

Assessment of the Reproductive Potential of *Lipaphis erysimi* Kalt. (Hemiptera: Aphididae) on the Four Most Cruciferous Species Produced in South Togo

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Abstract

Lipaphis erysimi (Hemiptera: Aphididae) is a cruciferous aphid that causes enormous yield losses in Togo. Due to its parthenogenetic reproduction, it develops very quickly and invades crops. This study aims to determine the biological and demographic parameters of *L. erysimi* on the four cruciferous species that are most produced in southern Togo. A survey was therefore conducted among 120 market gardeners to identify the four most produced cruciferous species. Then, 120 newborn nymphs of *L. erysimi* were followed on leaves of each of these cruciferous species in petri dishes until their death. Of the 120 producers surveyed, 64 (53.33%) produce cruciferous vegetables, with cabbage occupying first place at 93.75% (60 out of 64), followed by cauliflower at 37.5%, turnip at 20.31%, and radish at 17.19%. The number of surviving nymphs decreased gradually from the second day until the death of all individuals on cabbage on the 23rd day, on cauliflower and turnip on the 21st day, and on radish on the 22nd day. The average lifespan of *L. erysimi* on these cruciferous vegetables was 10.04 days \pm 5.14 days on radish, 10.53 \pm 5.35 days on cabbage, 10.72 days \pm 6.66 days on turnip, and 12.94 days \pm 4.8 days on cauliflower ($P = 0.00025$). The oviposition of *L. erysimi* started on the 7th day on these cruciferous plants, and the average fecundity per female was 31.9 \pm 13.71 nymphs on turnip, followed by radish at 29.01 \pm 13.06, then cauliflower at 25.55 \pm 10.5, and then headed cabbage at 22.3 \pm 8.28 ($P = 0.0016$). Respectively, in the presence of headed cabbage, cauliflower, turnip, and radish, its net reproduction rate was 12.789, 20.79, 18.978, and 16.149; its generation time was equivalent to 11.169, 11.647, 11.603, and 11.549 days; then its intrinsic rate of natural increase was 0.228, 0.260, 0.253, and 0.240; and the time during which its pop-

ulation doubled was 3.040, 2.66, 2.739, and 2.888 days.

Keywords

Cruciferous, *L. erysimi*, Life Table, Fertility, Demographic Parameters

1. Introduction

Market gardening is a sector of the agricultural domain that not only provides vegetables to feed populations in various countries, especially those in sub-Saharan Africa, but also constitutes a pillar of the economy of these countries [1]. The cultivation of vegetables within the framework of market gardening is an important element of the value-added cropping system, with an increase in production [2] because of the strong demands from consumers and the nutritional values it brings to food [3].

This sector employs most urban and rural youth who generally drop out of school early [4]. Among the various market garden products available to consumers, leafy vegetables are better represented than vegetables produced for their fruits, roots, bulbs, or tubers [5]. The Brassicaceae family includes species belonging to the genera *Brassica*, *Raphanus*, and others. Cultivated species of Brassicaceae include: headed cabbage (*Brassica oleracea* L. var. *capitata*), cauliflower (*Brassica oleracea* L. var. *botrytis*), kale (*Brassica oleracea* L. var. *sabellica*), broccoli (*Brassica oleracea* L. var. *italica*), Brussels sprouts (*Brassica oleracea* L. var. *gemmifera*), turnips (*Brassica rapa* L.), radishes (*Raphanus sativus* L.), rutabaga (*Brassica napus* L. var. *napobrassica*), rapeseed (*Brassica napus* L.), and various mustards [6]. Their production has been very flourishing for several years [7].

However, market gardening production has been declining for several years [8] [9]. Constantly threatened by the emergence of harmful insects and diseases, the incidence of which has increased in recent years, most producers abandon production that they consider unprofitable. On the other hand, other producers resort to the use of chemical inputs and fertilizers, which provide them with high yields and attractive products [10] [11].

Cruciferous cultivation is subject to significant pressure from insect pests at various phenological stages [5] [12], and the main insect pests recorded on these cruciferous plants belong to the orders Lepidoptera, Coleoptera, Hemiptera, and others. Aphids of the family Aphididae are small, sap-sucking insects of plants. They are among the most notorious, cosmopolitan, louse-like, and obligate ectoparasites, which are responsible for excessive qualitative and quantitative losses of *Brassica* crops worldwide [13]. Among these aphids, *Lipaphis erysimi* (Hemiptera: Aphididae) is one of the most important pests of cruciferous plants worldwide [14]. It infests cruciferous plants from transplanting to maturity, causing direct and indirect damage to its various hosts [13]. Stunting, deformation, yellowing, and wilting are noted as direct damage, usually resulting from sap sucking from

infested plants [15] [16], while indirect damage includes black sooty mold formed by fungal growth on honeydew excretion, and it is also a vector of several viral diseases [17] [18].

L. erysimi is a specialist aphid species on *Brassica* hosts, which poses a serious threat to their cultivation [19] [20], consequently seriously affecting yield by 65 to 100% under various agrosystems [21]-[24].

This threat pushes producers to use insecticides, especially synthetic ones [25], which leads, among other things, to the development of resistance among pests, the resurgence of diseases, and toxic residues for humans and their environment. It is urgent to find alternative techniques for managing these pests, and to achieve this, knowledge of the biological, reproductive, and demographic parameters of this aphid is essential in order to find effective and sustainable control techniques [26]. The development and stability of insects are considerably influenced by the quality and variety of host plants; conversely, the quality and variety of host plants can also influence the dynamics of the populations of this aphid [21] [27].

