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Comparative bionomics and life table studies of *Lipaphis erysimi pseudobrassicae* (Davis) and *Myzus persicae* (Sulzer) (Hemiptera: Aphididae) on three cabbage varieties

Research Paper

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Abstract

Lipaphis erysimi pseudobrassicae (Davis) and *Myzus persicae* (Sulzer) are important pests of brassica crops, causing significant yield losses on cabbage in Ghana. To inform the development of ecologically sound and sustainable pest management strategies for these pests, their biological and population growth parameters were studied on three cabbage varieties (Oxylus, Fortune, and Leadercross). The study was conducted in a screen house under ambient conditions at 30 ± 1°C and 75 ± 5% RH and 12:12 h photoperiod from September to November 2020. The parameters of the preadult developmental period, survival rates, longevity, reproduction, and life table were evaluated following the female age-specific life table. There were significant differences in the nymphal developmental time, longevity, and fecundity on the cabbage varieties for both aphid species. The highest population growth parameters, net reproductive rate (R_0), intrinsic rate of increase r, and finite rate of increase (λ) were recorded on Oxylus variety for both *L. e. pseudobrassicae* and *M. persicae*. The lowest was recorded on Leadercross variety for *L.e pseudobrassicae* and Fortune for *M. persicae*. The results from this study suggest that Leadercross is a less suitable host for *L. e. pseudobrassicae* and Fortune for *M. persicae*, thus, should be considered as less susceptible varieties for use in primary pest management by small-scale farmers or as a component of an integrated pest management strategy for these pests on cabbage.

Introduction

The mustard aphid *Lipaphis erysimi pseudobrassicae* (Davis) (Hemiptera: Aphididae) and *Myzus persicae* (Sulzer) (Hemiptera: Aphididae) are important pests of brassica crops (Yue and Liu, 2000). They attack crops such as cabbage, kale, cauliflower, radish, and mustard, causing enormous losses estimated at 50–100% (Yue and Liu, 2000; Adenka *et al.*, 2021). *Lipaphis e. pseudobrassicae* was first reported in Ghana in 2016, as the major aphids on cabbage, cooccurring with *M. persicae* (Fening *et al.*, 2016, 2020; Forchibe *et al.*, 2017). For both aphid species, all life stages invariably cause direct and indirect damage to crops (Hughes, 1963). Direct plant damage includes stunting, distortion, yellowing, and wilting, usually resulting from sucking sap from infested plants (Hughes, 1963; Aslam *et al.*, 2011), while indirect damage includes black sooty mold formed from fungus growth on honeydew excretion and transmission of plant viruses that results in diseases (Blackman and Eastop, 2000; Ng and Perry, 2004). Apart from preventing adequate photosynthesis, sooty mold and honeydew also reduce the aesthetic value and marketability of crops (Blackman and Eastop, 2000; Fening *et al.*, 2013; Forchibe *et al.*, 2017).

Lipaphis erysimi pseudobrassicae is a specialist aphid on brassica crops, and is highly prolific and can have up to 35 generations annually in tropical conditions (Blackman and Eastop, 2000; Capinera, 2008). Adult aphids have been reported to live for about 15–18 days during summer periods (Sidhu and Singh, 1964). *Myzus persicae* on the other hand is an extremely polyphagous aphid feeding on a wide variety of plant species in over 40 different families (Blackman and Eastop, 2000; Margaritopoulos *et al.*, 2002). Adult longevity varies depending on the host plant, and there can be 20 generations in a year during warmer climates (Blackman and Eastop, 2000). Both aphids have four nymphal stages, and adults maybe winged or wingless (Blackman and Eastop, 1984). The pest status of aphids is often enhanced by their capability to reproduce fast, and adapt to new environments (Myburgh, 1993). Despite their cooccurrence on cabbage in Ghana, they show varying population dynamics (Forchibe *et al*., 2017; Adenka *et al*., 2021), and there is inadequate information on the bionomics of these aphids on cabbage varieties cultivated in Ghana.

In Ghana, major methods of controlling aphids have focused on using synthetic insecticides, which are readily available and fast-acting, regardless of their well-documented adverse effects on human health, non-target organisms, and the environment (Obeng-Ofori, 2007; Ahmad and Akhtar, 2013; Bass *et al*., 2014). To counter these effects, other control measures that are considered compatible with food safety should be explored (Yun *et al*., 2017; Ahmad *et al*., 2019). Host plant resistance can be an important component of an integrated pest management (IPM) system used in synergy with other control measures (Shah *et al*., 2015; Ahmed *et al*., 2018; Taghizadeh, 2019). The use of insect-resistant cultivars has been reported to enhance food production in some major agricultural areas of the world (Smith, 2005). Although screening for resistant plant lines against aphids requires in-depth knowledge of resistant sources within crossable germplasms and associated genetics (Bhatia *et al*., 2011), some studies have reported successful trials for resistant cabbage lines against *Brevicoryne brassicae*, *L. pseudobrassicae*, and *M. persicae* (Shah *et al*., 2015; Ahmed *et al*., 2018). Furthermore, it is well documented that different cultivars/varieties of a plant can alter the life history attributes of herbivores by interfering with development, reproduction, and, consequently, population growth (War *et al*., 2012; Kant *et al*., 2015; Ali *et al*., 2021).

