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Nutritional Physiology of the Brown Rice Planthopper, *Nilaparvata lugens* STÅL (Hemiptera: Delphacidae) I. Effect of Sugars on Nymphal Development

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As part of the research on the nutritional physiology of the brown rice planthopper, the nutritive value of sugars for larval growth was studied. Hatched larvae were reared on an MED-1 diet supplemented with one of the following sugars: sucrose, glucose, maltose, fructose, raffinose, or trehalose at concentrations of 5%. All larvae died within several days on diets supplemented any one of these sugars except sucrose. Larvae reared on diets containing glucose, fructose, or maltose grew to adults when the diet was supplemented with 1% sucrose, while those reared on raffinose or trehalose with an additional 1% sucrose still died within several days. When the larvae were reared on diets containing sucrose as the sole sugar, adult emergence depended on the sucrose concentration, which ranged from 3% to 50%. The shortest nymphal period was observed on the diet containing 5% sucrose.

INTRODUCTION

The ability to rear brown rice planthoppers on a completely synthetic diet (KOYAMA, 1979) has offered many opportunities to perform basic studies on the insect's nutritional requirements, feeding stimulants and inhibitors. However, little is known about its nutritional physiology except that larvae survive on solutions with several kinds of sugars (KOYAMA, 1981).

The present investigation deals with one aspect of the nutritional physiology of brown rice planthoppers, examining the effects of various sugars on the growth of the larvae. Sugars are assumed to be important nutrients and feeding promoters.

MATERIALS AND METHODS

Brown rice planthoppers, *Nilaparvata lugens* STÅL, obtained in Saitama Prefecture, were bred in small test tubes (20 mm × 100 mm) on rice seedlings under long-day conditions at 25°C. Details of the rearing apparatus and conditions, as well as the methods for obtaining the eggs, have been described previously (KOYAMA, 1979). In all experiments, larvae which had not been in contact with a rice plant were reared on a synthetic diet. MED-1 (MITSUHASHI and KOYAMA, 1971, 1972) was used as a basal diet. MED-1 contained only 5% sucrose as a sugar. To investigate the effect of sucrose concentration on the growth of the larvae, the concentration in the basal diet was varied from 0 to 50%. In addition, in order to examine the effect of sugars other than sucrose, synthetic

Table 1. Survival of *N. lugens* within 20 days after hatching (%)

Sucrose (g/100 ml)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
0	36	4	0																	
1	81	81	20	16	16	8	4	4	2	2	1	1	0							
3	81	54	32	29	25	21	20	20	20	20	19	19	19	18	18	18	17	17	17	17
5	95	84	62	60	58	58	56	55	55	54	54	54	51	46	44	44	41	40	40	39
10	90	65	57	51	48	46	44	43	41	39	39	38	38	37	35	35	35	35	34	34
15	95	88	80	79	78	73	73	73	71	70	67	66	65	61	61	60	60	56	56	54
20	94	84	65	58	55	52	48	47	45	43	42	42	41	38	36	36	35	35	33	32
25	93	76	72	72	69	68	68	68	68	68	67	66	66	65	65	64	63	62	61	61
30	82	44	36	33	31	29	29	27	27	26	23	23	22	21	21	21	21	21	21	20
35	95	90	86	82	79	78	75	71	69	68	67	65	63	63	60	60	60	59	57	57
40	89	78	71	59	55	50	49	49	49	49	44	44	41	38	36	36	36	36	36	36
45	97	91	79	72	70	68	67	65	63	59	58	55	55	54	54	54	53	50	49	48
50	91	57	49	41	41	39	39	37	33	29	28	27	27	27	27	27	27	27	27	27

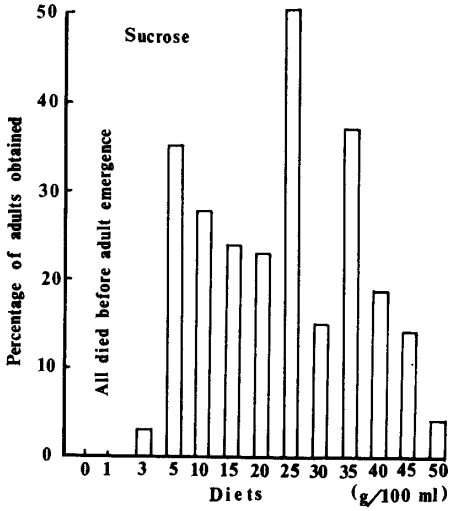

Fig. 1. Effect of sucrose concentration in MED-1 diet on percentage of adult emergence.

