North America, however, *Gastrophysa* spp. have been recorded from such non-Polygonaceous plants as mustard, beans, grape vines, cotton, etc. They have sometimes attained pest status on some of these crops. For this reason as many plants as possible that belong to the same species, genera or families as those recorded in literature were used in this present study.

The adult of *G. atrocyanea* showed more or less definite feeding response to all the Polygonaceous plants tested. Not all these plants, however, are suitable as hosts for the complete life cycle of the insect; some do not support ovarian development in the overwintered adult and some cannot support larval development to maturity. Of 21 Polygonaceous species tested, at least eight seem able to support the full sequence of the life-cycle of the insect. Of these *Rumex* (*Lapathum*) spp., *P. persicaria* and *P. filiforme* are the most satisfactory judging by the laboratory feeding tests and by the choice tests where significant preference was shown for these plants. These results suggest that they are suitable as hosts if and when they

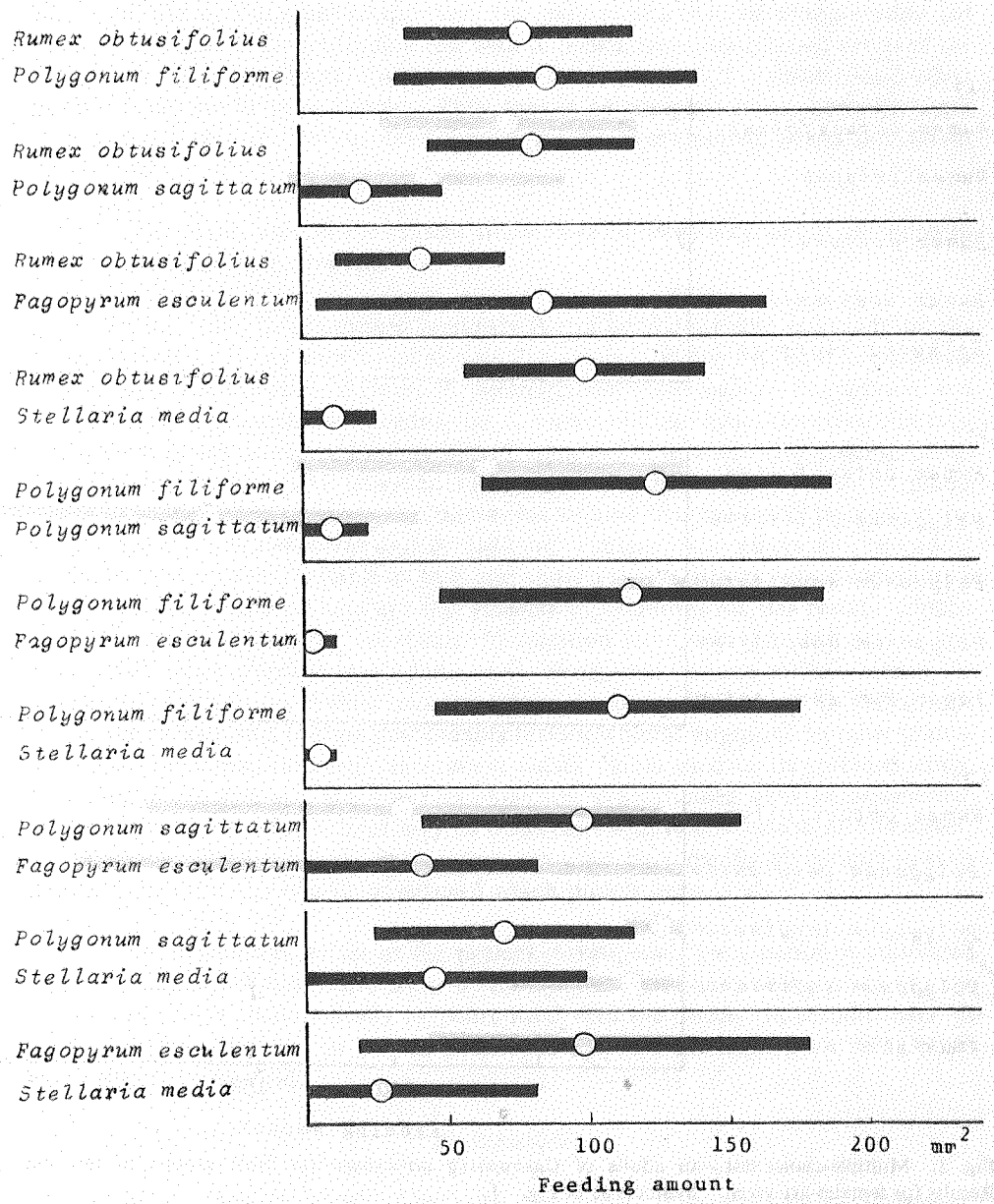

Fig. 2. Coupled plant test with adults of *Gastrophysa atrocyanea* on every combination between *Rumex obtusifolius*, *Polygonum filiforme*, *P. sagittum* var. *aestivm*, *Fagopyrum esculentum* and *Stellaria media*. Results for females are given. Symbols as in Fig 1.

