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Research Article

Effect of diverse locations on the biological attributes of predatory bug, *Andrallus spinidens* (Fabricius) (Hemiptera:Pentatomidae) thriving in North-Western Himalayan region

BHOJENDRA*, R. P. MAURYA, LATIKA BRIJWAL, HIMANSHU PATWAL and PARUL SUYAL
Department of Entomology,College of Agriculture, G.B. Pant University of Agriculture and Technology, Pantnagar-263145, U.S. Nagar, Uttarakhand, India
******Corresponding author E-mail*: patelbhojendra95@gmail.com

ABSTRACT: Investigations were carried out during 2018-2019 to study the effect of different geographical locations of North-Western Himalayas on biology and predation efficiency of *Andrallus spinidens* thriving in different crop ecosystems. Present analysis showed that there was no siginicant difference in predation efficiency and biology of *A. spinidens* from different altitudes of five different locations. Incubation period of predatory bugs varied from 6.41 ± 0.09 to 6.77 ± 0.29 days. Total nymphal period varied from 16.33 ± 0.67 to 18.67 ± 0.88 days. Adult longevity of unmated male and female ranged from 12 ± 1 to 13.66 ± 1.86 and 17.32 ± 0.88 to 19.33 ± 0.67 days, respectively. Adult longevity of mated male and female ranged from 4.66 ± 0.33 to 9 ± 0.58 and 11.67 ± 0.88 to 15 ± 0.58 days, respectively. Survival rate of female predatory bugs was observed longer than unmated male predatory bugs. In their first nymphal instar, predatory bug feed on plant sap, while the second instar nymph prey on its laboratory host, *Spodoptera litura* **(**Fabricius) (Lepidoptea: Noctuidae). The predation efficiency of the adult male varied from 57.54 ± 1.48 to 63.50 ± 1.92 per cent, whereas, in adult females it varied from 64.58 to 67.58 ± 0.73 per cent. By comparing the predation efficiency of adult *A. spinidens* from all five geographical locations it was observed that female predatory bugs are better predators than male predatory bugs. The study showed that no significant differences were observed in the biology or predatory efficiency of *A. spinidens* when present in different climatic and geographical locations. This suggested that the predator has adapted itself in different climatic conditions by maintaining its biological attributes which enhance the success rate of its potential as predator on commercial level.

Key words: *Andrallus spinidens*, biology, biological control, predation efficiency, predator

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INTRODUCTION

Andrallus spinidens F. (Hemiptera: Pentatomidae) is an important predatory bug distributed worldwide (Distant, 1902; Thomas, 1992; Thomas, 1994). This predator was found to be associated with lepidopteron pests of rice, wheat, soybean, urd, moong, pigeonpea, maize, sugarcane, cowpea and poplar ecosystems (Ghosh, 1914; Singh and Gangrade, 1975; Rajendra and Patel, 1971; Singh and Singh, 1989; Cherian and Brahmachari, 1941; Shylesha and Sravika, 2018). It mainly feeds on *Helicoverpa armigera*, *Spodoptera litura*, *Chilo suppressalis* and *Naranga aenescens* (Rajendra and Patel, 1971; Rao and Rao, 1979; Mohaghegh and Massod, 2007; Claver and Jaiswal P. 2013). In India and other countries, both nymphs and adult stages have also been reported as a potential biocontrol agent in rice and different field crops (Rao, 1965; Manley, 1982; Mohaghegh and Najafi, 2003). In north western Himalayas, this predator was found to be associated with *Mythimna separata* on wheat, leaf folder on paddy, *Spodoptera litura* on pulses viz. pigeonpea, soybean, moong and urd bean (Pawar, 1976; Agnihotri *et al*., 2012) and also on Mexican beetle, *Zygogramma bicolorata* (Pandey *et al*., 2002). Liquefaction of prey by extra-oral digestion is important to predaceous nature of heteropterans as their mouthparts permit uptake of only liquid food so they inject their stylet into the prey's body (Cohen, 1995; 1998).

