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Population dynamics and sex ratio of two biocontrol agents of water hyacinth

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ABSTRACT

Population dynamics and sex ratio of two co-existing species of Water hyacinth weevils, *Neochetina bruchi* Hustache, 1826 and *N. eichhorniae* Warner, 1970 (Coleoptera: Curculionidae) were studied. The weevil attack on Water hyacinth was investigated monthly for four years in different water bodies. The weevil's abundance was affected by temperature, humidity and rainfall. The population of the weevils in general was highest (14.97 weevils/plant) in September when the humidity level was very high (88%) with the average of temperature almost 26^{o} C. The lowest abundance (2.49 weevils/plant) was in January when the temperature was the lowest (15.7^{o} C). The abundance of *N. bruchi* was significantly higher than the population of *N. eichhorinae* (1:0.04) in Jabalpur, India. Statistical studies revealed that the sex ratio was in favour of female in both the species (1:0.52 and 1:0.70 for *N. bruchi* and *N. eichhorniae*, respectively).

Key words: *Eichhornia crassipes*, *Neochetina* spp., Population dynamics, Seasonal variation, Sex ratio, Water hyacinth

Water hyacinth, *Eichhornia crassipes* (Mart) Solms. (*Pontederiaceae*), of South American origin is one of the most troublesome aquatic weeds in several tropical and subtropical regions of the world. Its explosive growth rate and ability to infest a wide range of fresh water habitats have created enormous environmental and economic problems. Among the proposed methods, the use of the water hyacinth weevils, *Neochetina bruchi*, Hustache 1826 and *N. eichhorniae*, Warner 1970 (Coleoptera: Curculionidae) as potential biocontrol agent has been widely researched (Firehun *et al*. 2015). For instance, several authors have studied the biology and host range of water hyacinth weevils (Borkakati *et al*. 2007, Hamadina 2015), while several others have focused on the damage potential and impact of the weevils on water hyacinth (Ray *et al*. 2009, Sushilkumar 2011). It was also found that these weevils were very effective in slowing the rate of expansion of water hyacinth mats by reducing new growth along the rapidly growing plant parts while the larval tunneling into the petiole causes severe internal damage causing the leaves to wilt and prone to secondary invasion by other organisms including aphids, mites and pathogens (Wilson *et al*. 2007, Ray and Hill 2012). However, the seasonal variation and population dynamics of these two species of the water hyacinth weevils, occupying same habitat at the same time has not yet been fully explored.

Hence, population dynamics and sex ratio of two biocontrol agents of water hyacinth narcly *Neochetina bruchi* and *N. eichhorniae* were evaluated.

MATERIALS AND METHODS

Periodical monitoring of various water bodies infested with water hyacinth in Jabalpur (India) was done for 4 years during 2004-2008. Twenty five water hyacinth plants infested with weevils were randomly collected every month from at least 5 different water bodies. The weevils were removed from the plants and identified into species and sexes and averaged. External morphology of the adults was studied in 70% ethanol by a stereomicroscope (Leica WILT-M3Z). The species of water hyacinth weevils were identified as per the description given by Julien *et al*. (1999) *i.e.* on the basis of the elytral marking. The sexes of *N. eichhorniae* and *N. bruchi* were separated by the attachment of antennae to the rostrum (Deloach 1975).

Correlation studies were also undertaken to determine the role of weather variables on population built up of the weevils. The weather data (Table 1) were recorded from meteorological observatory of Jawaharlal Nehru Agricultural University, Jabalpur,

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India. Water quality parameters (Table 2) were also taken to determine the effect of water quality on population find in both the species (APHA, AWWA and WEF 1998).

The four year data were taken as replication for analysis of variance (ANOVA). Monthly analysis of population density of *Neochetina* spp. was done using one-way ANOVA with means separated using Duncan's multiple range test (DMRT) for multiple comparison of weevil population in various months. The comparison of the month wise mean population, temperature and relative humidity data for 4 years was analysed using multiple correlation analysis, taking population (Y) as the dependent variable while temperature (X_1) and humidity (X_2) as independent variables. The statistical analysis for the population dynamics and sex ratio of the two species was done as per factorial ANOVA with month and sex as two factors, using statistical software package MSTAT-C. The population means for the two species for different months were compared with DMRT also using MSTAT-C.

