Studies on the Ecology and Behaviour of the Larvae *Plutella Xylostella* (Linnaeus) (Lepidoptera: Plutellidae). III. Effects of Size and Shape of the Host Plant Leaves[1]

*P.J. Salinas**

ABSTRACT

Experiments were carried out in controlled temperature rooms (20 ± 1°C); 16 hours of light per day; 44-52% relative humidity, with recently hatched larvae of *Plutella xylostella* (L.) (Lepidoptera: Plutellidae) placed at different densities (1; 2; 4; 8 and 32) on rectangles of tender leaves of young cabbage, of sizes varying from 1.25 x 0.5 cm to 5.0 x 2.0 cm. The larvae reared singly did not show noticeable differences in behaviour from single larvae reared on whole leaves (4). The larvae reared in pairs did not show any detectable differences from those of similar number per whole leaf. At four larvae/rectangle the larvae became more active in making holes (10 times more than at one or two larvae/rectangle). At all densities, the smaller the rectangle the more feeding places were found. The developmental time was lowest (11.6 days) at four larvae/rectangle and highest (16.8 days) at eight larvae/rectangle. Mortality was lowest (14.3%) at two larvae/rectangle and highest (92.9%) at 32 larvae/rectangle. The pupae were longer (6.2 mm) at two larvae/rectangle and shorter at 32 larvae/rectangle; and were heavier (5.9 mg) at one larvae/rectangle and lighter (4.0 mg) at two larvae/rectangle. The adults were heavier (4.0 mg) at two larvae/rectangle and lighter at 32 larvae/rectangle. The size and weight of the pupae are positively correlated in both sexes (Females: Y = 2.6625 x – 9.56; Males; Y = 2.3274 x – 8.02). As fecundity is positively correlated with the weight, the pupae size or weight can be used as an index of fecundity. Any increase in fecundity combined with a shorter period of development is probably of importance in the preservation of this species.

COMPENDIO

Se hicieron experimentos en cuartos con temperatura controlada (20 ± 1°C); 16 horas por día de luz, 44-52% humedad relativa, con larvas recién eclosionadas de *Plutella xylostella* (L.) (Lepidoptera: Plutellidae) colocadas a diferentes densidades (1; 2; 4; 8 y 32) en rectángulos de hojas tiernas de repollo joven, de varios tamaños, desde 1.25 x 0.5 cm hasta 5.0 x 2.0 cm. Las larvas criadas solitarias no mostraron diferencias notables en comportamiento con las larvas solitarias criadas en hojas completas. Las larvas criadas en pares no mostraron ninguna diferencia notable con aquellas en números similares en hojas completas. A cuatro larvas/rectángulo las larvas estuvieron más activas en hacer huecos (10 veces más que una o dos larvas/rectángulo). En todas las densidades, cuanto más pequeño el rectángulo se encontraron más orificios de alimentación. El tiempo de desarrollo fue más bajo (11.6 días) a cuatro larvas/rectángulo y más alto (16.8 días a ocho larvas/rectángulo. La mortalidad fue más baja (14.3%) a dos larvas/rectángulo y más alta (92.9%) a 32 larvas/rectángulo. Las pupas fueron más largas (6.2 mm) a dos larvas/rectángulo y más cortas (5.3 mm) a 32 larvas/rectángulo, y más pesadas (5.9 mg) a una larva/rectángulo y más livianas (4.0 mg a dos larvas/rectángulo. Los adultos fueron más pesados (4.0 mg) a dos larvas/rectángulo y más livianos a 32 larvas/rectángulo. El tamaño y el peso de las pupas están correlacionadas positivamente en ambos sexos (hembras: Y = 2.6625 x – 9.56; machos: Y = 2.3274 x – 8.02). Como la fecundidad está correlacionada positivamente con el peso, el tamaño o el peso de las pupas puede ser usado como un índice de fecundidad. Cualquier incremento en fecundidad combinado con un período más corto de desarrollo es probablemente de importancia en la preservación de esta especie.

INTRODUCTION

The importance of *Plutella xylostella* (Linnaeus) (Lepidoptera: Plutellidae) as a serious pest of cruciferous crops has been described elsewhere by Salinas (5). The world distribution and the description of the immature stages (egg, larval instars, prepupa and pupa) have also been given earlier (2, 3).

This paper describes the results of experiments that were carried out in order to determine the effects of the size and shape of the leaf on the behaviour, dispersion and survival of the larvae, especially young ones, at different densities, and on the size and weight of pupae and weight of adults. Comparisons were made between those larvae kept on whole plants and on leaf discs.

MATERIALS AND METHODS

The experiments were carried out in controlled environment rooms at 20 ± 1°C, hours of light per day and 44-52% relative humidity, as already described (4)

1 Received for publication 7 November 1988
I should like to thank Prof. T.R.E. Southwood for granting facilities at Imperial College Field Station; to Prof. M.J. Way for his supervision, and criticism of the manuscript, and to all those who collaborated in the conclusion of the present work. The financial support by the Fondo Nacional de Investigaciones Agropecuarias, the Universidad de Los Andes and the CDCH-ULA, is gratefully acknowledged.

