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Immigration, Population Development and Dispersal of *Lipaphis erysimi* (Kaltenbach) in Relation to Phenology and Quality of Mustard Crop

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Incoming migrant alatae of *L. erysimi* showed a positive influence in its settlement and initial population growth on the mustard crop. Thereafter population growth and its structure were related to the crop phenology. Rich nutrients in vegetative and flowering stages of the crop supported growing aphid populations which showed corresponding increase in the proportion of the nymphs and the alatae. The food quality varied with the growth of the mustard crop as it grew from the seedling stage to maturity. Maximum fecundity and faster rate of development were observed when individual nymph fed on young leave. Average adult life span and rate of increase were the maximum in aphids fed on young leaves. Conversely aphids feeding on mature leaves were significantly less efficient in these aspects. Population density and food quality, thus, affected the production of alatae. The mustard aphid exhibited facultative dispersal for most part of its incidence on mustard crop.

Key Words: Aphids, Crop age, Host quality, Population development, Dispersal, *Lipaphis erysimi*

Introduction

Lipaphis erysimi (Kaltenbach) is the principal insect pest of the mustard crop in India (Bakhetia et al. 1989) and other tropical and subtropical parts of its distribution (Blackman & Eastop 1984). Yield loss in rape seed mustard due to this pest, in India, ranges from 24 to 90% in different mustard growing states (Prasad & Phadke 1984). Because of the magnitude of loss and appearance of the pest every year, *L.erysimi* has been extensively studied for its population incidence and chemical control (Bakhetia et al. 1986, Singh & Singh 1986, Yadav & Kalra 1990).

There is evidence to suggest that phenology (Howard & Dixon 1992) and food quality of host (Dixon 1970, van Emden & Bashford 1971) significantly influence the population dynamics and biology of aphid and other insects (Murugan & George 1992). Ghosh (1980) observed that the population of *L.erysimi* was much higher in moderate age of the crop than in the young or old ages. Singh et al. (1990) reported that maturity of crop induced higher production of alatae. Flowering shoots of mustard plant prolonged nymphal development and reduced fecundity in adult apterae compared to growing stem (Singh & Verma 1990). Bakhetia & Ghorbandi (1989) observed a positive correlation between population of *L.erysimi* and per cent plant infestation and considered it to be a reliable criterion for field estimation of aphid incidence on the mustard crop. The available works only suggest possible effect

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of age and quality of the host on the population dynamics and alatae production of *L.erysimi* but do not adequately elucidate their influence on the development time, reproductive performance, adult survival and dispersal pattern in this aphid species.

The present paper illustrates the influence of phenology and food quality of mustard crop on the immigration of *L.erysimi* and its subsequent population development and dispersal.

Materials and Methods

Field Study

Immigration of *L.erysimi* was monitored by collecting air-borne aphids using 'O' hair brush, once at 8 AM, at 2-day interval from yellow pan water trap (YPT). Four YPTs, each $51 \times 30 \times 13$ cm in size and painted with bright yellow enamel paint inside and bottle green outside, were placed at about 90 cm from ground level, one in each direction of the periphery of a plot which measured 20×15 m^2. The YPTs were operated three weeks before the sowing date of mustard crop till harvest.

The study plot was prepared for a commonly grown mustard variety *Brassica juncea* cv.M 27 adopting recommended agronomic practices. Seeds of this cultivar were procured from the ICAR Experimental Station, Lembucherra, Tripura. No Insecticide was applied to crop. Application of insecticides in the adjoining fields used for potato and cabbage cultivations was kept to a minimum in order to avoid insecticidal drift to the experimental plot. Crop infestation of *L.erysimi* was monitored by recording total number of nymphs and adults, both non-winged and winged, from terminal 10 cm shoot portion of each of the 100 plants selected at random at 7-day intervals between 8 AM and 12 noon starting from the 7th day of crop sowing till the last week before harvestation of crop. Population growth rate was determined as

$$GR = \frac{\text{Change in population number}}{\text{Time}}$$

The field study was conducted for two consecutive cropping seasons in the years 1990 and 1991.

Laboratory Study

Stock culture of *L.erysimi* was maintained on saplings of mustard plant *B.juncea* cv. M 27 at ambient temperatures during November, 1992 to March, 1993.

