Feeding Site of *Palomena angulosa* MOTSCHULSKY (Hemiptera: Pentatomidae) on Potato Plants and Injury Caused by the Feeding^{1,2}

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The bugs *Palomena angulosa* MOTSCHULSKY sucked plant sap from the leaf vein and petiole of the potato plant at significantly higher frequency than from the stem. On the leaf, adults tended to take the plant sap from the midrib more willingly than from the lateral vein, whereas nymphs more frequently sucked sap from the lateral vein. It was also observed that the 3rd instar nymphs fed on the flower bud. Twenty-one percent of the bugs fed at the tip (growing) part of the plant. Almost all completed feeding within 30 min, though starvation prolonged their feeding time. Above the feeding point the plant began to wilt 1 to 7 days after the infestation and withered when the attack was severe. Histological observation showed that the insects usually sucked plant sap from the phloem tissue resulting in destruction of the phloem and occasional plugging of neighboring xylem with sheath material.

INTRODUCTION

Palomena angulosa MOTSCHULSKY (Hemiptera: Pentatomidae) is a polyphagous insect which feeds on various plants (KAWASAWA and KAWAMURA, 1977). Although not one of the serious crop insect pests in Japan, it sometimes invades fields injuring various cultivated plants and causing extensive damage. However, the feeding and injuring processes are not clear.

In general, pentatomid bugs are of the stylet-sheath feeding type when feeding on plant sap (cf. MILES, 1972). They make local lesions which sometimes cause development of secondary symptoms on the plant (cf. CARTER, 1962), quite different from mirid bugs which belong to the lacerate-and-flush feeding type and which form various tissue malformations on a plant after feeding (cf. TINGEY and PILLEMER, 1977).

In the present study, the feeding site of *P. angulosa* on potato plants and the injury caused by the bug were investigated externally and histologically, and the types of feeding and injury were compared with those of some other species reported.

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MATERIALS AND METHODS

Insects used. Hibernating adults collected from the field from early June to late July were reared in cages with food plants and a layer of filter paper at the bottom. Eggs laid were removed to plastic petri dishes and kept till hatching at room temperature. After hatching, the nymphs were reared with green beans as food in 16L-8D at $25^{\circ}\text{C} \pm 2^{\circ}\text{C}$. Second, 3rd, 4th and 5th-instar nymphs and the adults which developed from the eggs were used for the experiments.

Potato plants used. The potato variety May Queen cultivated in the experimental field of Obihiro University according to the usual procedure was used for the experiments. To use plants of nearly the same growth stage in each experiment, seed potatoes were planted at 10-day intervals from June 1 to August 15. Plants 17 to 25 cm in height with 3 compound leaves in each portion (upper, middle and lower parts) were chosen and transplanted in pots (25 cm in diameter and 20 cm in height) 5 days before the experiment started. The pots were placed in the laboratory.

Observations of feeding site and feeding time. A plastic cylinder with gauze-covered top to cage the insects was placed on the pot. Fifteen to 20 bugs starved for 1 to 3 days were put into this cage and allowed to feed. The feeding sites were then recorded and marked with white paint, and the time from start to end of feeding (feeding time) was determined. Feeding observations were repeated 40 times for each developmental stage of the bug.

Observations of diseased symptoms after the feeding. After removing the insects, the external diseased symptoms of the potato plants attacked were observed in comparison with control plants.

Histological observations of injured plant tissue. The feeding sites or injured parts were cut out of the plants and fixed with CARNOY's fluid. According to the usual paraffin method, plant tissue sections of the feeding sites were prepared and doubly stained by MAYER's haematoxylin and safranin for observation with an optical microscope.

RESULTS AND DISCUSSION

*Feeding site and feeding time**Feeding site*

Table 1 shows the number of bugs (2nd, 3rd, 4th and 5th instar nymphs and adults) which fed on each part of the potato plant; forty were observed for each developmental stage. The bugs sucked plant sap from the leaf vein (40.8%) and petiole (40.8 %) at significantly higher frequency than from the stem (17.1 %), while adults of the 1st generation were fond of sucking from the stem (37.5 %) as well as the petiole (40.4 %). This may be due to the fact that the adults feed actively and have stylets long enough to suck from stems. On the leaf, the adults (hibernating and new-emerged) tended to take plant sap more willingly from the midrib than the lateral vein, whereas nymphs of all stages sucked sap from the latter at significantly higher frequency than from the former. This may be due to the fact that the stylets of the nymphs are too short to reach the phloem tissue of the midrib. It was also observed that 3rd instar nymphs fed on the flower bud. (Potato plants with flower buds were supplied only to this stage.)