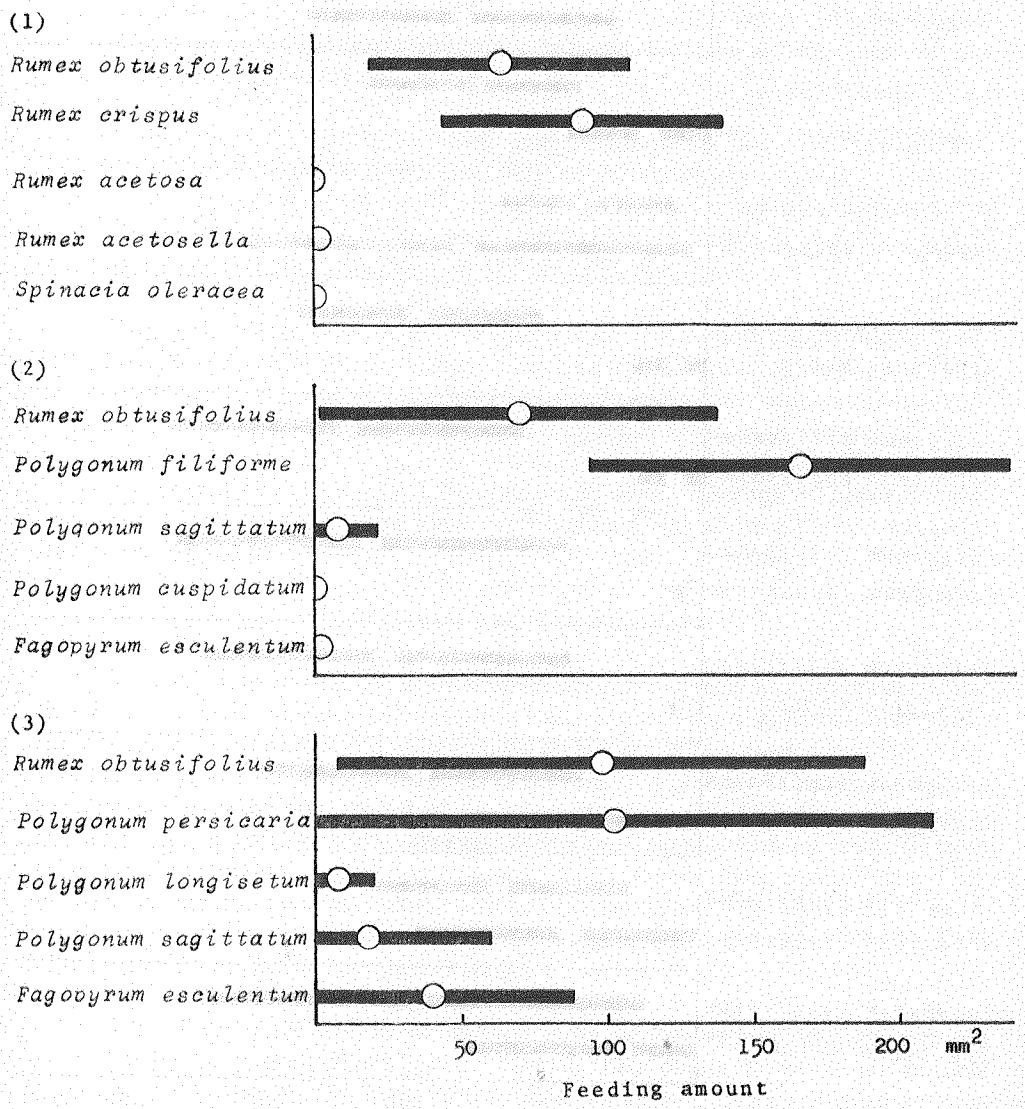

Fig. 3. Multiple-choice test with adults of *Gastrophysa atrocyanea* on three groups of test plants. Results for females are given. Symbols as in Fig. 1.

are accessible to the insect. Among the non-Polygonaceous plants, *S. media* and *M. aquaticum* of Caryophyllaceae were the only plants that were appreciably fed upon by the insect. In the feeding test with *S. media*, some adults have survived for more than 50 days. Therefore these plants could serve as facultative food when normal hosts are in short supply. They cannot be complete hosts, however, since they support neither ovarian development in the overwintered adults nor larval development.

Other plants used in the present study have not been accepted at all, or were nibbled in insignificant amounts.

In the field, *G. atrocyanea* is mostly found on *Rumex* spp. especially of the subg. *Lapathum*. It has been found also on *P. persicaria*, *P. longisetum*, *P. caespitosum* Blume ssp. *Yokusaianum* Danser, *P. lapathifolium*, *P. aviculare*, *P. filiforme* and *P. sagittatum* var. *aestivum*. Feeding on *S. media* and *M. aquaticum* was observed when these plants were contiguous with *R. obtusifolius* infested with a dense population of the insect. It is, however, rather rare that the insect is found on plants other than *Rumex* spp. It may be interesting to note that the insect does not commonly occur on *P. persicaria* and *P. filiforme*, whereas these plants are, according to the laboratory tests, suitable as host and show a strong attractiveness