RESULTS AND DISCUSSION

The water hyacinth weevils occurred throughout the year in all the water hyacinth infested water bodies under observation. Though both the weevil species coexisted successfully in the same habitat throughout the study period, they showed high variation in abundance in various months (F=12.35; df= 11, 36; p<0.01) (Table 1). Weather parameters in correlation with each other also had an impact on the weevil population (Table 1, Fig. 1). Though both temperature and humidity showed effect on population of the weevils, the standard partial regression coefficient showed that humidity is the factor creating more variation in population as compared to temperature. The population of weevils was highest during monsoon with peak during September (14.97 ± 0.7 weevils/plant) (mean ± standard error) due to congenial climatic conditions with temperature ranging from 18.9 to 30.6^o C while average humidity was 68 to 90%. The population of weevils in September was at par with that in October (12.6 ± 0.94 weevils/plant) followed by the population in August (10.61 ± 0.17 weevils/plant) and July (9.03 ± 0.60 weevils/plant). The population of the weevils was recorded low during winter with lowest in January (2.49 ± 0.48 weevils/ plant), followed by December (3.4 ± 0.70 weevils/plant) and February (3.82 ± 0.62 weevils/plant). Low population in winter especially in January can be attributed to low temperature (maximum= 24.2^o C and minimum 8.9^o C) inspite of appreciable rainfall (35.5 mm) and humidity (40.5 to 92%).

Further in March (maximum and minimum temperature 33 and 15.8^o C, relative humidity 26.3 to 72.8% and average rainfall 27.5 mm) there was an increase in weevil population (7.5 weevils/plant) while high temperature and low humidity in summer caused the population to decrease. During May, the temperature went up to more than 40^o C and relative humidity ranging from 16.8 to 42.3% and average rainfall 15.9 mm. The consequences of such climatic condition could be seen in the population of June where there is a decrease in weevil population (6.9 weevils/plant).

The population of *N. bruchi* (Fig. 1a) predominated that of *N. eichhorniae* (Fig. 1b) throughout the study period with a ratio of 1: 0.04 respectively. The population of *N. bruchi* (F= 13.10; df= 11, 36; p=0.000) was highest in monsoon with peak in September (12.15 ± 0.78 weevils/plant) while

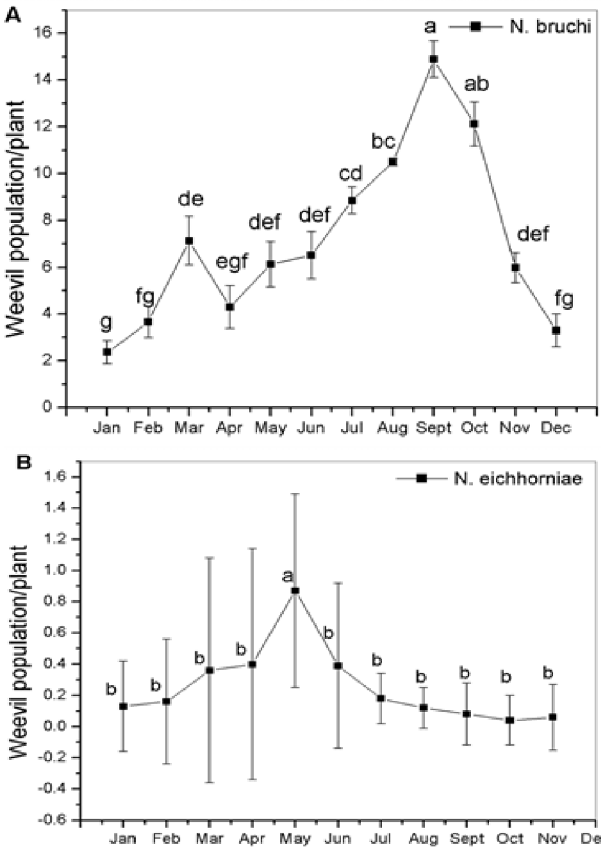

Fig. 1. Mean comparison of population of two species of water hyacinth weevil, (A) *N. bruchi* and (B) *N. eichhorniae* during different months years 2004-2008. DMRT: for each species, mean marked by same letter(s) are not significantly different from each other (P=0.05). Vertical bars indicate standard error of the mean.

the population of *N. eichhorniae* (F= 2.97; df= 11, 36; P=0.007) was slightly higher in summer compared to its own occurrence in other seasons with maximum in May (0.08 ± 0.8 weevils/plant).

