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Host preference and performance of cabbage aphid *Brevicoryne brassicae* L. (Homoptera: Aphididae) on four different brassica species

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Host preference and performance of cabbage aphid *Brevicoryne brassicae* were studied on seven brassica varieties under Greenhouse. Nymphs, apterous and alate aphids were significantly different on day three and day 15 among tested varieties. Higher total number of aphids per plant was recorded on *Brassica carinata* and lower on *Brassica oleracea*. Alates of *B. brassicae* preferred more to feed and reproduce on *B. carinata* varieties than the other tested varieties. Developmental and reproduction periods, fecundity and longevity of *B. brassicae* were significantly different among tested varieties. Shortest and longest developmental period were recorded on Holeta-1 (6.4 days) and Kale (8.9 days), respectively. The aphid had the highest fecundity on *B. niger* (79.5 nymphs/adult) and the lowest on cabbage (62.4 nymphs/adult).The reproductive rate, intrinsic rate of increase, generation time, doubling time of *B. brassicae* were significantly different among tested varieties. The intrinsic rate of increase of *B. brassicae* was 0.337, 0.310, 0.286, 0.276, 0.262, 0.250 and 0.239 days^{-1} on Holeta-1, Yellow Dodola, Axana, Blinda, *B. niger*, Cabbage, and kale respectively. Varieties of *B. carinata* were more suitable for cabbage aphid feeding and reproduction than the other tested varieties.

Key words: *B. brassicae*, reproduction, development, intrinsic rate of increase, fecundity, Ethiopian mustard.

INTRODUCTION

Cabbage aphid *Brevicoryne brassicae* (L.) (Hemiptera: Aphididae) is a specialized aphid on brassica plants and creates problem worldwide with a significant negative impact on brassica crops (Pontoppidan et al., 2003; Bashir et al., 2013). Aphid cause direct damage by causing chlorosis and leaf curling on the leaves while disrupting the normal plant growth and development (Colette et al., 2008) and indirect damage through the transmission of viral diseases (Jahan et al., 2013). Brassicaceae plants are most popular vegetable crops consumed all over the world and good source of bioactive phytochemicals (Beekwilder et al., 2008) and they are

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characterized by their secondary metabolites (Glucosinolates) (Al-Gendy et al., 2010; Polat, 2010). The type and concentration of glucosinolates have been found to vary between *Brassica* species, cultivars and between the plant parts within the same plant (Rangkadilok et al*.,* 2002; Windsor et al*.,* 2005; Zytynska and Preziosi, 2011).Variation in plant quality such as physical, chemical or biological traits influences herbivores' performance such as growth rates, fecundity, and survivorship (Awmack and Leather, 2002; Zehnder and Hunter, 2008).

The cabbage aphid *B. brassicae* is a phloem sucking insects that have a strategy for manipulating toxic substance from Brassicaceae crops, which is harmful to other brassica insects (Rebecca et al., 2011). These substances are important as plant defense response and provoked consequently after insect herbivore feeding on the plant (Muhammad et al., 2009; Bones et al., 2011). Glucosinolates are strong stimulant substances for cabbage aphid, and used as signal to select its host plants (Gabrys and Tjallingii, 2002). The toxic effect of the plant substance on cabbage aphid *B. brassicae* is avoided by elimination, detoxification, sequestration methods and behavioral responses of the aphid (Hopkins et al., 2009). Mirmohammadi et al. (2009) and Aziz et al. (2016) studied the effect of *B. napas* and *B. oleracae* cultivars on the performance of cabbage aphid. However, the effect of Ethiopian mustard varieties on the performance of cabbage aphid has not been studied. The variation on quantity and quality of phytochemicals among plant genotypes, tissues and ontogenetic stages has an effect on insect performance (Ode, 2006).Therefore, the aim of the present study was to evaluate the effect of different brassica species on the preference and performance of cabbage aphid *B. brassicae* in Ethiopia.

MATERIALS AND METHODS

Host plant material

The preference and performance of cabbage aphid was studied on seven different brassica varieties; six varieties from three species (two varieties from each species) and one local variety of *B. niger* (red mustard) (Table 1). Seeds of the brassica were sown on plastic pots (15:15:10 cm height, bottom and top diameter respectively) containing 3:2:1 proportion of soil, sandy and manure, respectively to ensure the fertility of the soil for the plant growth and development. The pots were kept under the greenhouse of the, College of Agriculture, Hawassa University.

