pared as in the case of the larvae of the sweet potato weevil (SATÔ et al., 1977), except that the larvae were homogenized with 1.4-fold distilled water instead of 1.0-fold.

As shown in Table 1, the H fraction indicated terpene-inducing activity, but the L fraction did not. Furthermore, heated H fraction did not induce terpene production. Thus, the authors concluded that the terpene-inducing factor of the larvae was heat-unstable high molecular weight substance. Addition of the L fraction to the H fraction did not induce as much terpene production as the H fraction alone. This result indicates that the H fraction may not require any low molecular weight cofactor-like substance for the terpene induction, or may be tightly combined with cofactor-like substance such as iron-porphyrin moiety of the cytochrome in the case of the larvae of the West Indian sweet potato weevil. On the contrary, in the case of the larvae of the sweet potato weevil, the addition of the low molecular weight component (L fraction) to the H fraction was prerequisite for the terpene induction (SATÔ et al., 1977). These

results indicate that the biochemical properties of the terpene-inducing factor of the larvae of the West Indian sweet potato weevil are different from those of the factor of the larvae of the sweet potato weevil.

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Feeding Stimulation of Flavonoids for Various Leaf Beetles (Coleoptera : Chrysomelidae)¹

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A previous study showed that four species of Polygonaceae-feeding leaf beetles, *Galerucella vittaticollis* BALY, *Gastrophysa atrocyanea* MOTSCHULSKY, *Gallerucida bifasciata* MOTSCHULSKY and *Gallerucida nigromaculata* BALY were stimulated to feed by flavonoids such as quercitrin and rutin (MATSUDA, 1976a). The effects of flavonoids as feeding stimulants for phytophagous insects have been studied in some other insects. HAMAMURA et al. (1962) reported that isoquercitrin and morin served as

feeding stimulants for the silkworm, *Bombyx mori* L. GUERRA and SHAVER (1969), working with the tobacco bud worm, *Heliothis virescens* (F.) and the bollworm, *H. zea* (BODDIE) larvae, showed that quercitrin, isoquercitrin and rutin stimulated feeding. HEDIN et al. (1968) found that quercetin, quercimeritrin and quercetin-3-glucoside stimulated feeding of the boll weevil, *Anthonomus grandis* BOHEMAN. According to ZIELSKE et al. (1972), 7- α -L-rhamnosyl-6-methoxyluteolin elicited a feeding response from *Agasicle* on alligator weed. LEVY et al. (1974) indicated that taxifolin, pinocembrin and dihydrokaemferol exhibited high activity on the feeding of the fruit tree bark beetle, *Scolytus mediterraneus* (EGGER). SÔGAWA (1976) showed that four kinds of rice flavonoids, tricin-5-glucoside, glucotricin, orizatin and homoinetin exhibited probing stimulatory effects for the feeding of brown planthopper, *Nilaparvata lugens* (STÄL). In this paper, to investigate the possibility of the feeding stimulation of flavonoids, six flavonoids (quercitrin, rutin, quercetin, myricitrin, myricetin

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and morin) were tested for eight species of leaf beetles.

The host ranges of the leaf beetles used in the experiments are shown in parentheses following the insect names as follows: *Plagioderma versicolora distincta* BALY (genus *Salix*), *Altica oleracea* (LINNÉ) and *A. nipponica* OHNO (genus *Oenothera*), false melon beetle, *Atrachya menetrisi* (FALDERMANN) (polyphagous), Japanese alder leaf beetle, *Agelastica coerulea* BALY (genus *Alnus*, *Betula*, *Corylus*, *Populus* and *Salix*), *Gastrolina depressa* BALY (family Juglandaceae), daikon leaf beetle, *Phaedon brassicae* BALY (family Cruciferae), and rice leaf beetle, *Oulema oryzae* KUWAYAMA (rice plant). The beetles used in the experiments were collected in the adult stage in the field except for two species. *O. oryzae* were collected in the pupal stage, and kept under laboratory conditions until adult emergence. *P. versicolora* were gathered in the larval stage and reared on leaves of the host plant. The effects of the respective flavonoids as feeding stimulants were examined by the bioassay method on filter papers, as described previously by MATSUDA and MATSUMOTO (1974). All assays were conducted at 24–25°C with beetles that were starved prior to the tests. Because the insects used in these assays were different in physique and food consumption, test conditions were differed with species as follows: *P. versicolora*, *A. oleracea*, *A. nipponica*, *P. brassicae* and *O. oryzae* (starvation period 24 hrs; test duration, 24 hrs; number of released insects, 20); *A. menetrisi*, *A. coerulea* and *G. depressa* (starvation period, 15 hrs; test duration, 8 hrs; number of released insects, 15). Comparisons were made at the concentration of 0.01 M of test chemical in combination with 0.5

M sucrose, according to the results of the previous paper (MATSUDA, 1976a) in which active flavonoids were shown to elicit the most intensive feeding response in *G. vittaticollis* at this concentration. Tests were replicated 5 times. The degrees of feeding stimulation were judged by the differences in the condition of the test filter papers nibbled by insects from that of the control papers coated with 0.5 M sucrose and expressed by a graded number of the symbol "S". The symbol "N" was used to indicate no stimulative effect and the symbol "In" to indicate the inhibition of feeding of the beetle by test substance.

