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Relationships between Wing-Form Response to Nymphal Density and Black Colouration of Adult Body in the Brown Planthopper, *Nilaparvata lugens* (Homoptera: Delphacidae)¹

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During successive selection for adults with a special wing form from a population of the brown planthopper, *Nilaparvata lugens*, a negative correlation was found between the proportion of brachypters and the grade of black pigmentation in the adults: population including more blackish individuals tended to exhibit a lower ratio of brachypters. The selection for blackish macropters finally generated a population producing predominantly macropters, while the selection for yellowish brown brachypters produced a population exhibiting totally brachypters, over broad ranges of nymphal densities in both sexes. Two populations from Malaysia and the Philippines were quite similar to this brachypter producing population in their wing-form responses to density. All of 14 populations collected in Saga and Nagasaki Prefectures during 1986 and 1987 were highly macropterous and their body colours were blackish. During these two years, population density of the immigrants in paddy fields was unusually high in the rainy season in both prefectures, but the insects did not cause severe damage to rice plants in most districts. Whether these unexpected events were due to the immigration of hoppers with highly macropterous character was discussed.

INTRODUCTION

The brown planthopper, *Nilaparvata lugens* shows wing dimorphism, i.e., macropters and brachypters, mostly depending on nymphal density. When compared with the brachypters, the macropters tend to have longer nymphal duration, show more melanized body colour (KISIMOTO, 1965), and longer pre-oviposition period (KISIMOTO, 1965; IWANAGA and TOJO, 1986).

IWANAGA et al. (1985, 1987) showed that there are wide inherent variations in wing-form responses to density among populations of this species collected in Japan and Southeast Asian countries: the females of a few populations are predominantly brachypterous in broad ranges of densities, those of dominant populations have an increased ratio of macropters with increasing nymphal density, while some are highly macropterous even at low densities. The brachypterous population shows shorter nymphal duration and narrower relative wing-length than the population showing

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density-dependent wing morphism and these characters are not influenced by the density during their nymphal stage (IWANAGA and TOJO, 1988). About ten generations of successive selection for brachyptery from a population showing usual density-dependent wing morphism generated a highly brachypterous population, while the selection for macroptery could not produce a population showing more macropterous character than the mother population (IWANAGA et al., 1985).

In this study, we have again tried to generate both brachypterous and macropterous populations from a population changing wing-form in density-depending manner, and compare the characters of the selected populations with those collected in fields.

MATERIALS AND METHODS

A strain (Saga strain) collected in July, 1983 at Saga-shi was maintained in our laboratory, and has been used for selection experiments since April, 1986. Six populations collected in July, 1986 in Nagasaki Pref., eight populations collected in July-September, 1987 in Nagasaki and Saga Prefs., one strain collected in Manila in the Philippines and the other one collected in North Sumatora in Indonesia, both of which were imported to the Kyushu National Agricultural Experiment Station, were used for comparative studies.

For comparison of wing-form density relationships of these strains, first-instar nymphs within a day after hatching were reared at densities of 10, 20, 50 and 150 (three replicates) in cylindrical vessels (5.4 cm in diameter, 20 cm in height), on rice seedlings of the Reiho variety, and the wing-forms of adults were checked, as described by IWANAGA et al. (1985). All experiments were conducted at $25 \pm 1^\circ\text{C}$ under 16L-8D photoperiod.

For macroptery selection from the Saga strain, insects of both sexes with macropterous wing form within 24 hr of emergence, occurring from the 20 density plots mentioned above were selected for mating. The progenies were reared at 20 density and further crossings between macropters were repeated. For brachyptery selection, matings of brachypterous adults obtained from 50 density plots were repeated.