Life tables are powerful and essential tools for analyzing the effect of host plant quality on the growth, survival, reproduction, and population growth parameters of insect populations (Chi and Su, 2006). They facilitate the understanding of pest population dynamics by providing a complete description of the demographic parameters of an insect population under specific environments (Qayyum *et al*., 2018). The lifetable parameters of a pest on a specific host plant provide crucial indications about the pest's fitness on that host plant (Liu *et al*., 2004). Various studies have evaluated the effect of different brassica varieties on the lifetable of *L. erysimi* (Phadke, 1982; Qayyum *et al*., 2018; Taghizadeh, 2019), and host plant variations on *M. persicae* (Hong *et al*., 2019; Baral *et al*., 2020; Ali *et al*., 2021). Additionally, Saleesha *et al*. (2022) studied the development of *M. persicae* under different temperature regimes on cauliflower and other studies have focused on the demographic parameters of *L. erysimi* and its predators under different temperature and field conditions (Ali and Rizvi, 2009; Boopathi *et al*., 2020). However, there is little to no information on the comparative bionomics of both aphid species on the same plant varieties, given that they cooccur on cabbage. Thus, understanding the life table parameters of *L. e. pseudobrassicae* and *M. persicae* on some cabbage varieties grown in Ghana will provide valuable information on potentially less susceptible varieties, which could be adopted as an integral part of developing an IPM tool against these important aphid pests of cabbage. Therefore, this study focuses on assessing the life history parameters of *L. e. pseudobrassicae* and *M. persicae* on three cultivated cabbage varieties under ambient conditions.

Materials and methods

Growing of host plants

Three varieties of white cabbage (*Brassica oleracea* var. *capitata*), Oxylus (Seminis®), Fortune (Technisem®), and Leadercross (Technisem®), were used as host plants for the experiment. Different varieties of cabbage usually have different morphological features, and these varieties were used by hypothesizing that they show varied responses to aphids' feeding and may also affect aphids' behavior, reproduction, and survival. The Oxylus variety used is green in color, heat tolerant, resistant to alkalinity, has soft leaves, and is well adapted to a wide range of agroecological zones (Seminis® product catalog). Fortune variety has soft bluish-green leaves, resistant to fusarium wilt, and is well adapted to hot and humid climates. Leadercross, on the other hand, has tough leaves, bluish-green in color, resistant to pests, and is suitable for dry seasons (Technisem® product catalog). These varieties were selected because Oxylus and Fortune are widely grown by farmers (Timbilla and Nyarko, 2004; Amoabeng *et al*., 2017) and have been reported to be susceptible to aphid infestation (Adenka *et al*., 2021), while Leadercross is one of the least grown varieties (Forchibe, 2021) reported to be pest resistant by the manufacturer (Technisem® product catalog). Seeds of the above cabbage varieties were obtained from Agriseed Ltd Ghana and sown in small plastic buckets (15 × 12 cm). When plants reached the third leaf stage unfolded (BBCH-code 13; Feller *et al*., 1995), they were individually transplanted into 30 plastic pots (12 cm × 12 cm) containing a mixture of soil and Gro-Plenty organic compost (Green-Gro, Ghana) in a ratio of 2:1 as recommended by Gro-Plenty. The potted plants were maintained in a screen house under ambient conditions at 30 ± 1°C and 75 ± 5%RH at the University of Ghana Soil and Irrigation Research Centre, Kpong, from September to November 2020. Irrigation was carried out daily till the end of the study. Plants were used for the study when they reached the six true leaf stage.

Rearing of L. e. pseudobrassicae and M. persicae

Lipaphis erysimi pseudobrassicae and *M. persicae* were collected from a cabbage (Variety: KK Cross) field in Kpong and reared on potted cabbage plants of the respective varieties, covered with micro-perforated bread bags (Seal Packaging, Luton, UK) secured around the pots with rubber bands to restrict the aphids from moving out of the plants. These two aphid species were used for the study because these are the only species reported to occur on cabbage in Ghana (Forchibe *et al*., 2017; Fening *et al*., 2020), and particularly because *L. e pseudobrassicae* is a specialist aphid of Brassicaceae, while *M. persicae* is a generalist feeder (Blackman and Eastop, 2000). The aphids were reared for three generations to obtain a suitable population of aphids void of any influence from the previous host. To control inbreeding, newly emerged aphids were gently transferred onto new cabbage plants, using camel hair brushes every week until the third generation was attained, before transfer onto study plants.