Table 1. Feeding site of *P. angulosa* on potato plant

Feeding site		Number of bugs						Total	%
		Hiber-nating adult	Instar				New-emerged adult		
			2nd	3rd	4th	5th			
Leaf vein	Midrib	9	5	4	8	2	6	34	14.2
	Lateral vein	5	16	8	11	8	2	50	20.8
	Veinlet	0	3	1	3	6	1	14	5.8
Total		14	24	13	22	16	9	98	40.8
Petiole		21	10	22	13	16	16	98	40.8
Stem		5	6	2	5	8	15	41	17.1
Flower bud		— ^a	—	3	—	—	—	3	1.3

^a Without flower bud.Table 2. Stages of *P. angulosa* feeding on various parts of potato plant

Plant part		Hiber-nating adult	Instar				New-emerged adult	Total
			2nd	3rd	4th	5th		
Tip								
Number		0	6(3) ^a	14(8)	9(7)	14(12)	8(4)	51(34)
%		0	15.0	35.0	22.5	35.0	20.0	21.2
Other parts								
Number		40	34	26	31	26	32	189
%		100	85.0	65.0	77.5	65.0	80.0	78.8

^a Values in parentheses indicate the number of bugs which sucked sap from the petioles.Table 3. Feeding time of *P. angulosa* on potato plant

Feeding time (min)	Number of bugs					New- emerged adult	Total	%
	Hiber- nating adult	Instar						
		2nd	3rd	4th	5th			
1- 9	21	19	18	14	21	15	108	45.8
10-19	7	12	9	16	11	5	60	25.4
20-29	4	5	5	8	2	4	28	11.9
30-39	3	1	1	1	2	1	9	3.8
40-49	4	1	3	1	3	1	13	5.5
50-59		1			1	2	4	1.7
Over 60	1		1			12	14	5.8

Table 2 shows the frequency of feeding on parts of the potato plants. Although the frequency at the tip was less than at other parts, 21 % of the bugs fed at the tip, especially at the petiole (14.5 %).

Feeding time

Table 3 shows the feeding time of the nymphs and adults. In this experiment, adults were not distinguished by sex, though their feeding times seemed to differ. As

Table 4. Feeding time of starved *P. angulosa* on potato plant

Developmental stage	Period of starvation (hr)	Mean feeding time (min)
Hibernating adult	0	13.5
	12	39.3
2nd instar	0	15.8
	12	14.0
	24	23.2
3rd instar	24	4.8
	48	20.2
4th instar	24	6.2
	48	11.6
	72	19.5
5th instar	24	8.4
	36	18.7
New-emerged adult	36	9.5
	72	48.1

before, 40 determinations were made at each developmental stage. Irrespective of stage, many bugs (45.8 %) completed one feeding within 10 min and almost all (83.1 %) finished feeding within 30 min. Those which continued feeding over 60 min were mostly of the adult stage. At this point, it cannot be inferred that the adult feeds longer than the nymph because bugs starved for different times were among those observed. Table 4 shows the feeding time of the insects in relation to starvation. In all stages, the longer the starvation time, the longer was the feeding time. Moreover, the feeding time of an adult starved for a long period seemed much longer than that of a nymph.

External diseased symptoms of the plants injured by the bugs

Figures 1 and 2 show the diseased symptoms of the potato plants injured by the 5th instar nymphs of *P. angulosa*; the nymphs in other instars and the adults caused symptoms quite similar to these. The plant part above the feeding point began to wilt 1 to 7 days after the infestation (Fig. 1) and then withered when the attack was severe (Fig. 2) or recovered when it was mild. Such diseased symptoms appeared especially at the growing part of the plant.

