SEASONAL POPULATION FLUCTUATIONS OF THE DIAMOND-BACK MOTH Plutella xylostella (L) AND ITS LARVAL PARASITOIDS IN THE UPLANDS OF SRI LANKA

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ABSTRACT

Studies on the population dynamics of *P. xylostella* in a pesticide free environment at Sita Eliya in 1978 and 1979 indicated three distinguishable periods of pest incidence that roughly followed three arbitrary growing seasons. High pest incidence between mid-January and mid-May was coincidental with high accumulated day degrees, low wind velocities and low rainfall. In contrast, high wind velocities and high rainfall decreased pest incidence between mid-May and mid-September. Pest incidence was moderate between mid-September and mid-January. Parasitoids accounted for about 65% reduction in the pest population during the peak period between mid-March and mid-April, which together with other natural enemies probably cause the sudden decline in DBM population after March. Pesticide use for DBM control in these areas should thus be selective in favour of the natural enemies.

Apanteles plutellae (Kurdjumov) was the major parasitoid species contributing to around 70% of the parasitoid complex followed by *Diadegma eucerophaga* (Horstman) and *Thyraeella collaris* (Graveley).

INTRODUCTION

The diamond-back moth, *Plutella xylostella* (Linnaeus) (=*P. maculipennis* Curtis) (Lepidoptera : Plutellidae) is a worldwide pest of cruciferous crops (Shaw 1959, Salinas 1977). This was found to be the dominant species of the cabbage caterpillar complex in the uplands of Sri Lanka by Fernando in 1964 and 1965. The caterpillar was parasitized to a low degree by *Apanteles plutellae* (Kurdjumov) and *Anilastus* sp., (Fernando 1964.)

Attempts were made in 1964 and 1965 to introduce two ichneumonid parasitoids, *Horogenes cerophaga* Grav. and *Thyraeella collaris* (Graveley) from Australia and India (Fernando 1965, 1966). The pupal parasitoid, *T. collaris* introduced from India produced a low degree of parasitism (Fernando 1965). The survival *en route* of the parasitoids from Australia was so poor that these could not be eventually tested in Sri Lanka (Fernando 1966).

In Sri Lanka the monsoonal rains describe the major cultivation seasons, the Maha which receives rains from the North East monsoon and the Yala which receives rains from the South West monsoon. In the upland areas where crucifers are cultivated extensively, adverse weather conditions in June and July, which may extend a month either way in different years, curtail farming activities between the months of May and September. Due to this reason and the limited availability of land the farmers undertake a major extent of cultivation from September to May. Cultivation seasons in the upland areas are thus not well defined as in the rest of the country. Farmers do however, time their planting of cruciferous and other crops to meet the enhanced demand during Christmas and the Sinhala-Tamil New year In mid-April. In this area it is thus possible to divide the year into three arbitrary growing seasons, each of four-month duration, the first beginning in mid-January.

Several reports are available on the seasonal abundance of the DBM, including the effect of different climatic factors (Harcourt 1954, 1957, 1963; Wu 1968; Razumov 1970; Butts and McEwen 1981) as well as natural enemies (Matsuura 1976; Goodwin 1979; Nagarkatti and Jayanth 1982) on the pest. However, these are mainly from developed countries where factors affecting insect life were studied perhaps with the view of integrating them in their control programmes. Such basic information is not available to several crop/pest situations in Sri Lanka.

A continuous study was undertaken at the Agricultural Research Station, Sita Eliya, in 1978 and 1979 to identify and evaluate the major factors which affect DBM abundance.

MATERIALS AND METHODS

Two hundred seedlings (4—6 weeks old) of popular cabbage variety, A–S cross were planted at monthly intervals at a spacing of 50×40cm. These seedlings were not treated with any pesticide. Other agronomic practices were followed in accordance with the recommendations of the Department of Agriculture, Sri Lanka. The plants were sampled for DBM larvae at 4–6 weeks after transplanting. The sample unit was the leaf that had just separated from the inner whorl of leaves. At this stage of the plant this leaf was about the 8th to the 10th from the outermost. This leaf was removed from 100 plants selected at random and placed in polyethylene bags. Sampling was done on the 1st and 15th day of each month.

