J. Biol. Control, 17(1): 47-55, 2003

Field life tables of *Chilo partellus* (Swinhoe) (Lepidoptera: Pyralidae)

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ABSTRACT: **Field life tables of *Chilo partellus* (Swinhoe) were constructed for 6 generations from summer 1994 to *rabi* (winter) 1995 in Bangalore on fodder maize. Positive trend indices were obtained in the 2nd, 3rd and 4th generations, which corresponded to late summer to *kharif* (monsoon) seasons and negative trend indices in the 1st, 5th and 6th generations corresponding to late *kharif* (late monsoon) to *rabi* seasons. Positive trend indices signified greater pest activity during those generations. Maximum contribution to real generation mortality was in egg stage in all the generations as k_s of egg period were invariably closer to generation K in each season. Key mortality factor analysis revealed direct density dependence in egg stage with egg parasitoids having highly significant regression coefficient. Mortality due to unknown causes in younger larvae exhibited inverse density dependence. During larval stage, hatching failure, and in pupal stage all mortality factors exhibited delayed density dependence. The result provided rational ecological basis for developing biocontrol – based programme for suppression of *C. partellus* on fodder maize.**

KEY WORDS: **Abiotic factors, biotic factors, *Chilo partellus*, field life tables, population dynamics**

Stem borer, *Chilo partellus* (Swinhoe) is the most important and destructive pest of maize and sorghum in many countries in Asia and Africa (Chatterji *et al.*, 1969; Seshu Reddy, 1989). It is native to the Indian sub-continent, but has spread from India to Africa is resulting in the displacement of indigenous stem borers (Kfir, 1990; Overholt *et al.*, 1994). Conventionally this pest is mainly suppressed by the use of chemical pesticides, resistant varieties and cultural practices. In India about 80 per cent of the crop is under rain fed farming system where resources are a major constraint. In such situations, biocontrol based integrated pest management is perhaps the appropriate solution. However, without basic information on changes in population pattern through the year, it is not possible to develop biocontrol based integrated pest management. The use of life tables showing changes in population during different developmental stages throughout the life cycle of an insect species or a crop season has been considered one of the most important approaches in understanding population dynamics (Harcourt, 1969). Atwal and Singh (1974) studied the life table of *C. partellus* in Punjab on grain maize during 1971-74. They reported greatest mortality due to abiotic factors and to a little extent, larval parasitoid during *kharif* season in Punjab. In Kenya, life table analysis of data from a three - year study on *C. partellus* during 1984 - 86 on maize and sorghum showed 92.9 per cent mortality of eggs and early instar larvae

* A part of Ph.D. thesis submitted by senior author to Mysore University, Mysore

due to unidentified factors and predators (Oloo, 1990).

The present study provides detailed population study throughout the year leading to an understanding of the role of the various abiotic and biotic factors so as to formulate biocontrol based pest management of *C. partellus*.

MATERIALS AND METHODS

Life table studies on *C. partellus* were carried out in the field in Bangalore. Population of this insect was recorded for one year from late summer to winter and a series of six life tables were prepared. As it was not possible to count the exact number of eggs in the field, the stages sampled included the young larvae, grown up larvae and pupae. Numbers of eggs were derived indirectly. The sample quadrant included 50 plants and seven such quadrants were sampled in a 0.4 ha field. From each spot 10 per cent infested plants were removed at weekly intervals. In the case of very low infestation a minimum of 10 per cent plants were removed on each sampling date. A generation was based on 2 weeks peak moth collection in pheromone traps in each generation (Jalali, 2000). Infested plants were brought to the laboratory for count of the insect population. The larvae and pupae obtained from infested plants were observed for computing the extent of the parasitism and disease in the laboratory. Predatory population were counted in the field except those that were inside the whorls or the stem. Egg parasitism was recorded by keeping 'seed card' from the laboratory reared *C. partellus* in the field on each observation date and collected back after 24 hours. In each seed card, one egg mass of *C. partellus* consisting of about 30 – 40 eggs was pasted before exposure in the field.

For preparing the life table the following column heads were used (Harcourt, 1969; Southwood, 1978).

x = Stage interval at which sample was taken

lx = the number living at the beginning of the stage noted in the column x

dx = the number dead within the age interval stated in the column x

dxF = the stage interval

100qx= the mortality factor responsible for dx

100rx = per cent real mortality

All lx and dx values represent the number of individuals per sample. On account of overlapping of developmental stages present in each sample, integration of samples was done by taking means of the count relating to different developmental stages in each season.

