THE EFFECT OF POPULATION DENSITY ON PROGENY POPULATIONS OBSERVED IN THE DIFFERENT STRAINS OF THE AZUKI BEAN WEEVIL*

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Introduction

In experimental population of the azuki bean weevil, *Callosobruchus chinensis*, the influence of population density upon the progeny populations was fully analyzed in quantitative term (Utida, 1941). The mode of this influence is different, when it is compared with the results obtained with different species in each other (Utida, 1943). The mode may change considerably with different breeding strains in a species, too. The present paper is mainly concerned with this problem.

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Material and method

Various kinds of experiments have hitherto been made using a strain which was multiplied from some individuals captured from the beans obtained at a cereal chandler in Kyoto (Utida, 1941). Other two strains were used for the material of the present experiment. One was the strain of the weevil found in the small lentil bean imported from Iran, and another was that from Mozanbique. These two strains have been reared under the controlled condition of laboratory since the time of these importations.

The method of experiment was almost the same to that described fully in the previous paper (Utida, 1941). Rearing was done in the small dark room where temperature and humidity were regulated at about 30°C and 75% R. H., respectively. The container used was the Petri-dish 1.8 cm. in height and 8.5 cm. in diameter. Dainagon variety of the azuki bean, *Phaseolus radiatus*, which was maintained at a moisture content of about 14%, was used as food material of larvae and site of the oviposition.

Under this condition, where all the factors of the controllable environment were maintained constant, the density of rearing population was changed, as 1, 2, 4, 8…pairs. The weevils were introduced in the dish, where 20 grams of the bean were placed. The emergence of the adult weevils of new generation continued from 3 to 6 weeks after the start of rearing. The count of population was made separately of the males and females until the emergence was over.

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Results

The influence of population density of adult weevils upon the number of their progeny is shown in Table 1, each strain and sex separately.

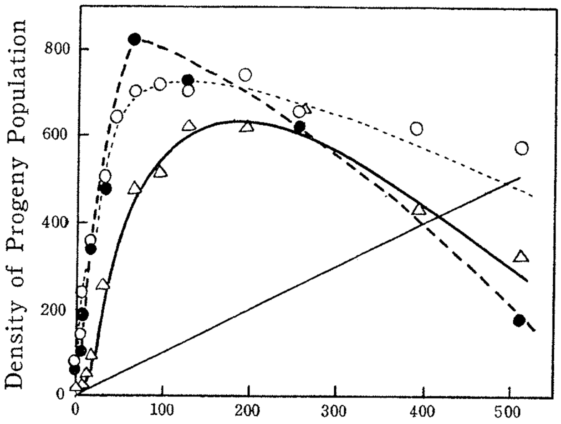

Fig. 1: The relations between the density of parent population and that of progeny.
△: Mozanbique strain. ●: Iran strain. ○: Kyoto strain.

The number of progeny from a pair of weevils was 56.8 in Iran strain in average, while 9.0 in Mozanbique strain. With the increase of the number of parent population, however, the number of progeny did not increase at the rate of this number obtained at the single pair. In both strains the relationship between the density of weevils and the number of their progeny is shown by a kind of optimum curve having a maximum number of progeny at a certain intermediate density as shown in Fig. 1, where the result obtained in Kyoto strain (Utida, 1941a) is also given together with.

The curve representing such a relation is frequently called the reproduction curve, which has been classified into two types by the difference in its shape (Utida, 1956). One is the so-called "saturation curve," and another is the mountain shaped curve as obtained previously in the experimental population of the azuki bean weevil. It will be seen that all of the obtained curves belong to the latter type, but being different in the mode of curve in each other. At large, the height of peak and the increasing and decreasing trends at both sides of the slope are different in these three curves, which are considered to be the main important features of the curve from the view point of population dynamics.