Besides having a potential as biocontrol agent, yet less attention has been made to use this predatory bug at commercial level. A limited number of published data is available on their ecology, biology and mass rearing (Cherian and Brahmachari, 1941; Rajendra and Patel, 1971; Rao and Rao, 1979; Manley, 1982; Singh and Singh, 1989; Mohaghegh and Najafi, 2003; Uematsu, 2006; Mohaghegh and Massod, 2007). The major constraint in rearing of the predatory bug is to maintain adequate supply of laboratory

host. Presently no information is available on the effect of geographical changes and environmental conditions like temperature, humidity, parasite and toxins on biology and predatory efficiency of *A. spinidens*. This study will give better understanding of predatory bug as biological control agent for successful implementation of the pest management program at field level (Alcock 1984; Tauber *et al*., 1986; Foster and Harris 1997; Renou and Guerrero 2000).

India's North-Western Himalayas region, Uttarakhand is bestowed with different environmental conditions due to virtue of extensive geographical stretch viz., high hill, middle hill, foot hill and *Tarai* region (Samant *et al*., 2007). Environmental changes having complex interaction with insect population and their behavior even within a species which suggested that change in geographical condition will also affect their morphology, feeding, reproduction, predatory efficiency, mortality, fecundity, prey selection and longevity of insect (Dingle and Hegmann, 1982; Tauber *et al*., 1986; Gatehouse, 1989; Dempster and McLean, 1999; Sokolowski, 2001).Hence, present investigation was carried out to study the effect of different geographical locations on biology and predation efficiency of *A. spinidens* in Kumaon region of Uttarakhand.

MATERIALS AND METHODS

To study the effect of different geographical locations on the biological attributes of *Andrallus spinidens*, different stages of the predatory bug were collected from diverse locations viz., plain (*Tarai*), foot hills, mid hills and high hills of Kumaon region of North West Himalaya during 2017-2018 (Table 1). From each geographical location, three different crop fields were surveyed (Ellango *et al.,* 2015) and samples of *A. spinidens* were collected manually through hand picking method. Bugs were reared in Biological Control Laboratory, Department of Entomology, G. B. Pant University of Agriculture and Technology, Pantnagar, Uttarakhand, India.

Rearing and culture maintenance

For rearing of *A. spinidens*, collected egg batches and nymphal instar from different locations were placed into different plastic containers (20 × 20 × 15 cm). Bottom surface of the container was lined with blotting paper and provided with moist cotton balls to maintain humidity. The container was properly covered with muslin cloth to ensure suitable aeration. Adults were kept inside insect rearing cage (3' × 3' × 2.5'). All plastic containers and insect rearing cages were kept under a photoperiod regime of 16h light: 8h darkness (LD 16:8) at 32 ± 2°C temperature and 75 ± 5% relative humidity throughout the rearing period. During the culture maintenance green bean pods and moist cotton balls were provided for first instar nymph (Manley, 1982) and larvae of *Spodoptera litura* F. (Lepidoptera:Noctuidae) provided to be a factitious host for second instar predatory nymphs and onwards (Shintani *et al*., 2010).The culture of *S. litura* was also maintained for effective rearing of predatory bugs (Shorey and Hale, 1965; Kumar and Ballal, 1991).

Study on variability in biology of *Andrallus spinidens* collected from different locations

To study the variability in biology of *A. spinidens* due to diverse locations, newly hatched first instar nymph in group of five, were placed in plastic container (20 × 20 × 15cm) and provided chopped bean pods and moist cotton as feed. After the first moulting, third instar larvae of *S. litura* provided as feed to second instar nymphs and onwards. Duration of each nymphal instar and total nymphal period were recorded devotedly. After the adult emergence, to workout adult longevity in mated and unmated predatory bug individual male, female and pair of male and female adult were placed in separate containers. Inside the container of paired adults some strips of blotting paper was provided as substrate for oviposition. After oviposition, egg batches were removed with paper strips and placed in separate plastic containers (20 × 20 × 15cm) to record incubation period and hatching per cent (Shanker *et al.*, 2017; Tiwari *et al*., 2017). All experiments were performed with three replications for each location.

Study on variability in predatory efficency of *Andrallus spinidens* from different location

To study the variability in predatory efficiency of *A. spinidens* from different location, each nymphal instar reared on the larvae of *Spodoptera litura* was investigated. (Uematsu, 2006; Shanker *et al.,* 2017).

