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Biotic potential of aphid parasitoid, Diaeretiella rapae (Hymenoptera: Braconidae: Aphidiinae) at different temperature regimes

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Abstract

The efficiency and development of the insect's natural enemies affects greatly with changes in environmental conditions. Diaeretiella rapae M'Intosh (Hymenoptera: Aphidiidae) is one of the most common and successful parasitoids of the cabbage aphid *Brevicoryne brassicae* (L.) (Hemiptera: Aphididae). The biotic potential of D. rapae fed on B. brassicae was assessed in terms of parasitism rate, adult emergence, longevity and developmental period at different temperature regimes; 15, 20, 25, and 30 ºC. Results of the present research showed that maximum percent parasitism (41.16% ± 0.80) and adult emergence (75.43% ± 1.04) of D. rapae were observed at 25ºC and minimum at 15ºC of about 14.02% ± 0.97 and 36.72% ± 1.93 respectively. Total longevity and development period (egg-adult emergence) at higher temperature (30ºC) were observed about 6.33 ± 0.33 days and 7.67 ± 0.57 days respectively. Adult longevity of D. rapae was maximum at 25ºC of about 9.67 days ± 0.34. Development time of parasitoid was higher (17.33 days ± 1.16) at lower temperature regime (15ºC). The study indicates that development between 20-25oC was favorable for D. rapae parasitoid and it can tolerate to a higher temperature at 30oC. Therefore, it could be a preferable candidate for the biocontrol program for aphids in relatively warmer climates.

Keywords: Development time; *Diaeretiella rapae*; *Brevicoryne brassicae*, Parasitism; Threshold temperature.

Introduction

The cabbage aphid, Brevicoryne brassicae (L.) (Hemiptera: Aphididae) is a herbivorous perennial insect pest species attacks many cruciferous crops (1). It causes direct damage by resulting chlorosis and leaf curling, while disrupting the plant growth and development (2). It also causes indirect damage through transmission of viral diseases (3). Nowadays, biological control is being considered a satisfactory tool in integrated pest management (IPM). For the eco-

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friendly management of various insect pests, parasitoids have been applied successfully in the cropping system (4). Diaeretiella rapae M'Intosh (Hymenoptera: Aphidiidae) is a cosmopolitan and koinobiont endoparasitoid of many aphid species (5) and is being considered as a successful parasitoid of B. brassicae (6). D. rapae parasitizes more than 60 aphid species on a range of horticultural and agricultural insect pests (7). Parasitic attributes of many parasitoids are impacted by environmental conditions(8). Ambient temperatures are important to determine population dynamics of parasitoids and their dispersal in suitable habitats (9). The parasitism rates mainly depend on the ability of any parasitoid to locate the host successfully, select, and oviposit in or on the hosts. All these processes are often temperature dependent, so environmental variations may affect the interactions between the host and the parasitoid by altering virulence in parasitoids and resistance in the host (10). Temperature changes various biological aspects of insects such as sex ratio fertility, survival, adult longevity (11). Thermal low and constant temperature gives valuable information about the development rate of certain arthropods (12). However, the parasitoid's potential, adult longevity, development time, total life span and parasitism rate depend on the temperature (13).

The present study was performed to evaluate the biotic potential including parasitism rate, adult emergence, longevity and development period of D. rapae when fed on B. brassicae under different temperature regimes.

Materials and Methods

From reared culture one month old (2nd generation) of B. brassicae and newly emerged adult parasitoids were used for this experiment.

Experimental procedure: Colonies of about hundred aphids (both adult and nymph) were released on fresh twigs of canola plants into plastic cages (30×25×10 cm). Five pairs of parasitoids were introduced for twenty-four hours stinging period. At the end of oviposition period, the plants were exposed nymph were transfered into clean petridishes and placed in incubator at different temperature regimes (15, 20, 25 and 30 ºC and relative humidity for all temperature regimes was same 65-70 %). Aphid population was observed four times a day to check mummies formation. Mummies were collected in glass vials and reverted to same temperature. All mummies were observed daily until emergence of adult parasitoids. Adult parasitoids were transfered into plastic vials (25 × 10 cm) and kept under the same temperature. Adult were fed with 10% honey solution (14).

Study parameters, Percent parasitism: After mummies formation, percent parasitism was recorded by using by this formu

$$\text{Percent parasitism} = \frac{\text{No. of mummies}}{\text{Total number of aphids}} \; x\, 100$$

Percent emergence: For percent emergence of adult parasitoid, each mummy was put into Eppendorf tube. When mummies change into dark brown (near to emergence), a cotton soaked honey solution (9:1) was kept into tube (15). Percent emergence was recorded by using this formula,

$$\text{Percent emergence} = \frac{\text{No. of adult emerged}}{\text{Total number of mummies}} \; x\, 10$$

Adult longevity: To calculate adult longevity of D. rapae from each aphid density, emerged parasitoids were transfered into clean Eppendorf tube. Parasitoids were fed by 10 % honey solution. Daily observation was done to check the longevity until they died.