Aphid source and rearing

The aphid *B. brassicae* was collected from infected cabbage plants at Hawassa and introduced to each of the corresponding varieties planted on pot as stock culture. The plants were kept inside cages covered with fine net to prevent aphids from escaping and parasitoids and predators of the aphid from entering. The aphids were reared for two generations on respective host plants prior to the experiment. Aphids were transferred in to new potted plants when required to maintain the high aphid density for further experiment. The potted plants were kept under green house in ambient conditions at temperature of 28.86±0.82°C and 51.43±2 relative humidity.

Host preference of alate aphids of *B. brassicae*

The experiment was conducted in the greenhouse by placing the stock culture in one side and the aphid free plants in the opposite side direction two meters away. Forty two brassica plants; six plants for each of the seven varieties with high alate cabbage aphid densities on one side were used as aphid stock culture. Winged cabbage aphids were allowed to disperse and to feed on the healthy plants on another side. A total of twenty eight aphid free plants consisted of seven varieties replicated four times were used. Aphid free plants were approximately equal size with only five young, fully expanded leaves. The plants were labeled and randomly arranged on the opposite side in four rows. The number of nymphs, winged and non-winged adults on each plant were recorded three and fifteen days after the plants were exposed.

Performance of *B. brassicae*

Two seeds of each variety were sown on a plastic pot and thinned to one plants per pot two weeks after germination. To have a same age (<24 h) of the first nymphal stage; one young apterous adult was randomly collected from the stock culture and placed on the undersurface of the leaf on each plants. After 24 hours, one newborn nymph was left on the leaf and excess nymphs and adults were removed. Then all experimental pots were caged individually and arranged in completely randomized design with ten replications. Period for first, second, third and fourth instar, nymph developmental period, pre-reproductive, reproductive period, post-reproductive period, adult longevity, lifetime and fecundity were calculated.

Statistical analysis

Number of aphids per plant, developmental and reproduction period, intrinsic rate of natural increase, generation time, number of offspring per female and survivorship (%) on each tested varieties were subjected to PROC GLM analysis of variance procedure in SAS software version 9.0 (SAS Institute, 2002). Means were compared using Tukey's test at p=0.05.

Age specific life table were calculated for cabbage aphids on seven different brassica varieties. Parameters were calculated using *Euler–Lotka Equation* (Begon et al. 2006)*.* The intrinsic rate of natural increase was calculated with the following equation.

$$\sum L_x m_x e^{-rmx^*}{}_{=1}$$

$$L_x = \frac{l_x + l_{x+1}}{2} \quad \text{and} \quad x^* = \text{pivotal } x = \frac{x_l + x_{l+1}}{2}$$

Where, l_x is the fraction of individuals of the initial cohort alive at age x, m_x the number of female progeny produced per female in x and r_m the intrinsic rate of natural increase. The net reproductive rate ($R_o = \sum L_x m_x$), generation time ($T = \ln R_o / r_m$), population doubling time ($DT = \ln 2 / r_m$) and finite rate of increase ($\lambda = \exp.(r_m)$) were calculated.

Table 1. Brassica varieties used for the experiment and their sources.

Varieties	Species	Source
Yellow Dodolla	*B. carinata*	Holeta research Center
Holeta-1	*B. carinata*	Holeta research Center
Cabbage	*B. oleracea var. capitata*	Copenhagen Market
Kale	*B. oleracea var. Aciphala*	Local Market
Axana	*B. napus*	Kulumsa Research Center
Blinda	*B. napus*	Kulumsa Research Center
Red mustard	*B. niger*	Local Market

Table 2. Numbers of alate, nymph and apterae of cabbage aphid on seven brassica varieties after three and fifteen days of infestation.