As large samples of egg masses could not be collected from the field, the lx values for eggs were based on net house observations on fecundity during different seasons. For this, maize plants were raised in 30cm earthen pots and kept in 3 x 3m net house. All the moths which emerged from field-collected pupae during the season were released in the net house. Daily count on number of eggs laid was done and total eggs laid in each season were worked out. The dx values were worked out on the basis of egg viability in the net house. The lx values for the younger larvae (1st to 2nd instar) were obtained by deducting egg mortality owing to hatching failure and egg parasitism, from the initial number. Egg parasitism was worked out based on seed card kept in the field and number of eggs parasitised. Total number of eggs laid in net house was recorded in each season and possible egg parasitism was worked out based on field parasitism. The lx values for other larval instars were based on direct sampling. The lx values for moths represent the number of pupae giving rise to adults. The sex ratio was based on rearing of field-collected larvae and pupae in the laboratory.

Analysis to recognise the roles of factors in a series of successive life tables was done as suggested by Varley and Gradwell (1960 and 1963). The total generation survival was calculated by dividing number of moths by total eggs laid during the generation and trend index by dividing eggs laid in next generation by eggs laid during the present generation.

A budget was calculated by converting values to logarithms. The total generation mortality referred to as K was obtained by subtracting the log of population of adults entering the reproductive stage from the log maximum egg laying of the previous generation. The series of age specific mortalities were calculated by subtracting each log population from the previous one and these are referred as k's so that $K = k_0 + k_1 + k_2 + ... ki$. These series of k's - one series for each generation provide complete picture of population change. The visual correlation was done by plotting K and ks against each generation and to see which k is most closely correlated with K of the generation. The various ks were then tested for direct density dependence by regression of log number entering the stage against the log number of survivors and *vice versa*. The density dependence was taken as real if both the regression coefficients departed significantly from 1.0. The closer the regression coefficient to 1.0, the greater the stabilising effect of that regulatory factor. If the coefficient is exactly 1.0 the factor will compensate completely for any change of the density, that less than 1.0 or more than 1.0 implies under and over compensation. The k values were plotted against log initial density of the stage for each generation and then joining the points (Varley, 1953; Morris, 1959; Varley and Gradwell, 1965). The interpretation was done as suggested that direct density-dependent factors will trace a more or less straight line or narrow band of points and it tends to stabilise. The delayed density factors circles or spirals and it leads to oscillations. Density–independent factors trace irregular or zigzag plots and it leads to fluctuations and inverse density-dependent factors tend to accentuate the fluctuations. The data of various abiotic parameters were recorded from the field study during each season.

RESULTS AND DISCUSSION

The life-tables constructed for various generations are presented in Tables 1. The recognition of the key mortality factors in different generations in Fig. 1 and key mortality factors in time sequence plots in Fig. 2.

First generation (late summer to *kharif*)

The highest mortality during the generation was between the age interval from egg to younger larvae accounting for 93.5 per cent real mortality. The egg stage was affected most owing to sterility of eggs (54.9 per cent) and unknown causes (30.4 %). Mean temperature in the field was £35°C and in the laboratory experiment also in temperature £35°C, 90 per cent eggs did not hatch (Jalali, 2000). In younger and older larval stages real mortality due to unknown causes (i.e. losses or mortality due to high temperature, potential predators and other unidentified factors) was 3.8 and 2.2 per cent, respectively. In pupal stage per cent real mortality due to pupal parasitoids, *Xanthopimpla stemmator* (Thunberg) and *Tetrastichus howardi* (Olliff) was 0.4 per cent. The generation survival value of 0.01 and negative trend index of 0.57 indicates that mortality factors operating during the 1st generation of the pest in Bangalore were effective in causing decline in pest population. Total per cent real mortality during the generation was 98.9 per cent (Table 1). K factors of the generation indicated that the maximum contribution towards the generation mortality was in egg stage as k of hatching failure and unknown causes 0.3467 and 0.4888, respectively were close to total K (2.4942) of the generation (Fig. 1).

