A STUDY OF PEST-PARASITOID RELATIONSHIPS IN NATURAL HABITATS: AN AID TOWARDS THE BIOLOGICAL CONTROL OF *ELDANA SACCHARINA* (LEPIDOPTERA : PYRALIDAE) IN SUGARCANE

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Abstract

Regular surveys of *Cyperus papyrus* L., a natural host plant of *Eldana saccharina* Walker, have revealed a parasitoid and pathogen complex on the immature *E. saccharina* stages. The population fluctuations, over a two year period, of *E. saccharina* and its major biotic controlling agents in *C. papyrus* are presented and discussed in the context of their usefulness for the biological control of *E. saccharina* in sugarcane.

Introduction

For over one hundred years *Eldana saccharina* Walker (Lepidoptera : Pyralidae) has been a pest of sugarcane and a variety of other graminaceous crops in Africa (Carnegie[6]). The first reference to Eldana as a pest of sugarcane in South Africa was published by Dick[11]. Since 1973, in the Annual Proceedings of this Congress, numerous authors have focused attention on the effects of eldana on southern African sugarcane. However, very little is known of its ecology in its natural hosts, which are wetland sedges mostly of the family Cyperaceae (Atkinson[1]). Atkinson[1] and Girling[12] have listed the plant species which are attacked by eldana, and Atkinson[1] gives a brief synopsis on the oviposition and feeding sites of eldana in *Cyperus papyrus* L. and *Cyperus dives* Delile (=*Cyperus immensus* C.B. Cl), two of eldana's major indigenous host plants in southern Africa. The most recent publication (Atkinson and Carnegie[2]) discusses the phenology of eldana in northern Natal sugarcane. This has allowed a comparison of eldana phenology in one of its indigenous hosts (this paper) and sugarcane.

Information on the natural parasitoids of eldana in its indigenous host plants is virtually non-existent. The Commonwealth Institute of Biological Control lists seven Hymenoptera, six Diptera and a few nematodes of the genus *Hexonema* attacking eldana (Carnegie[7]), while Betbeder - Matibet[4] records two egg, ten larval and six pupal parasitoids. The majority of them are more common on stalkborers other than eldana, and have been collected from graminaceous host crops rather than indigenous host plants.

Since 1981, with the development of the Biological Control Unit at the SASA Experiment Station, much effort has been devoted to the search for indigenous parasitoids of eldana, both in sugarcane and indigenous host plants in southern Africa. Searches of sugarcane revealed no parasitoids, but searches of indigenous host plants, particularly papyrus, yielded six larval parasitoids, an entomogenous fungus and parasitic mermithid and rhabditid nematodes (Conlong and Hastings[9]). The larval parasitoids have been listed, the distribution of *Goniozus natalensis* Gordh (Hymenoptera : Bethylidae) has been mapped, and its parasitism of eldana at different locations and times has been recorded (Conlong *et al.*[10]). However, no information on temporal changes in host and parasitoid populations in one area was collected.

Population fluctuations of eldana and its major parasitoid and pathogen complexes have been monitored on a monthly basis at a papyrus-fringed lake on the farm Palm Ridge (28° 20'S, 32° 14'E) in the Mtubatuba area of Zululand since 1985. This paper documents the incidence, over a two year period, of *G. natalensis* and *Orgilus bifasciatus* Turner (Hymenoptera : Braconidae) the two most common larval parasitoids, and *Beauveria bassiana* (Bals.) Vuill., an entomogenous fungus belonging to the order Moniliales, on eldana larvae collected from papyrus umbels.

Materials and Methods

Sampling took place from the wetland margins, within quadrats measuring 8 m along the margin and 4 m into the wetland. Successive quadrats were cut deeper into the wetland once all the umbels, their rays, ray bases, associated bracts and umbel-bearing culms from the previous quadrat had been searched. Any rhizomes which were exposed above the water level were harvested for subsequent dissection.

All eldana, other borers and any parasitoid stages found were placed individually in numbered vials containing laboratory-prepared diet medium. These were kept until adults of either the borers or of their parasitoids had emerged. On the basis of their size at collection, the eldana larvae were assigned to one of six instar classes. For the purpose of this paper, the instars are divided into two groups: 1st to 3rd instars, and 4th to 6th instars. For comparative purposes the eldana infestations in sugarcane and papyrus are given as number of eldana per 100 sugarcane stalks and per 100 umbels searched.