Varieties	Number of aphids per plant						
	Day 3			Day 15			
	Alate	Nymph	Total	Alate	Apterae	Nymph	Total
Holeta-1	15.8^{a}	29.0^{a}	44.8^{a}	67.50^{a}	183.3^{a}	642.5^{a}	893.3^{a}
Yellow dodola	13.3^{b}	26.3^{a}	39.5^{b}	65.50^{a}	157.3^{ab}	568.0^{ab}	790.8^{ab}
Axana	10.5^{c}	17.0^{b}	27.5^{c}	49.50^{ab}	133.3^{bcd}	510.5^{bcd}	693.3^{bcd}
Blinda	9.3^{cd}	12.8^{c}	22.0^{d}	46.50^{b}	143.5^{abc}	538.5^{bc}	728.5^{bc}
Cabbage	8.3^{cd}	11.8^{c}	20.0^{d}	33.25^{bc}	108.8^{cd}	451.8^{cd}	593.8^{de}
Kale	7.8^{cd}	10.0^{c}	17.8^{d}	29.50^{c}	97.8^{d}	424.8^{d}	552.0^{e}
B. niger	8.0^{cd}	12.0^{c}	20.0^{d}	39.25^{bc}	112.3^{ab}	507.5^{bcd}	659.3^{cd}

Means in the same column followed by the same letters do not differ significantly at P=0.05 (Tukey's test).

RESULTS

Selection of brassicas by Alate *B. brassicae*

The number of cabbage aphid nymphs, winged adults and total aphids (nymph±winged adult) were significantly different on tested brassicae varieties on days three after infestation (Table 2).

Holeta-1 variety of *B. carinata* had the highest total number of alate aphids and nymphs (44.8 aphids/plant) and kale variety of *B. oleracae* the lowest (17.8 aphids/per plant) (Table 2). The number of alate, aptreous and nymphs on day 15 showed similar trend like that of the day three observation with the highest number of aphids on Holeta-1 (893.3 aphids/plant), the lowest on kale (552 aphid/plant) and the other varieties were in between (Table 2). Cabbage aphid preferred to feed on Holeta-1> followed by Yellow dodolla, Blinda, Axena, B. niger, cabbage and kale, in descending order of preference.

The day three pooled data of the varieties to species indicated that significantly more aphids were on *B. carinata* (44.38) than the remaining; *B. napus* (24.75), *B.* number of alates on *B. niger* and *B. oleracea* and the number of nymphs on *B. napus*, *B. niger* and *B. oleracea* were not significantly different. The trends were similar on day 15 and the highest number of aphids were on *B. carinata* (842 aphids/plant), the lowest on *B. oleracea* (572.9 aphids/ plant) and therewas no significant difference between *B. napus* and *B. niger* (Figure 1b).

Development and reproduction

The developmental times of the four instars and the total nymphal period of *B. brassicae* varied on the brassica varieties (Table 3). The longest development time for first and second instar was recorded on Blinda (1.53 days) and Holeta-1 (2.86 days), while the longest developmental time for third (2.26 days) and fourth (2.46days) instar were on kale. The first, third, and fourth instar aphids had the shortest period on Holeta-1 (Table 3). The total nymph period was significantly longer on Kale and there was no significant difference among the other brassicas. However, nymphal period were slightly higher on cabbage, Blinda and *B. niger* than Axana and *niger* (20) and *B. oleracea* (18.87) (Figure 1a). The Yellow dodolla. Adult aphids reared on Kale (2.1) had longer pre-reproductive period while those on Holeta-1(1.2 days) the shortest.