Effects of various flavonoids on the feeding of the leaf beetles are summarized Table 1. The feeding of *P. versicolora* was stimulated by all flavonoids tested. *A. oleracea* and *A. nipponica* were stimulated to feed by rutin, quercetin, myricitrin and myricetin, but were inhibited by quercitrin and morin. The feeding of *A. menetrisi*, *A. coerulea* and *G. depressa* was stimulated by quercitrin, rutin and myricitrin, and *A. menetrisi* was also stimulated by myricetin. Feeding of *P. brassicae* and *O. oryzae* was inhibited by all flavonoids tested.

As mentioned above, six out of eight species of beetles which have different host ranges were stimulated to feed by flavonoids. The four species of Polygonaceae-feeding beetles were also stimulated by quercitrin and rutin (MATSUDA, 1976a). Although it is known that flavonoids possess effective insecticidal or growth inhibitive properties for some phytophagous insects, i.e., *Heliothis zea*, *H. virescens* and *Pectinophora gossypiella* (LUKEFAHR, 1966, 1969), the leaf beetles used in these experiments not only have adapted to the toxic effects of flavonoids, but

Table 1. EFFECTS OF FLAVONOIDS ON THE FEEDING OF VARIOUS LEAF BEETLES^a

	Feeding stimulation for							
	<i>P. versicolora</i>	<i>A. oleracea</i>	<i>A. nipponica</i>	<i>A. menetriesi</i>	<i>A. coerulea</i>	<i>G. depressa</i>	<i>P. brassicae</i>	<i>O. oryzae</i>
Quercitrin	SS	In	In	S	S	S	In	In
Rutin	SS	SS	S	SS	SS	SS	In	In
Quercetin	SSS	SS	S	N	N	N	In	In
Myricitrin	SSS	S	S	SS	SS	SS	In	In
Myricetin	SSS	SS	S	S	N	N	In	In
Morin	S	In	In	N	N	N	In	In

^a Feeding responses are indicated by a graded number of S symbols, judged from the difference between the condition of the filter papers with 0.01 M flavonoid-0.5 M sucrose and that of the control papers with 0.5 M sucrose after being nibbled by beetles. Symbols N and In indicate no stimulatory response and inhibitory response, respectively.

have accepted them as feeding stimulants, suggesting that flavonoids play a significant role in the host selection of certain phytophagous insects. Coinciding with this suggestion, in a review on the co-evolutionary patterns between butterflies and plants, EHRLICH and RAVEN (1964) concluded that flavonoids and other secondary substances play the leading role in determining the kind of plants upon which the larvae feed.

The feeding of *P. brassicae* and *O. oryzae* was inhibited by all the flavonoids tested. Mustard oil glucosides, which are characteristic constituents of the host plant, stimulated feeding of crucifer-feeding leaf beetles, *P. cochleriae* (TANTON, 1965) and *Phyllotreta cruciferae* (HICKS, 1974). *P. brassicae* was also stimulated to feed by sinigrin, one of the mustard oil glucosides (MATSUDA, unpublished). These results support the hypothesis that *P. brassicae* may be stimulated to feed by mustard oil glucosides such as sinigrin, but is rather inhibited by flavonoids. In a previous paper, MATSUDA (1976b) showed that adenine and related substances, which are characteristic constituents of rice plant sap, were potential stimulants for *O. oryzae*. Therefore, it may be concluded that in the case of *O. oryzae*, adenine or characteristic plant constituents of the rice plant are the main stimulants for feeding.

The following leaf beetles were also used in this experiment: blue leaf beetle, *Linnaea aenea* (LINNÉ); wistaria leaf beetle, *Gonioctena rubripennis* BALY; *Lema decempunctata* GEBLER; striped flea beetle, *Phyllotreta striolata* F.; *Luperomorpha tenebrosa* (JACOBY); *Psylliodes angusticollis* BALY; *Longitarsus lewisii* BALY; hemp flea leaf beetle, *Psylliodes attenuata japonica* JACOBY. However, these leaf beetles were too inactive in food consumption or nibbling to obtain positive results.

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