Bionomics study

One 2-day-old adult aphid was placed on a potted cabbage plant using a camel hairbrush and confined in a clip cage for each variety of cabbage. Each setup was replicated 30 times for each variety. After 24 h, the adult aphid and newly born nymphs except one were removed from the plants. This remaining aphid in the clip cage on the potted plant was kept in the screen house at 30° ± 1°C, 75 ± 5%RH, and 12:12 h photoperiod, and monitored daily for the various aspects of the bionomics. Nymphal instars were determined to have molted when cast skin was observed. The developmental duration and survival of the nymphs were

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Table 1. Mean longevity of nymphal instars of *L. e. pseudobrassicae* and *M. persicae* on different cabbage varieties

		Varieties (days)					
Aphid species	Parameters	*n*	Oxylus	*n*	Fortune	*n*	Leadercross
L. e. pseudobrassicae	First instar	30	1.63 ± 0.11a	30	1.63 ± 0.11a	30	2.03 ± 0.10b
	Second instar	30	1.50 ± 0.09a	29	1.43 ± 0.11a	28	1.33 ± 0.16a
	Third instar	30	1.37 ± 0.09a	28	1.27 ± 0.13b	24	0.80 ± 0.14b
	Fourth instar	30	1.47 ± 0.09a	24	1.53 ± 0.18a	16	0.70 ± 0.13b
	Total nymphal duration		5.97 ± 0.13a		5.87 ± 0.37a		4.87 ± 0.43a
M. persicae	First instar	30	1.83 ± 0.10ab	30	1.60 ± 0.16a	30	2.07 ± 0.13b
	Second instar	30	1.60 ± 0.09 a	14	0.87 ± 0.19b	24	1.57 ± 0.18a
	Third instar	30	1.43 ± 0.09a	14	0.77 ± 0.18b	24	1.43 ± 0.164a
	Fourth instar	30	1.63 ± 0.10a	14	0.80 ± 0.18b	24	1.33 ± 0.15a
	Total nymphal duration		6.50 ± 0.13a		4.03 ± 0.67b		6.40 ± 0.56a

Means with different letters across rows are significantly different by the Dunn–Bonferonni test ($P \leq 0.05$).

monitored and recorded daily until adult emergence. After adult emergence, individuals' reproductive period, longevity, survival, and fecundity were recorded daily until the death of all individuals. All newly emerged nymphs were recorded during the reproductive period and then removed from the plant daily. This method was adapted from studies by Patel *et al.* (2017) and Qayyum *et al.* (2018). Time-specific life table parameters of aphids were generated to calculate the total survival rate, fecundity table, developmental duration, and life expectancy (e_x), which is the length of time that an individual at age (x) is expected to live.

Life table calculations

The fertility life table was constructed based on the female age-specific life table, consistent with Carey (1993) and Southwood and Henderson (2000). The life table was built with age-specific survival rate (l_x), age-specific fecundity (m_x), and age-specific maternity rate ($l_x m_x$). These data were used to calculate the life table parameters (intrinsic rate of increase (r_m), finite rate of increase (λ), net reproductive rate (R_0), and mean generation time (T)).

The R_0 values were calculated as:

$$R_0 = \sum_{x=0}^{\infty} l_x m_x$$

The intrinsic rate of increase (r) was estimated using the iterative bisection method from the Euler Lotka formula with age indexed from 0 (Goodman, 1982):

$$\sum_{x=0}^{\infty} e^{-r(x+1)} l_x m_x = 1$$

The finite rate was calculated as $\lambda = e^r$, the mean generation time is defined as the length of time that a population needs to increase to R_0-fold of its population size at the stable age-stage distribution, and is calculated as: $T = \ln R_0 / r$.

Biological parameter analysis

All analyses were carried out in IBM SPSS Statistics 22. All data for nymphal developmental duration, adult longevity, pre-reproductive, reproductive period, post-reproductive period, and fecundity were subjected to Shapiro–Wilk test to determine data normality. Data related to nymphal duration, reproductive period, longevity, and total life span for both aphid species did not conform to the normality test, even after log transformation. Consequently, comparisons were done using the non-parametric Kruskal–Wallis test followed by post hoc comparisons of means using Dunn–Bonferonni test. The fecundity life table parameters were analyzed by bootstrapping (1000-bootstraps) with seed for Mersenne Twister set at 2.000000 to determine the standard error and the means compared by Tukey's HSD test. Mean differences between both aphids were compared by an independent sample t-test. All analyses were conducted at 95% significance level.

Survival analysis

Survival was analyzed and curves fitted using the Kaplan–Meier survival probabilities, followed by a pairwise comparisons Mantel–Haenszel test (log-rank test) in IBM SPSS Statistics 22. Individual aphids that did not die by the end of the nymphal period were censored (0 = death event did not occur; 1 = death event occurred) during nymphal survival analysis. The adult aphids were not censored, because the experiment ended with the death of all insects.

Results

Developmental parameters

The developmental duration for each nymphal stage, of *L. e. pseudobrassicae* and *M. persicae* on the three cabbage varieties (Oxylus, Fortune, and Leadercross) are shown in table 1. Both aphids had four nymphal stages on all three cabbage varieties. Following Kruskal–Wallis test, a significant variation nymphal duration was recorded for *M. persicae* (χ^2 (2) = 12.41, P = 0.001), ranging from 4.03 to 6.50 days on Fortune and Oxylus, respectively (table 1). An independent t-test showed a significant variation in nymphal duration between both aphid species on all three varieties (t (58) = 2.85, P = 0.006 for Oxylus, t (58) = 2.39, P = 0.021 for Fortune, and t (58) = 2.19, P = 0.032 for Leadercross) with *M.*