Second generation (*kharif*)

During the second generation of *C. partellus*, the greatest mortality was in the egg stage accounting for 78.0 per cent of real mortality of the generation. Due to high temperature conditions prevailing in the field during the generation (temperature £35°C), 70.0 per cent eggs failed to hatch. Unknown causes also affected the survival of younger and older larvae causing 6.2 and 4.8 per cent real mortality, respectively. In the pupal stage, parasitism (mainly by *X. stemmator*) caused 0.9 per cent real mortality of the generation. The total generation mortality obtained during the second generation was 96.9 per cent (Table 1).

The generation survival value of 0.03 and positive trend index of 1.9 indicated that mortality factors in the second generation of the pest in Bangalore were not effective in causing decline of the pest population. The recognition of k factors in Fig. 1 revealed that during the generation hatching failure in egg stage (k_2=0.5229) and mortality of older larvae due to unknown causes (k_7 = 0.1891) were closer to K (1.8962) of the generation.

Third generation (*kharif*)

Per cent real mortality among the egg stage during the 3rd generation was 84.4 per cent of the generation, of which 74.1 per cent was due to abiotic and other unidentified factors. Unknown factors also caused 3.1 and 2.3 per cent real generation mortality in larval stages. Besides in older larval stage, parasitoids, especially *Cotesia flavipes* (Cameron) and *Myosoma chinensis* (Szépligeti) also caused 2.6 per cent real generation mortality. In pupal stage 0.9 per cent real mortality happened due to parasitoids like *X. stemmator* and *T. howardi*. The total generation mortality recorded during this generation was 97.9 per cent. The generation survival value (0.019) and positive trend index of 2.10 suggested that total mortality factors were not effective during the generation (Table 1). The recognition of key mortality factors in each stage is presented in Fig. 1. The analysis of key mortality factors suggested that unknown causes at egg stage causes maximum population reduction as k_1 value of 0.3389 followed by hatching failure (k_2 = 0.2490) were close to generation K value 2.0378.

Fourth generation (late *kharif* to early *rabi*)

The greatest mortality during the 4th generation of *C. partellus* was in egg stage accounting for 90.8 per cent real mortality of the generation. Egg parasitoid *T. chilonis* which caused 29.7 per cent real mortality of the generation alongwith rainfall and potential predators affected the survival of eggs in this generation. In older larval stage, 1.8 per cent real mortality occurred due to parasitoids like *C. flavipes*, *M. chinensis* and *Stenobracon nicevellei* (Bingham). In pupal stage, *X. stemmator*, *T. howardi* and *Brachymeria nosatoi* Habu caused 0.6 per cent real mortality of the generation. The generation survival of 0.009 and positive trend index of 1.65 indicated that the mortality factors, which operated during this generation, could not compensate for populations rise. The total generation mortality was 99.0 per cent, but due to greater number of eggs laid in this generation resulted in positive trend index (Table 1). The recognition of key factors is presented in Fig. 1. Key mortality factors of the generation indicated that maximum contribution towards the generation mortality was in egg stage, egg parasitism (k_3), hatching failure (k_2) and unknown causes (k_1) being 0.4239, 0.3208 and 0.2939, respectively, being close to the generation K of 2.2728.

Fifth generation (*rabi*)

Per cent real mortality in the fifth generation was again highest in egg stage with various factors accounting for 96.5 per cent mortality including rainfall and other unknown factors resulted in more egg mortality. Mortality in younger or older larval stages or pupal stages was very low during the generation. However, total generation mortality of 99.6 per cent was much higher than in any other generation. A very low generation survival of 0.003 per cent and negative trend index of 0.41 suggested that total mortality factors during the generation were very effective in causing the pest decline (Table 1).

The recognition of the key mortality factors is presented in Fig. 1. The data analysis suggested that key factor of the generation mortality was in the egg stage, the total k_s in egg stage (1.4515) being more than half of the generation K of 2.7467.