The field collected leaves were brought to the laboratory and DBM larvae of IIIrd and IVth instars were removed. They were then dissected under a stereo-microscope (magnification 40).

The parasitoids that were found inside the larvae were separated as braconids or ichneumonids. The total number of larvae examined, the number parasitized (by braconids or ichneumonids) and the number unparasitized, were recorded. From time to time some of the larvae collected were reared in test tubes with cabbage leaf sections about 1cm^2 supplied as food, until pupation or the emergence of the parasitoid. The pupae were observed until the emergence of the adults of the DBM or of the parasitoids.

Observations were maintained in the field for other natural enemies such as predators and diseases. The larvae of a predatory syrphid were reared to the adult stage. The diseases were identified based on the symptoms produced on the larvae. The extent of cultivation of crucifers in the region during the period of study was obtained from the Extension Division of the Department of Agriculture, Nuwara Eliya.

As oviposition, eclosion and early instars take about 14 days, climatic factors obtained at Sita Eliya for the fortnightly periods prior to the date of sampling were used in evaluating their effect on the DBM. The climatic factors were correlated to the mean number of DBM larvae as well as that of the associated parasitoids in a sample.

In the case of temperature, accumulated day degrees above a minimum threshold of 7.3°C (Butts and McEwen 1981 after Harcourt 1954) based on maximum and minimum day temperatures (Baskerville and Emin 1968) was used. For rainfall and wind velocities, total and mean respectively for the fortnightly period were used. Maximum rainfall for a day or maximum wind velocity during this period was used to evaluate the intensity of these factors on the DBM.

The percent parasitism on the DBM for the different arbitrary growing seasons during peak periods of pest incidence and for the study period was tabulated. The species composition of the parasitoids for these different periods was also tabulated.

RESULTS

Natural Enemies of the DBM

i. **Parasitoids:** The parasitoids that emerged from the larval collections during the period of this study were identified as :—

(*a*) *A. plutellae* (Braconidae: Microgasterinae)

(*b*) *Diadegma eucerophaga* (Horstman) (Ichneumonidae: Ophioninae). In Australia this species was earlier misidentified as *D. cerophaga* Gravenhorst (Gauld 1984). Synonyms *Nythobia, Horogenes, Angitia.*

(c) *T. collaris* (Ichneumonidae: Ichneumoninae) Synonym *Diadromus.*

ii. **Predators:** a predatory syrphid, *Platycheirus* sp., was observed to feed on the eggs of the DBM. Adults of this syrphid were found in large numbers in the months of March and April.

iii. **Diseases:** The larvae of the DBM were affected by fungal and viral diseases in the field.

Availability of Cultivated Host Plant

The total acreage under crucifers in the Nuwara Eliya region is shown in Table 1. Total extent under crucifers was slightly variable for Maha and Yala seasons and for the years 1978 and 1979.

Seasonal fluctuations of the DBM and associated parasitoids in relation to climatic factors

The seasonal changes in the larval numbers of DBM and associated parasitoids are shown in Figures 1 and 2.

In 1978 (Fig. 1a), three distinguishable periods of DBM activity were obtained. A period of high incidence from February to the end of April, followed by a period of low incidence from May to September and a period of moderate incidence from October to December. Almost the same pattern was obtained for 1979 (Fig. 2a), though the first period was from January to mid-May. The data for the third period for 1979 were not obtained.

The DBM incidence roughly follows the arbitrary growing seasons mentioned earlier. In both years a major peak for larval incidence was obtained in late March.

Parasitoid activity followed the same seasonal trend as the DBM. A high degree of synchrony between DBM and the parasitoids was evident with *A. plutellae* providing the most obvious correlation (Fig. 1a, 2a).

Accumulated day degrees show a positive realtionship with the DBM population and associated parasitoids (Fig. 1, a & b; 2, a & b). High wind velocities (Fig. 1, a & c; 2, a & c) and high rainfall (Fig. 1, 2 & d; 2, a & d) show a negative effect on the pest and the parasitoids.