In the present study, there was high eutrophication in the water bodies from which the weevils were collected (Table 2). The DO measured during the fourth year of study, was found to range from 3.6 to 10.2 mg/L. The pH ranged from 7.2 to 8 while TDS ranged from 200 to 600 mg/L. Nitrate-nitrogen ranged from 3.2 to 4 mg/L while phosphate-phosphorus was found between 0.3 to 0.6 mg/L.

Alike many insect species, the population of the female weevils was higher than that of male throughout the study period. The sex ratio of *N. bruchi* throughout the study period was highly significant (p=0.000) while the difference between sex ratio of *N. eichhorniae* was non-significant (p=0.0536). The mean female: male sex ratio of *N. bruchi* per plant was found to be 1:0.52 and that of *N. eichhorniae* was 1: 0.75 (Table 3). The highest number of *N. bruchi* was found in September with 9.41 ± 0.59 female and 5.48 ± 0.59 male weevils/ plant. Similarly highest number of females (0.59 ± 0.56 weevils/plant) and males (0.28 ± 0.30 weevils/ plant) of *N. eichhorniae* was found in May (Table 4). Least number of *N. bruchi* were found in January (1.47 ± 0.30 female and 0.89 ± 0.45 males per plant) while though lowest number of *N. eichhorniae* were found in October, there was no significant difference in the two sexes of *N. eichhorniae* during various months (p> 0.05).

The growth and development of the weevils have been found to be dependent on several ecological factors including the combined interaction between humidity and temperature (Khaliq *et al.* 2014). The humidity exerts a relatively greater effect on insects at the extreme temperatures and *vice-versa*. The temperature has significant influence on the biochemical activities like hormone secretion, which subsequently influences the insect growth (Fenemore and Prakash 1992). In this present study, humidity had a greater impact on the population dynamics of the two weevil species, as compared to temperature. High humidity and congenial temperature during the monsoon helped in higher population build up of the weevils.

Deloach and Corodo (1976) also observed that *N. bruchi* survived better at low temperature and laid more eggs as compared to *N. eichhorniae*. Contrary to this, Coulson (1978) reported that *N. bruchi* adults are much more abundant than *N. eichhorniae* throughout the spring and summer and early fall, but *N. eichhorniae* is most abundant in late fall and winter**.** This increase in population can be attributed to the fact that *N. bruchi* develops better under eutropic conditions (Heard and Winterton 2000).

Table 1. Influence of weather parameters on population of *Neochetina* spp.

Month	Weevil population/ per plant	Avg. temp. (° C)		Avg. humidity (%)		Avg. rainfall (mm)
		Max.	Min.	Max.	Min.	
January	2.5^{e}	24.2	8.9	92.0	40.5	35.5
February	3.8^{de}	28.1	11.9	87.0	35.5	11.0
March	7.5^{bcde}	33.0	15.8	72.7	26.2	27.5
April	4.7^{bcde}	38.5	21.3	47.2	15.2	2.0
May	7.0^{bcde}	40.8	25.9	42.2	16.7	15.9
June	6.9^{bcde}	38.4	27.4	56.5	36.0	141.4
July	9.0^{bcd}	30.5	24.6	88.5	73.7	486.9
August	10.6^{abc}	29.0	23.9	91.2	78.5	423.3
September	15.0^{a}	30.6	23.7	90.0	68.5	467.6
October	12.2^{ab}	30.5	18.9	88.5	47.2	28.8
November	6.0^{ade}	29.0	16.5	79.0	33.5	12.6
December	3.4^{e}	25.5	12.8	79.2	35.2	3.5

One-way ANOVA: Mean number of *Neochetina* spp. per plant is replicated over 4 years (F=12.35; df= 11, 36; P= 0.00). Mean population bar marked by same letter(s) are not significantly different at P=0.05 as determined by DMRT.

Correlation matrix of average population (Y), temperature (X_1) and humidity (X_2) - Humidity: Temperature = - 0.415; Y: X_1 = 0.289; Y: X_2 = 0.445. Regression equation: Y= -12.764 + 0.445 X_1 + 0.445 X_1 + o.149 X_2; R^2=0.469; R=0.685.