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Table 2. Mean adult growth stage period of *L. e. pseudobrassicae* and *M. persicae* on different cabbage varieties

Aphid species	Parameters	Varieties (days)					
		n	Oxylus	*n*	Fortune	*n*	Leadercross
L. e. pseudobrassicae	Adult longevity	30	11.70 ± 1.04a	24	8.60 ± 0.97ab	16	5.23 ± 0.97b
	Pre-reproductive period		0.20 ± 0.07a		0.13 ± 0.06a		0.13 ± 0.08a
	Reproductive period		10.57 ± 1.01a		7.70 ± 0.87ab		4.77 ± 0.87b
	Post reproductive period		1.13 ± 0.26a		0.90 ± 0.14ab		0.47 ± 0.15b
	Fecundity (nymphs/female)		44.77 ± 5.18a		31.27 ± 4.31a		12.97 ± 2.60b
	Total lifespan		17.67 ± 1.02a		14.47 ± 1.13a		10.10 ± 1.32b
M. persicae	Adult longevity	28	12.83 ± 1.20a	14	5.47 ± 1.24b	22	8.73 ± 1.08b
	Pre-reproductive period		0.40 ± 0.11a		0.13 ± 0.08a		0.23 ± 0.11a
	Reproductive period		11.27 ± 1.30a		4.36 ± 1.11b		8.13 ± 1.03ab
	Post reproductive period		1.56 ± 0.30a		1.10 ± 0.31ab		0.60 ± 0.11b
	Fecundity (nymphs/female)		31.27 ± 3.96a		7.67 ± 2.09b		14.13 ± 2.18b
	Total lifespan		19.33 ± 1.24a	14	9.50 ± 1.77b		15.13 ± 1.45a

Means with different letters across rows are significantly different by the Dunn–Bonferonni test ($P \leq 0.05$).

persicae recording a significantly higher duration of 6.50 and 6.40 on Oxylus and Leadercross, respectively (table 1).

The reproductive period and adult longevity varied significantly among varieties for both *L. e. pseudobrassicae* (χ^2 (2) = 14.82, $P < 0.001$ and χ^2 (2) = 6.97, $P < 0.001$) and *M. persicae* (χ^2 (2) = 16.99, $P < 0.001$ and χ^2 (2) = 15.73, $P < 0.001$). The reproductive period and adult longevity were significantly higher on Oxylus variety, with a mean reproductive duration of 10.57 days and adult longevity of 11.70 days for *L. e. pseudobrassicae*, and with a mean reproductive duration of 11.27 days and adult longevity of 12.83 days for *M. persicae* (table 2). As further listed in table 2, the adult longevity for aphids reared on Leadercross (5.23 days) was low for *L. e. pseudobrassicae* and on Fortune (5.47 days) for *M. persicae*. A similar trend was recorded for the reproductive period of both aphid species. Significant differences in reproductive period were recorded between both aphid species on Fortune (t (58) = 2.35, $P = 0.022$) and Leadercross (t (58) = −2.49, $P = 0.016$) varieties, with *L. e pseudobrassicae* recording a higher reproductive period on Fortune and *M. persicae* on Leadercross. Longevity also varied significantly between both aphid species only on Leadercross variety (t (58) = −2.41, $P = 0.019$). Total lifespan varied significantly among varieties for both *L. e. pseudobrassicae* (χ^2 (2) = 15.52, $P < 0.001$) and *M. persicae* (χ^2 (2) = 14.59, $P < 0.001$) (table 2), with a significant t-test between both aphid species on Fortune (t (58) = 2.36, $P = 0.022$) and Leadercross (t (58) = −2.56, $P = 0.013$) varieties.

The fecundity of *L. e pseudobrassicae* and *M. persicae* was highly influenced by feeding on different cabbage varieties. A significant variation in the fecundity was recorded for both *L. e. pseudobrassicae* (χ^2 (2) = 23.91, $P = 0.001$) and *M. persicae* (χ^2 (2) = 24.07, $P < 0.001$). *Lipaphis erysimi pseudobrassicae* was most fertile on Oxylus variety (44.77 nymphs/female) and least fertile on Leadercross variety (12.96 nymphs/female), while *M. persicae* on Oxylus (31.27 nymphs/female) and least fertile of Fortune variety (7.67 nymphs/female) (table 2). Comparison between the mean fecundity of both aphid species showed a significantly higher fecundity of *L. e pseudobrassicae* on Oxylus (t (58) = 2.07, $P = 0.043$) and Fortune (t (58) = 4.93, $P < 0.001$) varieties compared to *M. persicae*.

Life table parameters

The nymphal survival rate (Mantel–Haenzel test; $\chi^2 = 21.47$, $P < 0.001$) and adult survival rate (Mantel–Haenzel test; $\chi^2 = 8.19$, $P = 0.017$) of *L. e. pseudobrassicae* differed significantly among the three varieties (fig. 1). For *M. persicae,* only the nymphal survival rate significantly differed among the cabbage varieties (Mantel–Haenzel test; $\chi^2 = 23.64$, $P = 0.001$) (fig. 1). Between both aphid species, the nymphal survival rate varied significantly on Fortune variety (Mantel–Haenzel test; $\chi^2 = 11.35$, $P = 0.001$), while adult survival rate varied significantly on Fortune (Mantel–Haenzel test; $\chi^2 = 5.49$, $P = 0.019$), and Leadercross (Mantel–Haenzel test; $\chi^2 = 7.75$, $P = 0.005$) varieties (fig. 2).