The overall objective of this study is to contribute to the management of *L. erysimi* in vegetable production. Specifically, it aims to 1) identify the four most commonly grown cruciferous species in southern Togo and to 2) determine the biological and demographic parameters of *L. erysimi* on these cruciferous species in southern Togo.

2. Materials and Methods

2.1. Survey of Market Gardeners

A survey form was specially designed for producers to collect the necessary information on the various cruciferous crops produced and the constraints related to their production. The survey was then carried out in all localities with high market gardening production in southern Togo, particularly in the Maritime and Plateaux regions, after prospecting. This survey was conducted among 120 market gardeners to identify the four most commonly grown cruciferous species. The criteria for selecting respondents were as follows: they had to be producers of vegetables, including cruciferous vegetables, in the market gardening areas of the Maritime and Plateaux regions in southern Togo, regardless of their age, level of education, or experience in market gardening.

2.2. Cultivation of Host Plants for Rearing and Recording of Physical Parameters

The experiments were carried out at the Laboratory of Ecology and Ecotoxicology (LaEE) at the University of Lomé, at geographical coordinates 6° 17' 62.58" North latitude and 1° 21' 12.72" East longitude. It is located in the Maritime region in southern Togo. The seeds of cabbage (*Brassica oleracea* var. capitata), cauliflower (*Brassica oleracea* var. botrytis), turnip (*Brassica rapa*), and radish (*Raphanus sativus*) were obtained from TOGOSEM Ltd in Togo and sown in a monitored nursery. After germination at the four-leaf stage, these plants were transplanted into trans-

parent pots in the laboratory and protected by a net to make healthy leaves available for aphid rearing. The plants are watered once every two days, and the soil placed in the pots is enriched with compost. Thermal and hygrometric variations were noted daily.

2.3. Rearing of the Aphid *L. erysimi* on the Leaves of Host Plants

L. erysimi adults were collected from crops of the four cruciferous species at the Lomé Agronomic Experiment Station (SEAL), brought back to the laboratory, and placed in large petri dishes (90 × 15 mm). Neonate nymphs of *L. erysimi* from these adults were reared on leaf rings (3 cm in diameter) from plants of each cruciferous species at the 10-leaf stage, placed in small petri dishes (50 × 15 mm), and renewed every two (2) days until aphid death. The average temperature and relative humidity under the experimental conditions were 30.45°C ± 0.17°C and 75.45% ± 0.65%. The photoperiod was 12:12 (L:D) hours.

2.4. Determination of Biological Parameters

To obtain newly born larvae (first instar), adult females of *L. erysimi* on each of the four crucifer species were brought to the laboratory. Females identified by their large size and prominent cornicles were selected, delicately placed on a leaf disc of each crucifer species in petri dishes, and then observed. As soon as the first-stage larvae were born from these females, they were removed from the leaf disc, and the larvae were followed until their death. One hundred twenty (120) first-stage larvae were followed individually on each crucifer species. The various biological parameters (duration of nymphs, oviposition period, longevity of adults, and fecundity) and demographic parameters were meticulously documented at a frequency of one observation per day.

2.5. Treatment of Survey Data and Statistical Analysis of Biological Parameters

Excel software was used to enter the survey data. The data were processed to obtain results in accordance with the study objective.

For the statistical analysis of the various results obtained during our experiment (lifespan and fecundity of *L. erysimi*), we used PAST 4.0 software. Comparisons of means were made after analysis of variance (ANOVA) using the Student-Newman-Keuls test at the 5% threshold.

2.6. Construction of the Survival Table

The parameters measured during the experiments and calculated were used to construct survival tables of *L. erysimi* according to the methodologies used by [28] and [29]. The life table was built as follows. Per column, x represents the age classes. Each age class corresponds to a two-day interval. Age classes O^a to O^d represent the pre-imaginal stages, while the adult stages (from imaginal molt to death) are designated by age classes 1 to n . P corresponds to the median of each age class.

n_x gives the number of surviving individuals at the beginning of each class. l_x represents the probability of survival from the first stage larvae to the beginning of class x . d_x corresponds to the number of individuals who died during class x . L_x represents the probability of survival between age class x and age class $x + 1$. T_x represents the number of age classes x remaining beyond each of the age classes x (Equation (1)).

$$T_x = \sum_{x=0}^w L_x \quad (1)$$

where w = last age class and x = base age class. e_x represents life expectancy: $e_x = T_x/l_x$. q_x corresponds to mortality by age group: $q_x = d_x/l_x$. S_x represents survival by age group x : $S_x = n_x/n_{x-1}$.

2.7. Construction of Fertility Table

The parameters measured during the experiments and calculated were used to construct fertility tables of *L. erysimi* according to the methodologies used by [28] and [29]. A fertility table was built with m_x , which represents the average number of female offspring per female of age x ; V_x , which gives the reproductive value, i.e., the contribution of a female of age x to the future population (Equation (2)); in addition to x , P , n_x , S_x , m_x and $l_x \cdot m_x$ per column.

$$V_x = \sum_{t=x}^w (l_t/L_t) m_t \quad (2)$$

where t = any age class between x and w .

2.8. Determination of Growth Parameters

The population growth parameters (R_0 , G , r_m and DT) of *L. erysimi* were deduced according to the methodologies used by [29].