Sixth generation (late *rabi* to early summer)

The highest mortality during the sixth generation was in egg stage and in younger larval stage accounting for 97.1 per cent real mortality. The egg stage was affected most by unknown causes and hatching failure recording 52.6 and 34.9 per cent real mortality. The low temperature during the generation resulted in lower egg hatching, thereby causing pest decline. In younger larval stages also

Table 1. Field life-tables of *Chilo partellus* for various generations on fodder maize

Generations	Per cent real generation mortality	Trend index	Survival of generation
First generation (late summer to *kharif*)	98.9	0.57	0.010
Second generation (*kharif*)	96.9	1.90	0.030
Third generation (*kharif*)	97.9	2.10	0.019
Fourth generation (late *kharif* to early *rabi*)	99.0	1.65	0.009
Fifth generation (*rabi*)	99.6	0.41	0.003
Sixth generation (late *rabi* to early summer)	99.1	0.63	0.007

unknown factors caused 2.5 per cent larval mortality. The total generation mortality during the sixth generation was 99.1 per cent (Table 1). The negative trend index of 0.63 indicated that the total mortality factors were effective during the generation in causing pest decline.

The recognition of the key mortality factors of the generation indicated hatching failure (k_2) and unknown causes (k_1) 0.5819 and 0.3241, respectively were close to generation K of 2.4643 (Fig. 1). These factors caused maximum pest decline during the generation.

Life tables were constructed for *C. partellus* and its natural enemies recorded on fodder maize for six generations from late summer to *rabi* season in Bangalore. The observed high generation mortality (78.0 – 96.5%) at the egg stage seems to imply that egg stage is most vulnerable stage in the generation of the pest. During larval and pupal stages, parasitoids and insect pathogens contributed less than 3.0 per cent to generation mortality; thereby signifying that these are not significant factors in the generation mortality.

Therefore, perusal of age specific mortality in a life table indicated that highest mortality in *C. partellus* occurred in the age interval from egg to early larval instar. The main factors being hatching failure, abiotic factors, predators and other unidentified factors. In Kenya, in a life table analysis of data from a 2 year study on *C. partellus* on maize and sorghum showed 97.9 per cent generation mortality in eggs and early instar larvae due to unidentified factors and predators (Oloo, 1989). Larval parasitoids and microbial agents contributed non-significantly at various life stages.

The negative trend index values less than 1.0 indicates that during that particular generation total mortality factors are effective in causing pest decline and positive trend index value more than 1.0 indicates that total mortality factors are not effective in causing pest decline. In the present study, for six continuous generations, negative trend index was obtained in the generations where total generation mortality was ≥99.0 per cent. This happened during 1st, 5th and 6th generations. Though during 4th generation also total mortality was 99.0 per cent, due to more egg laying from moths obtained from 3rd generation, it resulted in positive trend index. The analysis of data indicated that by just 1 per cent more survival, it can result in positive trend index as obtained in 2nd, 3rd and 4th generations, thereby signifying that small proportion of survival can result in greater pest activity in the field. These observations on negative and positive trend indices are similar to findings of Atwal and Singh (1974).