Results

Oviposition and feeding sites of eldana in C. papyrus

Atkinson[1] recorded finding larvae and pupae in papyrus and *C. dives* umbels and rhizomes, especially when the latter were exposed. Current surveys confirmed this, and more detailed examination of papyrus umbels showed that eldana moths laid eggs on the brown papery bracts at the base of the mature umbels (Fig 1) and even in young umbels in which the rays had not yet opened. When the larvae hatched they bored into the basal portions of the rays adjacent to the bracts on which the eggs were laid (Fig 1). After a short feeding period in the ray, the larvae bored into the top of the culm, in the meristematic area of the ray bases (Fig 1). They were never found in the supporting tissue of the culm itself.

The papyrus rhizome consists of an inner core of supporting tissue (medulla, similar to that found in the culm), and an outer core of softer meristematic tissue (cortex) from which rootlets develop. The rhizome is covered by large tightly fitting fibrous bracts (Fig 2).

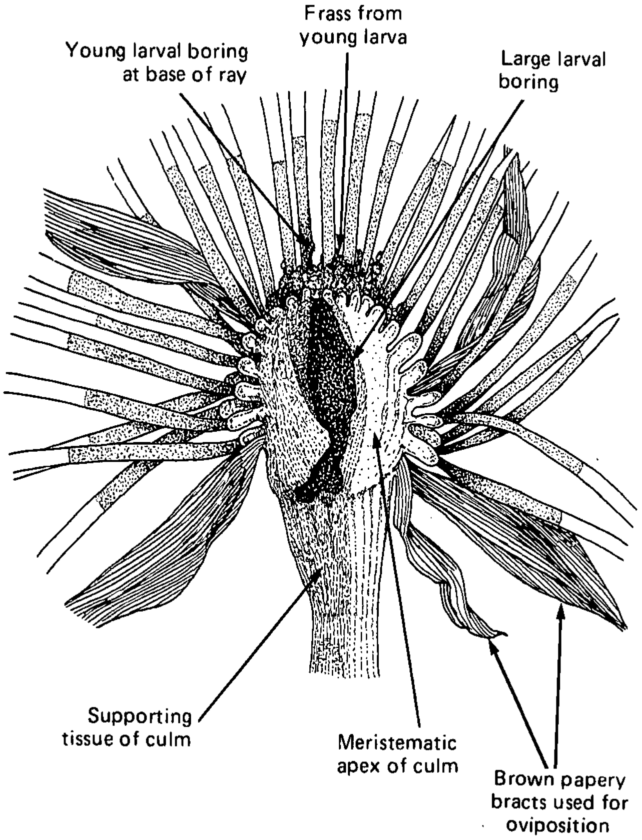

FIGURE 1 General oviposition and feeding sites of Eldana in a *C. papyrus* umbel.

Eldana larvae were found only in the cortex of the rhizome.

Atkinson[1] has speculated that the choice of feeding site by eldana larvae may be determined by nitrogen content, with the high nitrogen content sites being preferred in its natural hosts. This is confirmed by Atkinson and Nuss[3], and to a lesser extent by analyses undertaken during this study (Table 1).

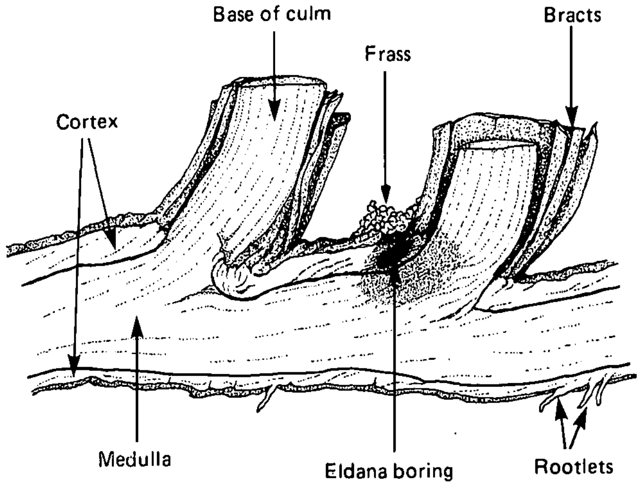

FIGURE 2 Feeding site of Eldana in a *C. papyrus* rhizome.

Table 1
The nitrogen content (%) of the sections of *C. papyrus* favoured and not favoured as boring sites (*Data from Lind and Visser[14])

	Culm*	Rays*	Rhizome cortex	Rhizome medulla
% N	0,49	1,71	1,37	0,49

General eldana - parasitoid population trends in C. papyrus

The total immature eldana population curve (Varley *et al.*[15]) is given in Fig 3. Populations increased during the summer, with a peak of 68 eldana per 100 umbels during December 1985. During the winters (April to October), eldana numbers fluctuated between 8 and 15 per 100 umbels.