Nymphal Development: Newly born nymphs (–1 day) were used from stock culture and gently transferred, one each, on lower surface of a leaf which has been freshly detached from mustard plant. Individual leaf was placed in an aphid culture box of the type described by Blackman (1975). It was looked after for its requirement of water at periodical intervals. Ten such boxes were kept in a tray in a slantic position (about 45°) for maximum run of moisture to detached leaf. Each box was observed at 24 hr interval for the moulting of aphid and any mortality in development until each of the surviving nymphs became adult and laid its first progeny. This was repeated 10 times each using new, young and mature leaves for each of winged and non-winged morphs.

Reproduction: Adults obtained from nymphal development study were used. Each of the adult (-1 day) was gently released at the base of a freshly detached leaf from mustard plant of stock culture, and then transferred to an aphid culture box. Experimental set-up was similar to nymphal development study. Each box was observed at 24 hr interval for the first nymph born to adult, subsequent birth of new nymphs which were soon removed, last nymph born and post-reproductive period.

Experiments on nymphal development were designed to determine development time (DT), development rate (DR) and developmental mortality (DM) – [*DT*, interval from birth to adult moult (approx. time in day; *DR*, reciprocal of the development period (1/DP); and *DM*, number of nymphs suffering death during DP, expressed in percentage)].

Experiments on reproduction were designed to determine the reproductive period (RP), fecundity (F), intrinsic rate of increase (r_m) and adult longevity (AL).

[*RP*, interval from the birth of first nymph to the last nymph of an adult aptera vivipara; F, total number of offsprings produced to a female during its reproductive period; *AL*, number of days an adult survived from the adult moult.]

r_m , the combined effect of pre-reproductive time and reproductive rate, was calculated following Wyatt and White (1977):

$$r_m = \frac{0.738\,(\log e\, Md)}{d}$$

where 0.738 is a constant, *d*, the time from birth to first reproduction; *Md*, the number of nymphs laid during the time equal to 'd'.

Biochemical Analysis of Mustard Plant

Qualitative estimation (mg/g) of primary metabolites such as total proteins (Lowry et al. 1951), carbohydrates (Dubois et al. 1956), amino acids (Moore & Stein 1948) and percentage of nitrogen (Vogel 1963) was carried out in new, young and mature leaves of mustard plant in the cropping season of 1992. Water content (%) of new, young and mature leaves was determined by oven dry method which was repeated 20 times for each of the three leaf stages.

Results and Discussion

Effect of Crop Phenology

Influence of migrant alatae on population development of the mustard aphid

Migrant alatae of *L. erysimi* became active in the cropping area 20-day in advance of actual settling of aphids in crop (figure 1a,b). Total YPT-catch of migrant alatae in the first two weeks (before settling on crop) was higher than the succeeding two weeks (after settling on crop) in the two consecutive years of field samplings (Fisher Exact Test 1990: $p < 0.02$; 1991: $p < 0.06$).

Crop infestation, as evidenced by the collection of first adult aphid, was first observed in the third week of sowing in both the years. The YPT-catch in first four weeks of crop age (seedling stage) was positively and significantly cor-

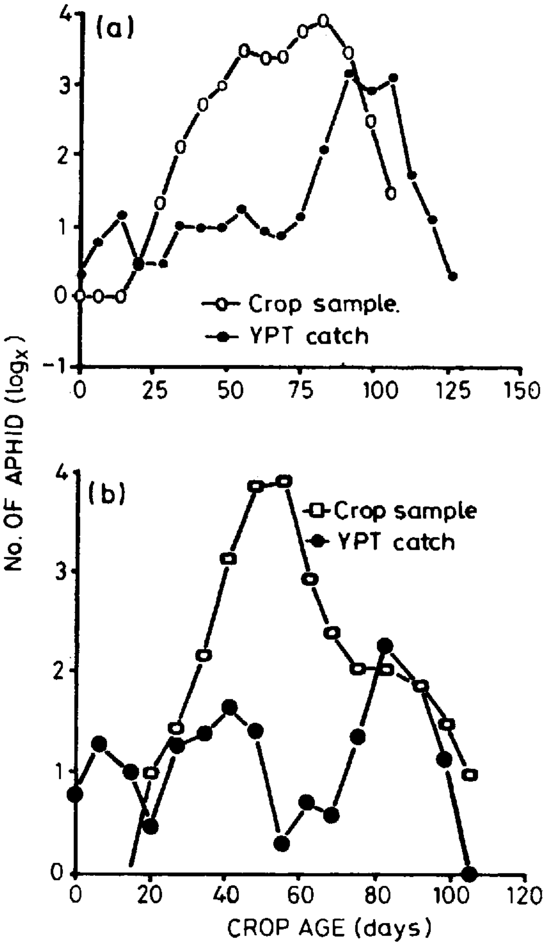

Figure 1 Number of aphids of *L.erysimi* (log x)/100 plants and number of alatae (log x) collected in YPT in relation to the crop age in the years (a) 1990 and (b) 1991