Significance of Parasitoids of DBM

The effect of the parasitoids on the DBM are shown in Table 2. Total parasitism varied during the different arbitrary growing seasons. It was 57.0% between mid-January and mid-May (Table 2, Column 1b), with *Apanteles* 39.9% and the ichneumonids the balance 17.1%. Parasitoid activity decreased to 29.4% between mid-May and mid-September, with *Apanteles* 21.9% and the ichneumonids 7.5% (Table 2, Column 2b). During the third period between mid-September and mid-January total parasitism was 39.8% with *Apanteles* 28.5% and the ichneumonids 11.3% (Table 2, Column 3b). During peak periods of larval incidence between mid-March and mid-April parasitism increased to 64.6%, with *Apanteles* 45.1% and the ichneumonids 14.5% (Table 2, Column 4b).

A. plutellae emerged as the major larval parasitoid of the DBM contributing to around 70% of the parasitoid complex. The species composition did not alter significantly during the different periods of the year (Table 2, Columns 1c, 2c, 3c, 4c).

DISCUSSION

There were doubts regarding the establishment of the introduced ichneumonids, *T. collaris* and *D. eucerophaga;* however, this study shows that they are well established and are at present important parasitoids of the DBM along with the indigenous species *A. plutellae*.

Over 90 species of parasitoids of the DBM have been recorded from different parts of the world. Despite this range of parasitoids some species tend to dominate the complex wherever they occur. In North America, *Diadegma insularis* (Meus.) and *Micropolitis plutellae* (Cress.) are dominant (Harcourt 1963, Pimental 1969, Oatman and Platner 1969, Putnam 1973) ; *Diadegma* sp., and *Diadromus* sp., dominate in Europe (Hardy 1938), South Africa (Ullyett 1947), New Zealand (Hardy 1938, Todd 1959); in Russia *Diadegma* sp., *Diadromus* sp., and *Apanteles* appear dominant (Kopvillem 1961) and in Victoria, Australia *Diadegma* was the dominant species (Goodwin 1979).

In this study *A. plutellae* dominated the parasitoid complex. This finding agrees with the general conclusions of Fan and Ho (1971), Chieu and Chien (1972), Wang *et al* (1972), Chang (1974) and Nagarkatti and Jayanth (1982) that *Apanteles* is an important genus in Asia.

Host Plant and DBM

The slight differences in the acreage under crucifers between Maha and Yala in the region (Table 1) could not have produced the noticeable differences in the incidence of the pest during the different periods of the year (Fig. 1a, 2a). Further, the effect of the availability of the cultivated host plant would have been nullified due to the preponderance of wild mustard, *Brassica arvensis* Ktze (Georgia 1914) a cruciferous weed and a known host of the DBM in the region.

Climatic Factors and DBM

The effect of temperature on insect development has been widely studied (Uvarov 1931). Temperature has a positive effect on development within a maximum and minimum range. Harcourt (1954) has shown that under laboratory conditions DBM requires an accumulated day degree total of 283°C above a minimum threshold of 7.3°C to complete a generation. This was estimated as 290°C above the same threshold under field conditions by Butts and McEwen (1981). Higher accumulated day degrees inducing faster development would result in overlapping generations and a higher incidence of the pest.

Intense rainfall can wash out the different stages of the insect from the plants. It can also affect the mating and egg-laying activities of the adults. The detrimental effects of rainfall on DBM abundance have been reported (Harcourt 1963, Oatman and Platner (1969, Butts and McEwen 1981). Similarly high wind velocities can also affect the mating and egg-laying activities of the adults and may also dislodge the larvae from the plants (Uvarov 1931). The effect of these detrimental factors on insect populations can be cumulative as well as incidental and are thus difficult to evaluate in field situations.

Uvarov (1931) favours the concept that "climate is the ever present complex of phenomena in an insect's life and other factors of the environment are subordinate to it in importance". However, the sudden drop in DBM numbers (Fig. 1a, 2a) after the major peak in late-March when climatic factors and host plant availability were favourable, could be accounted for only to the effect of the parasitoids and other natural enemies of the DBM.