First nymphal instar of *A. spinidens* was provided green bean pod and moist cotton as they showed non predatory behaviour (Waddill and Shephard, 1974; Manley, 1982). For observing predation rate in each nymphal instar of *A. spiniens,* daily a fixed number of host larvae was provided as feed. After 24 hour, numbers of larvae consumed were counted and recorded and fresh larvae provided for next day. During experiment daily ten third instar *S. litura* larvae per box were provided to each nymphal stage of *A. spinidens*.

To observe the predation rate in different sex, individual male and female were placed into different containers (20 × 20 × 15 cm). Each container provided ten number of third instar *S. litura* larvae per day. Same procedure was repeated with predatory bugs of five different locations with three replications.

Data analysis

All experiments were carried out in three replications and results were expressed as mean value ± standard error (SE). The statistical analyses was carried out in SPSS (Statistical Package for Social Science, version 16). Analysis of variance was performed by ANOVA as described by Arkkelin (2014). The significance of each group was verified with one-way ANOVA and statistical significance of result measured by using Duncan's multiple range post hoc test at $P < 0.05$.

RESULTS AND DISCUSSION

In the present study predatory bugs from different altitudes like Almora (1212mt/3976ft), Majhera (922mt/3026ft), Ramnagar (367mt/1204ft), Tanakpur (255mt/837ft) and Pantnagar (235mt/771ft) were sampled (Table 1). Results obtained from investigation conducted on biology revealed that there were no significant differences in life duration, fecundity and incubation period among the samples of predatory bug *Andrallus spinidens* collected from five different geographical locations (Table 2).

Study on biology of *A. spinidens* prey on *Spodoptera litura* revealed that this predatory bug completed their nymphal life in five instars (Table 2). Investigation on nymphal period showed that shortest nymphal period was first nymphal instar which ranged from 2 ± 0.12 to 2.67 ± 0.24 days whereas, longest nymphal period was fifth instar which varied from 4.33 ± 0.33 to 5 ± 0.00 days. The result for ANOVA (Table 3) and developmental nymphal satge summarized through Duncan's multiple range post hoc test (Table 2) showed that there was no significant effect on the homologous subset of nymphal period (during 1st to 5th nymphal mean square between locations varied between 0.100 to 0.33 with 0.30 to 2.488 F ratio at *p* 0.11 to 0.87 significant value; at df 14) of predatory bugs collected from different geographical locations with reference to their five nymphal satges. The total nymphal period ranged from16.33 ± 0.67 to 18.67 ± 0.88 days with 3.23 mean square between location groups and 2.55 F ratio at *p* 0.10 significant value at 14 df (Table 2 and Table 3). Lam (2000) also reported first instar as shortest nymphal instar with period of 2.56 days, fifth nymphal instar as longest with period of 5.01 days and total nymphal period of 18.53 days. Manley (1982) studied biology of *A. spinidens* on grain moth larvae *Plodia interpunctella* and reported first and fifith nymphal instar as shortest and longest nymphal period of 2.6 and 5.4 days, respectively with total nymphal period of 19 days. Khodarverdi *et al.* (2012) also observed five nymphal instars in *A. spinidens* during their biology study. Kumar *et al.* (2007) reported on another predatory bug *E. furcellata* (Hemiptera:Pentatomidae) where they provided *S. litura* as feed and found 16.78 days as total nymphal period with similar five nymphal stages. Mohaghegh and Amir-Maffi (2007) studied the effect of live and frozen larve of *Galleria mellonella* and *Ephistia kuhniella* and observed five nymphal instars of *A. spinidens*.