The net reproduction rate (R_0) (Equation (3)) corresponds to the average number of female offspring produced by each female during her lifetime.

$$R_0 = \sum_{x=0}^w (l_x \cdot m_x) \quad (3)$$

Generation time (G) (Equation (4)) is the average time interval between the birth of parents and the birth of offspring.

$$G = \left[\sum_{x=0}^w (l_x \cdot m_x \cdot P) \right] / R_0 \quad (4)$$

The intrinsic rate of natural population increase (r_m), which is the instantaneous growth rate expressed when the population is growing in an unconstrained environment and when the age structure has become stable, was calculated by trial-and-error substitution in the [30] equation (Equation (5)):

$$\sum_{x=0}^w \exp(-r_m x) l_x \cdot m_x = 1 \quad (5)$$

Population doubling time (DT) (Equation (6)) is the time required for the population size to double.

$$DT = \ln 2 / r_m \quad (6)$$

3. Results

3.1. Production of Cruciferous Vegetables by Market Gardens

Out of one hundred and twenty (120) producers surveyed, 64 (53.33%) produce cruciferous vegetables, of which headed cabbage (*Brassica oleracea* var. capitata) occupies first place at 93.75% (60 of the 64 producers), followed by cauliflower (*Brassica oleracea* var. botrytis) at 37.5% (24 of the 64 producers), radish (*Raphanus sativus*) at 20.31% (13 of the 64 producers), turnip (*Brassica rapa*) at 17.19% (11 of the 64 producers), broccoli (*Brassica oleracea* var. italica) at 4.69% (3 of the 64 producers), and watercress (*Nasturtium officinale*) at 1.56% (1 of the 64 producers).

3.2. Biological Parameters

3.2.1. Survival of Nymphs of *L. erysimi* on the Four Most Commonly Cultivated Cruciferous Species

The number of surviving larvae decreased progressively from day 2 until all individuals died on cabbage on day 23; on cauliflower and turnip on day 21; and on radish on day 22, as shown in **Figure 1**.

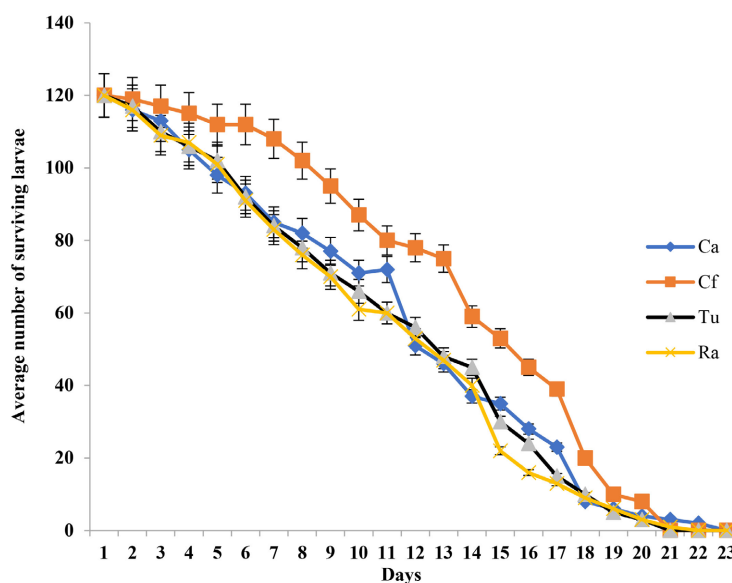


Figure 1. Average number of surviving *L. erysimi* larvae depending on the day. Ca = cabbage; Cf = cauliflower; Tu = turnip; Ra = radish.

The average lifespan of *L. erysimi* on these cruciferous vegetables was 10.04 days \pm 5.14 days on radish, 10.53 days \pm 5.35 days on cabbage, 10.72 days \pm 6.66 days on turnip, and 12.94 days \pm 4.8 days on cauliflower. The values obtained show a significant difference in the lifespan of *L. erysimi* on the four cruciferous vegetables ($P = 0.00025$ and $F = 6.494$). The comparisons of the lifespans of this aphid on these cruciferous vegetables showed that between cauliflower and cabbage, cauliflower and turnip, and cauliflower and radish, the differences are significant with $P = 0.0003$, $P = 0.004$, and $P = 0.000009$, respectively. On the other

hand, between cabbage and turnip ($P = 0.814$), cabbage and radish ($P = 0.468$), and between turnip and radish ($P = 0.380$), the differences are not significant. Therefore, the lifespan of *L. erysimi* is only significantly different between cauliflower and the other three cruciferous vegetables (Figure 2).

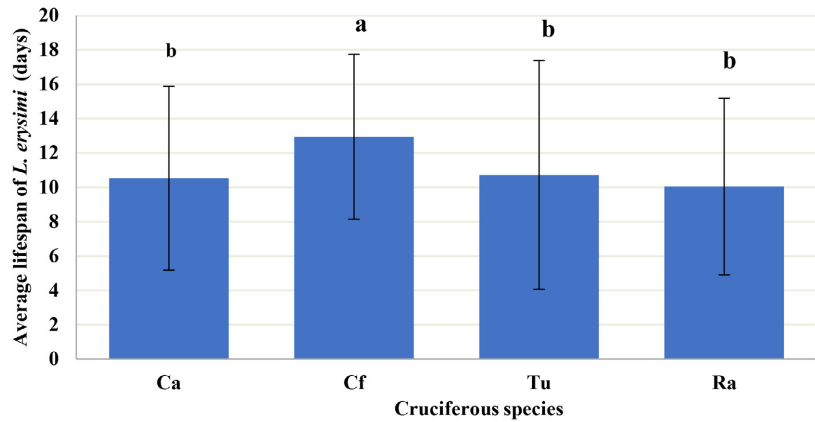


Figure 2. Average lifespan of *L. erysimi* on cruciferous species. Ca = cabbage; Cf = cauliflower; Tu = turnip; Ra = radish. Bars with the same letter are not significantly different.