The total parasitoid population curve for the same period is also shown in Fig 3. Peaks in parasitism were normally recorded approximately two months after peaks in eldana

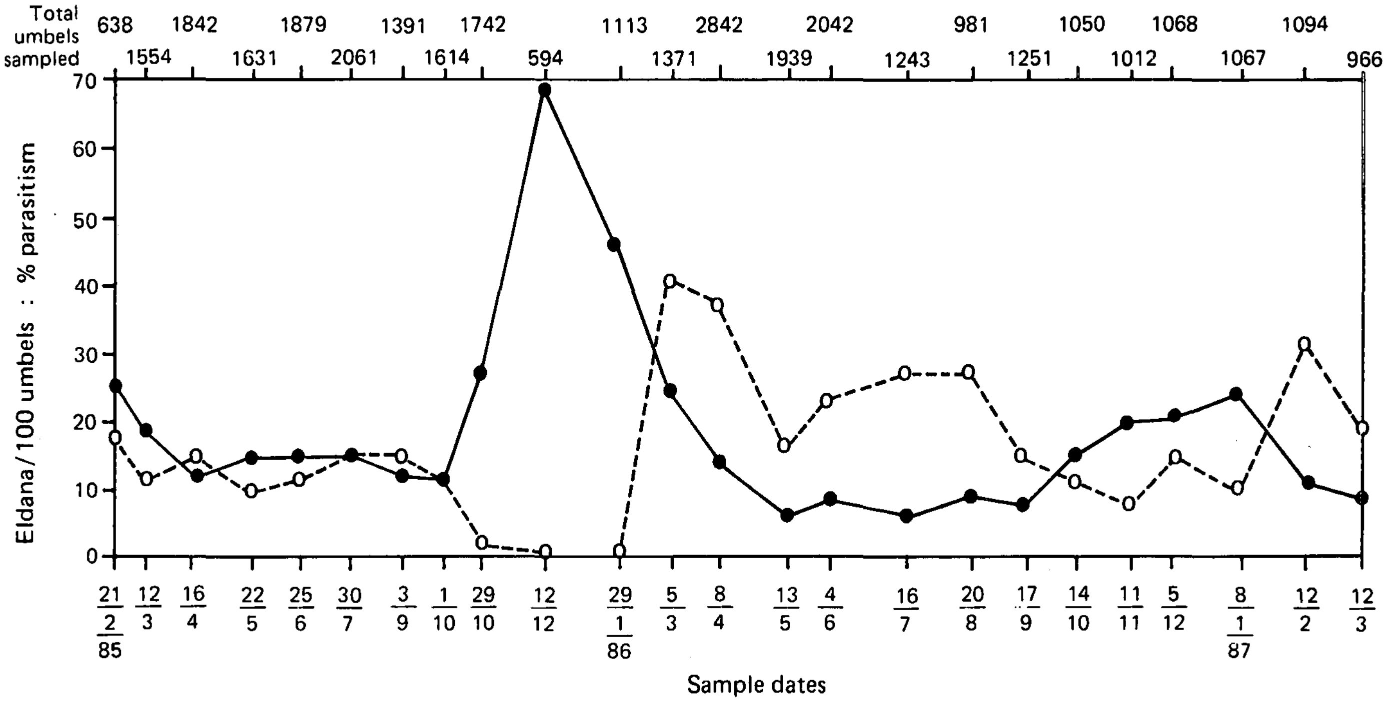

FIGURE 3 Total population curves of the immature eldana (—●—) and their parasitoids (--o--) found in *C. papyrus* umbels sampled at Palm Ridge. The total number of umbels searched on each sample date is displayed at the top of the figure.

levels. There were very low levels of parasitism (0-1,5%) from October 1985 until January 1986. Parasitism levels were usually around or below 10% during the summer periods, and greater than 10% during the winter periods.

The composition of the eldana population in C. papyrus

From February until October 1985, the numbers of 1st to 3rd, and 4th to 6th instar eldana larvae were approximately the same (±8 per 100 umbels; Fig 4). However, from December 1985 until March 1987, there were always more 4th to 6th instars in the population than 1st to 3rd instars. As a result, the partial population curve of the 4th to 6th instar larvae follows that of the total population curve most closely, and reflects the peaks in total eldana numbers recorded in summers spanned by the study period. Although pupal numbers were low, they were present throughout the two year study period, and peaks of 2, 3, 2 and 0,5 pupae per 100 umbels were recorded in September and December 1985 and August and December 1986 respectively. The lowest pupal numbers were recorded from March to July in 1985 and 1986.