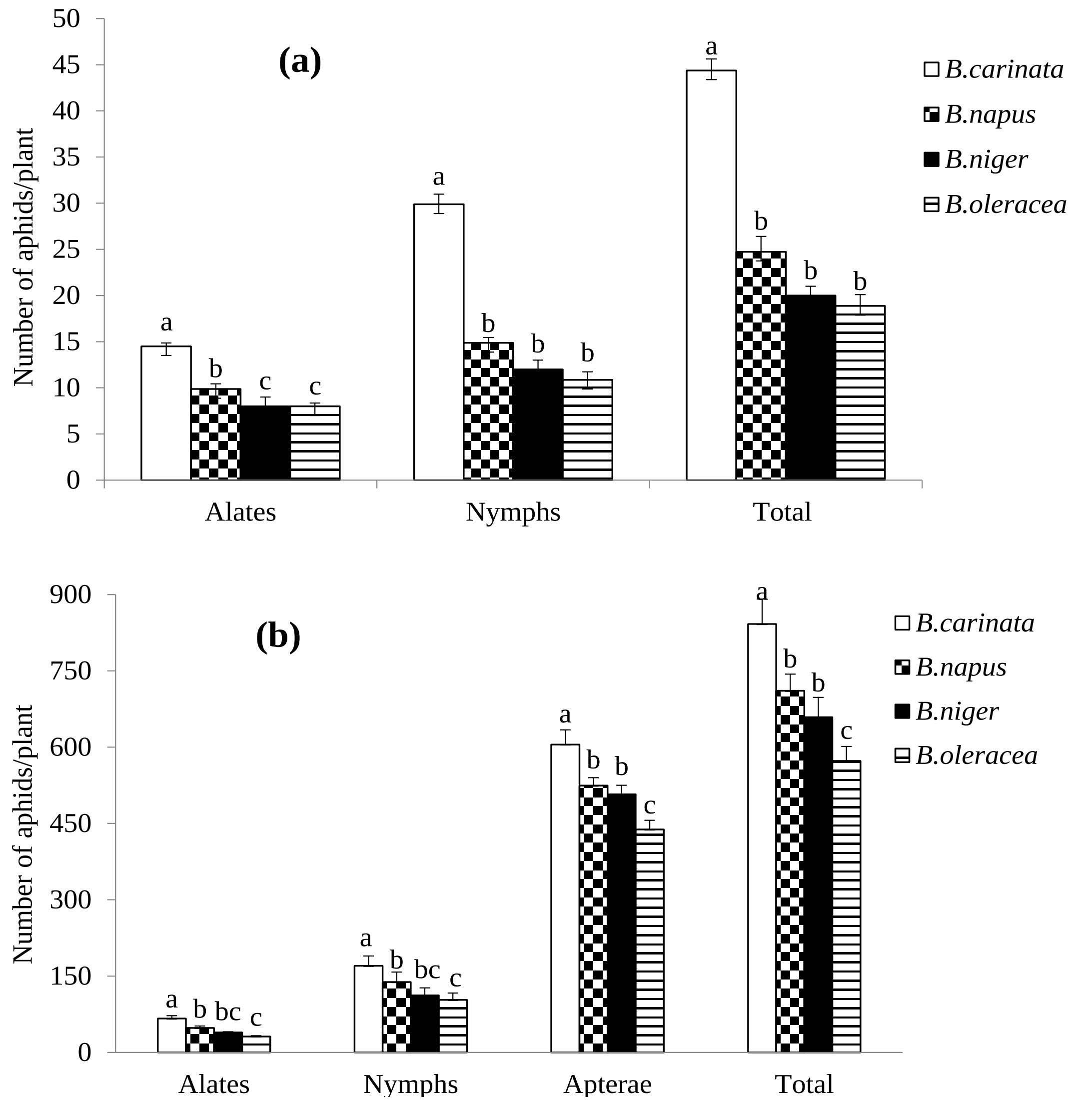

Figure 1. Number of nymphs, alate and apterae adults of *B. brassicae* on four brassica species on day three (a) and day fifteen (b) after infestation. Means ± SE in the same developmental stage (alate, apterae, nymphs) followed by the same letter do not differ significantly at P=0.05 (Tukey's test).

Table 3. Developmental period of nymphal instars of cabbage aphid, *B. brassicae*, on seven brassica varieties (Mean ±SE).