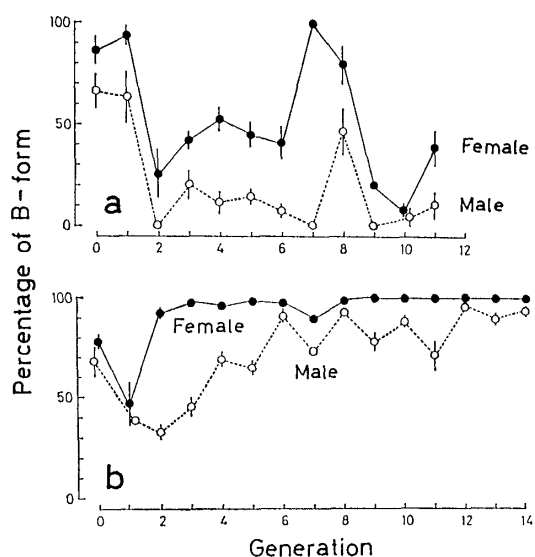
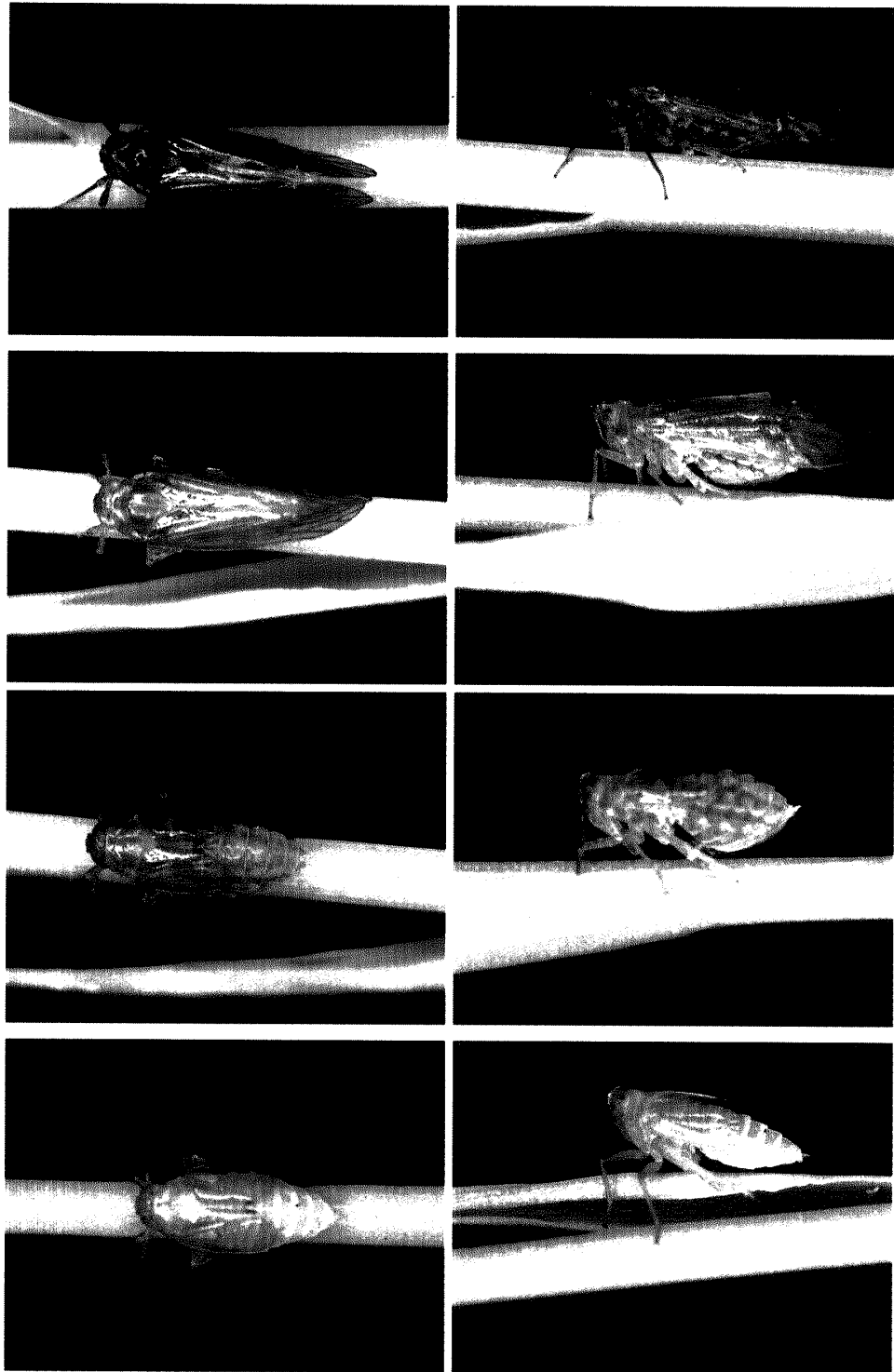


Fig. 1. Changes in % of brachypterous form (B-form) at 20 (a) and 50 (b) density plots by successive special wing form selection from the Saga strain. For macroptery selection (a), 20 newly hatched nymphs were enclosed in a cylindrical vessel (5.4 cm in diameter, 20 cm in height) containing rice seedlings, reared at 25°C under 16L-8D photoperiod, and matings between macropters emerged from the vessel were repeated. For brachyptery selection (b), 50 larvae were reared in each vessel and brachypters emerged from it were selected for mating. Values are averages \pm S.E. (three replicates).