As shown in fig. 3, the Oxylus variety revealed the highest life expectancy for both *L. e. pseudobrassicae* ($e_x = 18.20$) and *M. persicae* ($e_x = 18.76$) among the three cabbage varieties tested. In this variety, the life expectancy (e_x) was highest at the beginning of the life cycle and reached 0.0 after 26 days for *L. e. pseudobrassicae*, and 27 days for *M. persicae* (fig. 3). Similarly, this variety revealed the highest survival rate for both aphid species. The survival rate obtained at this stage (nymphal) was 100% for both aphid species, thus recording zero mortality at the preadult stage compared to the other varieties (fig. 1). The lowest life expectancy of *L.e. pseudobrassicae* was observed on Leadercross variety, which was 9.76 at the beginning of life and reached 0.0 after 19 days, while the lowest e_x for *M. persicae* was recorded on Fortune variety; 8.96 at the beginning, and reached 0.0 after 26 days (fig. 3).

The age-specific fecundity (m_x) peaks of both aphids on Oxylus variety were higher than those obtained from the other two varieties. Peaks were generally recorded between 9 and 12 days for all three varieties, for both aphid species (fig. 4).

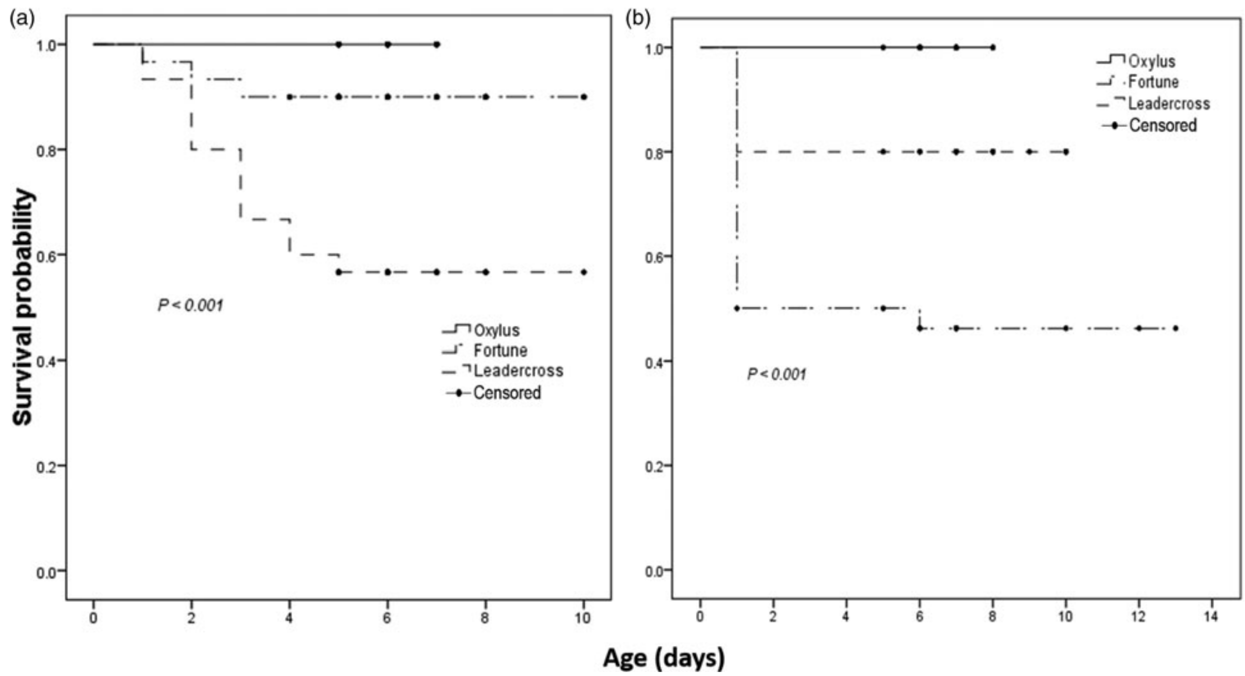

Figure 1. Kaplan–Meier nymphal survival curve for (a) *Lipaphis erysimi pseudobrassicae* and (b) *Myzus persicae* on three cabbage varieties.