Natural Enemies and DBM

The parasitoids effected 49.4% (Table 2, Column 5b) reduction in larval numbers during the period of the study. This increased to 64.6% (Table 2, Column 4b) during peak periods of larval incidence. It is difficult to distinguish between the larvae of the two ichneumonids from the dissected specimens of the DBM. It is possible that *T. collaris* which is variously described as a prepupal-pupal (Matsuura 1976) or pupal (Chuo 1975) parasitoid, may have contributed to a greater reduction in pest numbers than what is apparent. Field observations showed that the incidence of the predatory syrphid, *Platycheirus* sp., was high during peak periods of larval incidence in the months of March and April. The combined effect of the natural enemies would account for the sudden decline in pest incidence after the major peak in late March. However, this is not fully resolved in this study and prompts further investigations on the effect of the natural enemy complex on all stages of the DBM, particularly during peak periods of its occurrence.

The disappearance of *T. collaris* from the Bangalore area in India (from where it was probably introduced to Sri Lanka) was attributed to the excessive use of pesticides on cabbage in that area (Nagarkatti and Jayanth 1982). *Anilastus* sp., observed by Fernando (1964) as effecting a low degree of parasitism, was not encountered during this study. Since parasitoids are seen to effect an appreciable degree of control of the DBM, pesticide use in these areas should be selective in their favour.

CONCLUSIONS

1. Seasonal fluctuations of DBM incidence in the upland areas of Sri Lanka roughly follow three arbitrary growing seasons, each of four-month duration, the first beginning in mid-January. The high pest incidence during the first season will expose cruciferous crops to pest attack necessitating frequent adoption of control measures. During the second season between mid-May and mid-September DBM incidence was low. It should be possible to grow crucifers without any appreciable chemical measures to control DBM during this period. The third season between mid-September and mid-January had a moderate incidence of the pest. Control strategy during this period should be based on the level of incidence of the pest.

2. High accumulated day degrees favoured pest incidence. In contrast, high wind velocities and high rainfall reduced pest numbers and contributed significantly to the fluctuations in the pest population.

3. The introduced parasitoids *D. eucerophaga* and *T. collaris* are well established and together with *A. plutellae* are important parasitoids of the DBM.

4. *A. plutellae* was the dominant parasitoid species.

5. Parasitoid activity caused about 65% reduction in DBM larval numbers during major peak incidence. This, together with other natural enemies, probably caused the sudden decline in DBM population after March. Pesticide use for DBM control in these areas should thus be selective in favour of the natural enemies.

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Figure 1. **Seasonal fluctuations of DBM and associated parasitoids in relation to climatic factors at Sita Eliya (1978)**