3.2.2. Fecundity of *L. erysimi* on the Four Cruciferous Species

The birth of *L. erysimi* larvae on these various cruciferous plants began on the 7th day (Figure 3). Daily fecundity was higher on the 10th day on turnip with 6.34 ± 1.61 larvae laid and on radish with 6.47 ± 1.17 larvae than on the 11th day on headed cabbage with 5.46 ± 1.53 larvae and cauliflower with 5.01 ± 1.53 larvae laid. The larvae birth period for *L. erysimi* females on the four cruciferous plants was longer, with a duration of 13 days on headed cabbage and cauliflower, where it spanned from the 7th to the 20th day; then on turnip with a duration of 12 days, going from the 7th to the 19th day; and on radish, where it was shorter at 11 days, covering from the 7th to the 18th day.

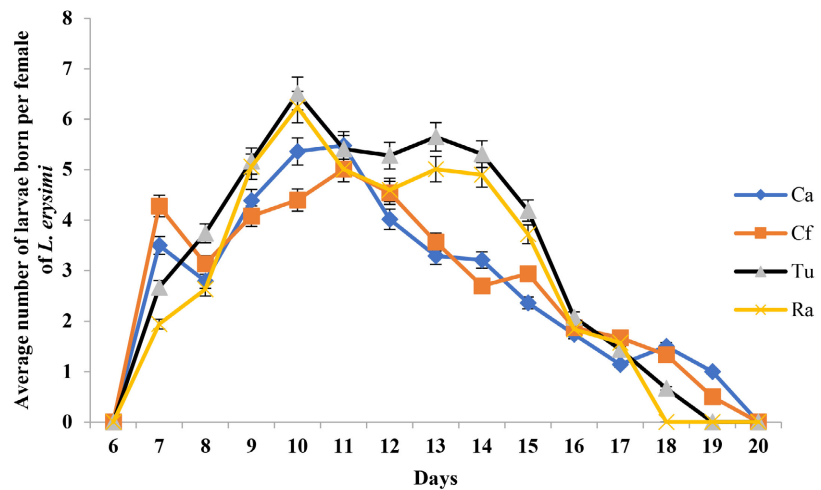


Figure 3. Average daily fecundity of *L. erysimi* across different cruciferous species over the observation period. Ca = cabbage; Cf = cauliflower; Tu = turnip; Ra = radish.

The average fecundity per female of *L. erysimi* was higher on turnip, with an average of 31.9 ± 13.71 larvae, followed by radish at 29.01 ± 13.06 larvae, cauliflower at 25.55 ± 10.5 larvae, and cabbage at 22.3 ± 8.28 larvae (Figure 4). The values obtained showed a significant difference in the average fecundity of *L. erysimi* on the four cruciferous plants ($P = 0.0016$; $F = 5.13$). Comparison of the average fecundity of this aphid on each host plant with that on each of the other three cruciferous plants showed that the differences between cabbage and cauliflower, cabbage and turnip, and cabbage and radish are significant, with $P = 0.0001$, $P = 0.00047$, and $P = 0.0052$, respectively. On the other hand, the differences between cauliflower and turnip ($P = 0.697$), cauliflower and radish ($P = 0.307$), and between turnip and radish ($P = 0.21$) were not significant (Figure 4).

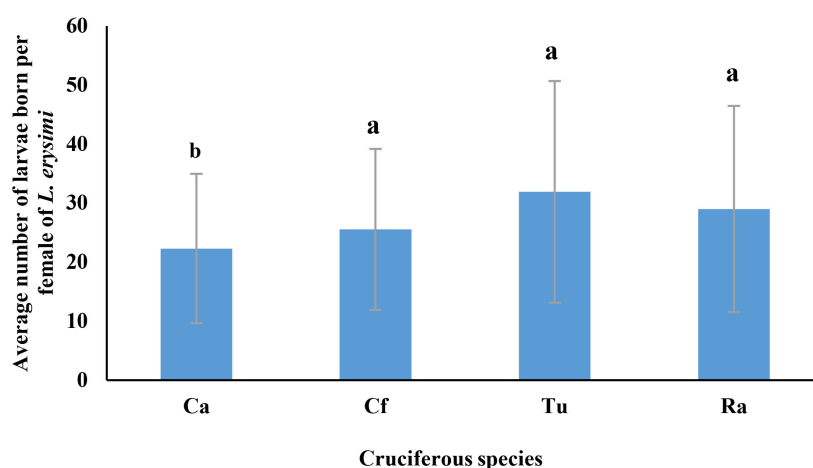


Figure 4. Average fecundity of *L. erysimi* on cruciferous species. Ca = cabbage; Cf = cauliflower; Tu = turnip; Ra = radish.