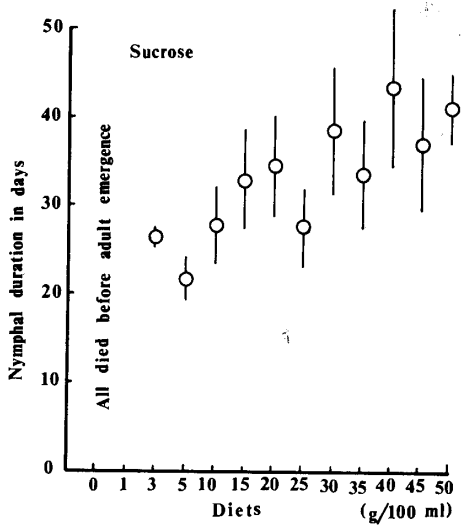

Fig. 2. Effect of sucrose concentration in MED-1 diet on nymphal period. ϕ : average ± standard deviation.

diets were prepared substituting a 5% concentration of glucose, fructose, maltose, raffinose, or trehalose for sucrose in MED-1. Synthetic diets containing 1% sucrose and 5% of one of sugars listed above were also prepared and used in other experiments. The synthetic diet was fed through Fuji Sealon films and was changed every other day. Replicates of 100 individuals were reared and moulting, adult emergence, and death were recorded.

RESULTS

1. Effect of sucrose concentration on larval developement

Larvae were reared on an MED-1 diet with a sucrose concentration ranging from

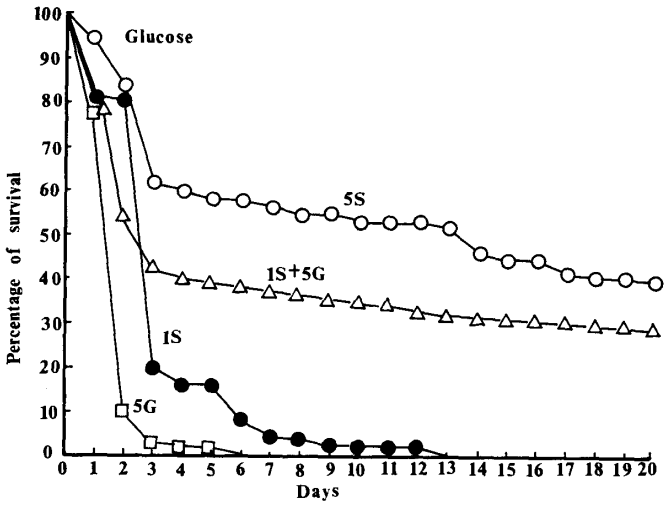

Fig. 3. Effect of the concentration of glucose and sucrose in MED-1 diet on nymphal survival. 1S: 1g/100 m*l* sucrose, 5G: 5g/100 m*l* glucose, 5S: 5g/100 m*l* sucrose, 1S+5G: 1g sucrose, 5g glucose/100 m*l*.

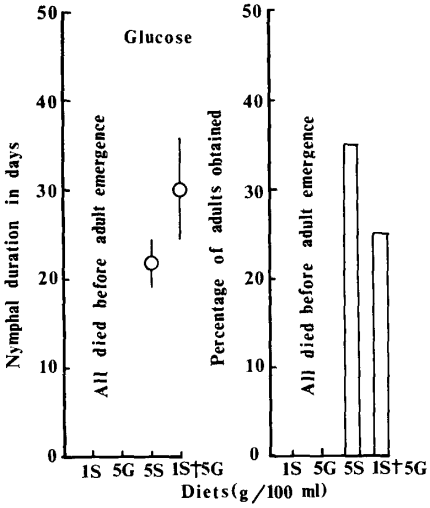

Fig. 4. Effect of the concentration of glucose and sucrose in MED-1 diet on nymphal period and adult emergence. ϕ: average±standard deviation. 1S: 1g/100 m*l* sucrose, 5G: 5g/100 m*l* glucose, 5S: 5g/100 m*l* sucrose, 1S+5G: 1g sucrose, 5g glucose/100 m*l*.

