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Survival of Smaller Brown Planthopper, *Laodelphax striatellus* FALLÉN, on Carbohydrate Solutions (Hemiptera : Delphacidae)

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Suitability of dietary carbohydrate for smaller brown planthopper, *Laodelphax striatellus,* was examined. Sucrose solution at the concentration of 5 % gave the best survivorship. Glucose gave the second best planthopper performance. Fructose, maltose, raffinose, trehalose, and soluble starch reduced surviving time of the planthopper drastically. Mixtures of glucose and fructose were inferior to sucrose of equimolar concentrations. No synergic nutritional effect was obtained from the mixtures of sucrose and maltose.

INTRODUCTION

Artificial rearing of hemipterous insects is successful only with aphid up to date (AUCLAIR and CARTIER, 1963; DADD and MITTLER, 1966; DADD and KRIEGER, 1967; EHRHARDT, 1968). Attempts to feed hemipterous insects on artificial diet had been initiated by CARTER (1927), and since then various feeding cages have been deviced by many investigators for this purpose. The principle of those feeding cages is based mostly on CARTER's membrane-feeding method. In addition to the improvement of the structure of the cage, many natural and synthetic membranes have been used to separate the insects from direct contact with liquid diet. Usable membranes must be very thin so as to allow insect's mouth parts to penetrate, but must be firm enough to keep the liquid diet and to bear multiple probing by the insect. The stretched Parafilm M satisfies these requisits well, and has brought about a great advancement for the artificial rearing of hemipterous insects. Thus it has become possible to rear aphids on artificial diet for indefinite generations, and the nutritional requirement of aphids has been studied extensively.

Recently it was confirmed that the technique to feed aphids on liquid diet (MITTLER and DADD, 1964) was applicable to smaller brown planthopper, *Laodelphax striatellus* FALLÉN (KOYAMA and MITSUHASHI, 1969). But the synthetic diets for aphids (AUCLAIR and CARTIER, 1963; DADD and MITTLER, 1966) were found to be unsatisfactory for *L. striatellus*. As a first step for improving the diet the present authors examined various carbohydrates in order to obtain information on what kind of and what concentration of carbohydrate is most suitable as an ingredient of the diet. The present paper describes the results obtained from the experiments carried out along this line.

MATERIALS AND METHODS

L. striatellus used in the present experiments was the red-eye strain which had been reared for years in the laboratory. The *L. striatellus* had alternated their generations on rice seedlings in short glass tubes. The experimental animals were reared on rice seedlings until the 2nd instar, and then transferred on to the carbohydrate solution to be tested. The feeding apparatus was essentially the same as that of MITTLER and DADD (1964). The stretched Parafilm M was used to make a sachet. Sucrose, maltose, glucose, fructose, raffinose, trehalose and soluble starch were tested as aqueous solutions of various concentrations. PH of all the solutions were adjusted to 6.5 with KOH because this hydrogen ion concentration was found to be suitable for the diet of *L. striatellus* (KOYAMA and MITSUHASHI, 1969). In each test, 50 nymphs were used. The experimental animals were caged individually and the sachets were replaced every two days. The number of dead nymphs was counted every day. All the experiments were terminated by the 20th day, and the results were expressed as survivorship curves. During the experiments, some nymphs moulted once regardless of the test solution on which they were fed, but none moulted twice or more.

RESULTS

Sucrose : All the sucrose solutions tested prolonged surviving time of *L. striatellus* compared with distilled water, although the difference was slight between 1 per cent sucrose and distilled water (Fig. 1, A and B). The best survivorship was obtained on 5 per cent sucrose, whereas the difference between concentrations ranging from 5 per cent to 25 per cent were not marked. Above 25 per cent, survivorship decreased. Surprisingly, *L. striatellus* could ingest the sucrose solution as high as 50 per cent, and survived for a period of time as in some aphids.