related with aphid population in the crop sample by a two week lag (1990: $r = 0.89$, $p < 0.007$; 1991: $r = 0.75$, $p < 0.02$). Proportion of immigrant alatae in the crop sample of the vegetative stage in the fifth week declined compared to those in earlier weeks (figures 1a,b), (1990: Z value = 2.92, $p < 0.003$; 1991: Z value = 1.84, $p < 0.06$). This was followed by a resurgence in the sixth week. However, population trend of the migrant alatae remained asynchronous with aphid density recorded on mustard crop for rest of the period (1991: $r = -0.05$, NS).

Results suggested that incoming migrant alatae of *L.erysimi* have a positive influence in the settlement and initial growth of aphid population on the mustard crop. Thereafter the crop-population becomes independent of the influence of the migrant aphids. This difference in the population between the crop samples and YPT catches may be explained by the fact that the growing stages of crop contains a significantly higher proportion of apterous morph than that of alate morph [Wilcoxon Signed Rank Test (2 samples, each sample size=15), 1990: 5.5, $p < 0.004$; 1991: 6.5, $p < 0.003$]. Moreover, an apterous morph is always more fecund than an alatae morph (Dixon 1985b). As a result, crop samples show higher aphid density compared to the YPT catches which represent migrant alatae of the crop population.

Population development and its structure

Population of the mustard aphid attained the highest growth rate (GR = 0.66) in later part of the vegetative stage and gradually declined during the flowering (GR = 0.23) and the fruiting stages (GR = 0.09) of the crop. Economic injury level (EIL) of *L.erysimi* (20-51 aphids/plant), as explained by Singh and Mishra (1986), was attained only in the vegetative stage when 35-45% of the mustard crop in the study plot was infested. Number of aphids recorded/100 plants showed a significant and positive correlation with the percentage of mustard crop plants infested in both the years (1990: $r = 0.72$, $p < 0.000$; 1991: $r = 0.92$, $p < 0.000$). Regression analyses showed a curvilinear relationship between aphid density and plants infested (%) with a threshold value of aphid density recorded at about 35% of crop plant infested in the late vegetative stage (figure 2).

Structure of aphid population showed synchrony with its development. Aphid density showed strong correlation with number of nymphs recruited (1990: $r = 0.98$, $p < 0.001$; 1991: $r = 0.96$, $p < 0.001$) and alatae produced on the crop (1990: $r = 0.89$, $p < 0.001$; 1991: $r = 0.86$, $p < 0.001$). Regression analyses between the aphid density and the proportion of nymphs in the population showed a linear relationship in both the years of study (figure 3). Similar relationships were also found between the aphid density and the proportion of alatae in the population (figure 4a,b). The overall correlations between number of nymphs recruited and alatae produced in population were found to be significant in both

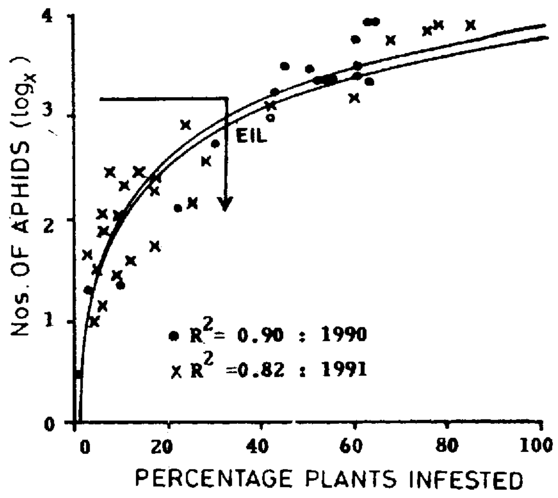

Figure 2 Regression analysis (log x) of aphid density/100 plants and percentage of plants infested in 1990 [$y = 0.17 + 1.87 \log(x)$] and 1991 [$y = 0.18 + 0.181 \log(x)$]