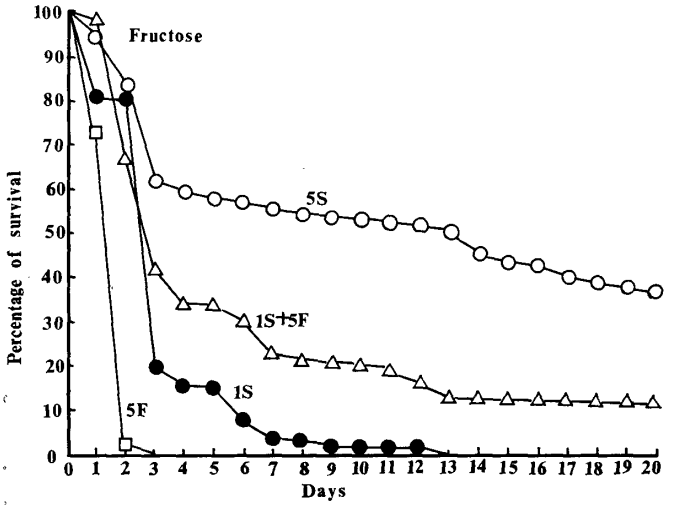

Fig. 5. Effect of the concentration of fructose and sucrose in MED-1 diet on nymphal survival. 1S: 1g/100 m*l* sucrose, 5F: 5g/100 m*l* fructose, 5S: 5g/100 m*l* sucrose, 1S+5F: 1g sucrose, 5g fructose/100 m*l*.

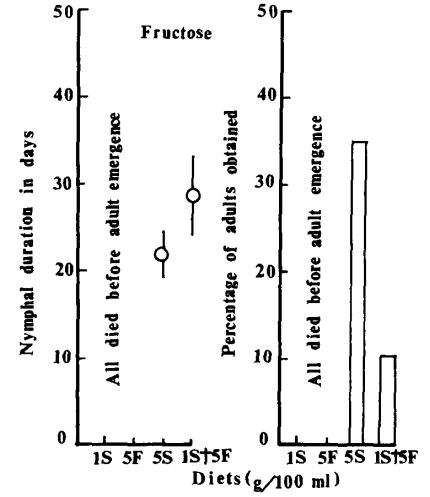

Fig. 6. Effect of the concentration of fructose and sucrose in MED-1 diet on nymphal period and adult emergence. ϕ: average±standard deviation. 1S: 1g/100 m*l* sucrose, 5F: 5g/100 m*l* fructose, 5S: 5g/100 m*l* sucrose, 1S+5F: 1g sucrose, 5g fructose/100 m*l*.

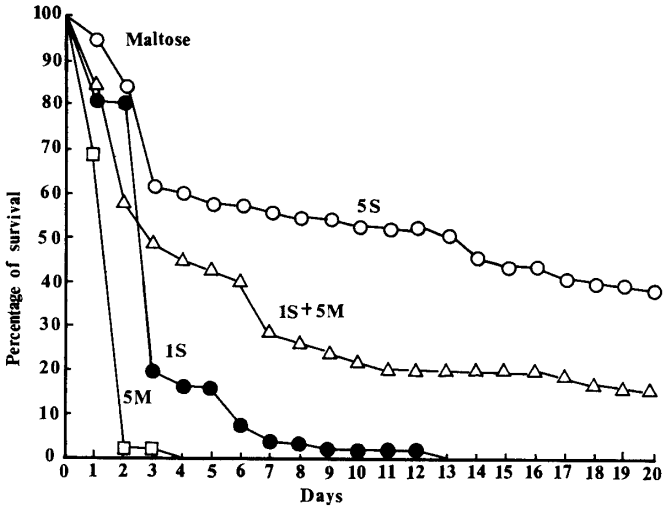

Fig. 7. Effect of the concentration of maltose and sucrose in MED-1 diet on nymphal survival. 1S: 1g/100 m*l* sucrose, 5M: 5g/100 m*l* maltose, 5S: 5g/100 m*l* sucrose, 1S+5M: 1g sucrose, 5g maltose/100 m*l*.

