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Impact of seawater on development and reproduction of red cotton bug, *Dysdercus cingulatus* (Fab.)

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Abstract

Distribution pattern of animals, modification of their life cycle and behaviours have been governed by climatic changes. It affects the insect from egg to adults. Eggs always face lot of stress either from biotic or abiotic threats. This study examined the flooding of *Dysdercus cingulatus* eggs with seawater alone and in combination with fresh water on the egg hatchability, survival and development, fecundity and hatchability of the hatched nymphs and adults, respectively under laboratory conditions. Flooding of egg in salt water, slightly and insignificantly increased the nymphal developmental period (24.2 days) of the insect. However, treatment has no impact on the survival of nymphs (95.4%). Fecundity (135.2 eggs female^{-1}), hatchability (77.51%) has been gradually decreased while the amount of sea water increased in the treated water. Results revealed that entering of seawater into the agriculture fields alter the reproduction of insects subsequently change the food web in the ecosystem.

Key words

Seawater impact, Red cotton bug, *Dysdercus cingulatus*

Introduction

When animals face any kind of stress, the immediate response of the animal is by its sense organs, including mechanisms of sensory integration. Egg of the insects has not exempted from this mechanism. The climatic stress to the eggs always firmly transmitted to the rest of the insect life cycle. Together these efforts will hatch a robust evolutionary and physiological ecology of insect eggs. A major impact of climate change on the marine environment is sea-level rise. Nicholls *et al.* (2007) estimated average, global sea-level rise by the end of the century, based on a moderate scenario of greenhouse gas emissions, to be 0.35 m. According to several estimates, the level of sea water would rise by 20-140 cm in various parts of the world. The sea level around the world has already risen by 30 cm over the past about 4-6 cm annum^{-1}, which is 2-6 times faster than that over the last 100 years (Sengar *et al.,* 2007). Furthermore, melting of the polar ice caps causes flooding in coastal areas and river estuaries (Sengar *et al.,* 2007). This leads to the entry of seawater in to our farm land and submergence of shorelines. Moreover, tsunami also causes this kind of impact, while the seawater entering into the agricultural field affects the plants and animals (pests) (Dahdouh-Guebas *et al*., 2005; Norbert and Tchiadje, 2007).

Cotton is an important fibre crop of India cultivated over an area of about 9.5 million ha representing approximately one quarter of the global area of 35 million ha. It has been cultivated in a variety of areas, including seashore (Ahmad *et al*., 2002; Ashraf, 2002). Nearly 1326 insects and mites all over the world and about 200 in India have been recorded as pests of cotton (Balakrishnan *et al.,* 2010). Among the insects, red cotton bug, *Dysdercus cingulatus* (Fab) (Hemiptera: Pyrrhocoridae) is a serious pest of cotton in many parts of the world including India (David and Ananthakrishnan, 2004; Karihaloo and Kumar, 2009). It is commonly known as red cotton bug and is an important pest of cotton, lady's finger, sambhal and hollyhock *etc*. (Kohno and Thingam, 2004). Though enormous amount of information was available on the impact of salinity on plants (Sato *et al*., 2004), very limited information is available on insects, for instance, impact of salinity on the physiology and ecology of insects in general and colembola in particular (Witteveen, 1988; Owojori *et al*., 2009), terrestrial and marine biota (Harvell *et al*., 2002). The present study aimed at recording the impact of seawater either alone or in combination with drinking water on the development and reproduction of red cotton bug, *D. cingulatus*.

Materials and Methods

Insect collection: *Dysdercus cingulatus* adults collected from cotton fields from Thirunelveli district, Tamil Nadu were maintained under laboratory condition (27 ± 2°C temperature, 70-75% RH) in plastic containers (20 x 10 x 15 cm) on water soaked cotton seeds.