Female predatory bugs at each location survived for more number of days than male bugs of that location and there was no significant difference with respect to sample collection because the longevity of unmated male varied from 12 ± 1 to 13.67 ± 1.86 (mean square 2.23 between location and 0.49 F ratio at *p* 0.78 significant value) and the unmated female varies 17.33 ± 0.88 to 19.33 ± 0.67 days, respectively (1.60 mean square with 0.47 F ratio at *p* 0.75 significant value). The total life period of unmated male and female varied from 34.33 ± 1.76 to 39.33 ± 0.67 days and 40.33 ± 0.88 to 45 ± 1.53 days, respectively (for unmated male mean square 12.56 with 1.94 F ratio at *p* 0.18 significant value and for unmated female mean square 9.93 with 1.50 F ratio at *p* 0.27 significant value). Longevity of mated male and female non-significantly varied from 4.67 ± 0.33 to 9 ± 0.58 and 11.67 ± 0.88 days to 15 ± 0.58 days, respectively (for mated male between location square mean 8.73 and 3.97 F ratio at *p* 0.35 and for mated female between location square mean 4.73 and 1.12 F ratio at *p* 0.39 significant value). Also, total life period of mated male and female non significantly varied from 29.33 ± 0.88 to 34 ± 1.73 and 34 ± 1 to 40.67 ± 0.67 days, respectively (for mated male between location square mean 13.23 and 2.87 F ratio at *p* 0.08 and for mated female between location square mean 20.90 and 4.41 F ratio at *p* 0.026 significant value) (Table 2 and Table 3).

Table 1: Details of locations covered in Kumaon region of Uttarakhand for collection of *Andrallus spinidens.*

S. No.	Location	Coordinates	Area described	Elevation
1	Pantnagar	29°3'0"N 79° 31'0"E	Tarai	235mt/771ft
2	Ramnagar	29°24'20"N76° 358'24" E	River valley/foot hills	367mt/1204ft
3	Tanakpur	29.0722° N, 80.1066° E	River valley/foot hills	255mt/837ft
4	Majhera	29°16'6" N 80° 5'19" E	River valley/ mid hills	922mt/3026ft
5	Almora	29°81'50" N 79° 29'02" E	River valley/ high hills	1646mt/5400ft

Table 2. Biology of *Andrallus spinidens* collected from different location of Uttarakhand

Life stages/ Location	First instar (in days)	Second instar (in days)	Third instar (in days)	Fourth instar (in days)	Fifth instar (in days)	Total nymphal period (in days)	Adult longevity (in days)				Total life (in days)				No of egg batch/ female	No of eggs/ egg batch	No of hatch/ egg batch	Incubation period (in days)
							Unmated male	Unmated female	Mated male	Mated female	Unmated male	Unmated female	mated male	mated female				
Pantnagar	2 ± 0.12a	2.33 ± 0.33a	3.33 ± 0.33a	4.33 ± 0.33a	4.33 ± 0.33a	16.33 ± 0.67a	12 ± 1.15a	17.33 ± 0.88a	7 ± 0.58ab	11.67 ± 0.88a	34.33 ± 1.76a	40.33 ± 0.88a	29.33 ± 0.88a	34 ± 1a	2.33 ± 0.33a	50.73 ± 3,24a	44.9 ± 3.29a	6.41 ± 0.09a
Ramnagar	2 ± 0.29a	2.67 ± 0.33a	3.33 ± 0.33a	4.33 ± 0.33a	4.67 ± 0.33a	17 ± 0.58a	13.67 ± 1.86a	18 ± 1.15a	9 ± 0.58b	13 ± 1a	37.67 ± 2.03a	42 ± 1.53a	33 ± 0.58ab	37 ± 1.15abc	2 ± 0.58a	42.67 ± 3.48a	38.03 ± 3.21a	6.55 ± 0.11a
Tanakpur	2.33 ± 0.17a	2.33 ± 0.33a	3.33 ± 0.33a	4.67 ± 0.33a	4.67 ± 0.33a	17.33 ± 0.67a	12 ± 1a	18.33 ± 1.45a	6.33 ± 0.58ab	12.33 ± 2.03a	35.33 ± 1.67a	41.67 ± 2.03a	29.67 ± 1.45a	35.67 ± 2.19ab	1.67 ± 0.33a	42 ± 0.58a	36.8 ± 1.2a	6.77 ± 0.29a
Majhera	2.67 ± 0.20a	2.67 ± 0.33a	4 ± 0a	4.33 ± 0.33a	5 ± 0a	18.67 ± 0.88a	13.67 ± 1.45a	19.33 ± 0.67a	4.67 ± 0.33a	13.33 ± 0.88a	39.33 ± 0.67a	45 ± 1.53a	30.33 ± 1.20ab	39 ± 0.58bc	2 ± 0.58a	47.33 ± 2.91a	40.8 ± 2.30a	6.77 ± 0.29a
Almora	2.67 ± 0.24a	3 ± 0a	3.67 ± 0.33a	4.67 ± 0.33a	4.67 ± 0.33a	18.67 ± 0.33a	12.33 ± 0.88a	18 ± 1a	8.33 ± 1.45b	15 ± 0.58a	38 ± 0.58a	43.66 ± 1.20a	34 ± 1.73b	40.67 ± 0.67c	2.67 ± 0.33a	52.33 ± 6.85a	47.9 ± 6.30a	6.65 ± 0.01a