comparable to that of *Rumex* spp. There are two possible explanations for this result. Firstly, phenological disagreement; the plants in question have not sprouted or are still very small, when overwintered adults of *G. atrocyanea* become active. Hence the overwintered adults necessarily take the earlier sprouting *Rumex* spp. as their hosts, where the greater part of their descendants remain without migrating to other plants. It should be emphasized here that many useful plants used in the present study, including *F. esculentum*, are not phenologically synchronized with *G. atrocyanea*. Secondly, preference for habitat may be concerned with host selection of this insect; *P. filiforme*, which grows in shady places, may not be a readily acceptable host in the field for an insect like *G. atrocyanea* which prefers open lands.

As a conclusion, so far as the present investigation goes, useful or cultivated plants in Japan are quite safe from *G. atrocyanea*. They are unacceptable to the insect and/or are phenologically asynchronized with the insect. In certain cases, as in *P. filiforme*, difference in habitat preference may prevent them from being hosts of the insect in the field.

REFERENCES

Force, Don C. 1966. Reactions of the green dock beetle, *Gastrophysa cyanea* (Coleoptera: Chrysomelidae), to its host and certain non-host plants. Ann. Ent. Soc. Amer. **59**(6): 1119-1125.

Ohno, M. 1956. Note on a Chrysomelid-beetle, *Gastrophysa atrocyanea* Motchulsky (Coleoptera: Chrysomelidae) in Japan. The Insect Ecology, **5**(13): 147-157.