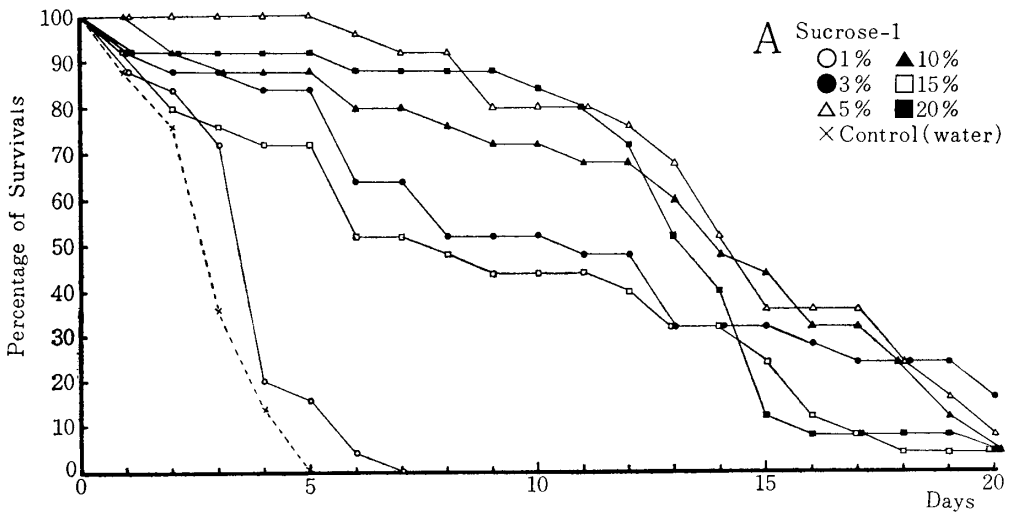

Fig. 1 A. Survivorships of *L. striatellus* on sucrose solutions -1.

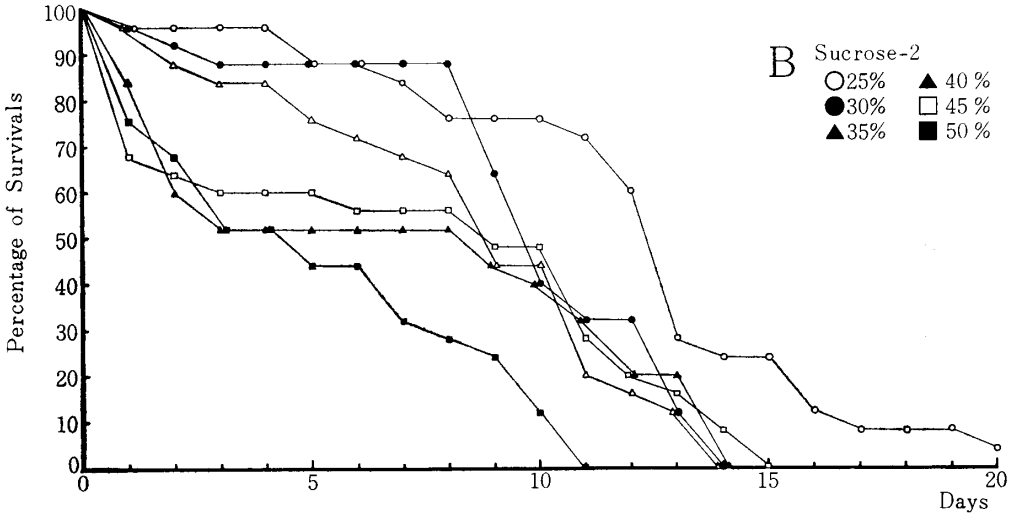

Fig. 1 B. Survivorships of *L. striatellus* on sucrose solutions –2.

Glucose : Glucose was found inferior to sucrose for the survivorship of *L. striatellus* (Fig. 2). The best survivorship was obtained on a 20 per cent glucose, but this was far poorer than that on 5 per cent sucrose. The survivorships on glucose less than 3 per cent or more than 30 per cent were close to that on distilled water.