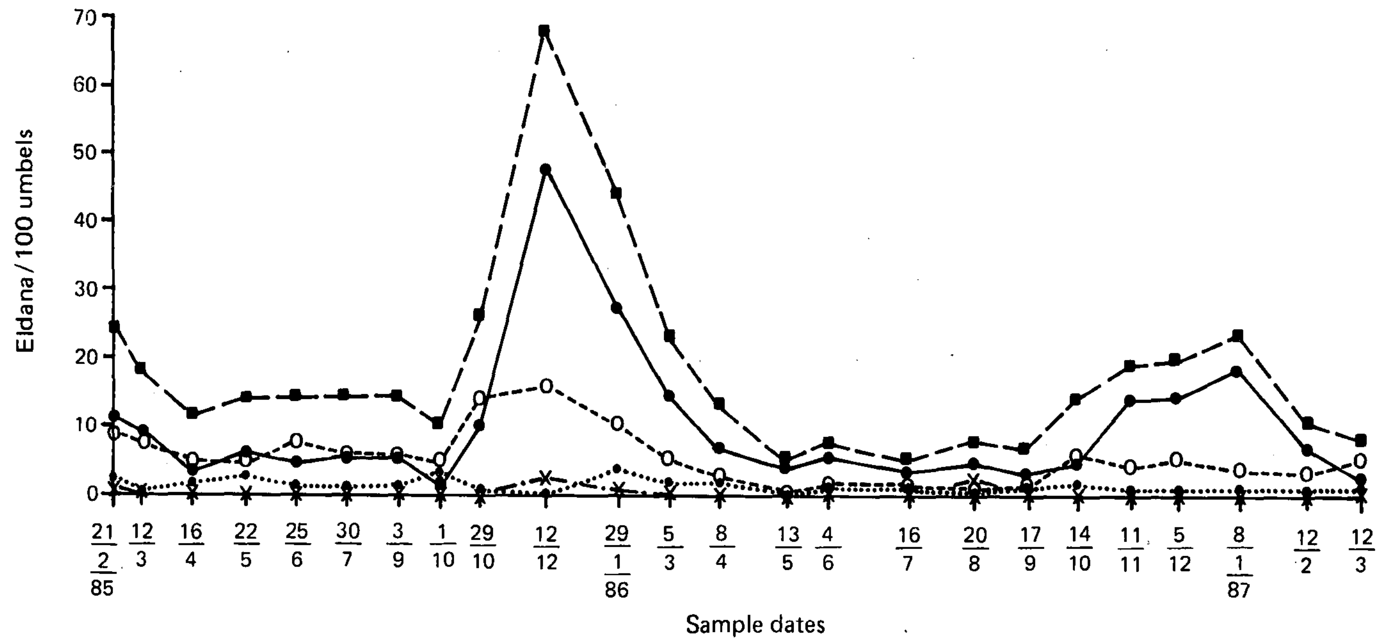

FIGURE 4 Partial population curves of the first to third instar larvae (--o--), fourth to sixth instar larvae(—•—), pupae (·—x—·) and empty pupal cases (····•····) contributing to the total population curve (—■—) of the immature eldana found in *C. papyrus* umbels sampled at Palm Ridge.