* Universidad de Los Andes, Mérida, Venezuela.

Rectangles of the following dimensions were cut from tender leaves of young cabbage plants: 5.0 x 2.0 cm; 5.0 x 1.0 cm; 5.0 x 0.5 cm; 2.5 x 1.0 cm; 2.5 x 0.5 cm; 1.25 x 1.0 cm; 1.25 x 0.5 cm.

The rectangles were placed in circular plastic cages (10.0 cm diameter x 4.5 cm height), already described (4). The part corresponding to the bottom of the leaf was inserted about 1 to 2 mm in the wet sand to provide a constant flow of water inside the leaf tissue.

Recently hatched larvae were placed in the centre of each leaf rectangle at the following densities: one, two, four, eight and 32 larvae per rectangle.

RESULTS AND DISCUSSION

Effects on larval behaviour, development, and mortality

Gallery-making stages

Experiments at densities of one, two and four larvae per rectangle.

One larva per rectangle: The larvae reared singly in the different rectangles did not show any noticeable difference from single larva on leaf discs or on whole leaves. The larva followed the general pattern of behaviour already described (4), which includes wandering, spinning, "sensing", and biting the leaf surface, until it made a hole and eventually a gallery. Consistent with previous observations, the larva avoided eating completely through thick veins, the borders of the rectangles, and its own previously made galleries. In the 0.5 cm wide rectangles, the galleries were obviously more irregular in their directions because of the reduced distance between the edges of the rectangle and the larva was compelled to turn its gallery more often.

Two larvae per rectangle: The larvae reared in pairs per rectangle did not show any detectable difference from those of a similar number per leaf disc or per whole leaf. The galleries in the 0.5 cm wide rectangles were more irregular than those in 1.0 cm wide rectangles because of the reduced distance between the edges. In the narrow rectangles the results are a series of irregularly directed mines very often shorter than normal (Fig. 1). Also, if a thick vein crosses the leaf rectangle the larvae will most probably make all the galleries on only one sector of the rectangle, avoiding crossing the vein (Fig. 1).

Four larvae per rectangle: When the density was increased to four larvae/rectangle the behaviour of the larvae changed visibly. They became more active in making holes. Only 15 hours after hatching the mean number of holes increased from the usual one gallery per larva, which is expected under low density, to over ten galleries/larvae in the smallest rectangles (Table 1). This increase in the number of galleries is probably due to mutual disturbance during the critical stage of starting the galleries and perhaps after gallery formation. In the smallest rectangles most of the feeding places were punctures and very few were true galleries.

Developmental time (including pre-pupation)

Table 2 indicates that at densities of one and two larvae per rectangle the times taken by the larvae to develop were 14.8 and 14.2 days respectively. When the density was increased to four larvae per rectangle the developmental time was reduced to only 11.6 days. Although no statistical analysis was carried out, it would appear that the reduction in the period of development could be regarded as beneficial for the

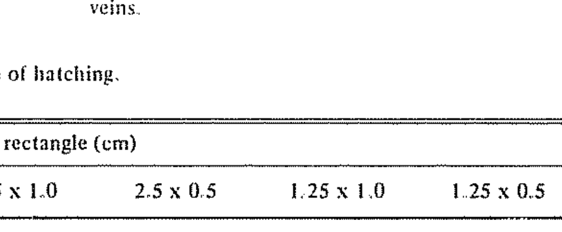

Fig. 1. Larvae feeding on one side of leaf, avoiding thick veins.

Table 1. Mean number of feeding places per larvae, 15-18 hours from time of hatching.

	Size of leaf rectangle (cm)						
Larvae/rectangle	5 x 2.0	5 x 1.0	5 x 0.5	2.5 x 1.0	2.5 x 0.5	1.25 x 1.0	1.25 x 0.5
1	1.0	1.0	1.0	2.0	3.0	1.0	1.0
2	1.0	1.0	1.0	1.0	1.0	1.0	1.0
4	4.3	5.0	3.8	3.8	6.3	10.8	10.0

Table 2. Larval developmental times (days) and mortalities (%).

	Number of larvae per rectangle				
	1	2	4	8	32
Mean number of days	14.8	14.2	11.6	16.8	16.3
Mortality of larvae (%)	28.6	14.3	50.0	91.1	92.9

insect since it can reach the pupal stage in a shorter period of time if food is in short supply.

The figures in Table 2 indicate that the times for the larval stage increased to 16.8 and 16.3 days at densities of eight and 32 larvae per rectangle. This could be interpreted in terms of optimum density of larvae per unit of available space or habitat. In other words it appears that the larvae may require a certain stimulus which is provided by the presence or contact with other larvae, but which has a limit, and when that limit is exceeded the effect is detrimental to the development of the larvae. Densities of one or two larvae per rectangle may be inadequate for optimum stimulation. At four larvae per rectangle the rate of development appeared be optimum, and increases above those densities caused the development period to be prolonged.