Wing Polymorphism of *N. lugens*



I
II
III
Fig. 2. Photographs of *N. lugens* females showing different colour types. Grade I, yellowish brown, having no blackish parts on the abdomen; grade III, highly blackish, having no yellowish brown parts on the abdomen; grade II, intermediate between I and III.

Colour grades of ventral abdomens of adults were checked about 24 hr after emergence as follows: grade I, yellowish brown, having no blackish parts; grade III, highly blackish, having no yellowish brown parts; grade II, all others which were not scored as grade I or III (see Fig. 2).

RESULTS

Selections for macroptery and brachyptery depending on wing form

As shown in Fig. 1, the ratios of brachypterous form in the Saga strain at the start of selection were 86 and 78% in females, and 66 and 68% in males at 20 and 50 density plots, respectively. Although selection for macroptery for three generations greatly decreased the ratio of brachypters in both sexes, further successive selection could not generate a population with more macropterous character, the ratios of brachypterous form in the resulting populations greatly fluctuating by generation (Fig. 1a). Successive selection for brachyptery considerably increased the ratio of brachypters, especially in females, so that it reached 100% after 10 generations, but in males the ratio fluctuated by generation, being under 100% even after 14 generations (Fig. 1b).

Selections for macroptery and brachyptery depending on wing form and body colour

During the course of specific wing form selection, a change was found in adult body colour: by macroptery selection the ratio of individuals with blackish parts showed a tendency to increase, while by brachyptery selection individuals with non-blackened parts became predominant. Accordingly, adult planthoppers were grouped mostly depending on the grade of black pigmentation in their abdomens, as follows, non-blackened (grade I), intermediate (grade II) and highly blackened (grade III) (Fig. 2).

For further macroptery selection, matings of macropters with body colour of grade III or near this grade were repeated, and for brachyptery selection, brachypters with body colour of grade I or near this grade were selected for mating. In blackish macroptery selection, the ratio of brachypters decreased as the average grade of adult colour

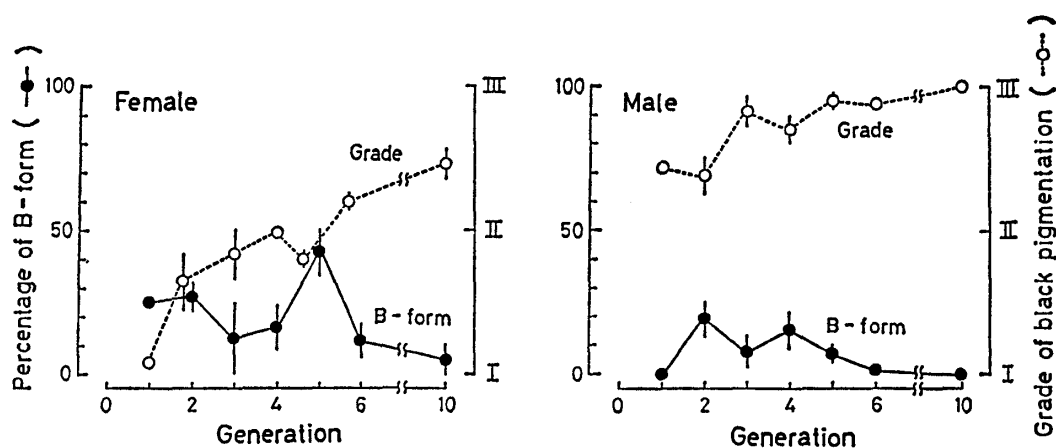


Fig. 3. Changes in % of brachypters and grades of black pigmentation at 20 density plots in adult planthoppers by successive selection for macropters with body colour of or near grade III (ref. Fig. 2). Matings of both sexes emerged from 20 density plots were repeated. B-ratio: % brachyptery. Values are average \pm S. E. (three replicates).