Varieties	Parameter					
	First instar	Second instar	Third instar	Fourth instar	Total Nymphal period	Adult Pre reproductive period
Yellow dodolla	$1.20±0.00^{ab}$	$2.40±0.19^{ab}$	$1.6±0.16^{b}$	$1.66±0.18^{b}$	$6.67±0.20^{b}$	$1.33±0.21^{bc}$
Holeta-1	$1.00±0.00^{b}$	$2.86±0.00^{a}$	$1.53±0.00^{b}$	$1.53±0.16^{b}$	$6.40±0.13^{b}$	$1.20±0.16^{c}$
Kale	$1.46±0.13^{ab}$	$1.60±0.17^{c}$	$2.26±0.13^{a}$	$2.46±0.12^{a}$	$8.86±0.55^{a}$	$2.06±0.13^{a}$
Cabbage	$1.33±0.00^{ab}$	$2.00±0.06^{bc}$	$1.86±0.16^{ab}$	$1.73±0.15^{b}$	$7.00±0.25^{b}$	$1.46±0.13^{bc}$
Axana	$1.46±0.10^{ab}$	$1.60±0.06^{c}$	$1.80±0.11^{ab}$	$1.80±0.17^{ab}$	$6.73±0.20^{b}$	$1.53±0.13^{abc}$
Blinda	$1.53±0.10^{a}$	$1.86±0.15^{bc}$	$1.80±0.12^{ab}$	$1.86±0.16^{ab}$	$6.90±0.19^{b}$	$1.80±0.13^{ab}$
B. niger	$1.33±0.00^{ab}$	$1.86±0.09^{bc}$	$1.67±0.06^{a}$	$1.66±0.12^{b}$	$6.93±0.16^{b}$	$1.26±0^{bc}$

Means in the same column followed by the same letters do not differ significantly at P=0.05 (Tukey's test).

Table 4. Biological parameters of *B. brassicae* on seven brassica varieties (Means± SE).

Varieties	Biological Parameter					
	Total pre reproductive period	**Reproductive period**	**Post reproductive period**	**Adult longevity**	**Life span**	**Total fecundity**
Yellow Dodolla	8.00±0.15[bc]	18.83±1.37[ab]	4.16±0.94[a]	24.52±2.17[ab]	30.90±1.94[ab]	73.1±2.9[ab]
Holeta-1	7.60±0.20[c]	18.50±0.67[b]	1.33±0.21[b]	21.29±1.05[b]	27.40±0.67[b]	76.3±2.1[ab]
Kale	10.93±0.18[a]	20.66±1.56[ab]	4.17±0.90[a]	27.00±2.03[a]	35.76±1.11[a]	66.8±1.8[ab]
Cabbage	8.40±0.23[bc]	20.83±0.98[ab]	2.67±0.98[ab]	25.17±1.27[ab]	31.90±1.58a	62.4±1.9[b]
Axana	8.26±0.22[bc]	15.66±1.52[b]	1.20±0.00[b]	18.56±1.76[b]	25.12±1.54[b]	64.6±5.6[b]
Blinda	8.73±0.25[b]	20.50±1.78[ab]	3.33±0.76[ab]	25.43±2.20[ab]	32.56±2.00[a]	72.2±2.9[ab]
B. niger	8.20±0.16[bc]	21.33±0.98[a]	3.50±1.45[ab]	25.66±0.98[ab]	33.03±0.91[a]	79.5±3.1[a]

Means in the same column followed by the same letters do not differ significantly at P=0.05 (Tukey's test).

Table 5. Demographic parameters for cabbage aphid *B. Brassicae* on seven brassica varieties (Means ± SE).

Varieties	Ro	T	r_m	DT	λ
Yellow Dodola	45.70±1.30[ab]	12.3±0.25[de]	0.310±0.01[ab]	2.23±0.1[de]	1.362±0.01[ab]
Holeta-1	47.75±2.87[a]	11.45±0.29[e]	0.337±0.02[a]	2.05±0.1[e]	1.399±0.02[a]
Kale	37.70±4.60[c]	15.2±0.16[a]	0.239±0.006[e]	2.9±0.08[a]	1.269±0.01[d]
Cabbage	38.25±2.19[bc]	14.5±0.28[ab]	0.25±0.01[de]	2.77±0.03[ab]	1.283±0.01[cd]
Axana	41.07±3.15[abc]	12.96±0.39[cd]	0.286±0.01[bc]	2.42±0.08[cd]	1.329±0.01[bc]
Blinda	39.7±1.36[abc]	13.3±0.18[cd]	0.276±0.01[cd]	2.51±0.04[bc]	1.316±0.01[c]
B. niger	38.70±2.90[bc]	13.9±0.24[bc]	0.262±0.006[cde]	2.65±0.07[abc]	1.298±0.008[cd]

The intrinsic rate of natural increase (r_m), net reproductive rate (R_0), finite rate of increase (λ), generation time (T) and doubling time (DT). Means followed by different letters within a column are significantly different at P=0.05 (Tukey's test).