Development periods (Egg laying to adult emergence) at different temperature regimes were also recorded.

Statistical analysis: Data on percent parasitism, adult emergence and adult longevity of parasitoid were analyzed using completely randomized design (CRD) to check the effect of different temperature regimes on parasitoid and means were separated by tukey's HSD all pair-wise comparison test.

Result

Analysis of variance for percent parasitism and adult emergence of Diaeretiella rapae at different temperature regimes: Analysis of variance for percent parasitism of the D. rapae and adult emergence of parasitoid at different temperature regimes under completely randomized design are shown in (Table 1). The result showed that temperature regimes as treatment had highly significant impact on the percentage parasitism and adult emergence of D. rapae. Because P-value is <0.001 for both analysis of variance.

Table 1 Analysis of variance for percent parasitism and adult emergence of *D. rapae* at different temperature regimes

SOV	DF	SS	MS	F	P
Percentage parasitism					
Treatments	3	1202.65	400.883	99.9	<0.001
Error	8	32.09	4.011		
Total	11	1234.74			
Percent emergence					
Treatments	3	2413.06	804.355	12.6	<0.001
Error	8	509.91	63.738		
Total	11	2922.97			

(P≤0.05) Highly Significant

Percentage parasitism of Diaeretiella rapae at different temperature regimes against Brevicoryne brassicae: Percent parasitism of D. rapae at different temperature regimes against aphid host, B. brassicae is shown in (Fig 1). The result showed that percent parasitism increased with the increased in temperature. But the parasitoid decreased parasitism rate when temperature is more than its capacity to parasitized due to the excessive temperature. This graph showed that maximum percent parasitism (41.16 % ± 0.80) was observed under 25 °C and minimum parasitism (14.02 % ± 0.97) was recorded at 15 °C of D. rapae. Other two temperature regimes, 20 °C and 30 °C showed the percent parasitism of 34.57 % ± 1.47 and 30.51 % ± 1.27 respectively. This result showed that temperature (20-25 °C) was most suitable for parasitism under laboratory conditions.

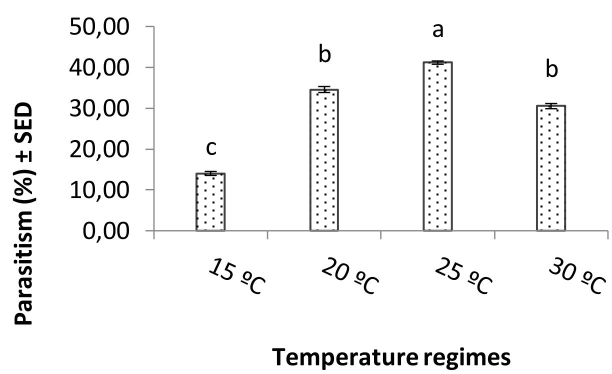

Figure 1. Percentage parasitism of D. rapae at different temperature regimes against *B. Brassicae* (Mean ± SED) mean followed by same letters are not significantly different for each temperature regime (Tuckey HSD, P≤0.05)

Adult emergence of Diaeretiella rapae from mummies at different temperature regimes against Brevicoryne brassicae: Diaeretiella rapae adult emergence from mummies at different temperature regimes is shown in (Fig. 2). The results showed that increased in temperature regimes the percent adult emergence from mummies of B. brassicae leads to increase. The maximum percent adult emergence (75.43 % ± 1.04) was recorded at 25 °C and minimum adult emergence (36.72 % ± 1.93) of D. rapae at 15 °C. Other two temperature regimes showed 49.17 % ± 2.04 and 59.35 % ± 1.35 adult emergence of D. rapae at 20 °C and 30 °C respectively.

All the temperature regimes used in present findings were significantly different to each other. But most preferable temperature for adult emergence of D. rapae from B. brassicae was 20-25 ºC.

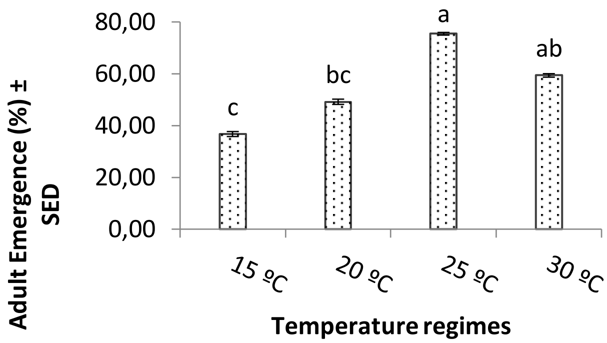

Figure. 2. Adult emergence of Diaeretiella rapae from mummies at different temperature regimes against Brevicoryne brassicae (Mean ± SEM) mean followed by same letters are not significantly different for each temperature regime (Tuckey HSD, P≤0.05)

