Phase Polymorphism of the Larger Pellucid Hawk Moth, *Cephonodes hylas* L. (Sphingidae). II.*

Effects of density in the successive generations

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Summary The transmission of density effects to successive generations of the larger pellucid hawk moth was investigated. The larvae were reared at densities of one and two individuals per container, 12×3 cm, at 24°C.

The coloration of the F_1 generation larvae was not affected by both the parental density conditions during their larval periods and the parental colour types exhibited clearly in the fifth instar of larvae. It changed progressively from pale to dark, depending upon the population density in each generation. The transmission of density effects from one generation to another was concerned with the rates of the larval and pupal developments and mortality.

The phase polymorphism of the larger pellucid hawk moth has been reported by Sasakawa (1967). The darkening of larval colour is determined by the density during the first instar and also the low temperature shows a particular effect in developing of the brown colour. So far as we are aware, no detailed investigation of the density-dependent polymorphism in other species belonging the Sphingidae and of a transmission of the density effects to successive generations as in locusts (Ellis, 1959; Albrecht *et al*, 1959) has been reported. The experiments were carried out to analyse the effects of population density in the successive generations on the phase characters of the larger pellucid hawk moth.

Before going further, we wish to express our sincere thanks to Director Jiro Fumoto, Kyoto Botanical Gardens, for his kind permission to collect the eggs and food-leaves in the gardens.

Material and Methods

The eggs of the larger pellucid hawk moth deposited probably by a common isolated female were collectd in the fields. On emergence the larvae were divided into two lots: one of them was kept in complete isolation and the other was kept crowded as two larvae per plastic container, 12x3 cm, throughout their life. The larvae were reared under constant temperature of 24°C, with relatively high humidity, maintaining by wet filter paper on the bottom of container and with a day-length of 8-10 hours. The colour types (P-1～4 in the fifth instar), duration of larval

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stage and mortality were recorded daily. The excremental pellets were dried in an oven at 80°C for two hours and measured by a constant weight in a desiccator. Other essential methods are quite similar to that described in the previous paper.

Results and Discussion

1. *Larval colouration*

The frequency distribution of colour types of the larvae in two successive generations is shown in Fig. 1. When a larva was kept in isolation throughout its