The total pre reproductive, reproductive and post reproductive period of *B. brassicae* were significantly different among the brassica varieties (Table 4). The longest total pre reproductive was recorded on Kale (10.93 days) and shortest on Holeta-1 (7.6 days) (Table 4). Longest reproductive period was observed on *B. niger* (21.33 days) and the shortest period was on Axana (15.66 days). The adults lived longer on Kale (27days) and shorter on Axana (18.56 days). *Brevicoryne brassicae* had significantly different fecundity when reared on the seven varieties of brassica (Table 4). Fecundity was higher on *B. niger* (79.5 nymphs/female) and lower on cabbage (62.4 nymphs/female) and the other varieties were in between.

Life table parameters

The intrinsic rate of natural increase (r_m), net reproductive rate (Ro), population growth rate (λ), generation time (T) and doubling time (DT) of *B. brassicae* on seven brassica varieties were significantly different (Table 5).The aphids reared on Holeta-1 had the highest Ro (47.75), r_m (0.337days^{-1}), λ (1.39) and the shortest generation (11.45 days) and doubling times (2.05days). On the contrary, Ro, r_m and λ of cabbage aphids were the lowest and T and DT the longest on kale (Table 5).

Adult survivorship

The age-specific fecundity (mx) and survival of cabbage aphid reproduced on the seven varieties of brassica were significantly different (Figure 2). The aphids had higher survival on Holeta-1 and Yellow Dodola and followed by kale during the first ten days. On Blinda the aphids were surviving for four days and the decline started onwards. In all remaining hosts the decline in survival was at uniform rate. The highest age specific fecundity (mx) was observed on Blinda (14.18 nymphs/day) and followed by Holeta-1(12.5 nymphs/day), Axana (10.7 nymphs/day), *B. niger* (9.82 nymphs/day), kale (9 nymphs/day), Yellow Dodola (9 nymphs/day) and Cabbage (7.5 nymphs/day).