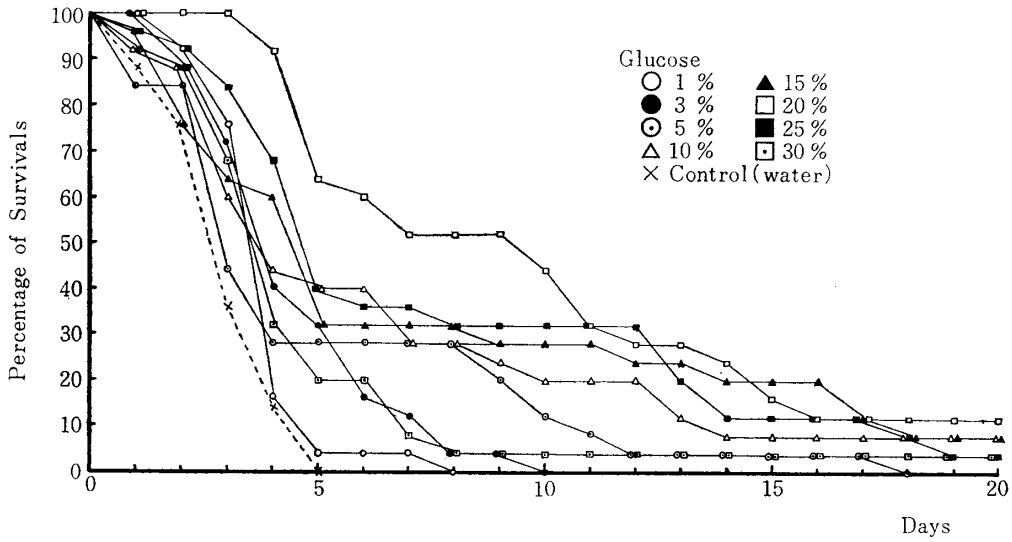

Fig. 2. Survivorships of *L. striatellus* on glucose solutions.

Fructose : Fructose was found unable to support *L. striatellus* any longer than distilled water could. The results were somewhat erratic; some concentrations gave slightly better survivorships than distilled water (Fig. 3), and others gave worse. Since there were very slight differences between distilled water and fructose solutions ranging from 1 per cent to 30 per cent, it may be said that fructose has no effect on the survivorship of *L. striatellus*.

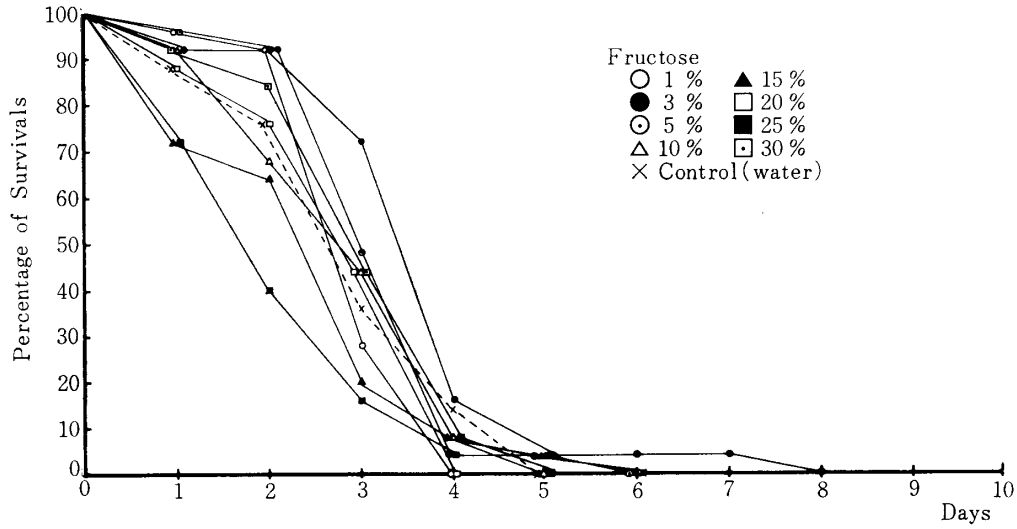

Fig. 3. Survivorships of *L. striatellus* on fructose solutions.