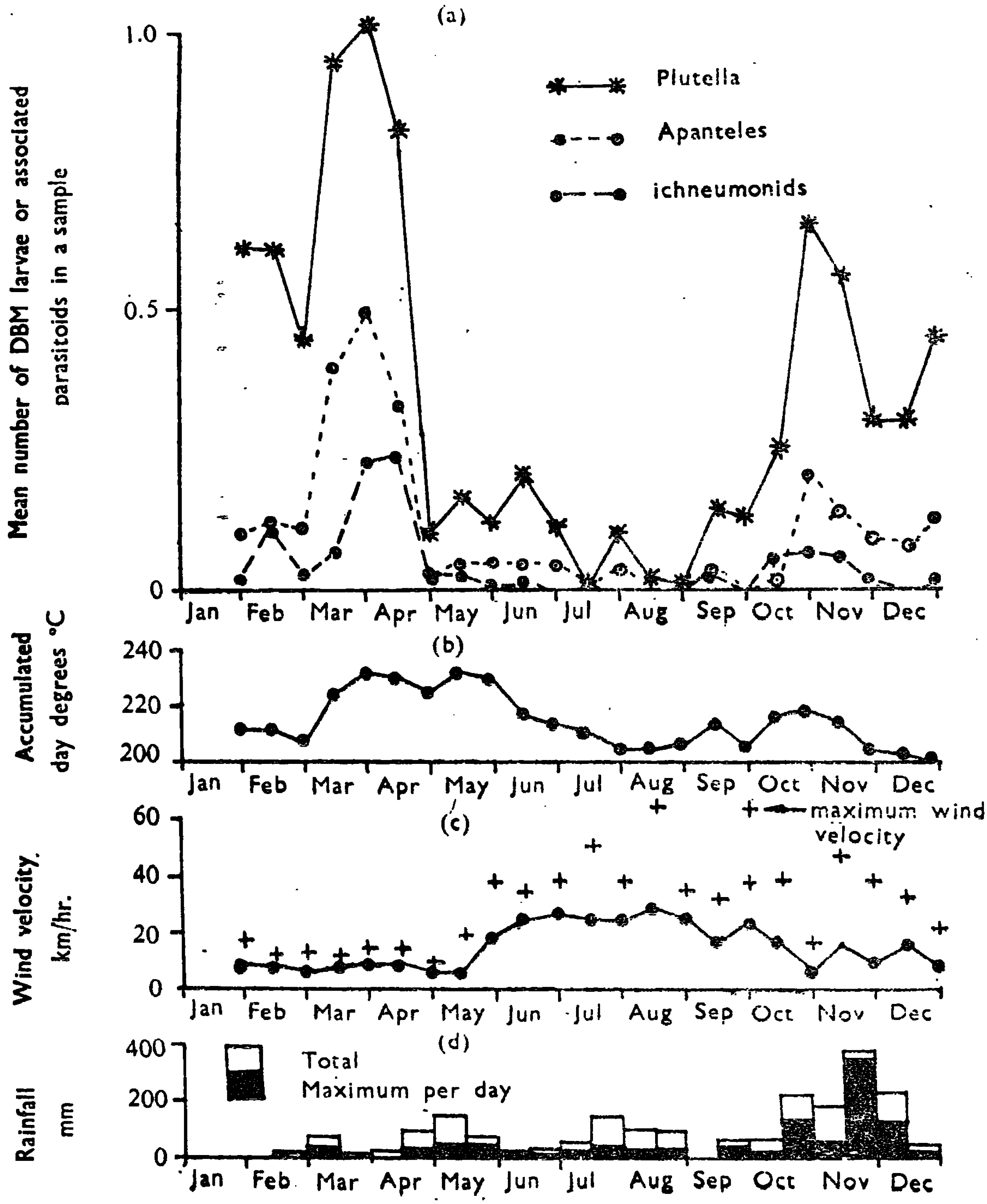

Figure 2. Seasonal fluctuations of DBM and associated parasitoids in relation to climatic factors at Sita Eliya (1979)