DISCUSSION

The host preference, biological and demographic

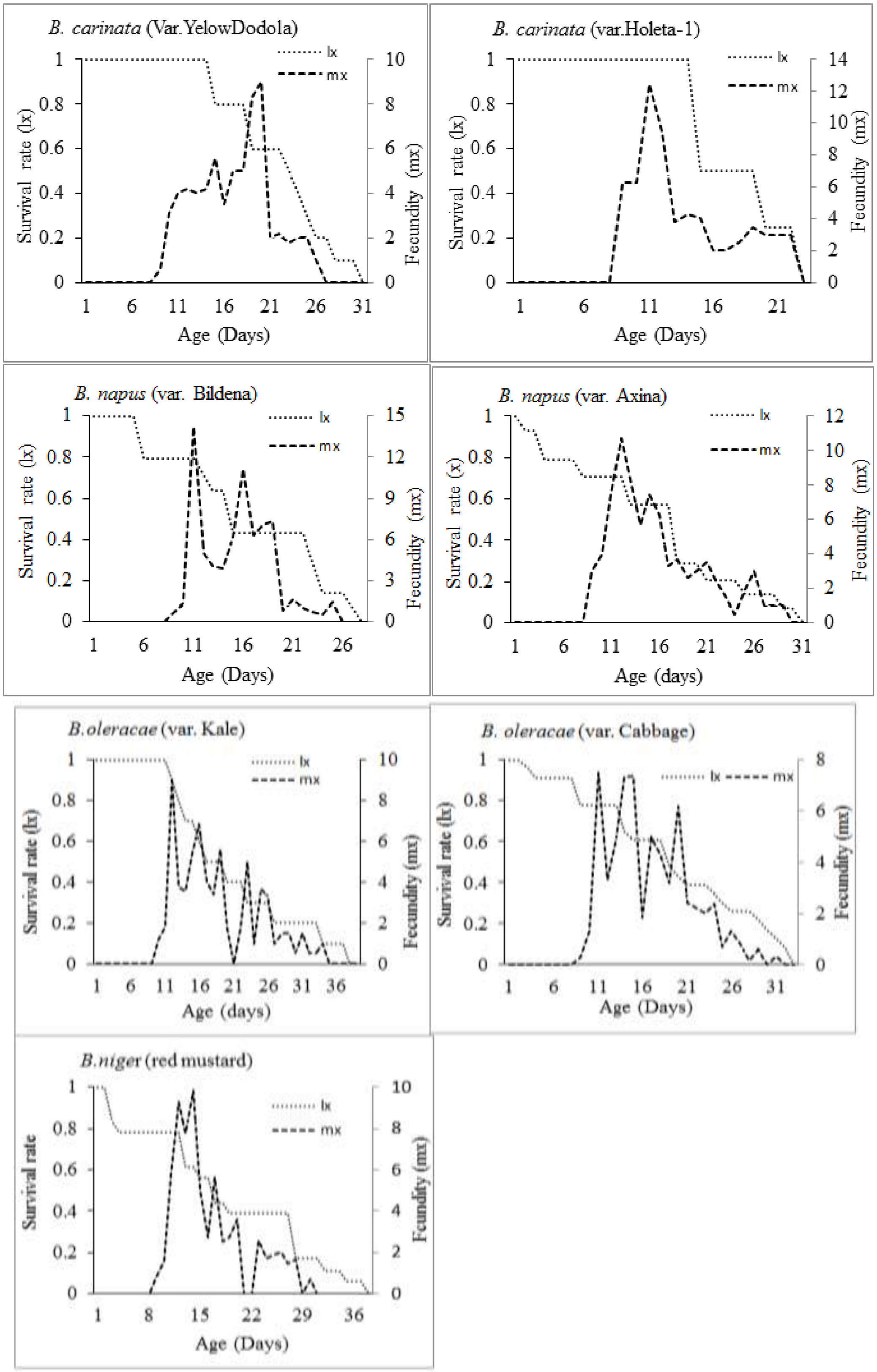

Figure 2. Age-specific survival rate (lx) and Age-specific fecundity (mx) of *B. brassicae* on seven brassica varieties.

parameters of cabbage aphid *B. brassicae* were significantly different on the seven brassica varieties. The aphid preferred to feed and reproduce on Holeta-1 more than the other tested varieties. As a result high number of nymph, apterae and alate aphids were recorded on this variety. The variation of insect performance on host plant could be described by the degree of plant resistance to a particular herbivore (Mirmohammadi et al., 2009). In the current study *B. carinata* variety Holeta-1 was found to be a suitable plant for aphid reproduction as compared to the other tested varieties.

The number of winged aphids varied among different species and between varieties of the same species. The variety Holeta-1 of *B. carinata* had significantly high number of winged aphids than Yellow Dodola. There was also more number of nymphs on Holeta-1 and Yellow Dodola than the other varieties. The higher number of nymphs could be due to the higher number of alates which preferred to feed on the host and the nutrition suitability of the host. In this study *B. carinata* was more suitable than the other tested species for the aphid reproduction. The variation on the number of aphid among the species could be due to the quality of the plant and the distribution of the different types of secondary metabolites among plant species. Quality variation in plant species influences the interactions between herbivore and its host plant and consequently its performance such as growth rates, fecundity, and survivorship (Zehnder and Hunter, 2008). The quality of the plants, such as physical, chemical or biological traits (for example size and structure, phenology, secondary compounds, and nutritional status) are important factor which influence the development, survival, longevity, and reproduction of herbivores (Mahdavi-Arab et al., 2014).