Maltose : The results obtained with maltose were similar to those with fructose (Fig. 4). No significant difference in 50 per cent surviving time was obtained between treatments. But after the 5th day, at which time all the test animals fed on 20 per cent or higher and those fed on 3 per cent or lower maltose solutions were dead, clear prolongation of surviving time was observed in some test animals fed on maltose solutions ranging from 5 to 15 per cent. The longest surviving time was obtained on 15 per cent maltose solution, but it is hard to determine the best concentration for *L. striatellus* because very few animals survived for such periods and the results obtained on 5 to 15 per cent maltose solutions were rather inconsistent even after the 5th day.

Trehalose : No marked difference in survivorship was observed between each

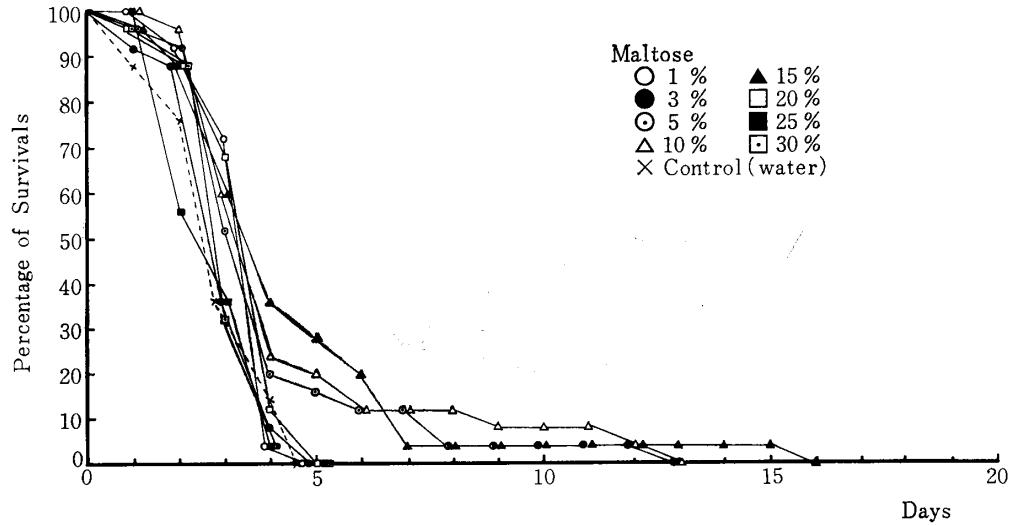

Fig. 4. Survivorships of *L. striatellus* on maltose solutions.