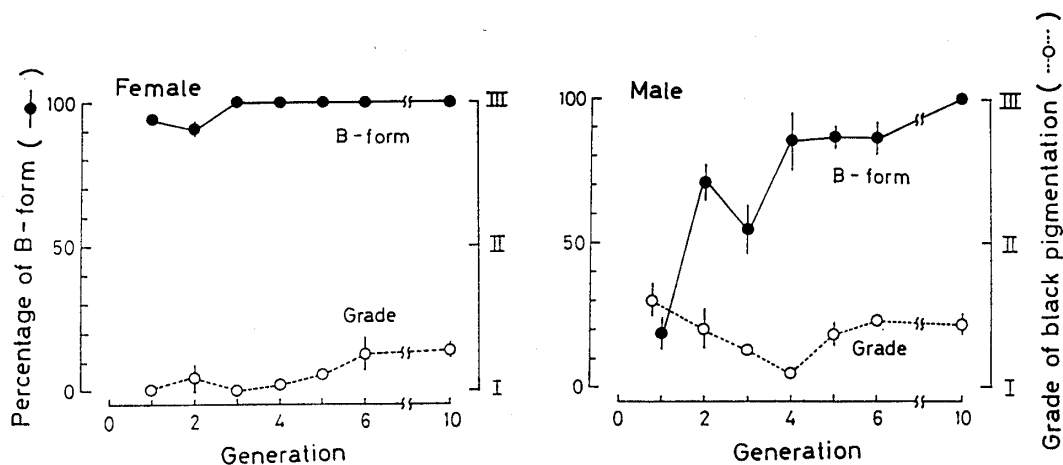


Fig. 4. Changes in % of brachypters and grades of black pigmentation at 50 density plots in adult planthoppers by successive selection for brachypters with body colour of or near grade I (ref. Fig. 2). Matings of both sexes emerged from 50 density plots were repeated. See Figs. 1 and 3 for others.

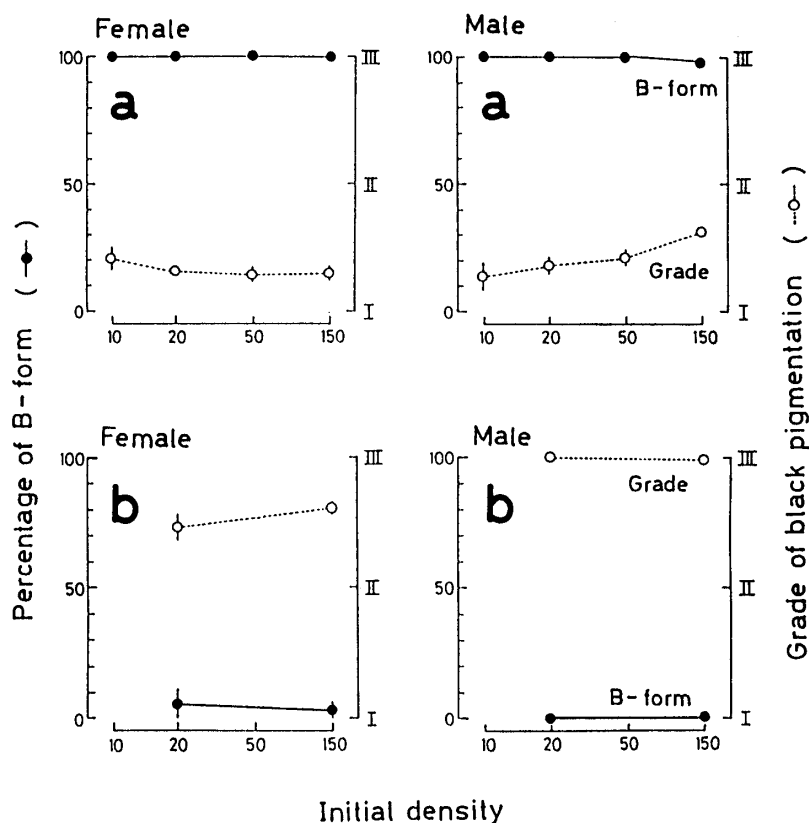


Fig. 5. Comparison of responses of adult wing-form and body-colour to nymphal densities in populations (a) and (b), generated after 10 generations of successive selection for brachypters with yellowish-brown body colour, and for macropters with blackish body colour, respectively, as shown in Figs. 3 and 4. See Figs. 1 and 3 for others.