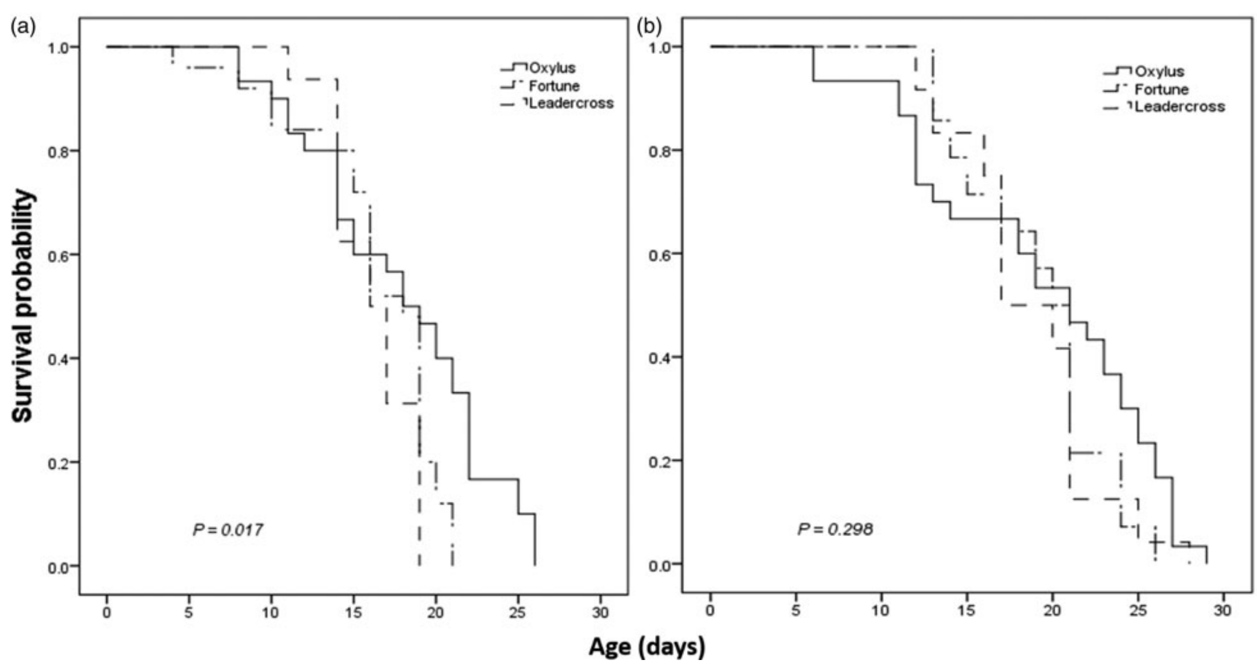

Figure 2. Kaplan–Meier adult survival curve for (a) *Lipaphis erysimi pseudobrassicae* and (b) *Myzus persicae* on three cabbage varieties.

Population growth parameters

The population growth parameters of *L. e. pseudobrassicae* and *M. persicae* on the three cabbage varieties are as shown in table 3. Statistical analysis showed significant differences in the net reproductive rates (R_0), intrinsic rate of increase (r), and finite rate of increase (λ) among varieties for both aphid species ($P < 0.001$) (table 3). The net reproductive rate of both *L. e. pseudobrassicae* and *M. persicae* was significantly higher on Oxylus compared to the other varieties. There was also significant difference in the doubling time (DT) ($P = 0.034$) for *L. e pseudobrassicae* among the three varieties. Between *L. e pseudobrassicae* and *M. persicae*, the R_0, r and λ varied significantly on Oxylus and Fortune varieties, while R_0 (t (33) = 2.76, $P = 0.0009$) and T (t (33) = 3.13, $P = 0.004$) varied significantly on Leadercross variety.

Discussion

Life tables are useful tools to assess the effect of external factors such as host plants on the growth and development of insects

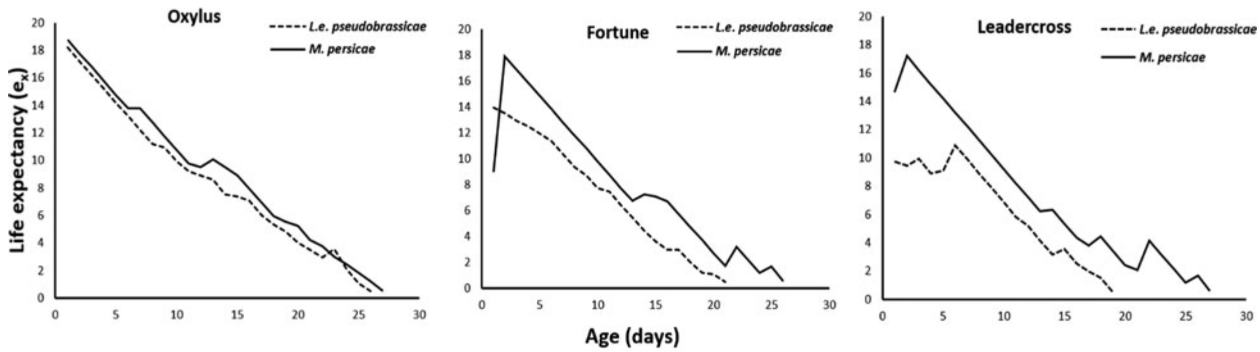

Figure 3. Life expectancy (e_x) of (a) *Lipaphis erysimi pseudobrassicae* and (b) *Myzus persicae* on three cabbage varieties.