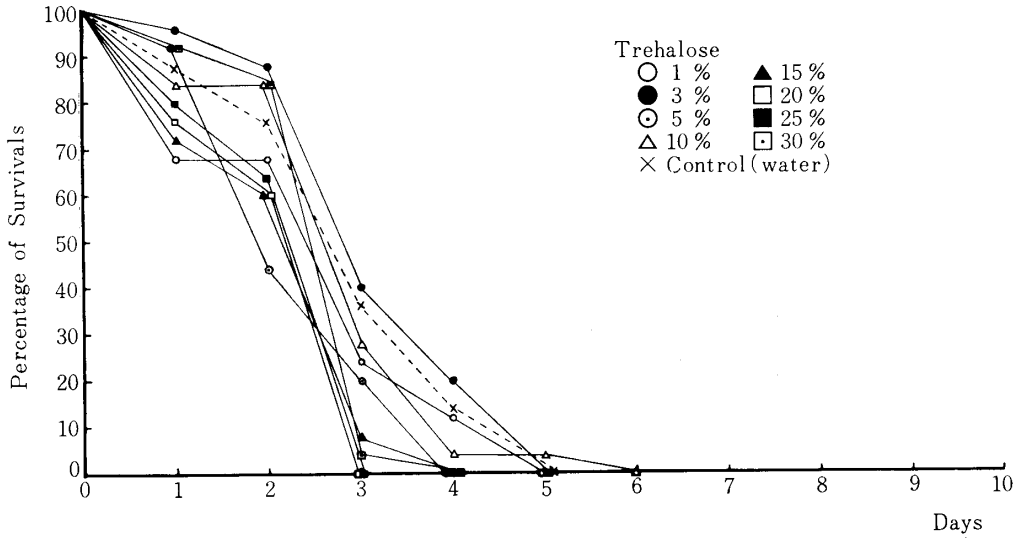

Fig. 5. Survivorships of *L. striatellus* on trehalose solutions.

trehalose solution and distilled water (Fig. 5). The trehalose solution was found rather deleterious to *L. striatellus* at certain concentrations. The best survivorship was obtained on 3 per cent trehalose solution, but this is very close to that on distilled water. Trehalose of other concentrations more or less reduced the surviving time of *L. striatellus* compared with the control fed on distilled water, and no consistent difference was observed between the effects of trehalose concentrations.

Raffinose : Survivorship of *L. striatellus* on raffinose solution was not better than that on distilled water in the range of the tested concentration from 1 to 30 per cent (Fig. 6). MITTLER (1967) reported that raffinose gave as good a survivorship

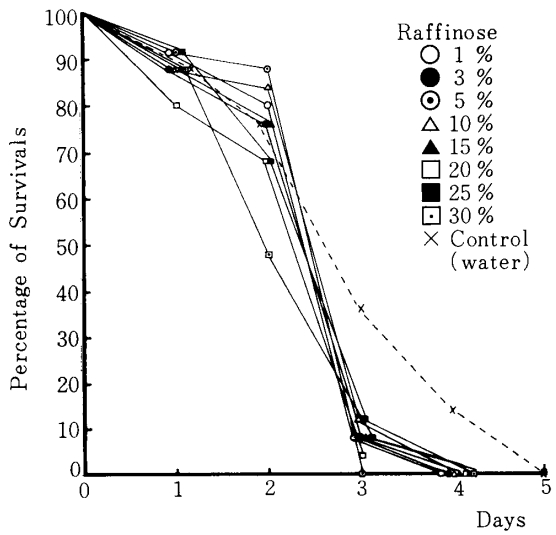

Fig. 6. Survivorships of *L. striatellus* on raffinose solutions.

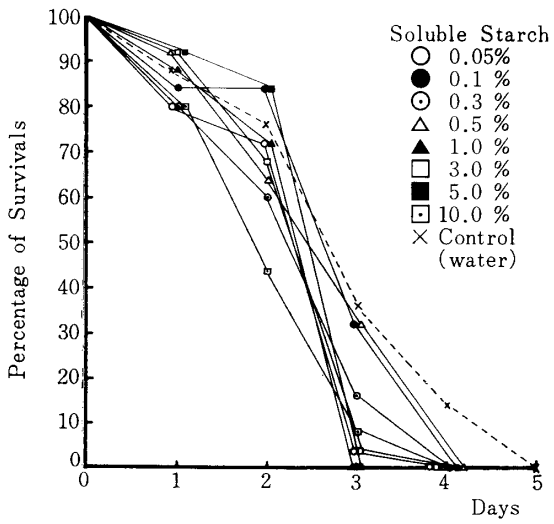

Fig. 7. Survivorships of *L. striatellus* on solutions of soluble starch.

as sucrose in the case of the green peach aphid, *Myzus persicae*, whereas in *L. striatellus* raffinose was found even toxic. No consistent difference was obtained between concentrations.