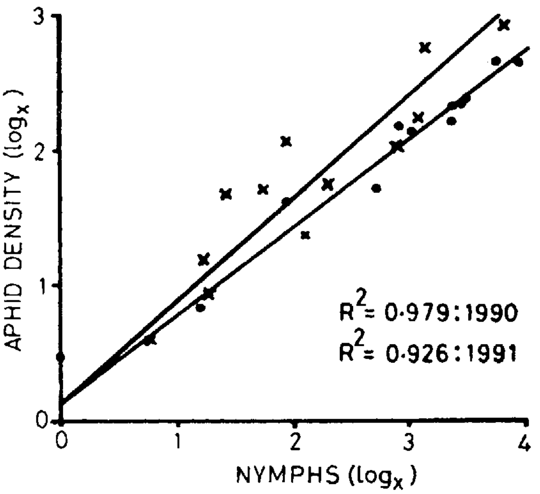

Figure 3 Linear regression between aphid density and number of nymphs/100 plants in 1990 (y = 0.1289 + 0.6581 x) and 1991 (y = 0.1188 + 0.7660 x)

the years (1990: $r = -0.89$, $p < 0.000$; 1991: $r = -0.71$, $p < 0.004$).

Results suggest that after an initial establishment of the population, population growth and its structure are related to the crop phenology. Vegetative and flowering stages of the crop support growing aphid population through increase in proportions of nymphs and alatae.

Dispersal of population and its importance

Polymorphic insects, like aphids, are adapted to produce some winged individuals because it serves to increase the chance of survival by the dispersing members of a clone in space. This ontogenic switch takes time and is usually in response to overcrowding or deterioration in host quality, or both (Dixon 1985a).

The crowding markedly influenced the production of winged aphids in this study (figure 4a,b) (cf. population development in relation to crop phenology). The positive correlation between aphid density and proportion of alatae in crop is the product of higher recruitment of nymphs by apterous adults in the population

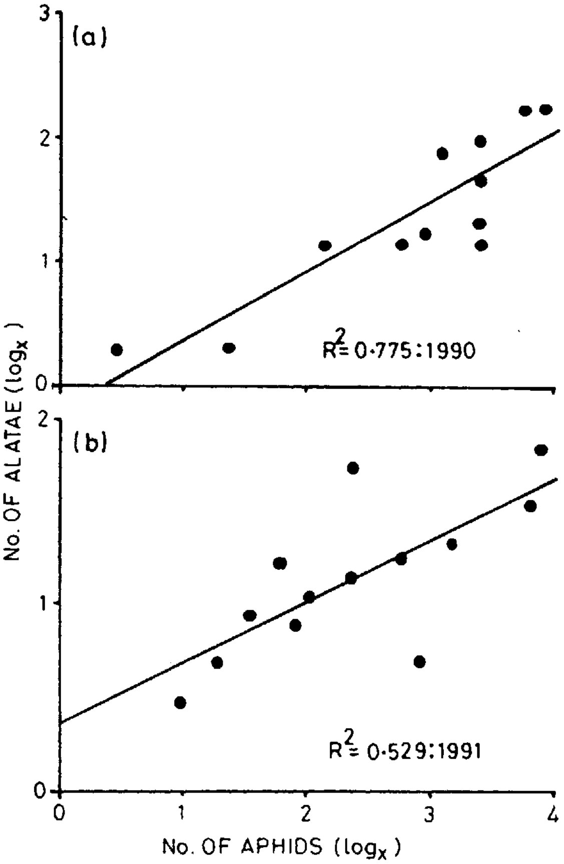

Figure 4 Linear regression of aphid density with number of alatae in (a) 1990 (y = 0.1990 + 0.5580 x) and (b) 1991 (y = 0.3680 + 0.3267 x)

when the host quality is still good (figure 3). However, as crop attained maturity, population growth rate declined from GR = 0.66 in late vegetative phase to GR = 0.09 in fruiting stage. Consequently population contained less proportion of winged aphids in the flowering and the fruiting stages of crop, but still this proportion was significantly higher compared to proportion of alatae in the growth phase (1991: $Z = 33.67$, $p \leq 0.000$). This is possibly on account of the alatae aphids responding to current cues of host quality which gets poorer as mustard crop approached fruiting stage (cf. effect of host quality).