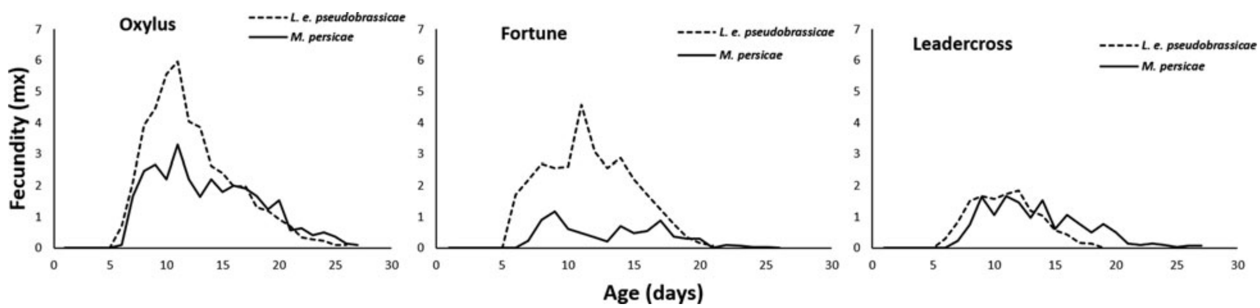

Figure 4. Age-specific fecundity (m_x) of *Lipaphis erysimi pseudobrassicae* and *Myzus persicae* on three cabbage varieties.

(Ramalho *et al.*, 2015; Qayyum *et al.*, 2018). It provides an integrated and extensive description of a population's survival, development, and reproduction, thus can give an accurate estimate of the growth rate of an insect pest population (Tuan *et al.*, 2015, 2016; Chang *et al.*, 2016). It is well-documented that the performance of any aphid species can be greatly influenced by host plants, be it different cultivars or varieties of the same plant (Dixon *et al.*, 1987; Yue and Liu, 2000; Tsai and Wang, 2001; War *et al.*, 2012; Kant *et al.*, 2015; Qayyum *et al.*, 2018; Hong *et al.*, 2019; Baral *et al.*, 2020; Ali *et al.*, 2021), and can inform the development of ecologically friendly pest management strategies (Qayyum *et al.*, 2018). Shah (2017) reported that the quality of host plants plays an important role in the growth and development of an insect, reflecting the suitability of a particular host plant for the sustenance of an insect's life cycle. In this study, we demonstrate that the biological parameters (developmental time, survival rate, adult longevity, and reproduction) of *L. e. pseudobrassicae* and *M. persicae* were significantly altered by the cabbage varieties, consequently reflected in the population growth parameters (r, λ, R_0, and T). The results of this study showed that *L. e pseudobrassicae* reared on Leadercross had the lowest net reproductive rate, intrinsic rate of increase, and finite rate of increase, while *M. persicae* reared on Fortune had the lowest of these parameters, suggesting that they are less favorable hosts. Studies have reported that host plants are considered less favorable host to aphid populations when the intrinsic rate of increase and net reproductive rate are lower (Atlihan *et al.*, 2017; Qayyum *et al.*, 2018; Hong *et al.*, 2019). The intrinsic rate of increase (r) is an important parameter often used by ecologists in demographic studies of insect populations to contrast population fitness across changing conditions (Birch, 1948; Tsai and Wang, 2001). According to Gotelli (2008), r determines if a population is growing exponentially ($r > 0$), remains constant ($r = 0$), or declining ($r < 0$). In the current study, the r for both aphids were greater than zero in all three cabbage varieties suggesting an exponential population growth during the fertile phase of their life cycle, following the assertion by Gotelli (2008).

Oxylus variety, on the other hand, was seen to be the most suitable variety for both aphid species compared to the other two varieties, following the high values of r, R_0, and finite rate of increase (λ). Although this finding presents Oxylus variety as the most susceptible to both aphid species, this variety is widely grown in Ghana and often noted as the farmer's choice (Timbilla and Nyarko, 2004). However, field studies by Adenka *et al.* (2021) reported Fortune as the most susceptible variety to both aphid species, which could be attributed to diverse biotic and abiotic factors that affect the dynamics of both aphids. Comparatively, the R_0, r, and λ were higher for *L. e pseudobrassicae* compared to *M. persicae* in Oxylus variety, suggesting this variety to be more suitable for the growth and development of *L. e pseudobrassicae*. Nevertheless, the intrinsic rate of increase of *M. persicae* has been reported to be comparatively lower in cruciferous vegetables (Chi and Su, 2006; Hong *et al.*, 2019), which is also comparatively lower in the current study. This can be attributed to the fact that *M. persicae* is polyphagous, and has high adaptability to complex environments and host plants (Hong *et al.*, 2019), as opposed to *L. e pseudobrassicae*, a brassica specialist aphid, thus highly adaptable for survival on the host plants used in this study. Furthermore, Fening *et al.* (2020) reported *L. e pseudobrassicae* as the key aphid pest of cabbage in Ghana, with a higher abundance compared to *M. persicae*.