Soluble Starch : The results were very similar to those obtained on raffinose (Fig. 7). Adverse effects were obtained on starch at all the concentrations tested. Differences in adversity between concentrations were not clear.

Mixture of Glucose and Fructose : Since glucose and fructose are the monosaccharide components of sucrose, and 1 M sucrose produces 1 M of each component, the mixtures of glucose and fructose of which molar quantities equivalent to 1, 3, 5, 10, 15, 20, 25 and 30 per cent of sucrose solutions were prepared. The mixing ratio of glucose and fructose was 1 : 1 in weight. The results obtained on the mixed sugars were very similar to those on maltose (Fig. 8). The survivorships on

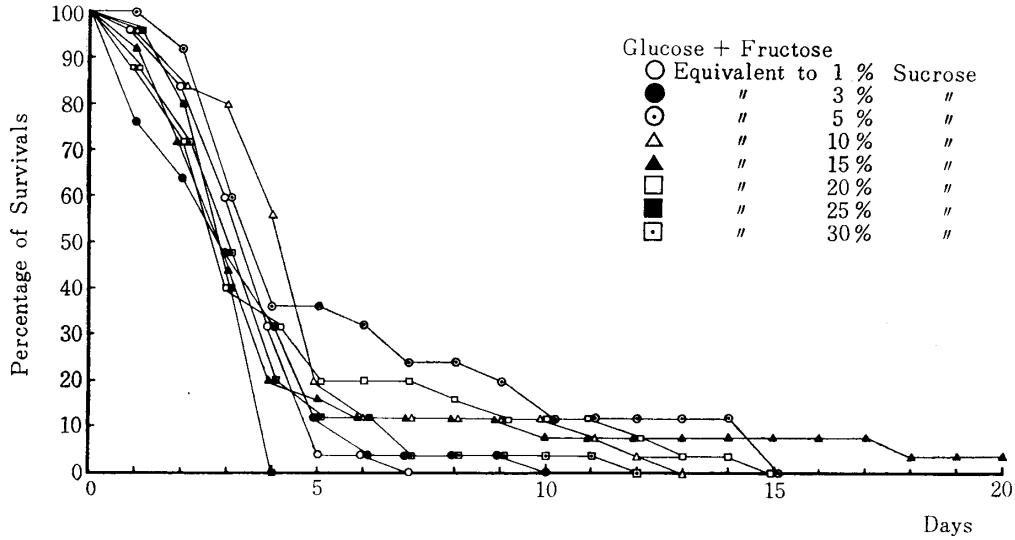

Fig. 8. Survivorships of *L. striatellus* on mixed solutions of glucose and fructose.

the mixed sugar solutions were slightly better than those on sole fructose solution, but not better than those on sole glucose solution. Moreover, the survivorships on the mixed sugars were greatly inferior to those on sole sucrose solution. Up to the 5th day, mortality increased rapidly at each concentration, while the individuals which survived for more than 5 days remained alive for a considerably long time thereafter. The decrease of survivals during the first 5 days was similar to that on distilled water. The prolongation of longevity of survivals after the 5th day resembled to that observed in maltose feeding experiments.

Mixture of Sucrose and Maltose : The efficiency of mixing two kinds of disaccharides was tested, because AUCLAIR (1967) obtained the synergic nutritional effect from the mixture of sucrose and maltose. Since the best survivorship was obtained on 5 per cent sucrose solution, the mixture of sucrose and maltose were prepared so as to provide that the total percentage of both sugars becomes 5 per cent. The survivorships on the mixed sugars all fell between that on sole sucrose and that on sole maltose (Fig. 9). No improvement of the survivorship by the mixture was recognized. The differences between each group were not clear, but there was a tendency that the higher the concentration of sucrose the better was the