Nymphs of the cabbage aphid took longer developmental time on kale (*B. oleracae*) and faster on Holeta-1 (*B. carinata*). Different varieties of Brassicaceae family plants influence differently on the performance of brassica specialized insect pests (Sznajder and Harvey, 2003). Rebecca et al. (2011) reported that aphids reached reproductive maturity 14% faster when reared on *B. nigra* than *B. oleracea* plants which is in line with the current study. Recent study by Aziz et al. (2016) indicated that development time of cabbage aphid on different *B. oleracea* varieties were different and longer time was observed on KnolKhol (7.45 days) and followed by china cabbage (6.64 days) and cabbage (6.33 days). Study by Seyyed et al. (2014) on different varieties of *B. napus* showed that the developmental time of cabbage aphid varied from 8.38 to 9.16 days which is longer than the present study on the *B. napus* species (var. Axana and Blinda). Other studies by Jahan et al. (2014) on *B. oleracea* cauliflower cultivars the developmental time for immature of *B. brassicea* was ranged from 6.7 to 8.1 days which is in agreement with the current study on *B. oleracea* varieties. Studies by Bashir et al. (2013) on developmental time for immature of *B. brassicae* observed 7.94 days on cauliflower and 8.71 days on turnip. The variation on developmental time of the aphid could be due to the variation on nutritional quality of plant species, varieties and cultivars. Less sinigrin content in turnip leaves causes decline in the growth rate of *B. brassicae* and leads to longer nymphal development (Bashir et al., 2013).

The study also showed that the reproductive period, adult longevity and fecundity (number of nymphs per female) of *B. brassicae* significantly varied on tested varieties of brassica species. Cabbage aphid adults lived longer on *B. oleracae* (var. kale). Study by Rebecca et al. (2011) supports the current study and they found longer life span of *B. oleracae* when they reared on kale. Fecundity was highest on *B. niger*, followed by *B. carinata* (var. Holeta-1) and the lowest on *B. oleracea*. Studies by Jahen et al. (2014) on fecundity of *B. brassicae* on cauliflower cultivars indicated that, the fecundity was smaller than the current study on cabbage and kale and ranged from 30.9 to 58.6 nymphs per female.

Intrinsic rate of increase is most useful life table parameter to compare the fitness of populations of a specific species across different food resources (Ulusoy and Bayhan, 2006). The intrinsic rate of natural increase (r_m) was significantly different among tested brassica varieties. Intrinsic rate of increase (r_m) depends on the percentage of surviving nymph, developmental time, duration of nymph and fecundity of insect (Seyyed et al., 2014). The variety Holeta-1 had higher intrinsic rate of natural increase and kale the lowest on kale. Aziz et al. (2016) found that high intrinsic rate of increase on China cabbage (0.247) followed by Broccoli (0.218) and Cabbage (0.209), while the minimum on Knolkhol (0.104) which is comparable with the current study on *B. oleracae* varieties. Other studies by Ulusoy and Bayhan (2006) found that, the intrinsic rates of increase for cabbage aphid was 0.235, 0.201 and 0.197 on Cauliflower, Cabbage, and Broccoli, respectively which is smaller than the current study on cabbage. Study by Mirmohammadi et al. (2009) indicated that, the intrinsic rate of increase were higher on Hayola 401 and lower on Zarfam which is higher than the current result on two *B. napus* varieties (Axina and Bildena).

The capacity of plant resistance to a given insect pest could be measured by the variation of the pest performance on the host plants. The differences in the biological parameters can be attributed to the differences in the nutritional quality, physiology, morphology and chemistry of the host. Evaluating the antixenosis and antibiosis effect of different brassica crops for cabbage aphid *B. brassicae* has been employed to develop resistant varieties and include in integrated pest managements programs. The use of crop varieties that support only the low pest population growth or even of moderately resistant varieties is an important part of integrated pest management. Hence, our results may present valuable information for the management of the cabbage aphid *B. brassicae* in Ethiopia. They suggest that growing brassica varieties that are more or less tolerant to the *B. brassicae* population growth, may suppress or delay pest outbreaks and reduce the need for chemical control measures.

Conclusion

The knowledge on host plant effects on reproduction, development, survival and preference of insect pest is essential for developing pest management options. And the current study deals on the effect of seven different varieties on performance and preference of the specialist aphid *B. brassciae*. The aphid preferences to feed and to continue its reproduction on variety Holeta-1. However, the reproduce slower on variety Kale and the other varieties are in between. The study showed that cabbage aphid *B. brassicae* prefers to feed and reproduce more on *B. carinata* plants than *B. napus*, *B. niger* and *B. oleracae. B. oleracae* varieties are resistant to cabbage aphid *B. brassicae* compared to the other tested Brassicae species.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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