Relationship of different temperature regimes with percent parasitism and adult emergence of *Diaeretiella rapae:* Relationship of different temperature regimes with percent parasitism and adult emergence of D. rapae from mummies of B. brassicae are shown in (Fig. 3). The present findings showed that with the increase in temperature the percent parasitism and adult emergence are also increases. The R2 value for percent parasitism and percent adult emergence are 0.3918 and 0.551 respectively. The linear trend line shows the positive relationship of temperature regimes with parasitism and emergence. But from its values and trend line it clearly shown that percent adult emergence showed strong relation instead of percent parasitism which showed weak relation with temperature regimes.

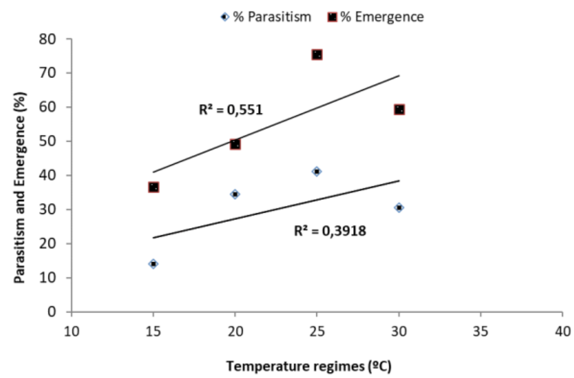

Figure 3. Relationship of different temperature regimes with percent parasitism and adult emergence of D. rapae

Total longevity and development time of Diaeretiella rapae at different temperature regimes: In (Table 2) total longevity and development (Egg-Emergence) of D. rapae at different temperature regimes are shown in this table. In case of total longevity of D. rapae at different temperature regimes, the maximum longevity (9.67 days) was recorded at 25 ºC and minimum longevity (6.33 days) was recorded at 30 ºC. Other two temperature regimes which are used in present studies showed 6.67 and 8.00 days at 15 ºC and 20 ºC respectively. The results showed that different temperature regimes strongly impact on adult longevity. Same results were noticed in case of development period of D. rapae at different regimes of temperature. The maximum development period (17.33 days) was recorded at 15 ºC temperature and minimum (7.67 days) at 30 ºC temperature. The results clearly shown that temperature increases lead to increase in total adult longevity and development period from egg laying to adult emergence. But due to maximum (30 ºC) and minimum (15 ºC) temperature the total longevity and development time period increased as well decreased. Because at low temperature parasitoid survival is minimum in case of average temperature. The best temperature range for development at longevity is 20-25 ºC in laboratory condition.

Table: 2 Total longevity and development time of D. rapae at different temperature Regimes

Temperature Regimes (°C)	Total longevity (Days) ± SE	Development (Days) ± SD
15	6.67 ± 0.67^{b}	17.33 ± 1.16^{a}
20	8.00 ± 0.58a^{b}	14.66 ± 0.58^{b}
25	9.67 ± 0.33^{a}	10.33 ± 0.57^{c}
30	6.33 ± 0.33^{b}	7.67 ± 0.57^{d}

ANOVA values for total longevity showed F= 9.19 and P= <0.005 and for development F= 96.2 and P= <0.001

Discussion

In biological control, natural enemies are unprotected from the ecological interaction such as temperature which change the biological parameters (16) Diaeretiella rapae is most popular among different other parasitoids. The efficacy of parasitoid, D. rapae is significantly temperature dependent. Their adult longevity, parasitism, adult emergence, and development time depend upon temperature. To check these parameters present study was conducted under laboratory. Result of this study showed that the percent parasitism increased with increased in temperature, but very high temperature negatively impacts on level of parasitoid potential. Present findings were that maximum percent parasitism (41.16 %) was observed under 25 °C and minimum parasitism (14.02 %) was recorded at 15 °C of D. rapae. Other two temperature regimes, 20 °C and 30 °C showed the percent parasitism of 34.57 % and 30.51% respectively. This result showed that temperature (20-25 °C) is most suitable for parasitism under laboratory conditions. Present findings confirmed with Fand et al. (2011) and Abdin et al. (2013) that due to changing in environmental condition the fitness of parasitoid affected. These finding similar to Sigsgaard (2000); Malina and Praslicka (2008) who reported that percentage parasitism of parasitoid increased with increased temperature. According to studies of Tahriri et al. (2007) and Appiah et al. (2013) the temperature showed significant impact on parasitism rate of parasitoid wasps. Present results are also correlate with the Zamani et al. (2007) and Pourtaghi et al. (2016) who concluded that parasitoids, A. colemani and A. matricariae showed maximum parasitism at 25 °C against A. gossypii. But due to increase in temperature (30 °C) the mortality rate of both parasitoids increased. Present results suggested that decrease in parasitization at 30 °C the parasitoid D. rapae cannot tolerate especially in month of summers.

