contrary to the experience of plant-pathologists in many plant diseases. He suggests that as the factor cannot be climatic in this case, "an investigation of conditions within the host plant itself is most likely to provide an explanation". I think in wheat rust similar study of conditions of growth within the wheat plant may yield some clue to the main problem of eradication. So far, at wheat rust study centres no attention in this direction seems to have been paid.

S. R. Bose

Botanical Laboratory,
Carmichael Medical College,
Calcutta.
July 24.

[1] Hyde, M. B., *Ann. App. Biol.*, **38**, 348 (1951).
[2] Bose, S. R., *Science*, **117**, 16 (1953).
[3] Hansen, E. H., and Christensen, J. J., *Min. Agric. Exp. Sta. Tech. Bull.*, **206**, 1 (1953).
[4] Personal communication from a member of the staff of the Central Rice Research Institute, Cuttack.
[5] Mehta, P. R., *Plant Protection Bull.*, New Delhi, 2, 50 (1950).
[6] Grainger, John, *Trans. Brit. Mycol. Soc.*, 37, 412 (1954).

Effect of Crowding during the Larval Period on the Determination of the Wing-form of an Adult Plant-hopper

The effect of crowding on the physiological and morphological characters of larvæ or adult has attracted much attention. Comprehensive reviews have been published by Allee[1], and recently by Chauvin[2]. The latter distinguished two categories in the general effect of crowding, "l'effet de masse" and "l'effet de groupe", which had been proposed by Grassé. Bonnemaison[3], in his studies on the factors affecting the appearance of the winged form in aphids, and Badonnel[4], working on the complete development of the wings in Psocoptera, found that the most important effect of crowding occurs during the developmental period.

I am investigating the factors determining the wing-form, macropterous or brachypterous, of plant-hoppers, and I have found that crowding during the larval period plays an important part in the determination of wing-form in the brown plant-hopper, *Nilaparvata lugens* Stål.

The brown plant-hopper is a serious pest of the rice plant in Japan. The macropterous form has normal fore- and hind-wings; but the brachypterous form has the fore-wings of half the normal length and rudimentary hind-wings, and this form consequently cannot fly. Macropterous males and females appear at first in the paddy fields in early summer. Brachypterous females appear afterwards and increase in number during the summer and autumn. By late autumn, when the rice plants ripen, the macropterous form becomes prevalent again. Brachypterous males appear in late summer and autumn but are less frequent than females.

Larvæ were put into test-tubes (2 cm. in diameter and 17·5 cm. in length) within 24 hr. of hatching, with a leaf blade of rice plant in each for food. A few drops of water were poured into each tube. Food and container were renewed at intervals of 1, 2 and 4 days in each series of density.

The result is shown in Fig. 1. At the lowest density the figures differ extremely with sex; all emerged females are brachypterous and males are macropterous. With increase of density, the percentage of the macropterous females increases and reaches almost 100 per cent at a density of 20. On the other hand, in

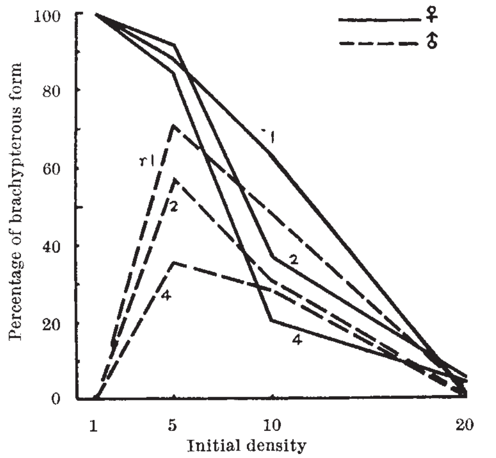

Fig. 1. Percentage of the brachypterous form of both sexes resulting from a breeding experiment in which the initial density and interval of renewal of the food and container were varied

the males, the brachypterous form appears in the middle range of density. At greater densities, the macropterous form increases again with the density in parallel with the females. Therefore, the optimal density for the appearance of the brachypterous male can be determined.

On the other hand, the effect of freshness of food and change of container has also to be appreciated. When the interval of renewing food and container is prolonged, the appearance of the macropterous form is accelerated in both sexes. This effect is most clearly shown in the middle range of density. It seems probable that the larvæ are at the critical state for determining their form at that density.

The larval period of the various forms is shown in Table 1; that for the brachypterous form of both sexes is shorter than that for the macropterous form. The former shows a rather constant period even at high densities, whereas that of the latter shows a lengthening effect. Examined in more detail, it is found that at the density of 5 at which the brachypterous male appeared in highest proportion, this form is the group having the shortest period of larval development. This larval period is shorter than that of the macropterous male, which appeared exclusively at a density of 1. This acceleration of

Table 1. Duration of the Larval Development of the Various Forms resulting from a Breeding Experiment in which the Initial Density and Interval of Renewal of the Food and Container are Varied. *B* denotes the Brachypterous Form and *M* the Macropterous Form

Interval of renewal = 1 day

Form and sex \ Density	1	5	10	20
B♂		14·2	14·1	
M♂	14·7	14·5	16·1	17·2d.
B♀	15·2	15·5	16·6	18·0*
M♀		15·5	17·5	18·9
r = 2				
B♂		14·2	14·3	
M♂	14·5	14·2	15·2	17·5
B♀	15·3	15·2	15·7	·
M♀		16·3	17·4	19·7
r = 4				
B♂		13·8	14·8	
M♂	14·5	14·6	15·4	17·0
B♀	15·1	15·1	16·0	18·0*
M♀		15·4	17·2	18·2

* Only one obtained

Table 2. NUMBER OF ADULTS OF THE VARIOUS FORMS RESULTING FROM BREEDING WITH THE LEAF BLADE IMMERSED IN VARIOUS SOLUTIONS OF SALT. INITIAL DENSITY WAS 5 PER TUBE IN EACH BLOCK

Solution	No. of replicates	No. of adults emerged				
		B♂	*M*♂	*B*♀	*M*♀	Total
Copper sulphate	10	0	0	0	0	0
Ammon. sulphate	10	1	26	3	17	47
Mag. sulphate	10	7	16	15	9	47
Pot. chloride	10	11	16	14	9	50
Control	10	13	13	19	2	47

larval development seems to be due to mutual stimulation among the members in a tube.