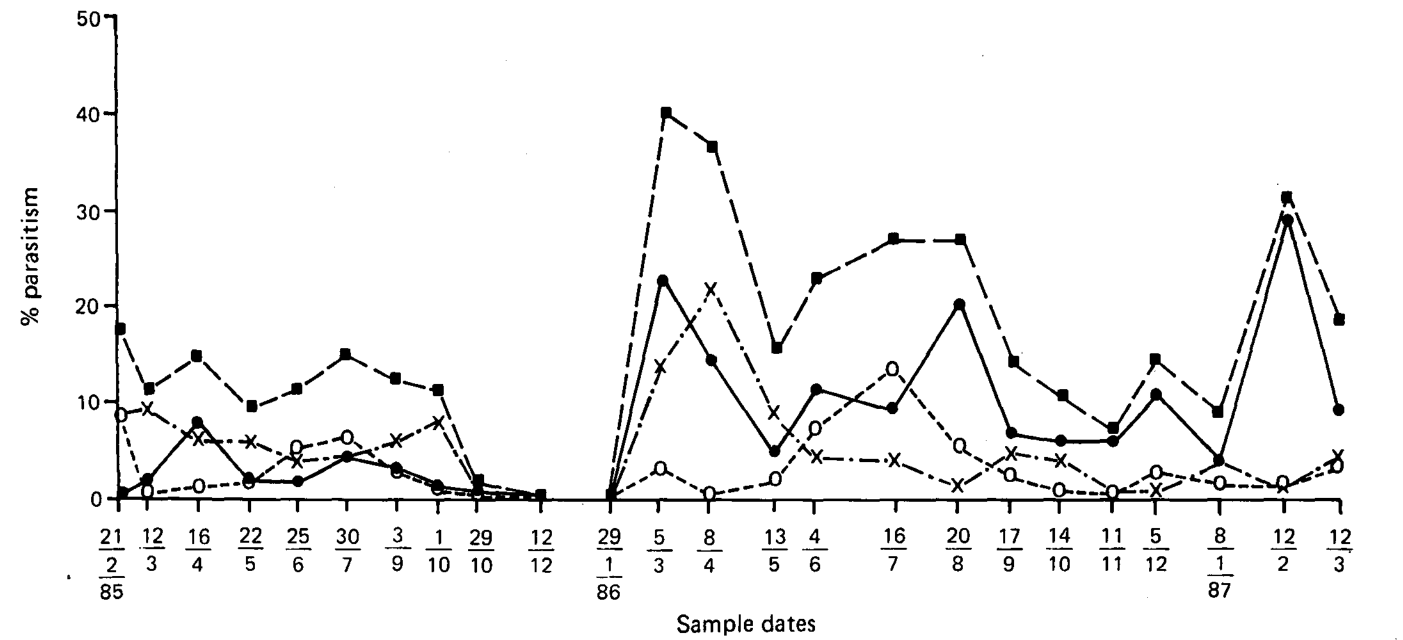

FIGURE 5 Partial population parasitism curves of *Goniozus natalensis* (—•—), *Orgilus bifasciatus* (--o--) and *Beauveria bassiana* (·—x—·) contributing to the total population parasitism curve (—■—) of the immature eldana stages found in *C. papyrus* umbels sampled at Palm Ridge.

The composition of the parasitoid population attacking the immature eldana population in C. papyrus

The populations of the three major parasitic controlling agents of immature eldana stages, expressed as individual percentages of the total parasitoid population, are shown in Fig 5. The partial population curves of *G. natalensis* and *O. bifasciatus* influence the total parasitism population curve the most. It is apparent that during the winter months (July to August) in 1985 and 1986, the *O. bifasciatus* curve followed the total parasitism curve most closely, while from February until April and again in July and August in both years *G. natalensis* was the greatest contributor to the total parasitism curve. *Beauveria bassiana* contributed most to the eldana reduction in September and October of both years. The low level of parasitism during October 1985 to January 1986 was not repeated during the corresponding period of the 1986/7 season (Fig 5).

Discussion

Immature eldana stages show a summer population peak in both papyrus (Figs 3 and 4) and sugarcane, with a second larger peak in winter in sugarcane (Atkinson and Carnegie[2]). The second peak was ascribed to the current harvesting schedules used for sugarcane, but it could be the result of lack of parasitoids, which are most active in autumn and winter (Fig 5).

Despite this major difference, there are a number of similarities in eldana population phenology in papyrus and in sugarcane. The multivoltine nature of the eldana population in papyrus is shown in Fig 4. Although no adults were trapped during the monitoring period, the presence of empty pupal cases (Fig 4) indicates that moths were present. Atkinson and Carnegie[2] also reported a spring pupation period. This was recorded in the papyrus population (Fig 4), both in terms of pupae and empty pupal cases. The high pupal count in December 1985 (Fig 4) was probably the result of lack of parasitism during that period (Figs 3 and 5). When parasitism was apparent during the subsequent December period, similar numbers of pupae were not recorded (Fig 4).

