NUMERICAL INTERACTIONS OF A HYPERPARASITOID *ALLOXYSTA PLEURALIS* (CAMERON) (ALLOXYSTIDAE : HYMENOPTERA) WITH ITS HOST *TRIOXYS INDICUS* (SUBBA RAO & SHARMA) (APHIDIIDAE : HYMENOPTERA)

RAJENDRA SINGH and P. N. SRIVASTAVA

Aphid-Biocontrol Laboratory, Department of Zoology,
University of Gorakhpur, Gorakhpur—273 009, India

Rajendra Singh and P. N. Srivastava (1988) Numerical interactions of a hyperparasitoid *Alloxysta pleuralis* (Cameron) (Alloxystidae : Hymenoptera) with its host *Trioxys indicus* Subba Rao & Sharma (Aphidiidae : Hymenoptera). *Bull. Inst. Zool., Academia Sinica* 27(3): 167-173. Laboratory experiments on the numerical interactions of *Alloxysta pleuralis* (Cameron) and its aphidiid host *Trioxys indicus* Subba Rao & Sharma are described. If 1, 2, 4, and 8 hyperparasitoids were released on 100 hosts (5-7 day post-parasitised aphid, *Aphis craccivora* Koch), the number of hyperparasitoids emerging was the greatest when 8 were put on. However, the rate of multiplication (hyperparasitoid emerging/initial hyperparasitoid) was the greatest when there was only one hyperparasitoid. This rate of multiplication declined as the number of tested hyperparasitoids increased. It indicates the existence of interference processes which bring down the search area of the individuals. Various aspects of the behaviour which could give rise to interference effects are discussed. The female hyperparasitoids' population of the hyperparasitoids in the next generation also decreased as the number of tested hyperparasitoids increased.

Key words: Numerical interaction, *Alloxysta pleuralis, Trioxys indicus, Aphis craccivora,* Hyperparasitoid.

*A*lloxysta pleuralis (Cameron) (Alloxystidae: Hymenoptera) is an endolarval hyperparasitoid of *Trioxys indicus* Subba Rao & Sharma (Aphidiidae: Hymenoptera). *T. indicus* has been reported to be a potential bioagent against *Aphis craccivora* Koch and *A. gossypii* Glover (Aphididae: Hemiptera) (Singh, 1980) in India and has recently (1986) been shipped to Australia by the senior author against *A. craccivora* on lupins. Recently we have noticed higher mortality of the parasitoid population in the field due to *A. pleuralis* than what Singh & Sinha (1980a) reported

earlier. The numerical interactions of the hyperparasitoid and its host in the field determine the potential of the parasitoids against the pest insects in the target areas. Therefore, the number of hosts (the primary parasitoids) that a known population of a hyperparasitoid can search for and destroy in a given area should also be known for effective biocontrol measures. In the past, Nicholson & Bailey (1935) suggested that the searching efficiency of the predators as measured by its "area of discovery (*a*)" is constant. However, Hassell & Varley (1969) had refuted their opinion and proposed a

new model in which the a declines exponentially with the increase of number of searching females and incorporated a mutual interference constant, m deriving an equation $a=QP^{-m}$ where Q is the quest constant, i. e., when only one female (P) is searching, m is the interference constant i. e., the slope of regression of log a on log P. The value of a is usually calculated by the formula $a=\frac{1}{P}$ log $\frac{N}{S}$ where N and and S are initial and surviving host densities. Though this model had been criticised on several grounds (Stinner & Lucas, 1976), but still is widely accepted for its simplicity. Although studies on the searching efficiency of parasitoids are very common, those on the hyperparasitoids are relatively seldom, (Chua, 1977).

The sex ratio of parasitoid, and hyperparasitoid, influences the biological control of the pest in as much as it is the female wasp which brings about the mortality of the host (Sinha & Singh, 1979). Although studies of the interrelationships between the number of first generation parasitoids and the sex ratio of the next generation have been done in several species of the parasitoids (Legner, 1967, Sinha & Singh, 1979), no information is available at present for any alloxystid hyperparasitoid.

The laboratory experiments reported herein were designed to examine the effect of various initial number of the hyperparasitoid, A. pleuralis, on: (1) the rate of hyperparasitism of the host, T. indicus, parasitised A. craccivora; (2) its area of discovery; (3) the indirect mortality of the host; and (4) on the sex-ratio of its next generation offspring.