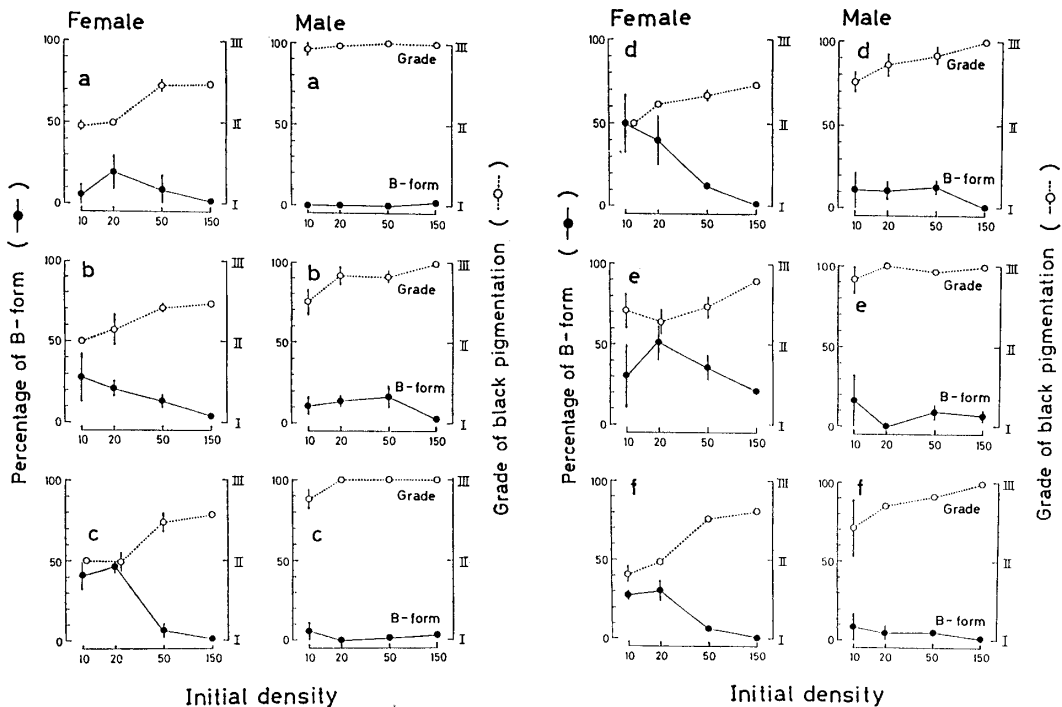


Fig. 6. Comparison of responses of adult wing form and body-colour to nymphal densities in six populations collected in Nagasaki Pref. in July 21–23, 1986. Comparison was carried out with the progenies after two or three generations of field collection. Site of collection: Isahaya (a); Kamigoto Is. (b, Akao; c, Arikawa); Shimogoto Is. (d, e, Tomie; f, Kirinoki). See Figs. 1 and 3 for others.

increased, and was less than 5% after 10 generations (Fig. 3). On the other hand, selection for brachypters with yellowish brown body was effective to increase the ratio of brachypters, especially in males, and to attain 100% after 10 generations (Fig. 4).

As shown in Fig. 5, 10 generations of successive selection for macropters with blackish body produced a population showing a macropter ratio of over 90% in broad ranges of densities with highly blackish body, prominently in males. In striking contrast, 10 generations of successive selection for brachypters with non-blackish body generated a population showing predominantly brachypters at any density tested, and having a yellowish brown colour near grade I.

Comparison in wing-form density relationships and body colour in field-collected populations

Six populations were collected in fields in July, 1986 just after the rainy season, which were expected to be immigrants from overseas. As shown in Fig. 6, males in all populations were highly macropterous and considerably blackish over broad ranges of densities. In females, all of the populations showed over a 50% macropter ratio even at low densities, and the grade of black pigmentation of their bodies tended to increase slightly with increasing density.