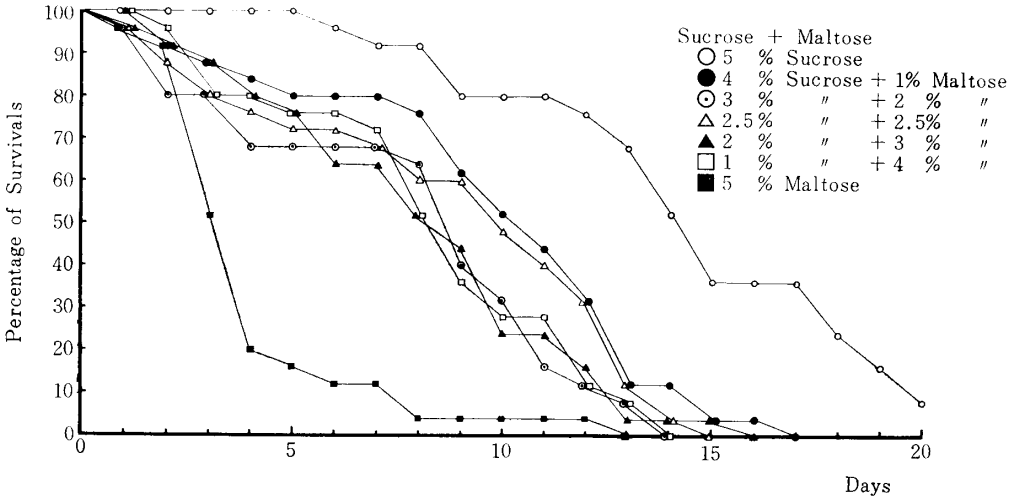

Fig. 9. Survivorships of *L. striatellus* on mixed solutions of sucrose and maltose.

survivorships. It may be noteworthy that the survivorship on 3 per cent sole sucrose solution was scarcely influenced by the addition of maltose, while that on 1 per cent sole sucrose solution was apparently improved by the addition of maltose (cf. Fig. 1 A). On the other hand, the survivorships on sole maltose solutions could be said to be improved by the addition of sucrose (cf. Fig. 4).

DISCUSSION

Sucrose at the concentration of 5 per cent was found most suitable to keep *L. striatellus* alive. In potato leafhopper, *Empoasca fabae*, the lowest mortality has been obtained on 7 per cent sucrose (DAHLMAN, 1963). In a plant bug, *Lygus hesperus*, 5 per cent sucrose was reportedly the best for its survivorship (AUCLAIR and RAULSTON, 1966). Aphids have been reported to survive well on sucrose solution, but the optimum concentration for them was usually much higher than that for *L. striatellus* (AUCLAIR, 1965, 1967; CARTIER and MORIN, 1965; DADD and MITTLER, 1965; MITTLER, 1967; KIECKHEFER and DERR, 1967; EHRHARDT, 1968). *L. striatellus* could imbibe 50 per cent sucrose and survived longer than on distilled water. In the San Jose scale, *Quadraspidiotus permiciosus*, no difference in longevity was recorded between 5 and 50 per cent sucrose, although 50 per cent sucrose gave better formation of white scales (DISSELKAMP, 1954).

Sucrose must be hydrolyzed to glucose and fructose before it is utilized in planthopper cells, but glucose was found less efficient than sucrose as the dietary carbohydrate. Nevertheless, glucose can be said to be the second best carbohydrate for *L. striatellus* if supplied solely. A similar result has been obtained with *E. fabae* (DAHLMAN, 1963). The pea aphid, *Acyrthosiphon pisum*, was unable to survive more than 4 days on glucose (AUCLAIR, 1965). The cotton aphid, *Aphis gossypii*, has also been reported to survive on glucose for shorter periods than on sucrose; i. e. the aphids survived 1 or 2 days on 15 per cent glucose, about the same time as on water (AUCLAIR, 1967).