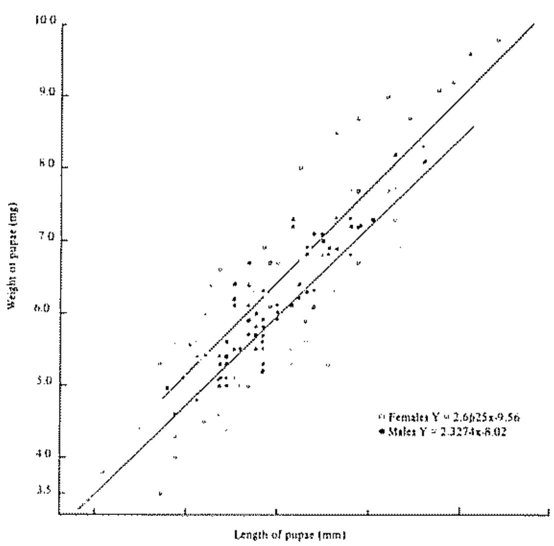

Fig. 2. Correlations of weight and length of pupae (○ Females Y = 2.6625x-9.65; • Males Y = 2.3274x-8.02)

Larval mortality

Despite the lack of statistical analysis, Table 2 indicates that the mortality of the larvae was higher at the density of one larva per rectangle (28.5%) than with that of two larvae per rectangle (14.3%). This may be insignificant but may also be a consequence of a mutual beneficial stimulus provided by the larvae. In this case the stimulus may be necessary from the beginning of the larval life, since the mortality of the isolated larvae occurred during the first instar.

When the density was increased to more than two larvae per rectangle the mortality increased rapidly. Less than 10% of the larvae survived at the higher densities.

Effects on size and weight of pupae and weight of adults

The figures in Table 3 indicate that the density of the larvae had a great effect on the size and weight of the pupae and adults. The mean size of the pupae from larvae reared at low densities was greater but the pupae and adults reared singly were a little smaller than those reared at two larvae/rectangle. This would appear to support the suggestion made above that the larvae need the presence of other larvae for optimum development.

The density of four larvae/rectangle could be considered to have a negative effect when the number of feeding places of early stages are counted and also when the mortality is calculated; however it had a favourable effect on the pupal size and weight and also on the adult weight (Table 3), when compared with the density of 32 larvae/rectangle. This would support the results obtained for developmental time and suggests that at low density the larvae tend not only to feed more quickly, but to make better use of

Table 3. Length (mm) and weight (mg) of pupae, and weight (mg) of adults.

	Number of larvae per rectangle			
	1	2	4	32
Mean pupal length (mm)	6.0	6.2	5.9	5.3
Mean pupal weight (mg)	5.9	4.0	5.6	4.9
Mean adult weight (mg)	3.5	4.0	3.4	2.7

the food consumed, which eventually results in larger size and higher weight of the pupae and adults However there was a nullifying effect in terms of mortality with the increase in density.

The size and weight of the pupae are positively correlated in both sexes as shown in Fig. 2. In all cases there was a high significance ($P = 0.01$) of the regression coefficients (Females: $Y = 2.6625\ x - 9.56$; Males $Y = 2.3274\ x - 8.02$)

The fecundity of the adults is also positively correlated with the weight (1), therefore the pupal size or weight can be used as an index to fecundity.

Finally it can be said that any increase in fecundity combined with a shorter period of development is probably of importance in the preservation of this species.

LITERATURE CITED

1 HILLYER, R.j.; THORSTEINSON, A.J. 1969 The influence of the host plant or males on ovarian development or oviposition in the diamondback moth *Plutella maculipennis* (Curt.) Canadian Journal of Zoology (47):805-816

2 SALINAS, P.J. 1972. Studies on the ecology and behaviour of the larvae of *Plutella xylostella* (Linnaeus) (Lepidoptera: Plutellidae). Ph.D. Thesis. University of London. Unpublished.

3 SALINAS, P.J. 1977. Studies on the ecology of the diamond-back moth, *Plutella xylostella* (L.) (Lepidoptera: Plutellidae). 1 Distribution and description of the different stages. Acta Biológica Venezuelica (9:271-282.

4 SALINAS, P.J. 1984 Studies on the behaviour of the larvae of *Plutella xylostella* (Linnaeus) (Lepidoptera: Plutellidae), a world pest of cruciferous crops. Normal and "spacing" behaviour. Turrialba 34:77-84.

5 SALINAS, P.J. 1986. Studies on diamondback moth in Venezuela with reference to other Latin American countries. Diamondback Moth Management. International Workshop (1985, Tainan, Taiwan) Proceedings Tainan, Taiwan p. 17-24