Further in 1987, seven populations collected in July during or shortly after the end of rainy season and one population collected in early September, which might be a descendant of earlier immigrants, were compared. As shown in Fig. 7, males in all populations emerged predominantly as macropters at any density tested, and females

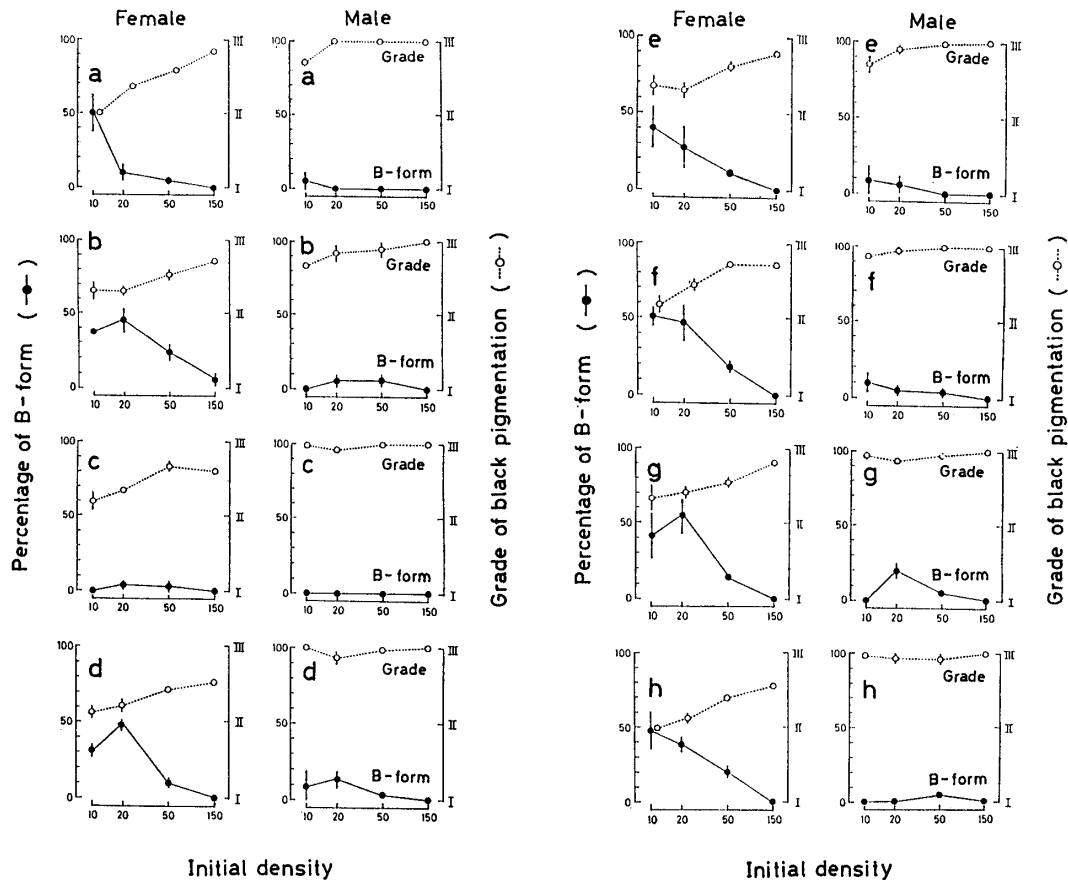


Fig. 7. Comparison of responses of adult wing-form and body-colour to nymphal densities in eight populations collected in Saga and Nagasaki Prefs. in 1987. Comparison was carried out with the progenies after two or three generations of field collection. Site and date of collection: Saga-shi and its vicinity (a, Kawazoe-machi, July 7; b, Honjyo-machi, July 20; h, Hyogo-machi, Sept. 9); Ureshino, Saga Pref. (c, July 22); Nagasaki Pref. (d, Isahaya, July 22; e, Nomosaki, July 23; f, Oseto, July 23; g, Tahira, July 24). See Figs. 1 and 3 for others.

also showed highly macropterous character. Thus, it could be pointed out that most of the immigrants to northern Kyushu in 1986 and 1987 had a character of exhibiting macropters in dominant ratio with blackish body colour.

Two foreign populations were also compared for their responses to density, as shown in Fig. 8. Both sexes of the population from North Sumatora produced only brachypters with yellowish brown body over broad ranges of densities, but the one from Manila was less brachypterous and slightly blackish. Compared to field collected populations in Japan in 1986 and 1987 (Figs. 6 and 7), the two populations from South Asia showed far higher tendency to exhibit brachypters with less-blackish body.