3.2.3. Survival Tables

Examination of the *L. erysimi* life table established on each of these four cruciferous plants showed that the probability of survival (I_x) from the nymph-laying stage to the beginning of class x decreased on the four cruciferous plants. It went from 1 to 0.741 (Table 1), 0.925 (Table 2), 0.733 (Table 3), and 0.725 (Table 4), respectively, for cabbage, cauliflower, turnip, and radish during the larval stages.

It decreased from 0.658 to 0.008 on cabbage; from 0.816 to 0.033 on cauliflower; from 0.625 to 0.016 on turnip, and from 0.608 to 0.016 on radish for the adult stage of the aphid on these cruciferous plants. Life expectancy (e_x) decreased from the nymph-laying stage to the last age class from 1.775 to 0.500 in cabbage; from 1.953 to 0.484 in cauliflower; from 1.873 to 0.500 in turnip and radish. These decreases are due to the mortalities observed during the life of *L. erysimi* individuals.

The survival probability between age class x and age class $x + 1$ (I_x) also decreased from the first larval stage to the last age class for these four cruciferous vegetables, from 0.975 to 0.004 for cabbage, from 0.991 to 0.016 for cauliflower, and from 0.970 to 0.008 for turnip and radish.

Table 1. Survival table for *L. erysimi* on cabbage (*Brassica oleracea* var. capitata).

x	P	n_x	l_x	d_x	L_x	T_x	e_x	q_x	S_x
0 ^a	1	120	1.000	6	0.975	1.775	1.775	6.000	0.950
0 ^b	3	114	0.950	12	0.900	1.695	1.784	12.631	0.894
0 ^c	5	102	0.850	13	0.795	1.494	1.757	15.294	0.872
0 ^d	7	89	0.741	10	0.699	1.307	1.763	13.495	0.887
1	9	79	0.658	12	0.608	1.087	1.651	18.237	0.848
2	11	67	0.558	19	0.479	0.829	1.485	34.050	0.716
3	13	48	0.400	12	0.350	0.608	1.520	30.000	0.750
4	15	36	0.300	10	0.258	0.395	1.316	33.333	0.722
5	17	26	0.216	19	0.137	0.182	0.842	87.962	0.269
6	19	7	0.058	3	0.045	0.065	1.120	51.724	0.571
7	21	4	0.033	3	0.020	0.024	0.727	90.909	0.250
8	23	1	0.008	1	0.004	0.004	0.500	125.000	0.000

x = age class of individuals from the first larval stage to the adult stage ($x = 2$ days): 0^a to 0^d are the pre-imaginal stages, and 1 to 8 represent the adult stage; P = median of each age class x ; n_x = number of individuals alive at the beginning of each age class x ; l_x = probability of survival from the first larval stage to the beginning of class x ; d_x = number of individuals that died during class x ; L_x = probability of survival between age class x and age class $x + 1$; T_x = number of age classes x remaining beyond each of the age classes x ; e_x = life expectancy of individuals of age x ; q_x = mortality per age class; S_x = survival per age class x .

Table 2. Survival table of *L. erysimi* on cauliflower (*Brassica oleracea* var. botrytis).

x	P	n_x	l_x	d_x	L_x	T_x	e_x	q_x	S_x
0 ^a	1	120	1.000	2	0.991	1.953	1.953	2.000	0.983
0 ^b	3	118	0.983	5	0.962	1.895	1.927	5.086	0.957
0 ^c	5	113	0.941	2	0.933	1.803	1.916	2.125	0.982
0 ^d	7	111	0.925	13	0.870	1.623	1.754	14.054	0.882
1	9	98	0.816	15	0.753	1.415	1.734	18.382	0.846
2	11	83	0.691	7	0.662	1.216	1.759	10.130	0.915
3	13	76	0.633	19	0.554	0.966	1.526	30.015	0.75
4	15	57	0.475	15	0.412	0.649	1.366	31.578	0.736
5	17	42	0.35	27	0.237	0.316	0.902	77.142	0.357
6	19	15	0.125	11	0.079	0.095	0.760	88.000	0.266
7	21	4	0.033	4	0.016	0.016	0.484	121.212	0.000

x = age class of individuals from the first larval stage to the adult stage ($x = 2$ days): 0^a to 0^d are the pre-imaginal stages, 1 to 7 represent the adult stage; P = median of each age class x ; n_x = number of individuals alive at the beginning of each age class x ; l_x = probability of survival from the first larval stage to the beginning of class x ; d_x = number of individuals dead during class x ; L_x = probability of survival between age class x and age class $x + 1$; T_x = number of age classes x remaining beyond each of the age classes x ; e_x = life expectancy of individuals of age x ; q_x = mortality per age class; S_x = survival per age class x .

Table 3. Survival table of *L. erysimi* on turnip (*Brassica rapa*).

x	P	n_x	l_x	d_x	L_x	T_x	e_x	q_x	S_x
0 ^a	1	120	1.000	7	0.970	1.873	1.873	7.000	0.941
0 ^b	3	113	0.941	9	0.903	1.702	1.808	9.564	0.920
0 ^c	5	104	0.866	16	0.799	1.478	1.706	18.475	0.846
0 ^d	7	88	0.733	13	0.679	1.254	1.710	17.735	0.852
1	9	75	0.625	12	0.575	1.054	1.686	19.200	0.840
2	11	63	0.525	11	0.479	0.853	1.624	20.952	0.825
3	13	52	0.433	14	0.374	0.611	1.411	32.332	0.730
4	15	38	0.316	19	0.237	0.349	1.104	60.126	0.500
5	17	19	0.158	11	0.112	0.153	0.968	69.620	0.421
6	19	8	0.066	6	0.041	0.049	0.742	90.909	0.250
7	21	2	0.016	1	0.008	0.008	0.500	62.500	0.000

x = age class of individuals from the first larval stage to the adult stage ($x = 2$ days): 0^a to 0^d are the pre-imaginal stages, 1 to 7 represent the adult stage; P = median of each age class x ; n_x = number of individuals alive at the beginning of each age class x ; l_x = probability of survival from the first larval stage to the beginning of class x ; d_x = number of individuals dead during class x ; L_x = probability of survival between age class x and age class $x + 1$; T_x = number of age classes x remaining beyond each of the age classes x ; e_x = life expectancy of individuals of age x ; q_x = mortality per age class; S_x = survival per age class x .

