Effect on Aphid Feeding of Dietary Methionine

RECENT behavioural and nutritional investigations on *Myzus persicae* (Sulzer) fed and reared on synthetic diets have shown that the sucrose concentration and the overall level of the twenty amino-acids in the diet markedly affect the rate of ingestion of the diet[1] as well as the rate of growth of the aphid[2]. Specifically with respect to the amino-acids, diets with a total amino-acid concentration of less than 1 per cent were fed on minimally and supported only poor or no growth. Rates of uptake and growth increased as the concentration was increased to 3·0 per cent; but whereas uptake declined somewhat, the growth rate continued to increase beyond that level to 4·8 per cent, the highest concentration tested.

Although these results can be viewed in terms of the behavioural and nutritional responses by the aphid to the overall concentration of amino-acids in the diet, it was realized that the adverse effect on growth, in particular, of an overall reduction in the concentration of amino-acids could primarily be the result of reduction below a critical level of only certain of the twenty amino-acids. Detailed investigations[3] of the growth of larvae of *M. persicae* on diets in which individual amino-acids were incorporated at various concentrations led to the conclusion that, of the five amino-acids (methionine, isoleucine, histidine, cysteine and lysine) which in any way adversely affected growth if omitted from the diet, methionine was the only one the omission of which completely halted growth in the first generation. Thus, in contrast to the results of investigations on carbon-14 incorporation[4], *M. persicae* appears from the nutritional investigations to be capable of adequate synthesis of at least six or seven of the ten amino-acids which are generally considered to be nutritionally essential for insects. Without knowledge of the relative uptake of diets differing in their methionine content, however, it was not justifiable to attribute impaired growth on methionine-deficient diets solely to an inability of the aphids to synthesize this amino-acid from the amino-acid pool supplied.

Behavioural studies[5] have shown that methionine is strongly phagostimulatory to *M. persicae*, when incorporated at 0·02 per cent to 0·10 per cent in pure sucrose solution; the routine concentration at which the amino-acid is incorporated into the complete diet is 0·04 per cent. The possibility, however, that diets lacking methionine, or with only a fraction of the routine concentration of methionine, but containing a total of almost 2·5 g of nineteen other amino-acids (including at least eight other phagostimulatory ones[6]) per 100 ml. of diet, might be less phagostimulatory has only recently been considered.

By difference weighing of sachets[7] containing the diets on which replicated groups of forty to fifty instar IV diet-reared larvae are fed for two successive 24 h periods, the uptake of the following four diets was compared: (*a*) standard diet containing twenty amino-acids at the routine concentration; (*b*) diet lacking methionine; (*c*) diet with methionine as the only amino-acid; and (*d*) diet lacking all amino-acids. The results of four experiments are given in Table 1.

Table 1. AVERAGE UPTAKE/APHID/DAY (μg)* OF SYNTHETIC DIETS CONTAINING VARIOUS CONCENTRATIONS OF AMINO-ACIDS

Experiments	Successive days	All twenty amino-acids	All but methionine	Only methionine	No amino-acids
1	*A*	707	287	—	—
	B	697	267	—	—
2	*A*	604	233	—	—
	B	621	254	—	—
3	*A*	639	466	300	196
	B	641	293	265	133
4	*A*	849	404	408	202
	B	840	338	440	230
Totals for III and IV		2,969	1,501	1,413	761

* Means of the average values obtained in each of three or four replicates of groups of forty to fifty five- or six-day-old larvae. For each experiment, uptake values are given for the same groups of larvae on successive days of the treatments, that is, on the fifth (*A*) and on the sixth (*B*) day of larval development.

In all cases the uptake of the methionine-free diet is about half that of the diet containing all twenty amino-acids. There does not appear to be an "acclimatization" of the aphids to the methionine-free diet because the uptake values for the second 24 h periods (*B*) in each experiment do not have a different relation to the uptake values for the complete diet than in the first 24 h period (*A*).

The smallest values for uptake were obtained with diets lacking all amino-acids, and were only about a quarter of those for the complete diet. When methionine was the only amino-acid in the diet, uptake was almost twice as great as with no amino-acids; however, the values for uptake were only half of those for the diet containing all the amino-acids. It follows that methionine, as the only amino-acid in the diet, does not provide the degree of phagostimulation given by the mixture of all twenty amino-acids, including methionine. The data indicate, furthermore, that the amount by which the uptake is reduced by the omission of methionine is very close to the amount of uptake attributable to the phagostimulant effect of methionine alone.

That the concentration of a single amino-acid in a complex mixture of amino-acids and other nutrients in the diet of *M. persicae* can affect the aphid's rate of feeding, and thus its growth, is a dramatic demonstration of the subtle dependence of aphids on the specific composition of their food. Although the recent finding, that the concentrations of certain other amino-acids (for example, histidine and isoleucine) markedly affect the proportion of *M. persicae* that develop wings[8], cannot as yet be linked to the present results, it strengthens the inference that can be drawn for the uptake data, that small differences in the composition of the sap of the host plants of aphids may have a marked effect on the ecology of these insects, and that a knowledge of these differences will make possible the prediction of the potential abundance and relative wingedness of aphid populations.

This work was supported in part by a grant from the U.S. National Science Foundation.

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[1] Mittler, T. E., *Entomol. Exp. App.* (in the press).
[2] Dadd, R. H., and Mittler, T. E., *J. Insect Physiol.*, **11**, 717 (1965).
[3] Dadd, R. H., and Krieger, D. L., *J. Insect Physiol.* (in the press).
[4] Strong, F. E., and Sakamato, S. S., *J. Insect Physiol.*, **9**, 875 (1963).
[5] Mittler, T. E., and Dadd, R. H., *Entomol. Exp. App.*, **7**, 315 (1964).
[6] Mittler, T. E., *Entomol. Exp. App.* (in the press).
[7] Auclair, J. L., *Ann. Entomol. Soc. Amer.*, **58**, 855 (1965).
[8] Mittler, T. E., and Dadd, R. H., *Ann. Entomol. Soc. Amer.*, **59**, 1162 (1966).

Relationship between Serotonin and the Circadian Rhythm in some Nocturnal Moths

THE presence of serotonin has been reported in various insect tissues; mainly in connexion with the venom glands of Hymenoptera[1,2], in head, thorax and abdomen or total insect extracts[2,3] and in the corpora cardiaca[4]. In several cases the corpora cardiaca and corpora allata have shown a relationship to a circadian rhythm[5–8], but the nature of the activating material secreted has remained obscure.

The structure of the corpora cardiaca in the orthopteroid insects, on which attention has largely been centred in the past, differs from that found in the Lepidoptera. In the latter, these organs are considerably smaller, in many species with as few as three intrinsic cells, and it appears in the adult insects to have very little storage capacity (my unpublished work). My histological investigations have confirmed that the neurosecretory material of the median and lateral cells of the pars intercerebralis is accumulated in the cell bodies and along the axons leading to the corpora cardiaca.

In an investigation of the circadian flight activity of various nocturnal moths during the past 2 yr I have produced evidence that serotonin is secreted by certain