As shown in Fig. 9, the percentages of brachypters were plotted against the grades of black pigmentation, with adults emerged from different density plots of the populations used in this study. In both sexes, there could be found a relationship indicating that more blackish populations tended to show a more macropterous character.

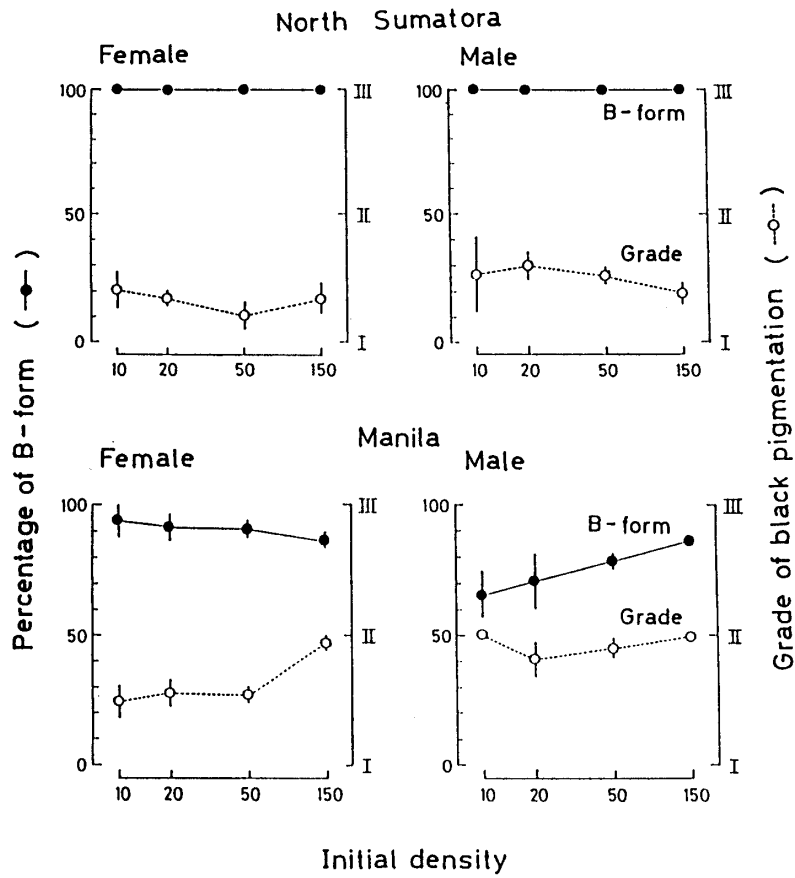


Fig. 8. Comparison of responses of adult wing-form and body-colour to nymphal densities in two foreign populations from North Sumatora in Indonesia and Manila in the Philippines. See Figs. 1 and 3 for others.

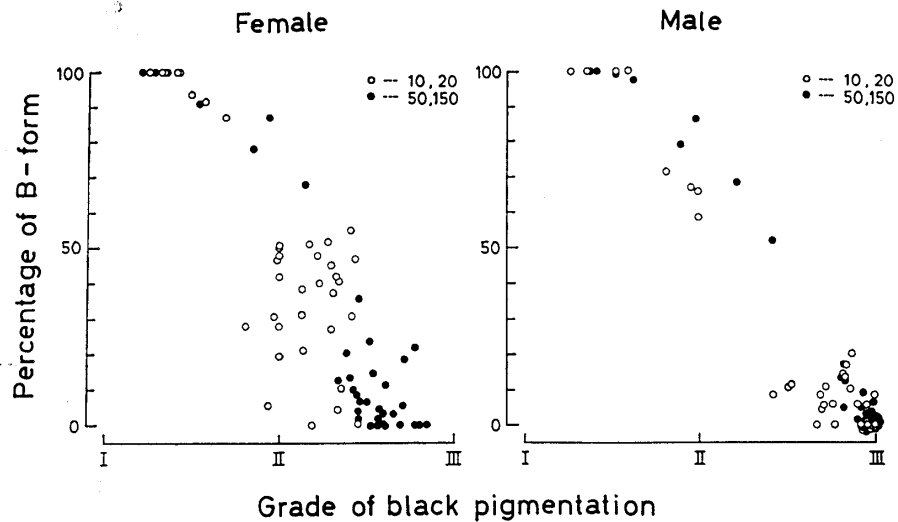


Fig. 9. Relationships between % of brachypters and grade of black pigmentation in the adults emerged from 10 or 20 density plots (O), or from 50 or 150 density plots (●) among the populations used in this study (ref. Figs 5-8).