Table 3. ANOVA summary of biology of *Andrallus spinidens* collected from different location of Uttarakhand

ANOVA						
Life stages	Comparison	Sum of Squares	df (Degree of freedom)	Mean Square	F value	Level of Significance
First instar	Between Location	1.333	4	.333	2.488	.111
	Within Location	1.340	10	.134		
	Total	2.673	14			
Second instar	Between Location	.933	4	.233	.875	.512
	Within Location	2.667	10	.267		
	Total	3.600	14			
Third instar	Between Location	1.067	4	.267	1.000	.452
	Within Location	2.667	10	.267		
	Total	3.733	14			
Fourth instar	Between Location	.400	4	.100	.300	.871
	Within Location	3.333	10	.333		
	Total	3.733	14			
Fifth instar	Between Location	.667	4	.167	.625	.655
	Within Location	2.667	10	.267		
	Total	3.333	14			
Total nymphal period	Between Location	12.933	4	3.233	2.553	.105
	Within Location	12.667	10	1.267		
	Total	25.600	14			
Adult longevity Unmated male	Between Location	8.933	4	2.233	.429	.784
	Within Location	52.000	10	5.200		
	Total	60.933	14			
Adult longevity Unmated female	Between Location	6.400	4	1.600	.471	.757
	Within Location	34.000	10	3.400		
	Total	40.400	14			

Adult longevity Mated male	Between Location	34.933	4	8.733	3.970	.035
	Within Location	22.000	10	2.200		
	Total	56.933	14			
Adult longevity Mated female	Between Location	18.933	4	4.733	1.127	.397
	Within Location	42.000	10	4.200		
	Total	60.933	14			
Total life Unmated male	Between Location	50.267	4	12.567	1.943	.180
	Within Location	64.667	10	6.467		
	Total	114.933	14			
Total life Unmated female	Between Location	39.733	4	9.933	1.505	.273
	Within Location	66.000	10	6.600		
	Total	105.733	14			
Total life Mated male	Between Location	52.933	4	13.233	2.877	.080
	Within Location	46.000	10	4.600		
	Total	98.933	14			
Total life Mated female	Between Location	83.600	4	20.900	4.415	.026
	Within Location	47.333	10	4.733		
	Total	130.933	14			
No. of egg batch	Between Location	1.733	4	.433	.722	.596
	Within Location	6.000	10	.600		
	Total	7.733	14			
No of egg/batch	Between Location	258.704	4	64.676	1.376	.310
	Within Location	469.958	10	46.996		
	Total	728.662	14			
No of egg hatch/batch	Between Location	260.831	4	65.208	1.610	.246
	Within Location	405.087	10	40.509		
	Total	665.917	14			
Incubation period	Between Location	.289	4	.072	.619	.659
	Within Location	1.166	10	.117		
	Total	1.455	14			

Findings on adult longevity revealed that both virginity and sex affects the total life period of predatory bugs. Mated and unmated female adults had longer life period compared to mated adults (Fig. 1). Singh and Singh (1987) studied biology of *A. spinidens* on the larvae of *Rivulia* sp. and reported longest adult longevity as 32.20 ± 0.22 days in virgin female than that of unmated male for 24.00 ± 1.67 days and adult longevity in mated female was 15.20 ± 2.03 days compared to 10.60 ± 1.20 days in mated male. Shanker *et al.* (2007) studied the life cycle of *A. spinidens* on *S. mauritia* and reported highest adult longevity of female which ranged from 12 to 16 days with mean period of 14.2 ± 1.64 days and total life period of 35.69 ± 2.79 and 38.79 ± 4.05 days in male and female, respectively. Related results reported on adult longevity *of Eocanthecona furcellata* (Hemiptera:Pentatomidae) by Ray and Khan (2011) where they recorded 16.8 and 24.7 days adult longevity in male and female, respectively. Tiwari *et al.* (2017) also reported 39.33 ± 2.30 days total life period of *E. furcellata* when they used *S. litura* as facticious host.