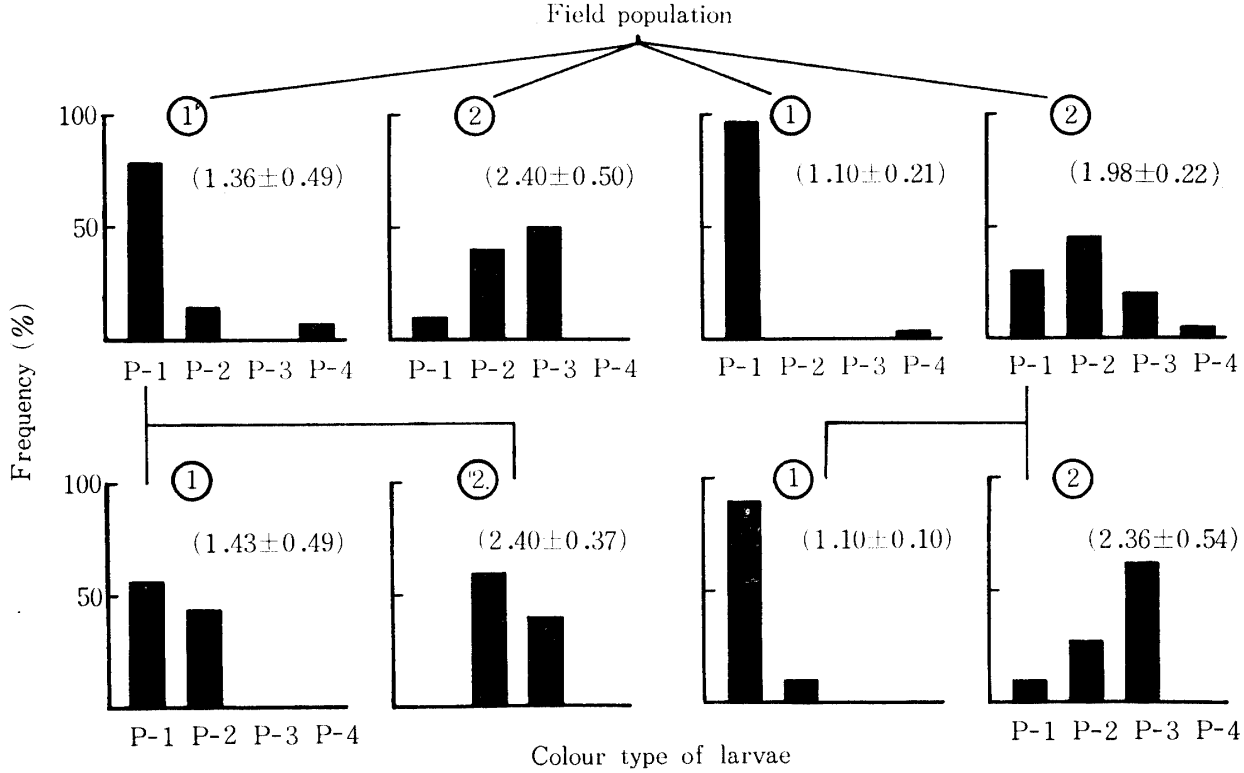

Fig. 1. Frequency distribution of the colour types of larvae in successive generations in relation to density

Rearing density—① : one and ② : two larvae per container, and colour grade in brackets ($\bar{x}\pm t._{05}S\bar{x}$).

life, the typical isolated P-1 type was maintained distinctly in both generations. On the other hand, when two larvae were kept together throughout their larval stages, there was evidence of a considerable trend away from the P-1 type as already demonstrated in the previous paper. The significant difference between isolated and crowded individuals in the colouration was observed in both generations. Judgeing from the mean colur grade, it may be also said that the density of parents as larvae does not affect the colour of the larvae of next generation, though a slight increase of darkend colour type is seen in both the isolated and the crowded lines. These results may be taken to indicate the larval colouration is determined within the earlier instars of each new density treatment in the following generation. Similar results were reported in the hoppers of *Locusta* and *Schistocerca*, but in locusts the density of parents during their adult life affected significantly the colour of hatchlings of the next generation (Hunter-Jones, 1958; Ellis, 1959). Also, it was not

found on these experiments to have the different transmission of the phase characters between the high- and low- density types in the armyworm, *Leucania separata,* in the successive generations as suggested by Iwao (1962). Moreover, as shown in Table 1, there was no difference between the mean colour grades of the larvae of the F_1

Table 1. Effect of larval density on phase characters in the F_1 generation larvae produced by the P-3 type females* ($\bar{x} \pm t_{.05}S\bar{x}$)

Rearing temperature (°C)	24		32	
Rearing density	1	2	1	2
Colour grade	1.00±0	2.38±0.27	1.00±0	2.11±0.25
Larval duration (days)	23.14±0.49	22.67±0.50	14.93±0.63	15.11±0.25
Pupal duration (days)	8.15±0.42	7.73±0.33	8.60±0.55	7.89±0.39
Excremental weight(g)	3.19±0.12	4.47±0.57	2.71±0.19	2.02±0.59
Mortality (%)	0	25.0	25.0	26.9

* Parental characters of P-3 type larvae : colour grade 3.00, larval duration 17.00±2.32 days, pupal duration 14.60±2.08 days, total mortality 30%, at 24°C.

generation produced respectively by the P-1 and P-3 type of parents as larvae, that is, in the latter case too, the colour grades showed the same difference between the both density lines by the following density treatment as mentioned above.

2. *Larval and pupal developments*

The durations of larval period between the isolated and crowded cultures made no difference statistically, but that of the F_1 generation in both the isolated and the crowded lines were distinctly longer than that of parental ones (Fig. 2, Table 1).