DISCUSSION

Successive brachyptery selection over 10 generations depending on wing form from a *N. lugens* population in a previous study (IWANAGA et al., 1985) could generate a population similar to the one from Manila (see Fig. 8), in which the females were totally brachypterous, while the males showed about 50% brachypter ratios in broad ranges of nymphal densities. The brachyptery selection also for yellowish brown coloured individuals in the present study was more effective to increase brachypter ratio, and generated totally brachypterous males, as in the population from North Sumatora (ref. Figs. 5a and 8). Although successive selection only for macroptery was not effective to increase the proportion of macropters (IWANAGA et al., 1985), the selection for blackish coloured macropters could produce a population producing almost totally macropters in both sexes, as presented in this study.

There was found a rather good correlation of blackish populations tending to show high proportions of macropters, while yellowish ones exhibited brachypters in dominant ratios (Fig. 9). This relationship may partly be due to the phenomenon that macropterous planthoppers are more melanized than brachypterous ones (KISIMOTO, 1965), as can be seen also in the females of some field-collected populations (Figs. 6 and 7). But, the profound effects of selections combined with wing form and colour type on generating populations exhibiting one-type wing form over broad ranges of densities as mentioned above support a presence of genetic correlation between wing form and colour type. Genetic analyses are now in progress to elucidate this relationship.

We have demonstrated that all field populations collected in Saga and Nagasaki Prefs. on Kyushu Is. in 1986 and 1987 were highly macropterous with blackish body, especially in males, and the females predominantly exhibited macropters at higher nymphal densities. This situation was considerably different from that during 1983 and 1984 in a previous study (IWANAGA et al., 1987), in which macropterous populations accounted for only one fourth of field-collected groups, those showing density-dependent responses in their wing forms were dominant, and some were highly brachypterous. The immigrant populations in 1986 and 1987 were huge in size in many places in Kyushu Is., but damage by *N. lugens* was not serious even in non-controlled paddy fields. These unexpected events during the two years may be explained as caused by immigrations of highly macropterous hoppers as shown in Figs. 6 and 7: progenies of these immigrants may become mostly macropters in the following generation(s), and disperse to other fields.

N. lugens feeds almost exclusively on rice, and so it can be accepted that this plant-hopper is originally a resident species in the tropics, limited to wild rice habitat areas, where brachypterous populations would become dominant by natural selection due to emigration of macropterous individuals outside their habitat, as suggested by previous studies (IWANAGA et al., 1985, 1987). Enlargement of paddy fields in broader and more northern areas in the Chinese continent might increase chances of survival for macropterous populations, which could return to year round rice growing locations after passing one or two generations in a cool area. Thus, macropterous populations are expected to become dominant, possibly near the year round breeding areas. Recent change in the wing form characters of immigrants to Japan may reflect the reformation of population composition in their migration sources.

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REFERENCES

- IWANAGA, K. and S. TOJO (1986) Effects of juvenile hormone and rearing density on wing dimorphism and oöcyte development in the brown planthopper, *Nilaparvata lugens*. *J. Insect Physiol.* **32**: 585–590.
- IWANAGA, K. and S. TOJO (1988) Comparative studies on the sensitivities to nymphal density, photoperiod and rice plant stage in two strains of the brown planthopper, *Nilaparvata lugens* STÅL (Homoptera: Delphacidae). *Jpn. J. Appl. Ent. Zool.* **32**: 68–74 (in Japanese with an English summary).
- IWANAGA, K., S. TOJO and T. NAGATA (1985) Immigration of the brown planthopper, *Nilaparvata lugens*, exhibiting various responses to density in relation to wing morphism. *Entomol. exp. appl.* **38**: 101–108.
- IWANAGA, K., F. NAKASUJI and S. TOJO (1987) Wing polymorphism in Japanese and foreign strains of the brown planthopper, *Nilaparvata lugens*. *Entomol. exp. appl.* **43**: 3–10.
- KISIMOTO, R. (1965) Studies on the polymorphism and its role playing in the population growth of the brown planthopper, *Nilaparvata lugens* STÅL. *Bull. Shikoku Agr. Exp. Stn., Japan* **13**: 1–106 (in Japanese with an English summary).