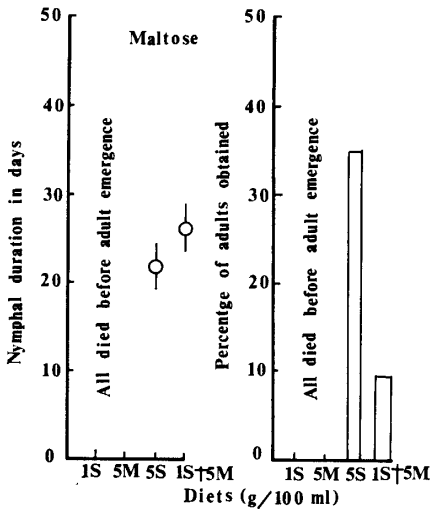

Fig. 8. Effect of the concentration of maltose and sucrose in MED-1 diet on nymphal period and adult emergence. ϕ : average±standard deviation. 1S: 1g/100 m*l* sucrose, 5M: 5g/100 m*l* maltose, 5S: 5g/100 m*l* sucrose, 1S+5M: 1g sucrose, 5g maltose/100 m*l*.

0 to 50%. On the 0% sucrose diet all individuals died in the 1st-instar within 3 days after hatching (Table 1). On the diet containing 1% sucrose, the larvae grew to some extent but all died before the 4th-instar. On diets containing 3% or more sucrose, most of the larvae grew to adults (Fig. 1). The shortest nymphal period was obtained with a sucrose concentration of 5%, indicating that the best growing conditions were attained at this concentration (Fig. 2). The nymphal period was longer on sucrose concentrations over 10%, and the mean nymphal period was longest, 44 days, on the diet containing 40% sucrose. This was about twice the duration of the shortest period, which was obtained on the diet containing 5% sucrose. Adult body-size was not affected by the duration of the nymphal period (data not shown). Percentage of adult emergence showed the highest value of 51% on the diet containing 25% sucrose, while it was very low, less than 5%, on diets containing either 3% or 50% sucrose (Fig. 1).

2. Effect of glucose on the growth of the larvae

Larvae reared on MED-1 diet whose sucrose was substituted with 5% glucose, died within 6 days after hatching (Fig. 3). Addition of 1% of sucrose to this diet, however, resulted in survival greater than that obtained on the 1% sucrose diet, and some larvae grew to adults. Nymphal period was longer and percentage of adult emergence lower than those on the diet containing 5% sucrose (Fig. 4).

3. Effect of fructose on the growth of the larvae

All larvae died by day-3 when reared on MED-1 diet containing 5% fructose as the sole sugar component (Fig. 5). A supplement of 1% sucrose to the diet resulted in larval growth and some larvae grew to adults; however, nymphal duration was longer

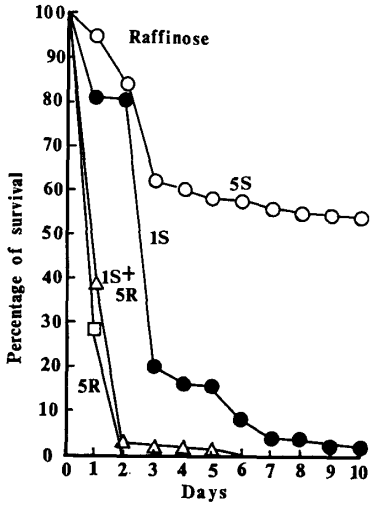

Fig. 9. Effect of the concentration of raffinose and sucrose in MED-1 diet on nymphal survival. 1S: 1g/100 m*l* sucrose, 5R: 5g/100 m*l* raffinose, 5S: 5g/100 m*l* sucrose, 1S+5R: 1g sucrose, 5g raffinose/100 m*l*.