Another monosaccharide, fructose, which is also the product of hydrolysis of sucrose, did not support the *L. striatellus*' life better than distilled water. It is

curious that *L. striatellus* can not utilize fructose, as most insects so far studied usually utilize fructose as well as glucose (HOUSE, 1962). This may be due to a lack of palatability. Similar results have been obtained with other hemipterous insects. In *E. fabae*, 50 per cent survival time on fructose was about the same as that on water and it was shorter than that on glucose or sucrose (DAHLMAN, 1963). *A. pisum* could not also utilize fructose (AUCLAIR, 1965). On the other hand, fructose gave better survivorship, weight gain and production of progeny than glucose in *A. gossypii* (AUCLAIR, 1967).

One to one mixtures of glucose and fructose were compared with sucrose of equimolar concentrations. The survivorships on the mixed sugars were greatly inferior to those on sole sucrose at any concentration. The survivorships on the mixed sugars were less than additive and not better than those on sole glucose. In *A. gossypii* mixture of 15 per cent glucose and 15 per cent fructose gave poorer survivorship, weight gain, and production of progeny than 30 per cent sucrose (AUCLAIR, 1967). It was also true when compared with 15 per cent fructose and this lead AUCLAIR to the assumption that glucose is slightly repellent or the results may be due partly to an excess osmotic pressure from the mixture of hexoses.

The mixture of 30 per cent sucrose and 10 per cent maltose has been reported to be the best dietary sugars for the growth of *A. gossypii* progeny born on the diet (AUCLAIR, 1967). In the present study, the survivorships of *L. striatellus* on various combination of maltose and sucrose or on maltose alone were examined. Maltose alone did not support *L. striatellus*' life better than distilled water, although a small number of *L. striatellus* fed on 5 to 15 per cent maltose survived for considerably long time. In *A. gossypii* maltose alone supports its life only for a few days at the concentration of 20 and 30 per cent (AUCLAIR, 1967). The combination of maltose and sucrose did not improve the survivorships of *L. striatellus*, except the mixture of 4 per cent maltose and 1 per cent sucrose on which the survivorship was better than that on 1 per cent sucrose or 5 per cent maltose. The survivorship on the mixed sugars seemed to depend mostly upon the amount of sucrose in the mixture.

Raffinose was found less efficient than distilled water to keep *L. striatellus* alive. In the present study, it was not determined whether raffinose was toxic or repelled. *M. persicae* survived on raffinose as good as on sucrose (MITTLER, 1967), but *A. gossypii* did not (AUCLAIR, 1967).

Like aphids (AUCLAIR, 1965, 1967) *L. striatellus* seeemed unable to utilize trehalose as a dietary sugar. Trehalose may be of poor nutritive value or palatability to *L. striatellus*, although it has been known to occur widely in insect haemolymph.

Starch was found rather deleterious to *L. striatellus*. Since the amout of imbibition was not determined in this study, it was not known whether *L. striatellus* repelled the starch or it lacks the enzyme digesting starch in its intestine.

From the present study, it can be said conclusively that sucrose is the best carbohydrate source in the diet for *L. striatellus*. There are many other sugars and their derivatives which were not tested, but among them melezitose, galactose, lactose, ribose, cellobiose and sorbose were reportedly of poor nutritive value for *A. gossypii* (AUCLAIR, 1967). Since *L. striatellus* is a phloem feeder (MITSUHASHI and KOYAMA, unpublished), and the sugar in phloem sap in many plant species

is mostly sucrose (ZIMMERMANN, 1957), it is reasonable that sucrose is the most adequate sugar for *L. striatellus*. In aphids, sucrose has been known to act as phagostimulant (MITTLER and DADD, 1963). To ascertain whether sucrose acts as phagostimulant for *L. striatellus* or not, the amount of imbibition must be compared. This quantitative experiment may also elucidate whether sugars with less nutritive value are not really utilized or just repelled because of their poor palatability. Since 5 per cent sucrose can maintain *L. striatellus* alive for a considerably long time, it may be possible to formulate an artificial diet for this species by adding amino acids, vitamins, minerals and so forth.

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