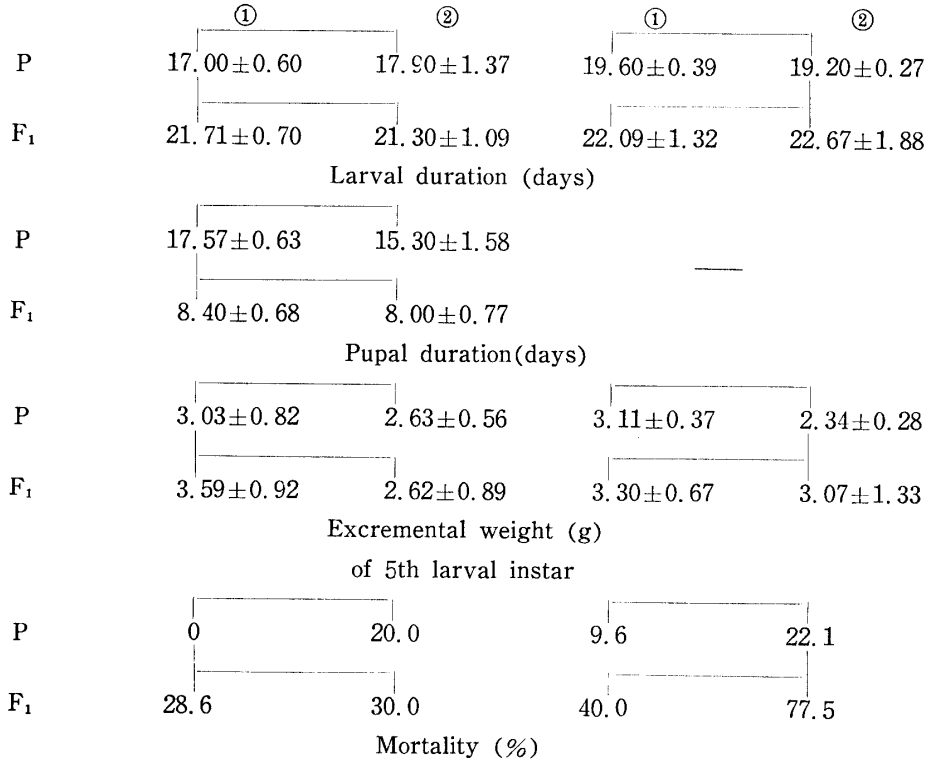

Fig. 2. Effects of density on phase characters of larvae and pupae in successive generations. Rearing density—① : one and ② : two larvae per container.

On the contrary, the rate of pupal development in the F_1 generation was distinctly accelerated. The solitary-reared larvae show reduced growth rates as compared with the crowded ones (Sasakawa, 1967) as in *Plusia gamma* (Long, 1953) and the cabbage armyworm, *Mamestra brassicae* (Hirata, 1966), but in this hornworm no extra moult occurred during the larval period. Similar effects are seen in the larval and pupal developments in the F_1 generation started from the P-3 type parents (Table 1). These sudden changes in their developments of both isolated and crowded lines suggest the residual effect of density from one generation to another. Unfortunately, in both breedings, the normal females with developed ovarioles were not emerged in the following generation and so we could not ascertain some more detailed transmission of characteristics.

Although it is known that the solitary-reared larva eats distinctly larger quantity of food, the weight of excremental pellets during the fifth instar of larvae was not different significantly between the successive generations.

The larvae isolated for all their life showed the lowest mortality, being less than 10%. But the high mortality occurred in the F_1 generation started from the P-1 type parents as larvae, especially the density treatment after one generation of crowding provided evidence of an extreme rise as compared with the transmission to the next generation in the isolated line. It follows from this that the effects of density were cumulative for only two generations.

As suggested already by the senior author, the phase polymorphism in the larger pellucid hawk moth larvae may be regarded as an adaptation for the conditions of their larval life.

要旨： クチナシの葉を食害するオオスカシバ幼虫の多型現象は幼虫期における生息密度に依存しておこり，また低温は褐色出現に影響を及ぼすことをさきに報告したが，本実験では，5令期幼虫体色，発育期間および死亡率に及ぼす生息密度の累代的影響について検討した。その結果，親世代の幼虫期における密度や5令期の体色型によって子世代の幼虫体色が決まるのでなく，むしろ子世代幼虫の発育初期における密度如何によって決定される。同一飼育密度を2代にわたって続けると，子世代には黒化型幼虫の出現がやや増すが有意でない。それに反して，同一密度での累代飼育によって，子世代幼虫の発育は特に遅延し，蛹の発育期間は著しく短縮する。さらに死亡率も累代的に増加する。しかし，5令期幼虫の糞重量に及ぼす累代的影響はみられなかった。このように，世代から世代への密度効果の伝達をみると，幼虫期における環境条件に対する適応として多型が存在するといえる。

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