MATERIALS AND METHODS

The procurement and culture of all the three insects, the aphid A. craccivora, the primary parasitoid T. indicus and the hyperparasitold A. pleuralis was described by Singh & Srivastava (1987a, b). Five to seven days post-parasitised aphids (PPA) were utilised as host because of more preference of the stage by A. pleuralis (Singh & Srivastava, 1987a). Only experienced female hyperparasitoids were utilized. To abtain such females, freshly emerged one day old, mated and fully fed (with 50% honey) females were individually placed in petri dishes each having about 25 5-7 d PPA on the leaf of the host plant (Cajanus cajan Millsp.) for 1 hour, thereafter, the females were withdrawn and treated as experienced ones.

For the study of numerical interactions, 1, 2, 4, and 8 hyperparasitoids were introduced into 4 separate cylindrical jars (10 cm diam. ×30 cm height) each having 100 5-7 d PPA placed on a twig of host plant inserted in a narrow mouthed 60 ml glass vial with the cut end dipped in water. The opening of the jars were closed by muslin cloths tightened with rubber bands. After 6 hours, the twigs were placed separately in marked insectaries (20×20×20 cm). The water of the glass vials were changed after 3 days.

After 3 days of the experiments the exposed PPA begin to mummify. The mummies along with a part of leaf of the respective sets were put in marked mummy holding tubes (3×10 cm, one end of the tube was closed with cork having a tube with moistened cotton while the other end was covered with a piece of fine meshed nylon screen). The emerged hyperparasitoids and parasitoids were sexed and recorded. The experiment was conducted at 60-75% RH and 22-25°C with ten replicates.

RESULTS AND DISCUSSION

The rate of hyperparasitism of T. indicus by A. pleuralis gradually increased up to 4 females and thereafter, it slowed down. This relationship can be explained by a curvilinear growth curve, $Y=90.8-48.7X^{-1}$ (Fig. 1). It implies that increase of the initial number of hyperparasitoids beyond a certain number fails to produce proportionately more progeny. Fig. 2 shows clearly that the rate of multiplication of the hyperparasitoid,

i. e., the contribution of individual wasp decreased curvilinearly with the increase of initial number of the hyperparasitoid ($Y = 42.3-35.6$ log X). Fig. 3 illustrates that the higher densities of hyperparasitoid has an inverse effect on her searching efficiency. The quest constant, Q of *A. pleuralis* (= 0.630, Fig. 3) is lower than that of *T. indicus* (=0.686, Sinha & Singh, 1980a), which indicates that its host searching efficiency is lower than that of *T. indicus*. However, the K-values (=log initial host density−log host surviving attack) for hyperparasitism of *A. pleuralis* were higher than parasitism of *T. indicus* at all densities (based on the data of Sinha & Singh, 1980b) (Fig. 4), which explains, in part, the high level of hyperparasitism found in the fields (Singh & Srivastava, 1987a). Earlier, Chua (1979) has shown a lower K-values for hyperparasitism of *A. brassicae* than parasitism of *Diaeretiella*
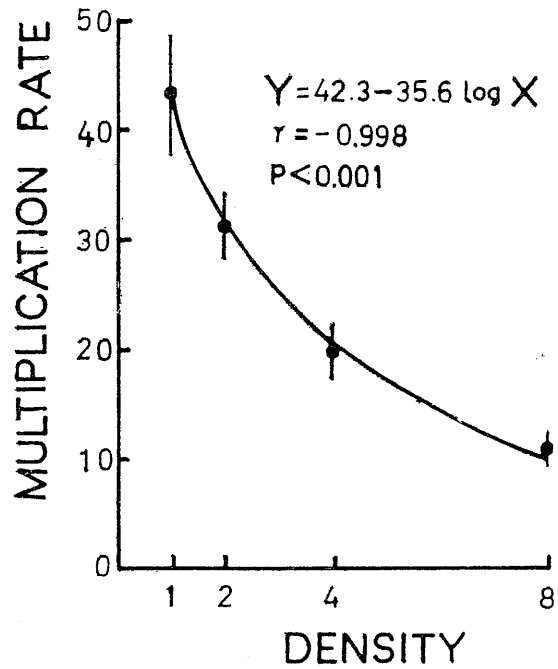