Other experiments have shown that the wilting of the host plant produces the macropterous female without the effect of crowding, accompanied by the considerable elongation of the larval period. This fact seems to be responsible for the prevalent appearance of the macropterous female in the field in late autumn.

Various solutions of salts were used instead of water in the test-tubes for examining their effectiveness for the determination of the various forms. The concentration of each solution was 0·05 mol. The initial density used was 5. Food and container were renewed every day and no wilting of the leaf blade was observed, except when copper sulphate solution was used; in that case all larvæ died in a few days (Table 2). These solutions show, more or less, the effectiveness on the production of the macropterous form in both sexes. Parallel decrease in the percentage of the brachypterous form is clearly shown in both sexes, though the absolute figures for the brachypterous females in each treatment always exceed those of males.

The observations lead to the following conclusions.

(1) Low density under favourable conditions of food supply during the larval period is necessary for the appearance of the brachypterous female. On the other hand, optimal density under favourable conditions of food supply produces the brachypterous male. The mechanism of the different responses of the sexes to crowding remains to be found.

(2) Optimal crowding accelerates the development of the larvæ, and this fact seems to be responsible for the mechanism inducing the appearance of the brachypterous male at the optimal density.

(3) Wilting of the host plant, overcrowding, contamination due to crowding and solutions of several salts have the effect of producing the macropterous form, and this effect is followed by lengthening of the developmental period of the larvæ subjected to these conditions.

(4) Factors causing the appearance of the brachypterous form must be studied in parallel with those leading to the appearance of the macropterous form, especially the males, as shown in the present communication.

The advice of Prof. S. Utida of this Laboratory is gratefully acknowledged.

RYÔITI KISIMOTO

Entomological Laboratory,
Kyoto University,
Kyoto.
March 3.

[1] Allee, W. C., "Animal Aggregation" (Chicago, 1931).
[2] Chauvin, R., Colloq. Int. Cent. Nat. Recherche Sci., **34**, 81 (1953).
[3] Bonnemaison, L., Ann. Inst. Recherche Agron., C, *Ann. Epiphyt.*, **2**, 1 (1951).
[4] Badonnel, A., *C.R. Acad. Sci., Paris*, **228**, 1517 (1949).

An Apparent Reaction of Fish to Linear Accelerations

IT has been reported that fish do not appear to react to rectilinear accelerations[1]. However, they have the sense organs to detect such movements; the otolith organs of the thornback ray are sensitive to linear translations in all three planes of space[2] and teleosts take up compensatory positions when subjected to centrifugal force[3]. Some experiments were therefore made to re-examine the reactions of fish to rectilinear accelerations, blinded minnows, goldfish and naturally blind cave characins, *Anoptichthys jordani*, being used in the preliminary observations. The fish were placed in an enclosed 'Perspex' tank, completely filled with water, and mounted on a rubber-wheeled chassis. They appeared to turn about when the tank was accelerated along a bench by hand.

The reactions of blind goldfish were then studied in a more quantitative manner. A fish was introduced into an enclosed 'Perspex' tank, 60 cm. long, 30 cm. × 15 cm. in section, which was filled with water. The tank was housed in a welded angle-iron chassis fitted with flat rubber-tyred wheels running on a 4-m. long railway made from ⅜-in. steel rod firmly attached to sleepers. The chassis was attached to a rope which ran over two pulley wheels so arranged that the vertical fall of heavy weights would accelerate the tank horizontally along the railway. When the weights hit the ground, the forward movement of the tank was checked by a rope attached at one end to a wall and at the other to the tank by a short length of rubber tubing. A range of accelerations and decelerations was covered by varying the weights and the forward run of the tank. The movement of the tank relative to the ground and that of the fish relative to the tank was recorded by a 16-mm. ciné camera mounted vertically above the railway. Releases were only made when the fish was in mid-water and well clear of the sides of the tank, and when it was swimming more or less in a straight line either with or against the movement of the tank.

The results showed that blind goldfish would turn about when suddenly stopped going forward, or when suddenly started backwards, but not when started going forwards or when stopped going backwards. An analysis of two typical results is given in Figs. 1 and 2. The orientation of the fish is given relative to the longitudinal axis of the tank, a bearing of 0° indicating that the fish was facing in the direction of the tank's movement. In Fig. 1 the tank was released so that the fish was accelerated backwards and it turned about. When the tank slowed down, the fish was decelerated while travelling forwards and turned again. In Fig. 2 there was no reaction to an acceleration when the fish was going forward, but the fish turned on deceleration. A positive reaction was thus only observed when the otolith organs were displaced anteriorly, as indicated diagrammatically in the figure.

The threshold acceleration to induce a reaction was high, positive results being obtained only with accelerations or decelerations greater than 160–200 cm./sec./sec. In both Figs. 1 and 2 it will be seen that the tank recoiled after its forward movement was checked. In some experiments a fish was observed to turn both when the tank slowed down and when the recoil movement slowed down.

While there is an apparent reaction of blind goldfish to linear accelerations, the results do not show con-