Table 4. Survival table of *L. erysimi* on radish (*Raphanus sativus*).

x	P	n_x	l_x	d_x	L_x	T_x	e_x	q_x	S_x
0 ^a	1	120	1.000	7	0.970	1.873	1.873	7.000	0.941
0 ^b	3	113	0.941	9	0.903	1.698	1.804	9.564	0.920
0 ^c	5	104	0.866	17	0.795	1.461	1.687	19.630	0.836
0 ^d	7	87	0.725	14	0.666	1.220	1.682	19.310	0.839
1	9	73	0.608	13	0.554	1.012	1.664	21.381	0.821
2	11	60	0.500	10	0.458	0.795	1.590	20.000	0.833
3	13	50	0.416	19	0.337	0.528	1.269	45.673	0.620
4	15	31	0.258	16	0.191	0.282	1.093	62.015	0.483
5	17	15	0.125	8	0.091	0.128	1.024	64.000	0.466
6	19	7	0.058	5	0.037	0.037	0.637	86.206	0.285
7	21	2	0.016	2	0.008	0.008	0.500	125.000	0.000

x = age class of individuals from the first larval stage to the adult stage ($x = 2$ days): 0^a to 0^d are the pre-imaginal stages, 1 to 7 represent the adult stage; P = median of each age class x ; n_x = number of individuals alive at the beginning of each age class x ; l_x = probability of survival from the first larval stage to the beginning of class x ; d_x = number of individuals dead during class x ; L_x = probability of survival between age class x and age class $x + 1$; T_x = number of age classes x remaining beyond each of the age classes x ; e_x = life expectancy of individuals of age x ; q_x = mortality per age class; S_x = survival per age class x .

Survival by age class (S_x) decreased progressively during the pre-imaginal stages from 0.950 to 0.887 for cabbage, from 0.983 to 0.882 for cauliflower, from 0.941 to 0.852 for turnip, and from 0.941 to 0.839 for radish. At the adult stage, we also observed a progressive decrease until the last age class on each of these plants, except at the 3rd and 6th age classes where we observed slight increases to 0.750 and 0.571, respectively, on headed cabbage; at the 2nd class where we observed an increase to 0.915 on cauliflower; and at the 2nd class where we observed an increase to 0.833 on radish.

3.2.4. Fertility Tables

The number of offspring per female (m_x) varied according to the age of the parent. At the first adult age class (2 days), the number of offspring per female was 5.755 on cabbage (Table 5), 7.561 on cauliflower (Table 6), 8.424 on turnip (Table 7), and 7.472 on radish (Table 8). This number increased in the second class (4 days), where the maximum number of offspring on all these cruciferous plants was observed: 10.250, 9.096, 11.681, and 10.753 on cabbage, cauliflower, turnip, and radish, respectively. It then decreased progressively until it reached zero at the 8th and last age class (23 days) on cabbage, the 7th and last age class (21 days) on cauliflower and turnip, and at the 6th age class (19 days) on radish.

Table 5. Fertility table of *L. erysimi* raised on headed cabbage (*Brassica oleracea* var. capitata).

x	P	n_x	m_x	$S_x m_x$	$I_x m_x$	V_x
0 ^a	1	120	0.000	0.000	0.000	14.310
0 ^b	3	114	0.000	0.000	0.000	15.063
0 ^c	5	102	0.000	0.000	0.000	16.836
0 ^d	7	89	0.000	0.000	0.000	19.314
1	9	79	5.755	4.880	3.786	21.751
2	11	67	10.250	7.339	5.719	18.862
3	13	48	6.745	5.058	2.023	12.015
4	15	36	4.810	3.472	1.041	7.029
5	17	26	2.157	0.580	0.125	3.082
6	19	7	2.500	1.427	0.082	3.447
7	21	4	1.666	0.416	0.013	1.666
8	23	1	0.000	0.000	0.000	0.000

x = age class of individuals from the first larval stage to the adult stage ($x = 2$ days): 0^a to 0^d are the pre-imaginal stages, 1 to 8 represent the adult stage; P = median of each age class x ; n_x = number of individuals alive at the beginning of each age class x ; I_x = probability of survival from the first larval stage to the beginning of class x ; S_x = survival per age class x ; m_x = average number of offspring per individual of age x ; V_x = reproductive value of individuals of age x .