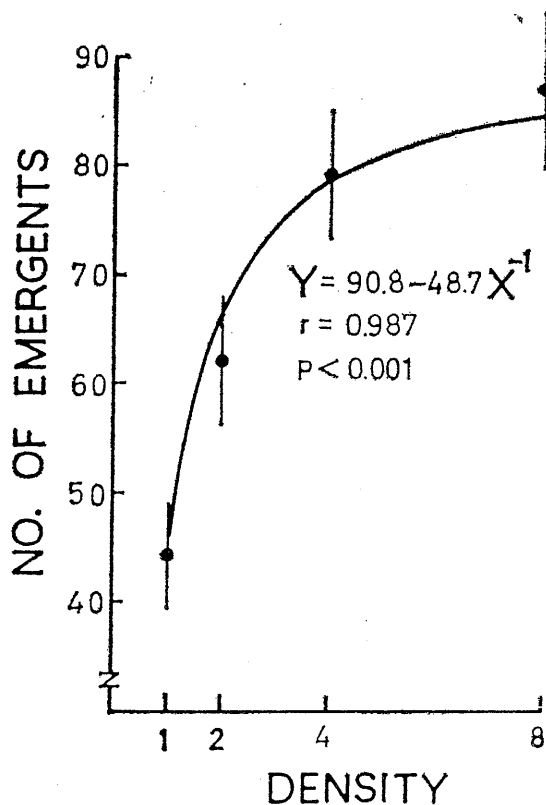Fig. 2. The relationship between the rate of multiplication of *A. pleuralis* and its density.

$$Y = 42.3 - 35.6 \log X$$
$$r = -0.998$$
$$P < 0.001$$

Fig. 1. The relationship between the number of emerging *A. pleuralis* and its density.

$$Y = 90.8 - 48.7 X^{-1}$$
$$r = 0.987$$
$$P < 0.001$$
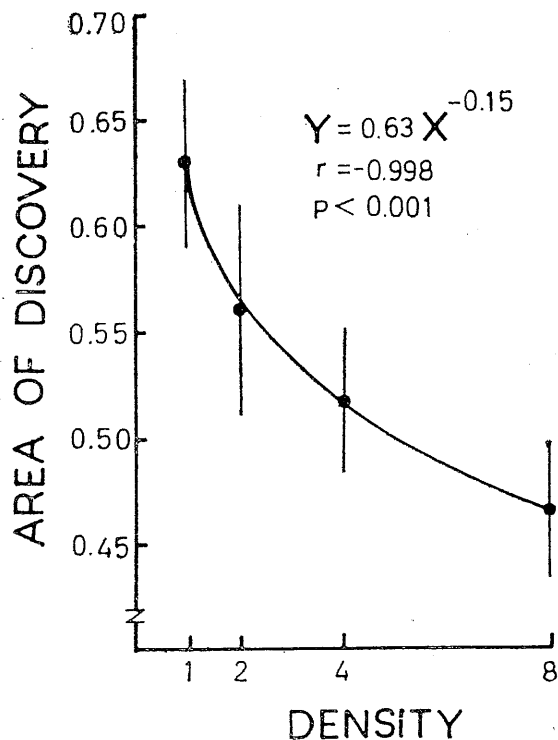
Fig. 3. The relationship between the area of discovery of *A. pleuralis* and its density.

$$Y = 0.63 X^{-0.15}$$
$$r = -0.998$$
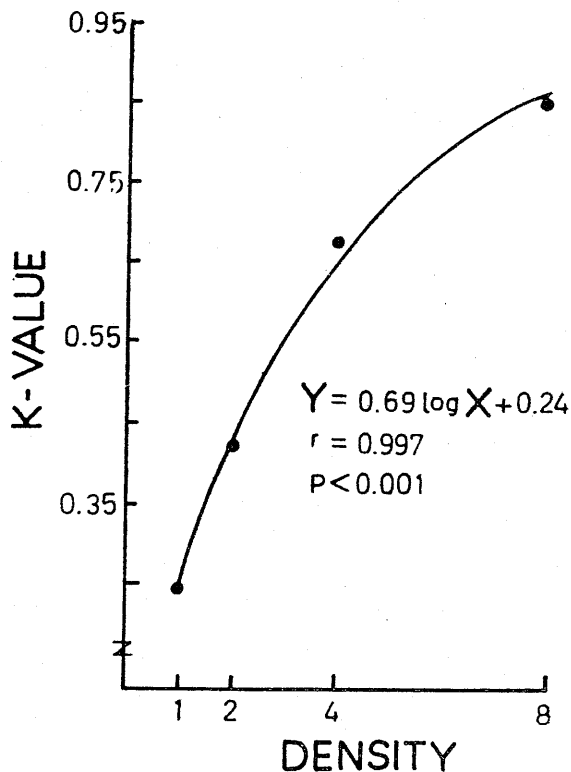$$P < 0.001$$