Histological observations of injured plant parts

Table 5 shows the point in the plant tissue to which the stylets reached as the insects fed. They usually sucked plant sap from the phloem tissue (64.3 %) (Figs. 3 and 4), except 2nd instar nymphs most of which took sap from the parenchymatous cells (59.6 %) and epithelia (25.0 %) (Fig. 5). When feeding at thin lateral veins and veinlets, however, the 2nd instar nymphs (15.4 %) may be able to suck up sap from the phloem tissue. The phloem attacked by the bugs was destroyed and plugged with sheath material, and neighboring xylem was also plugged. Thus the translocation of nutrient substances and water in the plant may be inhibited or stopped, followed by the wilting of the plant parts above the feeding points and finally by the withering of the parts. When provided with a budding plant, the 3rd instar nymphs

Fig. 1. Potato plant 1 to 2 days after infestation of the 5th instar nymphs of *P. angulosa*. The tip above the feeding point has wilted.

Fig. 2. Potato plant 7 days after infestation of 5th instar nymphs of *P. angulosa*. The tip above the feeding point has withered completely.

Fig. 3. Petiole tissue of potato plant injured by hibernating adults of *P. angulosa*. The salivary sheath terminates in the vascular bundle ($\times 285$).

Fig. 4. Stem tissue of potato plant injured by new-emerged adults of *P. angulosa*. The salivary sheath terminates in the vascular bundle. Phloem tissue was destroyed ($\times 125$).

Fig. 5. Petiole tissue of potato plant pierced by a 2nd instar nymph of *P. angulosa*. The salivary sheath ends in the parenchymatous tissue ($\times 285$).

Fig. 6. A flower bud of potato plant injured by a 3rd instar nymph of *P. angulosa*. The tetrum has been destroyed and the pollen in it has disappeared ($\times 125$).

Table 5. End point of the salivary sheath formed by the *P. angulosa* feeding in injured tissue of potato plant

Part of plant tissue	Number and % of salivary sheath						Total	Total (except 2nd instar)
	Hiber- nating adult	Instar				New- emerged adult		
		2nd	3rd	4th	5th			
Epithelium	0	34 (25.0) ^a	0	1 (33.3)	6 (26.1)	4 (13.8)	45 (21.8)	11 (15.7)
Parenchyma	2 (22.2)	81 (59.6)	1 (16.7)	0	6 (26.1)	5 (17.2)	95 (46.1)	14 (20.0)
Phloem	7 (77.7)	21 (15.4)	5 (83.3)	2 (66.7)	11 (47.8)	20 (69.0)	66 (32.0)	45 (64.3)

^a Values in parentheses show percentage in each stage.

imbibed from them and consumed immature pollen in the tetratetum to empty and partially destroy it (Fig. 6). A similar situation is found in *Leptoglossus corculus* (Coreidae) feeding on conelets of *Pinus echinata*. The bugs feed on ovules emptying and destroying them (DEBARR and KORMANIK, 1975).

The bugs of pentatomorpha usually form a stylet sheath (salivary sheath) around the stylets in the plant tissue when they feed on sap (cf. MILES, 1972) and suck up the sap without destroying many neighboring cells. In most cases, therefore, such necrosis and malformation as formed by mirid bugs (cimicomorpha) (cf. CARTER, 1962; HORI, 1971; cf. MILES, 1972) are not produced by pentatomorpha bugs. The cabbage bug *Eurydema rugosum* (Pentatomidae) (HORI, 1968) and *Labops hesperius* (TODD and KAMM, 1974) make a white spot at the feeding point. This is a local lesion according to the classification of external symptoms proposed by CARTER (1962). In the present study, it was found that *P. angulosa* was a phloem feeder when fed on potato plant and that it destroyed or plugged phloem and xylem, followed by the wilting and withering of the plant above the feeding point. This may correspond to the second type of symptom (a local lesion with development of secondary symptoms) defined by CARTER (1962); many pentatomid bugs (except seed feeders) are known to be of this type in the way of feeding and resultant injury. The injury to potato plant caused by the feeding of *P. angulosa* seems primarily mechanically produced and only slightly chemically, the result of contrary to the cases of mirid bugs where the injury is both mechanical and chemical factors (STRONG, 1970; VARIS, 1972; HORI, 1976).

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