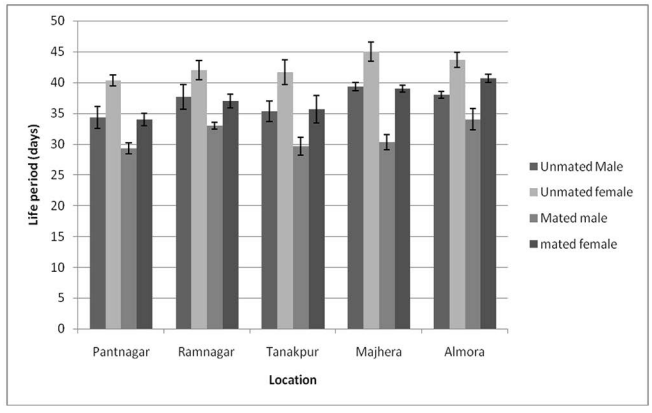

Fig 1. Comparison of total life period between male and feale reardng virginity.

Table 4. Predation efficiency of *Andrallus spinidens* from different location on their laboratory feed *Spodoptera litura*

Location	Predation efficiency (%) of different instar of *Andrallus spinidens*							
	First* instar	Second instar	Third instar	Fourth instar	Fifth instar	Male	Female	Mean predation
Pantnagar	0 ± 0a	51 ± 1a	56.91 ± 2.84a	73.47 ± 2.36a	75.21 ± 1.63a	61.16 ± 0.67ab	66.25 ± 0.72a	54.86 ± 9.71a
Ramnagar	0 ± 0a	48.83 ± 1.17a	61.08 ± 1.08a	72.87 ± 2.52a	78.54 ± 0.75a	57.54 ± 1.48a	67.33 ± 1.42a	55.17 ± 9.92a
Tanakpur	0 ± 0a	51 ± 1a	57.33 ± 2.07a	72.07 ± 0.52a	77.71 ± 1.46a	57.67 ± 2.02a	67.58 ± 0.73a	54.77 ± 9.78a
Majhera	0 ± 0a	52.17 ± 2.17a	62.92 ± 1.50a	68.73 ± 1.90a	75 ± 1.44a	62.08 ± 2.20ab	64.58 ± 0.91a	55.07 ± 9.54a
Almora	0 ± 0a	51 ± 1a	61.67 ± 1.67a	73.07 ± 2.03a	77.5 ± 1.44a	63.58 ± 1.92b	65.87 ± 1.06a	56.09 ± 9.88a

Table 5: ANOVA summary of predation efficiency of *Andrallus spinidens* from different location on their laboratory feed *Spodoptera litura*

Life stages	Comparison	Sum of Squares	df (Degree of freedom)	Mean Square	F value	Level of Significance
First instar	Between Location	.000	4	.000	.	.
	Within Location	.000	10	.000		
	Total	.000	14			
Second instar	Between Location	17.567	4	4.392	.808	.547
	Within Location	54.333	10	5.433		
	Total	71.900	14			
Third instar	Between Location	87.225	4	21.806	1.959	.177
	Within Location	111.333	10	11.133		
	Total	198.558	14			
Fourth instar	Between Location	44.123	4	11.031	.923	.488
	Within Location	119.493	10	11.949		
	Total	163.616	14			
Fifth instar	Between Location	30.354	4	7.588	1.331	.324
	Within Location	57.002	10	5.700		
	Total	87.356	14			
Male	Between Location	87.538	4	21.884	2.390	.120
	Within Location	91.574	10	9.157		
	Total	179.111	14			
Female	Between Location	17.564	4	4.391	1.459	.285
	Within Location	30.099	10	3.010		
	Total	47.664	14			

Average number of egg batch ranged from 1.67 ± 0.33 to 2.67 ± 0.33 per female and number of eggs per batch varied from 42 ± 0.58 to 52.33 ± 6.85. Number of hatching per batch ranged from 36.8 ± 1.2 to 47.9 ± 6.30 and incubation period varied from 6.41 ± 0.09 to 6.77 ± 0.29 days. Hence, there was no significant difference found during analysis of variance performed by ANOVA through Duncan's post hoc test at $P < 0.05$ (Table 2 and Table 3). Similar pattern of results was reported by Rajendra and Patel (1971) where they studied biology of *A. spinidens* on *Prodenia* larvae and found 54.47

eggs per masses with 5.29 ± 0.96 day's incubation period.The incubation period and hatching percentage were reported as 6 to10 days and 59.70 to 79.38 %, respectively by Shanker *et al.* (2007).