$Y = 0.69 \log X + 0.24$

$r = 0.997$

$P < 0.001$

Fig. 4. The relationship between K-values for
A. pleuralis and its density.

rapae (McIntosh). However, Kfir et al. (1976) showed that the encyrtid hyperparasitoids were more efficient than the primary parasitoids in discovering the hosts. It was argued that the hyperparasitoids have to be more efficient because they have to perform an additional step in host finding. However, we agree with the opinion of Chua (1979) that the area of discovery and K-values for the hyperparasitoid should not be higher than that for the primary parasitoid.

High searching capacity is also associated with high interference constant, m. This is indicated by the increase in Q with an increase in m, e. g., in A. pleuralis $(a=0.63$ $p^{-0.15})$ and T. indicus $(a=0.69 \, p^{-0.36})$. Similar observations have also been reported by Chua (1979) in the case of A. brassicae and D. rapae. Rogers & Hassell (1974) claimed that this direct relationship arises because both parameters are dependent on the level

of the parasitoids and hyperparasitoids' searching activity.

These above facts revealed that some sort of interferring factors at higher number of hyperparasitoids exist which may be explained by following accounts: (1) the mechanical interference in encounters between searching females (mutual interference); (2) an avoidance of superhyperparasitism; and (3) the mortality of the developing stages of the hyperparasitoids before emergence.

The direct interference among A. pleuralis happens mainly by antennal contact between searching females similar to that of A. brassicae (Chua, 1979). We have also noticed that some of the hyperparasitoids moving on the wall of the jars when their number is relatively higher. Such interferences among other parasitic wasps have also been demonstrated (Hassell, 1971; Cheke, 1974; Beddington, 1975; Latheef et al., 1977; Sinha & Singh, 1980b). Such response helps the parasitoids or hyperparasitoids in its dispersal (Hassell, 1971; Sinha & Singh, 1980a).

Most of the parasitic wasps are discriminatory during host selection and tend to avoid the superparasitism (Vinson, 1976; Singh & Sinha, 1982). However, superparasitism does occur in those species as the ratio of host to parasitoid decreases. Earlier, A. pleuralis was found to superhyperparasitise frequently because of less host discriminatory ability (Singh & Srivastava, 1987a), therefore, the role of superhyperparasitism cannot be ruled out in lessening the multiplication rate of the female at her higher densities. It is an established fact that the hyperparasitoids in general are less discriminatory than their primary parasitoids (Gutierrez & Bosch, 1970). As a single host supports the development of only one hyperparasitoid egg, the supernumerary eggs are lost, and thus efficiency of the hyperparasitoid is reduced.

The indirect mortality of the host due to physical injury caused by her ovipositor
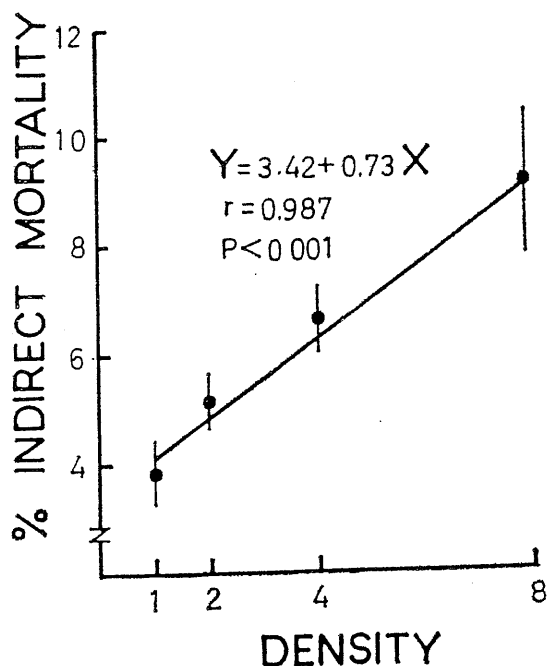
Fig. 5. The relationship between the percentage of indirect mortality of *A. pleuralis* and its density.