Table 2. Water quality parameters taken to show the condition of the water hyacinth infested water bodies

Parameter	pH	DO (mg/L)	Water temperature (° C)	TDS (mg/L)	NO_3-N (mg/L)	PO_4-P (mg/L)
Range	7.2 – 8.0	3.6 – 10.2	20.2 – 27.5	200 - 600	3.2 - 4	0.3 – 0.6

Table 3. Sex ratio of *N. bruchi* in different months

Month	Weevil population/plant		Mean*	Sex ratio (female: male)
	Female	Male		
January	1.47	0.89	1.18^{g}	1:0.61
February	2.32	1.34	1.83^{fg}	1:0.57
March	4.92	2.21	3.57^{de}	1:0.45
April	2.85	1.44	2.15^{efg}	1:0.51
May	4.01	2.12	3.07^{def}	1:0.53
June	4.48	2.04	3.26^{def}	1:0.46
July	5.85	3.00	4.40^{cd}	1:0.52
August	6.99	3.50	5.25^{bc}	1:0.50
September	9.41	5.48	7.44^{a}	1:0.58
October	8.00	4.12	6.06^{ab}	1:0.52
November	3.75	2.23	2.99^{def}	1:0.59
December	2.25	1.04	1.65^{fg}	1:0.46
Mean	4.69	2.45	-	1:0.52

2- way ANOVA:
Month- $LSD_{(p=0.05)}$ =1.55; SEm± = 0.41
Sex- $LSD_{(p=0.05)}$ =0.47; SEm± = 0.17
Month x Sex- $LSD_{(p=0.05)}$ = (NS); SEm± = 0.59
*Mean value superscripted by common letter(s) indicate no significant difference (p=0.05) between weevil population in different months as determined by DMRT.

Table 4. Sex ratio of *N. eichhorniae* in different months

Month	Weevil population/plant		Mean*	Sex ratio (Female: Male)
	Female	Male		
January	0.07	0.06	0.07^{b}	1:0.86
February	0.08	0.08	0.08^{b}	1:1
March	0.18	0.18	0.18^{ab}	1:1
April	0.27	0.13	0.20^{ab}	1:0.48
May	0.59	0.28	0.44^{ab}	1:0.47
June	0.27	0.12	0.19^{ab}	1:0.63
July	0.11	0.08	0.09^{a}	1:0.09
August	0.06	0.06	0.06^{b}	1:1
September	0.05	0.03	0.04^{b}	1:0.60
October	0.02	0.02	0.02^{b}	1:1
November	0.04	0.02	0.03^{b}	1:0.50
December	0.05	0.06	0.06^{b}	0.83:1
Mean	0.15	0.09	-	1:0.75

2- way ANOVA:
Month- $LSD_{(p=0.05)}$ = (NS); SEm± = 0.13
Sex- $LSD_{(p=0.05)}$ = (NS); SEm± = 0.05
Month x Sex- $LSD_{(p=0.05)}$ = (NS); SEm± = 0.19
*Mean value superscripted by common letter(s) indicate no significant difference (p=0.05) between weevil population in different months as determined by DMRT.

High nutrient in the water bodies resulted in better plant quality which aided the high population of *N. bruchi* as compared to *N. eichhorniae*. Studies by Julien *et al.* (1999) have shown that sites of poor plant quality, reflected by lower average tissue nitrogen concentration tend to have more *N. eichhorniae* while those of higher plant quality contain a higher proportion of *N. bruchi*.

Moorehouse *et al.* (2001) reported that weevils collected in September from Uganda had ratio of 0.92 female: 1.0 male in *N. bruchi* and 1.0 female: 0.84 male in *N. eichhorniae* population. Center and Durden (1986) reported that water bodies with poor quality water hyacinth had twice as many male as female (2.12:1) while water bodies with plants in good condition favoured female ratio (0.75:1). This could be attributed to the fact that females required more nutritious supplements to lay eggs.

The high female ratio of *N. bruchi* seems to be in favour of quick population build up of this biological control agent. Therefore, early control of water hyacinth by this species can be expected over *N. eichhorniae* in Indian climatic conditions. The present studies have focused mainly on influence of climatic conditions on population structure of the two species water hyacinth weevils. The further prospect lies in understanding the influence of water and plant quality on the population dynamics of the two species of weevils.

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