Initial velocity of population growth are influenced by the increasing trend of the left side of the curve, which took highest value in Kyoto strain and was very slowly in Mozanbique strain. The height of peak just corresponds to the density of population saturation. The order of it was Iran, Kyoto and Mozanbique strain in descending order. The density of equilibrium state can be represented in this figure by the point of intersection between the reproduction curve and the straight line passing through the points of density being equal in two successive generations. As estimated diagrammatically from Fig. 1, this density is also different in three strains. It is highest in Kyoto strain (about 500), lowest in Iran strain (about 400) and slightly over in Mozanbique strain (420). The levels of these three population characteristics mentioned above take different values in the three strains examined and do not take in the same order in each other.

To study the density effect distinctly, it is convenient to reduce the obtained result to the rate of reproduction or the number of progeny produced per female. As shown in Fig. 2, the rate of reproduction decreases with advancing density in a regular manner in Iran and Kyoto strains, and the curve drawn by plotting the relation looks like a rectangular hyperbola. But, this relation is not the case in Mozanbique strain. The rate of its reproduction takes the highest value at the density of 32 or 64 parent weevils, from where it decreases with decreasing the density. Beyond this range of density, the rate of reproduction also decreases rapidly in regular manner. In other words, the optimum density for the rate of reproduction is clearly found out in the population of Mozanbique strain. The optimum density for the rate of reproduction has already been found in the *Tribolium* population by Park (1932) who asserted of its significance in the population dynamics, but we have not obtained such clear example in insect population as the present case. In Iran population the rate of reproduction does not change so remarkably as in Kyoto strain at the low densities, and rather takes similar value. The mode of density effect on the rate of reproduction may be different in their grade in these three strains. The mode of Iran strain is the intermediate type between other two, one is the rectangular hyperbola as in Kyoto strain and another is the mountain shaped optimum curve as in Mozanbique strain.

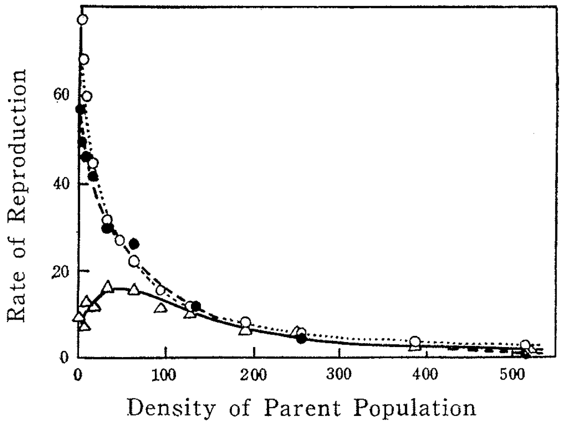

Fig. 2: The rate of reproduction under different densities of weevil population.
△: Mozanbique strain. ●: Iran strain. ○: Kyoto strain.

In the populations of both strains of Iran and Mozanbique, sex-ratio is easily calculated from the data shown in Table 1. It did not influenced by the density

Table 1. Number of progeny weevils produced at different densities of parent population, each strain and sex separately.

Density of population	Iran strain			Mozanbique strain		
	♂	♀	No. of replication	♂	♀	No. of replication
2	30.4	26.4	8	4.1	4.9	8
4	48.0	50.3	8	7.6	7.2	8
8	81.5	101.7	6	27.1	24.6	7
16	153.5	180.5	4	49.4	43.7	7
32	224.3	248.7	3	110.0	142.0	5
64	424	400	1	244.0	240.6	2
96	—	—	—	282	237	1
128	375	351	1	315	311	1
192	—	—	—	344	274	1
256	323	303	1	331.0	340.5	2
384	—	—	—	210.5	218.0	2
512	95	88	1	168	164	1

of parent population, holding the value of about 50 percent of female in whole range of the density tested.

It has already been ascertained in many kinds of insect that the rate of development is also influenced by the density of population. In the present experiment, as shown in Table 2, the acceleration of development in the high density was not so clearly proved in both of the populations of Iran and Mozanbique strains. In the population of Iran strain the days required for the development were short at the intermediate density as 64 parent weevils, where the number of emerged weevil was largest, and toward low and high densities it was slightly prolonged. In the result of the population of Mozanbique strain, however, there was any regular change in it with the change of density.

Table 2. Days required for the development from egg deposition to emergence of adult weevil at different densities of parent population, each strain and sex separately.