Table 6. Fertility table of *L. erysimi* grown on cauliflower (*Brassica oleracea* var. botrytis).

x	P	n_x	m_x	$S_x m_x$	$I_x m_x$	V_x
0 ^a	1	120	0.000	0.000	0.000	20.796
0 ^b	3	118	0.000	0.000	0.000	21.157
0 ^c	5	113	0.000	0.000	0.000	22.101
0 ^d	7	111	0.000	0.000	0.000	22.483
1	9	98	7.561	6.396	6.169	25.489
2	11	83	9.096	8.322	6.285	21.172
3	13	76	7.936	5.952	5.023	17.565
4	15	57	4.82	3.547	2.289	9.417
5	17	42	2.351	0.839	0.822	8.248
6	19	15	1.666	0.443	0.208	6.287
7	21	4	0.000	0.000	0.000	0.000

x = age class of individuals from the first larval stage to the adult stage ($x = 2$ days): 0^a to 0^d are the pre-imaginal stages, 1 to 7 represent the adult stage; P = median of each age class x ; n_x = number of individuals alive at the beginning of each age class x ; I_x = probability of survival from the first larval stage to the beginning of class x ; S_x = survival per age class x ; m_x = average number of offspring per individual of age x ; V_x = reproductive value of individuals of age x .

Table 7. Fertility table of *L. erysimi* grown on turnip (*Brassica rapa*).

x	P	n_x	m_x	$S_x m_x$	$I_x m_x$	V_x
0 ^a	1	120	0.000	0.000	0.000	18.979
0 ^b	3	113	0.000	0.000	0.000	20.169
0 ^c	5	104	0.000	0.000	0.000	21.916
0 ^d	7	88	0.000	0.000	0.000	25.893
1	9	75	8.424	7.076	5.265	30.367
2	11	63	11.681	9.636	6.132	26.123
3	13	52	10.466	7.640	4.531	17.510
4	15	38	8.666	4.333	2.738	9.652
5	17	19	1.694	0.713	0.268	1.972
6	19	8	0.666	0.166	0.044	0.666
7	21	2	0.000	0.000	0.000	0.000

x = age class of individuals from the first larval stage to the adult stage ($x = 2$ days): 0^a to 0^d are the pre-imaginal stages, 1 to 7 represent the adult stage; P = median of each age class x ; n_x = number of individuals alive at the beginning of each age class x ; I_x = probability of survival from the first larval stage to the beginning of class x ; S_x = survival per age class x ; m_x = average number of offspring per individual of age x ; V_x = reproductive value of individuals of age x .

Table 8. Fertility table of *L. erysimi* grown on radish (*Raphanus sativus*).

x	P	n_x	m_x	$S_x m_x$	$l_x m_x$	V_x
0 ^a	1	120	0.000	0.000	0.000	16.149
0 ^b	3	113	0.000	0.000	0.000	17.161
0 ^c	5	104	0.000	0.000	0.000	18.647
0 ^d	7	87	0.000	0.000	0.000	22.274
1	9	73	7.472	6.134	4.542	26.560
2	11	60	10.753	8.957	4.478	23.211
3	13	50	9.189	5.97	2.369	14.974
4	15	31	8.023	3.875	0.999	9.327
5	17	15	2.692	1.254	0.156	2.692
6	19	7	0.000	0.000	0.000	0.000
7	21	2	0.000	0.000	0.000	0.000

x = age class of individuals from the first larval stage to the adult stage ($x = 2$ days); 0^a to 0^d are the pre-imaginal stages, 1 to 7 represent the adult stage; P = median of each age class x ; n_x = number of individuals alive at the beginning of each age class x ; l_x = probability of survival from the first larval stage to the beginning of class x ; S_x = survival per age class x ; m_x = average number of offspring per individual of age x ; V_x = reproductive value of individuals of age x .

3.3. Demographic Parameters

Under our experimental conditions, the net reproduction rate of *L. erysimi* was 12.789, 20.79, 18.978, and 16.149, respectively, in the presence of headed cabbage, cauliflower, turnip, and radish (Table 9). The generation time was 11.169 days for headed cabbage, 11.647 days for cauliflower, 11.603 days for turnip, and 11.549 days for radish. The intrinsic rate of natural increase was 0.228 for headed cabbage, 0.260 for cauliflower, 0.253 for turnip, and 0.240 for radish. The time for the *L. erysimi* population to double was 3.040 days on cabbage, 2.66 days on cauliflower, 2.739 days on turnip, and 2.888 days on radish.

Table 9. Growth parameters of *L. erysimi* under laboratory conditions on the four cruciferous plants.

Settings	Equation	Values on Cabbage	Values on Cauliflower	Values on Turnip	Values on Radish
Net Reproduction Rate	$R_0 = \sum_{x=0}^w (l_x \cdot m_x)$	12.789	20.796	18.978	16.149
Generation Time (In Days)	$G = \left[\sum_{x=0}^w (l_x \cdot m_x \cdot P) \right] / R_0$	11.169	11.647	11.603	11.549
Intrinsic Rate of Increase	$\sum_{x=0}^w \exp(-r_m x) l_x \cdot m_x = 1$	0.228	0.260	0.253	0.240
Population Doubling Time (In Days)	$DT = \ln 2 / r_m$	3.040	2.665	2.739	2.888

4. Discussion

The results obtained show that in southern Togo, the most commonly produced

cruciferous vegetables are cabbage, cauliflower, radish, and turnip. Broccoli and watercress are produced in very low quantities, followed by other cruciferous vegetables not identified by the producers surveyed. This could be explained, on the one hand, by low consumer demand for these products and, on the other, by constraints related to their production. Several studies have shown that cabbage is more widely considered in research aimed at improving its production and management conditions than other cruciferous vegetables [31] [32]. This could also explain their high production (in addition to high consumer demand).