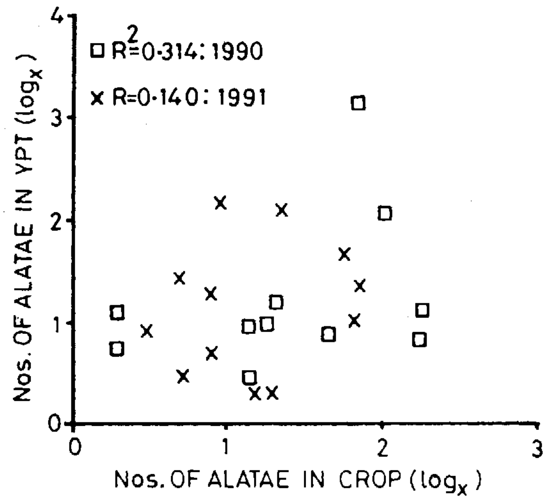

Figure 5 Regression analysis of alatae collected on 100 plants of mustard crop and in YPT in the years 1990 and 1991

Results indicate that alate morph of mustard aphid floated continuously in the air and showed facultative dispersal for most part of its incidence on the mustard crop (figure 5). The dispersal was highest when the species attained the peak population. Before and after this stage regular dispersal continued to take place. This characteristic of mustard aphid enables the species to scan large areas on a continuous basis. This possibly explains why mustard crop and similar other seasonal crops have higher frequency of aphid incidence compared to annual crops or tree-dwelling aphids (Dixon 1985b).

Effect of Host Quality

Biochemical profiles of host leaves

Table 1 provides data on biochemical analyses of the new, young and mature *B. juncea* leaves obtained in the cropping year 1992. Total quantity (mg/g) of proteins and carbohydrates recorded in young leaves was comparatively higher than in other stages in both the years. Similar pattern in total quantity of soluble nitrogen and water contents was also evident. Record of highest concentration of amino acids in mature leaves is possibly due to proteolysis which accompanies the old stage of plant (van Emden & Bashford 1971).

Biology of the mustard aphid

Data on duration of post-embryonic development, longevity and fecundity of adult apterae and alatae of the mustard aphid reared on new, young and mature leaves of the mustard plant are provided in table 2. In both apterae and alatae, nymphs developed faster and adults produced more offsprings when fed on young leaves. These adults also had longer average adult life and a higher intrinsic rate of increase (r_m). In comparison, aphids, which fed on mature leaves, showed significant differences. These differences in aphids which fed on new and young leaves were, however, not significant in both apterae and alatae.

Based on duration of development, reproductive period, fecundity, adult longevity and rate of increase of *L.erysimi*, host plant stages could be arranged in the order of their preference as young > new > mature.

Growth and reproduction of aphids is dependent upon the state of growth or level of soluble nitrogen in their host plants (van Emden & Bashford 1971). There is more nitrogen in the phloem sap of plants whose leaves are growing because nutrients are then being actively translocated into or out of leaves. The sap is not as nutritious when leaves are mature. Thus, the quality of host undergoes changes which are important for the biology of aphids. Greater efficiency of nymphs in its development, of adults in higher fecundity, longer survival, and higher rate of increase of the mustard aphid on young leaves in the vegetative stage is attributable to high nitrogen content of the mustard crop in that stage (table 1).

Table 1 *Biochemical analyses of mustard plant **B. juncea** cv. M 27 in the year 1992-1993*

Biochemical constituents	Mean ± se of 5 replicate of each leaf stages		
	New	Young	Mature
Proteins (Mg/g)	63.15 ± 1.44	86.12 ± 1.71	43.35 ± 1.52
Carbohydrates (Mg/g)	234.20 ± 3.47	281.20 ± 5.48	145.05 ± 2.25
Amino acids (Mg/g)	0.219 ± 0.001	0.328 ± 0.001	0.458 ± 0.002
Nitrogen (%)	3.17 ± 0.050	4.29 ± 0.018	2.56 ± 0.017
Water (%)	88.84 ± 4.34	91.95 ± 4.88	88.21 ± 6.07

Table 2 *Mean duration of developmental time (DT), reproductive period (RP), fecundity (F), adult longevity (AL) and intrinsic rate of increase (r_m) of the adult apterae and alatae of **L. erysimi** on new, young and mature leaves of mustard plant. (Figures in column followed by the same alphabet do not differ significantly at < 0.05: Student t- test, df = 26)*