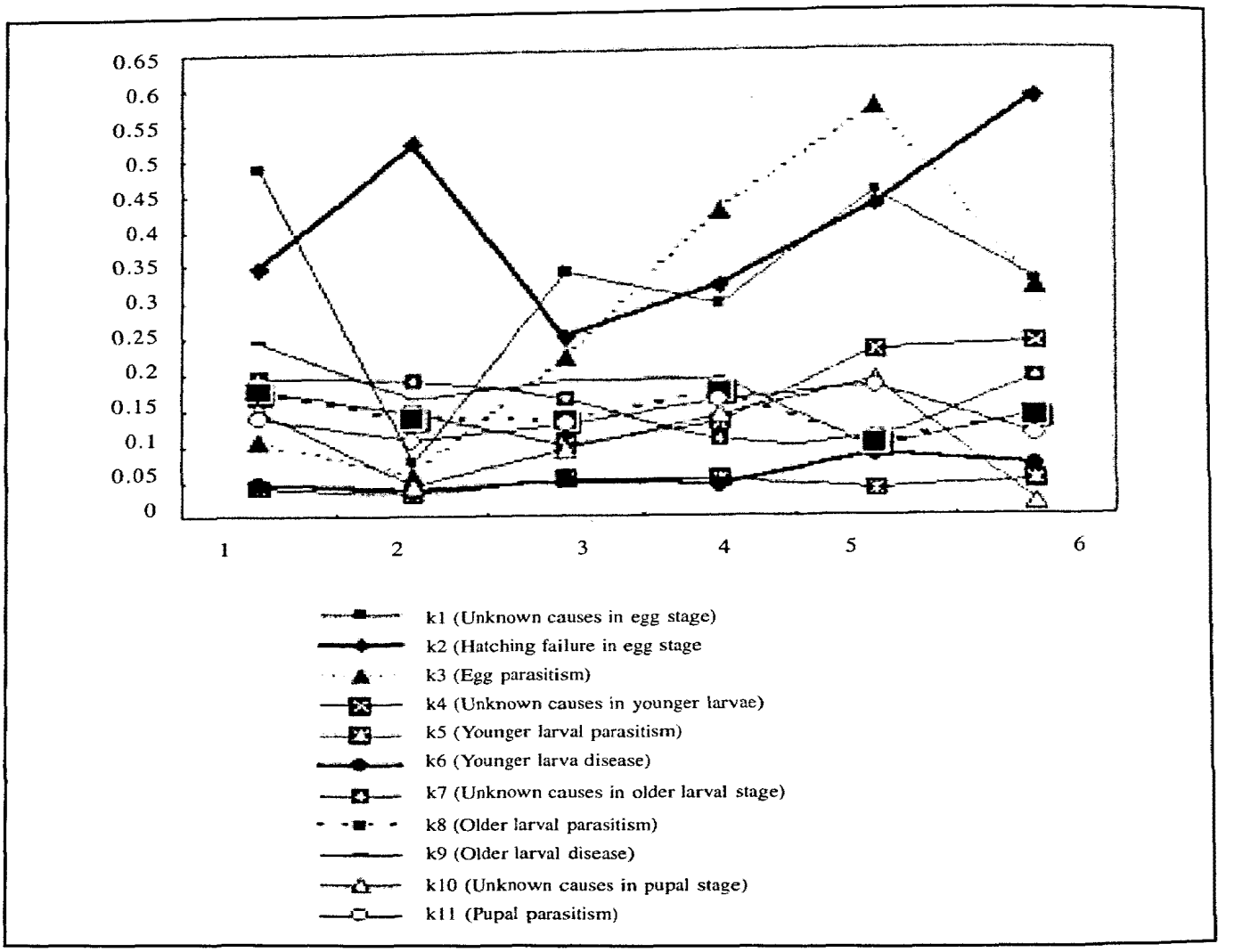

Fig. 1. The recognition of the k factor in *Chilo partellus* field population by the various stage ks' with total K of different generations

The k factor analysis of the life table was carried out by the regression of log numbers surviving on log initial numbers of the stage. The regression coefficients departed significantly from 1.0 only in case of egg mortality due to parasitoid and younger larval mortality due to unknown causes, thereby exhibiting density dependence (Fig. 2). In the time sequence plots, by plotting k value against initial log density of the stage revealed that during the egg stage, parasitoids exhibited direct density dependence ($b = 0.65$, $P = 0.001$) but could not compensate completely for the changes in the density caused by other disturbing factors. In the egg stage, other two factors, i.e. unknown causes (possibly weather factors, potential predators and other unidentified factors) traced density independent relation, while hatching failure due to low or high temperatures exhibited delayed density dependence. During larval stages, mortality due to unknown causes (possibly weather factors, potential predators and other unidentified factors) exhibited inverse density dependence ($b = -0.32$, $P = 0.05$) in younger larval stages. All other factors during younger or older