L. erysimi survival varied across the four cruciferous vegetables depending on the day. It was higher on cauliflower, with an average of 12.94 ± 4.80 , and lower on radish, with 10.04 ± 5.14 ; however, the last adult on cabbage died on the 23rd day, while on cauliflower the last adult died on the 21st day. This difference can be explained by the fact that individuals of *L. erysimi* achieve their growth on cruciferous vegetables. Aphids feed on sap in the leaves of these host plants, which undoubtedly have different textures and structures depending on the species or variety that may or may not favor their feeding for survival [33]. It may also be due to the composition of the sap in each of these cruciferous plants. Previous work obtained similar results, where the last adults of *L. erysimi* died on days 18, 17, 20, 16, and 17 on broccoli, cabbage, cauliflower, kohlrabi, and mustard, respectively [34]. This significant difference obtained in terms of survival of *L. erysimi* on the four cruciferous vegetables is also confirmed by the different number of larvae that pass to the adult stage. This number is higher on cauliflower, with 98 adults (an emergence rate of 81.67%), and lower on radish, with 73 (where the emergence rate is 60.83%), on the 10th day. *L. erysimi* is an aphid with a short life cycle that varies from one host to another [35]. This would depend on the nutritional values offered by the latter. The average temperature and relative humidity under the experimental conditions ($30.45^\circ\text{C} \pm 0.17^\circ\text{C}$ and $75.45\% \pm 0.65\%$) undoubtedly contributed to shortening the aphid's lifespan, which is approximately 12 days on cauliflower and 10 days on other cruciferous vegetables. At 20°C , *Myzus persicae* Sulzer (Aphididae) had a lifespan of approximately 30 days, and the emergence rate was 78% on the 10th day [12].

The life expectancy (e_x) and survival probability between age class x and class $x + 1$ (L_x) of *L. erysimi* decreased respectively from 1.775 to 0.500 on headed cabbage; from 1.953 to 0.484 on cauliflower; from 1.873 to 0.500 on turnip and radish and from 1.775 to 0.500 on headed cabbage; from 1.953 to 0.484 on cauliflower; from 1.873 to 0.500 on turnip and radish from the first stage to the last age class on all cruciferous vegetables. These results show that cauliflower offers more potential, followed by headed cabbage, than radish and turnip. Researchers [36] obtained the same result for *Plutella xylostella* L. (Lepidoptera; Plutellidae), which has a stronger preference for cauliflower than for other cruciferous plants.

Across the four cruciferous species, it was noted that more than half of the larvae reached the adult stage. Studies have shown that a single adult *L. erysimi* can produce 30 to 70 larvae before dying [37] [38], which may explain the severity of

L. erysimi infestations on crops when no treatment is applied, resulting in zero yields [13] [39].

L. erysimi has a high biotic potential on cruciferous vegetables [40] [41]. By the 7th day, all spawned larvae had become adults and started giving birth to other larvae. Peak oviposition was observed on turnip and radish on the 10th day and on cabbage and cauliflower on the 11th day, with a longer oviposition duration of 13 days on cabbage and cauliflower than on turnip and radish of 12 and 11 days, respectively. The maximum average fecundity per female was observed on turnip with 31.9 ± 13.71 larvae, while it was lower on cabbage with 22.30 ± 8.28 larvae. The controlled experimental conditions in the laboratory could probably impact aphid reproduction on cabbages (head and flower), which have harder and more resistant leaves than those of turnips, which are thinner and more flexible [42]-[44].

Growth parameters (or demographic parameters), which allow us to predict the dynamism of insect populations in order to consider and formulate appropriate management methods offering better control, have shown that the reproduction rate (R_0) was higher on cauliflower (20.796) and lower on headed cabbage (12.778). The generation time (G), which is the time between the birth of larvae by an individual and the first birth of larvae by its offspring, was also slightly higher on cauliflower (11.647 days) and lower on radish (11.549). Previous work has already discussed these variations in demographic parameters for the walnut aphid (*Panaphis juglandis*) [45].

L. erysimi has a very short generation time with very high reproductive power. The intrinsic rate of increase (R_m) is higher on cauliflower (0.260) and lower on headed cabbage (0.228). The doubling time of its population is 2.665 days on cauliflower (shorter than on other cruciferous vegetables). However, in less than four days, *L. erysimi* is able to double its population on all the cruciferous plants tested, according to the results of our studies. These results confirm those of previous works, which showed that *L. erysimi* could double its population in two to four days [46]-[48].

However, it is important to mention that no study to date has reported the aphid's feeding rates on these various crucifer species. This aspect could help better explain the biological and demographic parameters of *L. erysimi* on its hosts.

5. Conclusion

The various parameters studied on *L. erysimi* across these most commonly produced hosts in southern Togo show that the host plants influence the aphid's survival and its reproduction. The demographic parameters studied, such as the reproduction rate and population doubling time (the time required for the population size to double), allow for the better development of management strategies, namely: appropriate treatments to apply, whether with biopesticides or synthetic chemical insecticides, and the timing of treatment application for good efficacy and yield.

Authors' Contributions

Abla Déla Mondédji and Wolali Seth Nyamador designed and supervised the study. Atiyodi Awia and Abla Déla Mondédji performed the survey and laboratory activities. Atiyoti Awia carried out the data analysis. All authors drafted, revised, and approved the final version of the manuscript.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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