Density of population	Iran strain		Mozanbique strain	
	♂	♀	♂	♀
2	24.8	24.9	28.9	30.2
4	24.1	25.0	30.0	30.5
8	24.0	24.8	30.1	30.0
16	24.1	24.4	30.2	30.5
32	24 5	25.0	29.9	30.0
64	23.9	24.4	30.0	30.2
96	—	—	31.0	31.3
128	24.3	24.5	29.8	30.3
192	—	—	30.7	30.7
256	25.5	25.7	30.1	30.3
384	—	—	30.0	30.1
512	26.5	26.3	28.8	29.4

Discussion

The results obtained in the present experiment together with those fully described in the previous paper (Utida, 1941) prove beyond doubt that the effect of population density upon the progeny number is extremely clear in any strain. The difference between the strains in its physiological characters as well as in morphological does not modify the nature of density effect, though the absolute number of progeny individuals may differ. Therefore, the conclusions which have been deduced from the results obtained in the previous experiment (Utida, 1941) will hold good in the result obtained in any strain.

It has already been proved with the laboratory population of some insect species that the effect of density is different in its mode between the different cultural stocks (MacLagan, 1932), different geographical strains (Satomi, 1957) and several kinds of mutant (Pearl, 1926). MacLagan (1932) supposed, at least in his case of *Tribolium* population, that the shifting of the optimum density is perhaps due to the evolution of a strain to adapt to intense crowding. Satomi (1957) found the differences among several geographical strains of the rice weevil

Calandra oryzae and the small rice weevil *C. sasakii* on the decreasing trend of reproductive rate toward crowded population, and he considered that these changes may be due to the adaptation to the crowded life in the storage condition of products. The similar supposition may be applicable to the present case.

In Mozanbique strain, the optimum density for the rate of reproduction is clearly shown in Fig. 1, while in two other strains such a point can not be found in the range of population density tested. Therefore, when judging this evidence from the Allee's point of view (Allee, 1931), it seems to be probable that the former strain is more adapted to the gregarious life than two other strains. It is expected that both the estimated density at the saturation point of population and that of the equilibrium state should become high, if the population attains a character adapted to crowded population. On the contrary to this expectation, however, the obtained results are opposite, these densities of the population characteristic are rather lower in Mozanbique strain than those of other two strains. Further, it is noteworthy to point out that both the biotic potential (highest number of egg production) and the potential rate of reproduction (maximum number of adult progeny produced per one female) are relatively low in Mozanbique strain comparing to those of two other strains, which are considered to be less adapted to the gregarious life.

Now, the discussion turns to another side of the problem of population dynamics. From the result of the present experiment, it is presumed that the growth form of population in Mozanbique strain is different comparing that of two other strains at several important points of population dynamics mentioned below.

First, the velocity of initial stage of population growth is slow, secondly the saturation level of population is low, thirdly the mean level of equilibrium state is comparatively low, and fourthly the intrinsic damped oscillation of population density at the equilibrium state is not violent. In short, the population of Mozanbique strain is rather stable and takes low level in its density. It may unable to reach or keep high density such as the populations of two other strains do.

On the other hand, it might show some difficulties to increase its density at under-crowding condition. As shown in Fig. 2, in Mozanbique strain the optimum density for the rate of reproduction lies at the intermediate range of density examined and below this range the rate gradually decreases. From these behaviours at high and low densities, this strain may be limited its activity of life in relatively narrow range of population density. This will be called steno-density adaptability.

These comparisons among the strains are comparable to those of two dimorphic forms observed in the cowpea weevil, *Callosobruchus quadrimaculatus*, which is produced by the difference of population density itself (Utida, 1956a).

Summary

The effect of population density upon its progeny population was studied on the two different strains of the azuki bean weevil, *Callosobruchus chinensis*, which were imported from Iran and Mozanbique. The result obtained in Mozanbique strain is different from that in Iran strain and Kyoto strain which was described

in the author's previous paper, in respect to the mode of the density effect in quantitative term. The optimum density for the rate of reproduction is clearly shown in the former strain. These points were discussed from the view points of population dynamics.

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