Fig. 6. The relationship between the proportion of females in F_1 offspring of *A. pleuralis* and its density.

during host exploration, and the death during developmental stages before emergence are the other factors that reduce the multiplication rate of the hyperparasitoid. The percentage of indirect mortality at higher parasitoid density (9.1%, Fig. 5) is less than the average indirect mortality of the field collected mummies of *T. indicus* (Singh & Sinha, 1980b). Therefore, the indirect mortality, evidently, plays a minor role in the destruction of the host population (*T. indicus*).

In the past, Fisher (1958) and Hartl & Brown (1970) postulated 50% females in the offspring of sexually reproducing organisms assuming that the natural selection acts to ensure equal parental investment in the production of either sex. However, alteration of this ratio had been observed as a function of environmental changes particularly the size of the host (Charnov, *et al.*, 1981) and the density of host and parasitoid (Legner. 1967; Sinha & Singh, 1979) in cases of some parasitic wasps. The significant decrease in the percentage of females in the offsprings
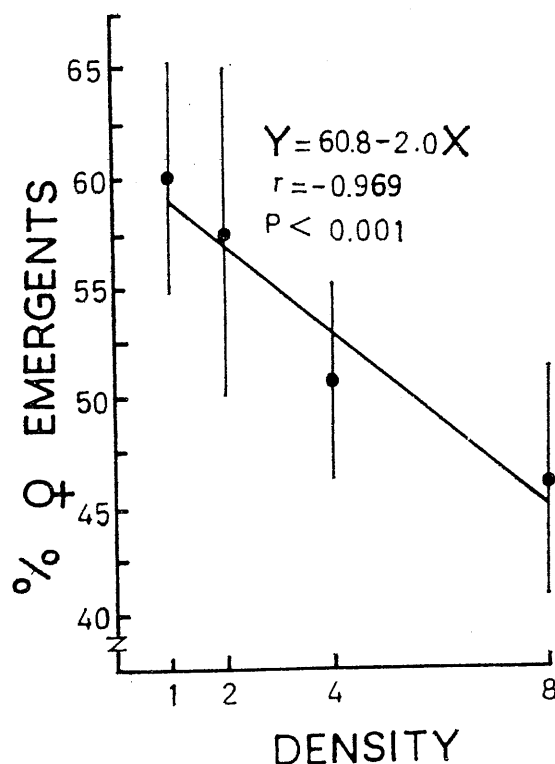
fo *A. pleuralis* with the increase of initial number of tested hyperparasitoids (Fig. 6) indicates that the hyperparasitoid's ability of differential placement of haplo-diploid eggs (Flanders, 1967) into the hosts is affected by variation in her initial numbers. Moreover, the predicted percentage of females (50%) in the offsprings was only achieved when 4 hyperparasitoids were exposed with 100 hosts (1: 25 ratio).

The results discussed so far revealed that (1) the high proportion of the parasitoid *T. indicus* can only be killed when the number of hyperparasitoid to parasitoid was very high (8:100), and (2) the high number of hyperparasitoid has negative effects on the area of discovery, the multiplication rate of the individuals and the percentage of females in the offsprings. Therefore, it implies that the hyperparasitoid *A. pleuralis* plays a little role in preventing the control

effect of the parasitoid *T. indicus* against the aphid *A. craccivora*.

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重複性寄生蜂 *Alloxysta pleuralis* 與其寄主 *Trioxys indicus* 間之數質關係

R. SINGH and P. N. SRIVASTAVA

本文研究重複寄生蜂 *Alloxysta pleuralis* 與其蚜寄小繭蜂科寄主，*Trioxys indicus*間之數質關係。當 1、2、4、8 隻 *A. pleuralis* 與 100 隻已被 *T. indicus* 寄生過之 *Aphis craccivora* 同處時，以 8:100（寄生蜂：寄主）時 *A. pleuralis* 之羽化數目最高，而羽化倍率（寄生蜂羽化數/寄生蜂最初放入數）以最初僅放一隻 *A. pleuralis* 時為最高。此羽化倍率隨 *A. pleuralis* 最初放入數目之增加而遞減，顯示 *A. pleuralis* 成蟲間會相互干擾而導致 *A. pleuralis* 個別之尋找寄主之範圍縮小，後代雌性比亦因 *A. pleuralis* 最初放入數目之增加而減少。