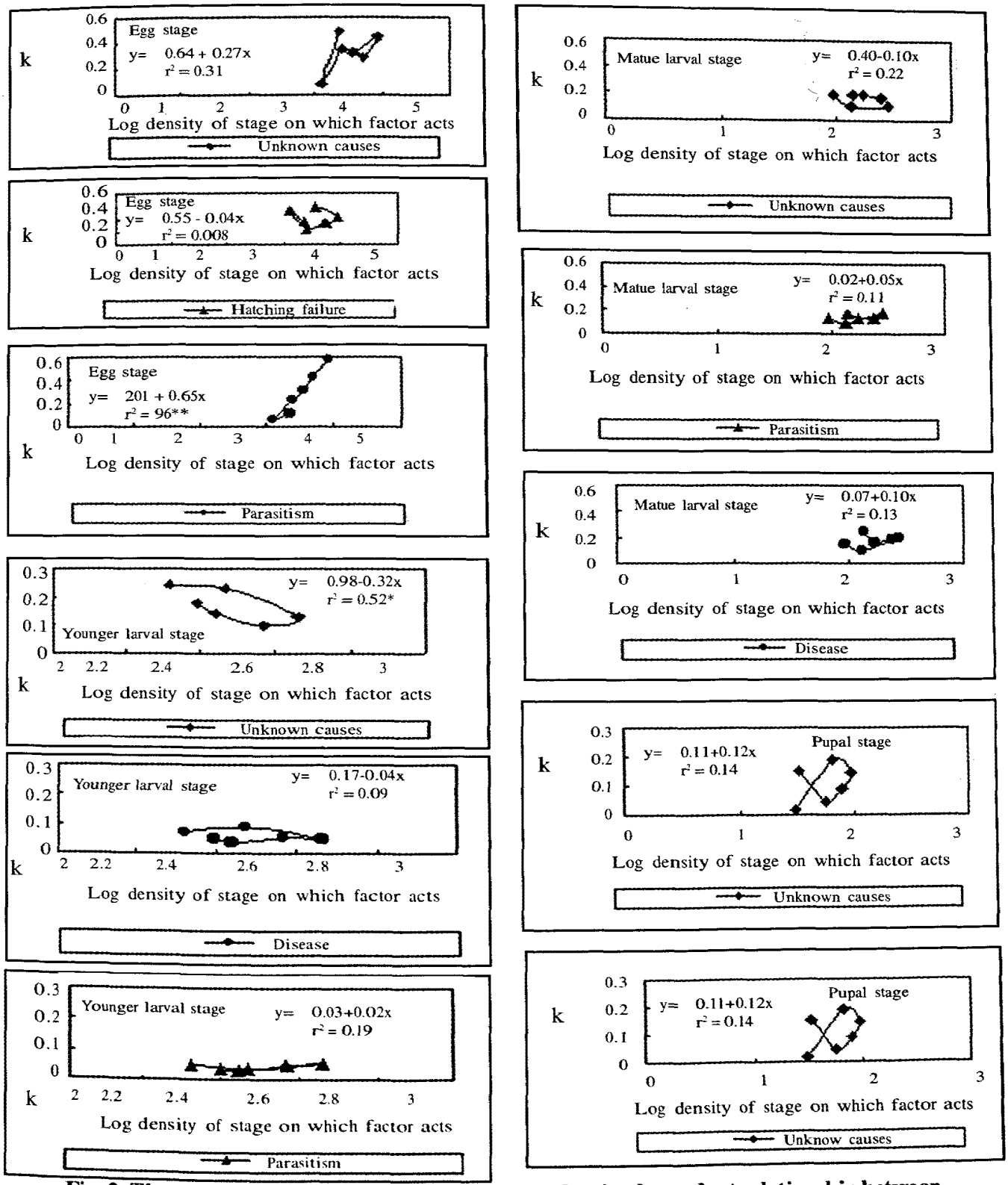

Fig. 2. Time sequence plots showing the different density dependent relationship between *C. partellus* and various mortality factors

larval stages had density independent relationship. In the pupal stage, both pupal parasiotids and unknown factors exhibited delayed density dependence with b = 0.07 and 0.12 (Fig. 2). The k factor analysis as suggested by Varley and Gradwell (1960 and 1963) helps in understanding how individual factors act and alter the pest population. In a k factor analysis if regression coefficients departs significantly from 1.0, density dependence is taken as real. In the present study, direct density dependence was obtained in egg stage for mortality due to parasitoid but factor was not able to compensate completely for the changes in density caused by other disturbing factors. This observation is in accordance with Varley and Gradwell (1963). The negative significant coefficient value signifies inverse density dependence, which was obtained in the present study in younger larval stage for mortality due to unknown causes. Mortality factors during egg stage due to hatching failure delayed density dependence. Such response was obtained by time sequence plotting and this is the only method by which such response can be obtained. The delayed density dependence factors leads to oscillation in the population (Hassell, 1966). Various other mortality factors which operated during *C. partellus* larval stage exhibited density independent relationship, which meansthat these factors contributed most for the population fluctuation. The results provide a basis of understanding the role of various factors in population fluctuation in the field and developing biocontrol programme for *C. partellus*, where releases should be aimed at enhancing the mortality.

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