The role of parasitoids can further be resolved into two components: the degree of depression in the host population density, caused by the observed level of parasitism, and the degree of stability conferred on the interaction in the long term (Hassell and Waage[13]). Fig 3 shows that during most of the two year sampling period, total parasitism maintained the immature eldana population levels at around 8 to 14 per 100 umbels during the winter months, and between 15 and 68 per 100 umbels during the summer months. The stability of the parasitoid - host interaction is thus well illustrated, as is the depression of the host population density by the parasitoids. The ability of the parasitoid population to depress the eldana population is further supported in this study. During the summer season of 1985 (October to January; Fig 3) minimal parasitism of eldana was recorded, which allowed the eldana population to increase dramatically to the 68 eldana per 100 umbels reported earlier. However, within 2 months, the parasitoid population had "recovered" to such an extent that within a further 2 month period they had brought the eldana level down to below 10 per 100 umbels. Waage and Hassell[16] define a successful biological control programme as one in which the introduction of a parasitoid should lead to a reduction in pest numbers to a level where "crop" damage is below some economic threshold. Furthermore, the host and parasitoid populations should persist at these low levels in a stable equilibrium. The eldana - parasitoid population equilibrium, albeit in a "natural" system, conforms to these criteria.

Both Waage and Hassell[16] and Cock[8] debate the merits of single versus multiple parasitoid introductions in biological control programmes. They both stress the importance of a knowledge of the indigenous natural enemy role in their natural habitat. This would contribute to an understanding of their effect on host population density. Such information can be used to predict the best agents available or used retrospectively to explain successes or failures, rather than to maintain the current approach of trying all available biological control agents in turn to "see" which will work (Cock[8]).

In this study, *G. natalensis* was the most common parasitoid found and was the parasitoid species which followed the total parasitism curve most closely (Fig 5). Its biology has been described in detail by Conlong *et al.*[10]. Parasitism by this species has been recorded only on the larger instar eldana larvae in their borings in the apex of the culm of papyrus. In June and July of both years, *O. bifasciatus* parasitism had the greatest impact on the total parasitism curve (Fig 5). This parasitoid attacks the smaller instar larvae which have bored into the rays of the umbel. The female will occasionally attack small larvae in the culm apex. The ovipositor which is 2 - 3 mm long, is used to pierce the epidermis of the rays where the young eldana larvae feed. An egg is deposited in the host and the parasitoid larva develops internally. Parasitism is therefore not evident until the parasitoid pupates outside the cadaver. Only one offspring develops per host.

B. bassiana, an entomogenous fungus, has been collected from all eldana larval instars and pupae in papyrus umbels. Eldana borings in umbels normally open skywards, and are seldom larger than the larva or pupa occupying them. The eldana immature stages are therefore susceptible to infestation by spores of *B. bassiana*, which can reach the borings by gravity, dew or rain. The insect fauna in an umbel is diverse, and many of the smaller insects such as thrips (Hemiptera : Thripidae) or the eldana larva itself could carry spores into the borings. The incidence of parasitism by *B. bassiana* was highest in March and April 1986 (Fig 5) which together with *G. natalensis*, probably reduced the high December 1985 eldana population to the low level prevailing during most of the study (Fig 3).

It is therefore evident that in papyrus the parasitoid complex observed on eldana has developed over time, and each parasitoid attacks a certain stage of eldana at a certain time of the year. The effect of introducing this complex of parasitoids into sugarcane will not negate the effect of a single parasitoid introduction. Carl[5] states that the question of single and multiple introductions when dealing with an indigenous pest with its own parasite complex does not arise, as multiple introductions from the indigenous habitat into the new habitat will stand an equal chance of success if the newly introduced species can be fitted into an empty niche in the system.

Waage and Hassell[16] illustrate how ecological and evolutionary theory can aid in the employment of parasitoids for biological control purposes. When combined with comparative studies on parasitoid biology they show how several general patterns can emerge in the dynamics and structure of parasitoid - host systems, which appear relevant to both natural interactions (e.g. parasitoid - eldana interactions in papyrus) and those in "reconstructed parasitoid communities" employed against insect pests (e.g. eldana in sugarcane).

Furthermore, they stress that fundamental research and theory are of enormous value in identifying what kind of information is necessary for the evaluation of biological control, and that theory and practise stand to benefit from detailed studies of pest and parasitoid before, during and after introduction. The study reported in this paper reflects much of this information, and reinforces the benefits outlined above.

Conclusion

This study of eldana in one of its natural host plants, C. papyrus, has revealed:

(i) a parasitoid complex living in equilibrium with its host. The system has the ability to recover to its equilibrium level should any perturbation occur;

(ii) eldana populations in sugarcane, where no parasitoids occur, have a winter peak. This does not occur in papyrus. The lack of parasitoids therefore, which are most active in papyrus in winter can contribute to this peak in sugarcane.

(iii) that if the apparent habitat barrier between sugarcane and papyrus could be overcome by the indigenous parasitoids, they could become effective biological control agents in sugarcane.

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