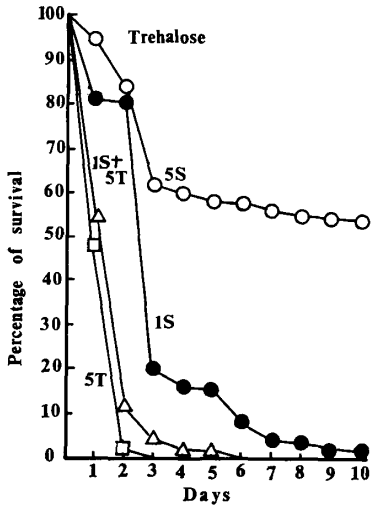

Fig. 10. Effect of the concentration of trehalose and sucrose in MED-1 diet on nymphal survival. 1S: 1g/100 m*l* sucrose, 5T: 5g/100 m*l* trehalose, 5S: 5g/100 m*l* sucrose, 1S+5T: 1g sucrose, 5g trehalose/100 m*l*.

than that on the diet containing 5% sucrose, and the rate of adult emergenece was only around 10% (Fig. 6).

4. Effect of maltose on the growth of the larvae

All larvae died within 4 days of rearing on MED-1 diet containing 5% maltose as the sole sugar component (Fig. 7). However, the larvae grew to adults when this diet was fortified by 1% sucrose as in the case of glucose and fructose. A slightly longer nymphal period and lower adult emergence rate were observed compared to larvae reared on the diet containing 5% sucrose (Fig. 8).

5. Effect of raffinose on the growth of larvae

All larvae died by day-2 when reared on MED-1 diet containing 5% raffinose. Again, all larvae died by day-6 when reared on the diet containing 1% sucrose and 5% raffinose (Fig. 9).

6. Effect of trehalose on the growth of larvae

All larvae died by day-3 when reared on MED-1 diet containing 5% trehalose as the sole sugar source. Addition of 1% sucrose to the diet did not significantly improve the situation and all the larvae died within 6 days after hatching (Fig. 10).

DISCUSSION

Larvae of the brown rice planthopper, *Nilaparvata lugens* STÅL, were reared on the basal MED-1 diet supplemented with one of the following sugars, sucrose, glucose, fructose, maltose, raffinose or trehalose. All larvae died within several days of rearing

on all sugar sources except sucrose. However, the larvae grew to adults on diets containing either glucose, fructose, or maltose if they were supplemented with 1% sucrose. Since the larvae could not grow to adults on the MED-1 diet containing 1% sucrose alone, it is presumed that glucose, fructose and maltose can function as nutrients in the presence of sucrose. For the growth of the larvae of brown rice planthopper, the present study showed that the nymphal period was shortest on the diet containing 5% sucrose. Although the reason why the nymphal period increased on 10–50% sucrose is not clear at present, it is likely that the quantitative balance between sucrose and other nutrients in the basal diet might be correlated closely with the growth rate of the larvae. In previous studies (KOYAMA, 1981), it was shown that sucrose concentration itself in the diet also plays an important role on larval growth, since administration of a higher concentration of sucrose to the 2nd-instar larvae resulted in a longer survival period.

The complete synthetic diets for leafhoppers and planthoppers so far described contained 5% sucrose as a sugar source: for the small brown planthopper, *Laodelphax striatellus* FALLÉN, (MITSUHASHI and KOYAMA, 1971); for brown rice planthoppers, *Nilaparvata lugens* STÅL, (KOYAMA, 1979); for white-backed rice planthoppers, *Sogatella furcifera* HORVÁTH, (KOYAMA and MITSUHASHI, 1980); for *Sogatella longifurcifera* ESAKI et ISHIHARA, (KOYAMA et al., 1981); for green rice leafhopper, *Nephotettix cincticeps* UHLER, and zig-zag rice leafhoppers, *Recilia drosalis* MOTSCHULSKY, (KOYAMA, 1973); for aster leafhoppers, *Macrosteles fascifrons* STÅL, (HOU and BROOKS, 1975). The present study showed that the optimal sucrose concentration in the diet was also 5% for brown rice planthoppers, and that glucose, fructose and maltose have nutritive value and could be utilized for studies on nutritional physiology in combination with sucrose.

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