Host leaves	DT (days)	RP (days)	F (no.)	AL (days)	r_m
APTERAE					
New	8.10 ± 0.16[a]	9.40 ± 0.42[a]	22.55 ± 1.20[a]	13.35 ± 0.58[a]	0.36 ± 0.009[a]
Young	8.63 ± 0.19[b]	10.65 ± 0.83[a]	30.00 ± 3.04[b]	14.10 ± 0.80[a]	0.24 ± 0.008[a]
Mature	10.71 ± 0.43[c]	4.00 ± 0.30[b]	6.14 ± 0.46[c]	6.53 ± 0.33[b]	0.11 ± 0.008[b]
ALATAE					
New	7.85 ± 0.19[a]	9.85 ± 0.54[a]	21.90 ± 1.75[a]	12.07 ± 0.56[a]	0.23 ± 0.007[a]
Young	8.00 ± 0.14[a]	10.35 ± 0.91[a]	27.25 ± 3.06[a]	12.94 ± 1.06[a]	0.22 ± 0.006[a]
Mature	10.93 ± 0.43[b]	5.00 ± 0.25[b]	7.46 ± 0.60[b]	6.88 ± 0.33[b]	0.12 ± 0.009[b]

Table 3 *Regression relationship between the mean of total populations and proportion of alatae at new, young and mature stages of leaves with the corresponding chemical constituents of the mustard plant*

Biochemical constituents	Mean total population		Proportion of alatae in aphid population	
	Regression equation	P	Regression equation	P
Protein	y = – 1878.5 + 50.670 x	***	y = 74.959 – 0.426 x	NS
Carbohydrate	y = – 2231.6 + 16.382 x	***	y = 297.03 – 3.049 x	NS
Amino acid	y = 3737.5 – 7052.5 x	**	y= 1.0296 e – 2 + 1.28e – 2x	**
Nitrogen	y = – 2557.9 + 1177.5x	***	y = 3.4632 – 4.885 e – 3x	NS
Water	y = – 9741.0 + 120.82 x	*	y = 85.321 + 0.885 e – 3 x	NS

P = level of probability at which regression coefficient is significant compared with its standard error.
*0.05, **0.01, ***0.001; NS not significant
! based on population census of 1992-93

Population dynamics

Food quality affected the population development of the mustard aphid. Crop in the early (new leaves) and late (young leaves) vegetative stages supported significantly higher population than mature leaves of older crops as evident from YPTs (figure 1a,b). The relationships between the mean of total populations and chemical constituents of new, young and mature stages of crop suggest significant regression coefficient in all the cases at $p < 0.05$ (table 3).

Results indicate that rich nutrient of the growing plant supports increasingly higher number of aphids which, however, respond in negative growth after the crop has stopped growing.

Dispersal

Unlike total population of aphids which showed positive relationship with nutrients of the crop, the proportion of alatae produced in the population showed poor regression relationship with nitrogen, amino acids, proteins, carbohydrates and water contents of the crop (table 3). This is expected because production of alatae on a seasonal crop is directly related to crowding effect and indirectly related to crop nutrients (Dixon 1985b). The response time of aphids to food quality is delayed by about two weeks, the time required by newly born aphids to develop into winged adults. This implies that proportion of alatae present in aphid population at a given time is the reflection of past experience of the population and its food plant. This also means that reproductive individual and developing nymphs in the population prepare in advance for the proportion of its number (through the winged aphid) required for dispersal. Thus the crop phenology and food quality influence aphids in its strategy to determine the volume of dispersal.

A number of studies on aphids has reported the way in which a developing plant can affect individual aphid. Leather & Dixon (1981) found significant differences in developmental time and fecundity in *Rhopalosiphum padi* (L.) reared on pot-grown plants at different developmental stages. Vereijkan (1979), working with *M. dirhodium* (Walker) on wheat in the field, found a significant decrease in nymphal and adult survival and a reduction in fecundity around the milky ripe stage of plant development. van Emden and Bashford (1971) found a reliable correlation between some of the amino acids and soluble nitrogen levels, and aphid performance in respect of *Brevicoryne brassicae* (L) and *Myzus persicae* (Sulzer). The optimum performance of individual aphids of *L.erysimi* on the young leaves and comparatively reduced level of performance on new and mature leaves conform to results obtained by others.

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