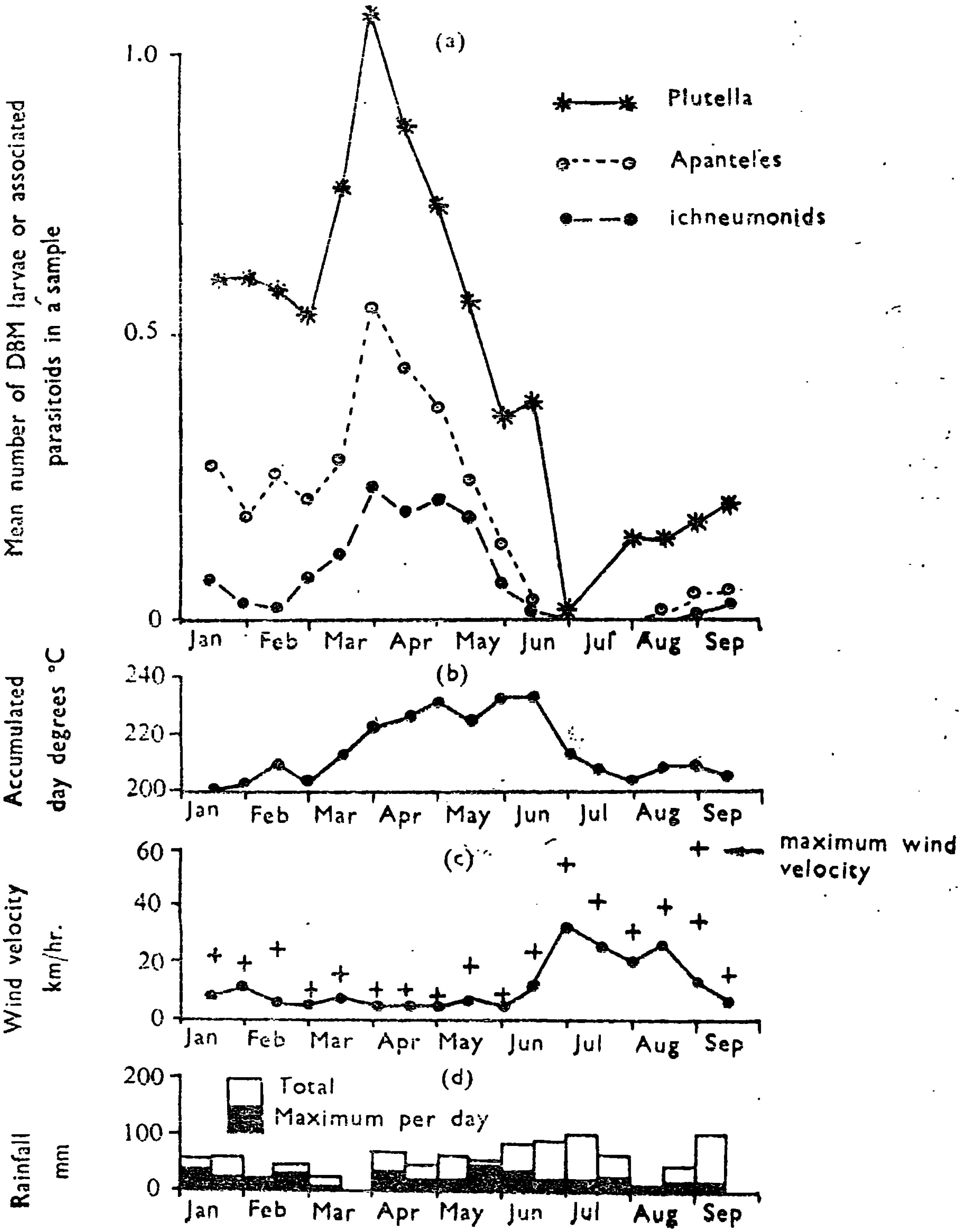

Table 1. Acreage under the major crucifers in the Nuwara Eliya region

Crop	*Acreage under Crucifers*			
	Maha 1977/78	*Yala 1978*	*Maha 1978/79*	*Yala 1979*
Cabbage	929	1213	1091	1064
Radish	693	1111	975	292
Cauliflower	14	27	14	18
Knol Khol	588	583	836	294
Total	2224	2934	2616	1668

Table 2. Parasitoids of the DBM and their significance at Sita Eliya

Columns	1			2			3			4			5		
	Mid-January to mid-May			*Mid-May to mid-September*			*Mid-September to mid-January*			*Mid-March to mid-April*			*February 1978 to September 1979*		
Sub Columns	a	b	c	a	b	c	a	b	c	a	b	c	a	b	c
Total number DBM larvae examined	1100			238			372			548			1710		
Number unparasitized	473			168			224			194			865		
Number parasitized	627	57.0		70	29.4		148	39.8		354	64.6		845	49.4	
Parasitoid species															
Braconidae:-															
A. plutellae	439	39.9	70.0	52	21.9	74.3	106	28.5	71.6	247	45.1	69.8	597	34.9	70.7
Ichneumonidae:-															
D. eucerophaga															
T. collaris	188	17.1	30.0	18	7.5	25.7	42	11.3	28.4	107	19.1	30.2	248	14.5	29.3

a – Number of DBM larvae or associated parasitoids.

b – Per cent DBM larvae parasitized.

c – Per cent of total parasitism effected by individual species of parasitoids.