Present findings resulted that R2 value for percent parasitism and percent adult emergence are 0.3918 and 0.551 respectively. The linear trend line shows the positive relationship of temperature regimes with parasitism and emergence. But from its values and trend line it clearly shown that percent adult emergence showed strong relation instead of percent parasitism which showed weak relation with temperature regimes. These findings also similar to Sigsgaard (2000) who showed that there is linear relationship was present between parasitism and temperature. So, it recommended that at higher temperature the parasitoid could not perform well.

In case of adult longevity, the results showed that D. rapae at different temperature regimes, the maximum longevity (9.67 days) was recorded at 25 °C and minimum longevity (6.33 days) was recorded at 30 °C. Other two temperature regimes which are used in present studies showed 6.67 and 8.00 days at 15 °C and 20 °C respectively. The results showed that different temperature regimes strongly impact on adult longevity. When physical factors such as temperature and relative humidity are maximum the fecundity rate affected the longevity of parasitoid. These present findings are correlated with the Miller and Gerth (1994) who observed that higher temperature negatively impact on adult longevity of A. matricariae. They also suggested that at higher temperature there is less emergence of adult parasitoid occur. These results are also same with present findings results. Same results are concluded by Van Tol and Van Steenis (1994) and Ohta et al. (2001) that A. colemani survival rate of decreased with increased in temperature and same effect present on A. gefuensis respectively. These results can be helpful for determination of stage of parasitoid which released in field level for biological control.

The results of present findings about development period of D. rapae showed that development period of D. rapae at different regimes of temperature. The maximum development period (17.33 days) was recorded at 15 ºC temperature and minimum (7.67 days) at 30 ºC temperature. The results clearly shown that temperature increases lead to increase in development period from egg laying to adult emergence. But due to maximum (30 ºC) and minimum (15 ºC) temperature the total longevity and development time period increased as well decreased. Because at low temperature parasitoid survival is minimum in case of average temperature. These results are also correlate with Malina and Praslicka (2008) who observed that development period for D. rapae under laboratory conditions are 8-15 days at 15 - 25 ºC, but at 30 ºC was lower (11 days). Results of present findings are similar to the results of (8) who observed that minimum development period (10.6 days) at 30 ºC and maximum period (24.3 days) at 15 ºC. They suggested that development period decreased with increase in temperature.

At higher temperature the metabolic rate of foraging insect increased with increased in temperature according to Wu et al. (2011). My results are similar to the results of (13) who observed that higher temperature increases the metabolic rate, parasitism rate and as well as egg laying capacity of parasitoid increased. According to Mohyuddin and Greathead, 1970; Overholt et al., 1997; Potting, 1997 and Wiedenmann et al., 1992) the interaction of relative humidity and temperature positively affect the adult longevity of C. flavepes. Results of this experiments are similar with Hayakawa et al., (2014) who investigated that reproductive potential and development period of D. rapae are maximum at 30 ºC, but at high temperature the longevity of parasitoid reduced which ultimately reduced the fecundity rate. The present findings show same results as Moayeri et al., (2013) who examined that searching rate and handling time are influenced by the high temperature. Present results are also similar with Goh et al., (2001) who reported that A. colemani population are influenced with temperature. The consequences of present research might be useful for mass rearing as well as release of D. rapae in field for the control of B. brassicae. Further experiments will also be conducted to investigate the role of temperature for the suppressing the population of B. brassicae in future.

In temperature regimes study the temperature play an important role in parasitism, development, adult longevity and as well as on adult emergence. The very low temperature and very high temperature affect all these parameters because at high temperature the development increased but adult longevity decreased. Due to decreased in adult longevity the fecundity rate of parasitoid decreased which decreased the emergence as well as percentage parasitism. The suitable temperature for parasitoid parasitism and adult emergence of D. rapae were 21-25 ºC. The relationship of temperature regimes with percentage parasitism and adult emergence was positive but not strongly relate in both cases such, percent parasitism and adult emergence. According to result of this experiment, temperature predict the presence of D. rapae in B. brassicae colonies when temperature at 21-25 ºC.

Conclucions

The present study showed that development and parasitism rate of D. rapae with B. brassicae as a host was greatly influenced by temperature. Temperature ranging from 20 and 25 °C resulted in a short developmental time and highest percentages of parasitism and emergence. Th temperature range of 20-25 ºC was best for rearing D. rapae on B. brassicae as a host at laboratory conditions. Further studies are needed under field conditions.

Declaration of Interest: The author declares that there is no conflict of interest regarding the publication of this paper.

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