Nymphal duration may be directly proportional to the level of host resistance or susceptibility because high resistance levels increased the time from birth to first reproduction compared to

Table 3. Population growth parameters of *Lipaphis erysimi pseudobrassicae* and *Myzus persicae* on three cabbage varieties

Aphid species	Parameters	Varieties		
		Oxylus	Fortune	Leadercross
L. e. pseudobrassicae	R_0 (offspring/individual)	35.96 ± 2.66a	21.89 ± 1.77b	6.46 ± 0.58c
	r_m	0.31 ± 0.02a	0.28 ± 0.02a	0.17 ± 0.03b
	λ	1.37 ± 0.02a	1.32 ± 0.02a	1.19 ± 0.02b
	T	11.47 ± 0.38a	11.15 ± 0.43a	10.70 ± 0.42a
	DT	2.22 ± 0.66a	2.51 ± 0.69a	3.97 ± 1.37a
M. persicae	R_0 (offspring/individual)	23.75 ± 1.76a	2.94 ± 0.21b	9.61 ± 0.86c
	r_m	0.25 ± 0.03a	0.09 ± 0.02b	0.18 ± 0.03a
	λ	1.28 ± 0.03a	1.09 ± 0.02b	1.20 ± 0.03c
	T	12.74 ± 0.47a	12.23 ± 0.40a	12.49 ± 0.46a
	DT	2.79 ± 0.39a	7.87 ± 6.06b	3.83 ± 1.86a

Means followed by the same letter per column do not differ by Tukey test ($P = 0.05$).
Reproductive net rate (R_0), mean generation time (T), intrinsic rate of increase (r_m), finite rate of increase (λ), doubling time (DT).

high susceptibility (La Rossa *et al*., 2013). Similarly, this study recorded longer nymphal duration for the respective aphids that survived on the less susceptible varieties; Leadercross and Fortune. Although not investigated in the current scope of work, we speculate that high nymphal mortality recorded on these cabbage varieties might be attributable to physical or chemical properties of the host plants that negatively impacted the development of aphids. We also hypothesize that no nymphal mortality recorded on the susceptible hosts (Oxylus) might have been due to favorable host plant conditions such as nutritional content. Some studies have reported that factors such as nutritional value, chemical composition, and physical properties often affect the performance of aphids on different host plants (La Rossa *et al*., 2013; Jahan *et al*., 2014; Ali *et al*., 2021). The survival curves showed high susceptibility of Oxylus variety to both aphid species, further indicating the suitability of this host for the development of these aphids. These findings support earlier studies that showed a significant effect of host plants on the growth, survival, and development of aphids on brassicas (Rana, 2005; Qayyum *et al*., 2018; Hong *et al*., 2019; Taghizadeh, 2019; Ali *et al*., 2021).

The fecundity and longevity of aphids have also been attributed to the physical and chemical properties, as well as the nutritional value of host plants (Tsai and Wang, 2001; Ulusoy and Ölmez-Bayhan, 2006). The differences in the average fecundity and net reproductive rate between *L. e pseudobrassicae* and *M. persicae* among the three cabbage varieties support the assertion that the net reproductive rate is an important indicator of population dynamics and often gives considerable insight into the reproductive capacity of an organism on different host plants (Richard, 1961). Based on the performance of both aphids on the three cabbage varieties, Oxylus which is the most popular variety grown in Ghana (Amoabeng *et al*., 2017) seems to be a more suitable host for *L. e pseudobrassicae* compared to *M. persicae*. Therefore, it is likely that the population buildup for *L. e pseudobrassicae* would take a lesser time on cabbage compared to *M. persicae* as seen with its comparatively higher reproductive period, average fecundity, and shorter DT and lifespan. This trend was also observed under field conditions, where *L. e. pseudobrassicae* population density was comparatively higher throughout the cabbage cropping seasons in different agroecological zones (Fening *et al*., 2020; Adenka *et al*., 2021; Forchibe, 2021).

The use of less susceptible cabbage varieties to control *L. e. pseudobrassicae* and *M. persicae* is considered a primary pest control measure (Qayyum *et al*., 2018). When used in combination with other control measures in an integrated approach, can contribute to effective pest suppression and increase in crop production (Smith, 2005). Long nymphal durations recorded on the less susceptible varieties could translate to low pest buildup on the field if these varieties are used, consequently leading to decreased number of spraying times per growing season, decreased amount of pesticides applied, decrease in the cost of inputs (pesticides), and subsequently increase in farmer's income. The results therefore suggest that the choice of variety is an important component when planning an IPM approach. It is also important to note that these two aphids often cooccur in the field, and they showed varied responses to the cabbage varieties used in this study, which may result in different competitive outcomes. Thus, it is recommended that field trials based on these findings be carried out to provide more information on the performance of each cabbage variety to attack by both aphid species.

Conclusion

From this study, it can be concluded that Oxylus is the most susceptible variety to both *L. e. pseudobrassicae* and *M. persicae*, while Leadercross is less susceptible to *L. e. pseudobrassicae* and Fortune to *M. persicae*. Therefore, Leadercross and Fortune varieties can be recommended to small-holder farmers as a cost-effective means to control aphids on cabbage, while minimizing the frequency of pesticide application. However, they must be used in combination with or as a component of an IPM strategy. Furthermore, Oxylus variety is recommended for laboratory mass rearing of *L. e. pseudobrassicae* and *M. persicae* for other studies, while Fortune and Leadercross varieties could be explored for resistant genes against *M. persicae* and *L. e. pseudobrassicae* for the development of resistant cabbage lines.

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