The attribute of *A. spinidens* survival at different altitudes by naturally adapting to its habitat will enhnance the success rate of being used as potential predator on commercial level. Predation efficiency is major factor in success of the predator for being considered in biological control programme. In the present study highest per cent mean predation by *A. spinidens* was noticed from five different locations of Almora samples 56.09 ± 9.88%, followed by Ramnagar 55.17 ± 9.92%, Majhera 55.07 ± 9.54%, Pantnagar 54.86 ± 9.71% and Tanakpur 54.77 ± 9.92%, respectively (Table 4). In present work difference in predation efficiency in different samples of predatory bugs were compared from five different locations and it was observed that the predation efficiency of *A. spinidens* during second nymphal instar as well as adult varied non-significantly from location to location at $P < 0.05$ (Table 5).

Observations on predation efficiency showed that *A. spinidens* was non predaceous during first nymphal instar and survived on plant juices, similar behavior was previously reported by Manley (1982) and Tiwari *et al.,* (2017) on predatory bugs. Predatory behavior was observed from second instar onwards and the predator was more voracious during in its fifth instar with high predation rate in all five populations of different locations (Table 4). Similar pattern of results was seen by Singh and Singh (1989) also by Khodaverdi *et al.* (2012) where they found that the fifth instar of *A. spinidens* kills 85% of provided *Spodoptera littoralis* larvae. When comparison was made between predation efficiency of male and female adult, the female adult was found to be more voracious (Fig 2). The study of biological control agent and their pest with respect to their habitat could be effective in pest management program (Foster and Harris, 1997; Renou and Guerrero, 2000). In present work it was observed that the female *A. spinidens* was better predator in comparison to male predatory bugs on the basis of their predation efficiency from all five geographical locations. It also revealed that the changes in the environmental conditions did not affect the predation efficiency of *A. spinidens* to a high extent.

CONCLUSION

Present study on *Andrallus spinidens* has provided first information about the effect of different geographical locations and enviromental conditions on biology and predatory efficiency of predatory bug in North-Western Himalayas region of India. Enviromental factors with respect to their geographical locations did not significantly affect their biology and predation efficiency. This predatory bug survived at every altitudinal location by maintaining their progeny and efficiency which implies that *A. spinidens* has adapted itself to altered climatic conditions and has maintained their biology and predation efficiency. Hence, it can be concluded that *A. spinidens* can be mass reared in the laboratory and due to its potentiality in biological control programme it can be utilized as biocontrol agent against lepidopteran pests of different crops at varied locations. This research can be furthermore explored at molecular level to study the reason behind the adaptation of predator in different geographical locations and understand the molecular mechanisms responsible for its adoption. *A. spinidens* can be successfully used as potential predator in biological control programmes on commercial level by developing a continuous rearing methodology for this predatory bug.

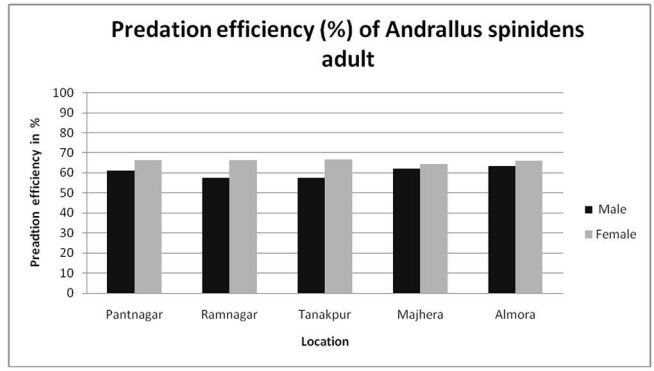

Fig 2. Comparison of predation efficiency of *Andrallus spinns* adults

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