Seawater was collected from Thoothukudi coastal area, Tamil Nadu during morning hrs within 10 m from the shore. It was mixed with drinking water in the following proportion. T_1 : (control) – no water treatment; T_2 : seawater alone; T_3 : 75 ml seawater + 25 ml drinking water, T_4 : 50 ml seawater + 50 ml drinking water, T_5 : 25 ml seawater + 75 ml drinking water and T_6 : drinking water alone. Incubation period and hatching percent were recorded. Laboratory emerged first instar *D. cingulatus* nymphs were used for further studies.

Newly emerged 50 first instar *D. cingulatus* nymphs were maintained in each treatment with five replications. Nymphs were daily provided with water soaked cotton seeds and they were replaced every day. During the experimentation, effect of sea water on the nymphal survival rate, developmental period and moulting were recorded. Number of males and females that emerged from each category was also recorded and used for calculate the sex ratio (sex ratio = number of females emerged / total number of nymphs emerged). Male and female *D. cingulatus* emerged from each treatment were allowed for random copulation. Mated pairs were separately maintained in small plastic containers (250 ml capacity) under laboratory conditions till their death. Number of eggs laid by a female, pre-oviposition, oviposition and post-oviposition periods and adult longevity of both males and females were noted.

Data analysis: Chi – square test was performed for sex ratio between the different categories of the treatment. Mean data of all biological parameters were subjected to Turkeys test and the significance was expressed at 5% level (Zar, 1974).

Results and Discussion

Butterfield and Coulson (1997) highlighted the impact of climatic changes and their impact on invertebrates. It has been suggested that the timing of reproduction, nymphal development, migration and diapauses of *Dysdercus* species depend on the diet, temperature, relative humidity, precipitation and photo period (Stadler *et al*.,1987; Arif and Mubashshera, 2005). During the treatment of eggs with different concentrations of seawater, the eggs sank immediately in 4: 0 proportions (T_2). The eggs sank within a second in 3: 1 proportion (T_3). Eggs were immersed at the moment (2-3 seconds) in 2: 2 proportions (T_4). *D. cingulatus* eggs were floated for a few seconds (4 or 5 sec) and then immersed in 1: 3 proportion (T_5). They got immersed within 10 seconds in 0: 4 proportion (T_6). When the sea water concentration increased, the egg's shrinking

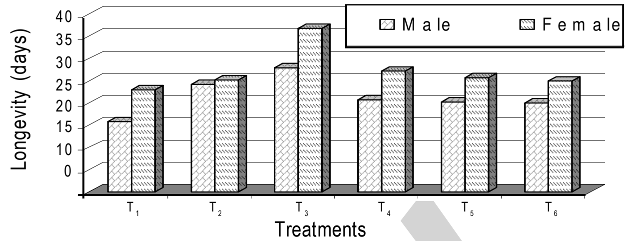

Fig. 1: Impact of seawater treatment (T_1 to T_6) on male and female adult longevity (days) of red cotton bug, *Dysdercus cingulatus*

ratio was increased. As a result, the egg's hatching percentage decreased. When the egg flooded in drinking water, the hatching percentage was increased (77.5%) and it was further decreased, when the seawater was added along with fresh water, further decrease in egg hatching was recorded while the sea water proportion was increased from 25 to 50% and also from 75 to 100%.

Since we used uniform sized eggs, this factor has been considered here. Usually the incubation period of *D. cingulatus* was 6 days in control category. At first, the eggs were creamy white in colour. After 2 to 3 days of incubation, they became yellow and within 4 to 5 days, they were shining. The incubation period was reduced to 4.3 days while the eggs were immersed with tap water. From the results, it was very clear that when the sea water concentration was increased, the incubation period also increased (Fig. 1).

In control category, the nymphal developmental period ranged from 19 to 24 days (mean value is 20.1 days), whereas in the experimental categories, the nymphs emerged from the eggs with freshwater (T_6) had the developmental period of 24.2 days. Statistical analysis between the T_1 and T_2 categories were highly significant at 5% level by DMRT. But the total nymphal developmental period was reduced to 22.5 days while the eggs were treated with 25% of sea water (Table 1). The mean nymphal developmental period of *D. cingulatus* was not changed while sea water concentration was increased. The present result also showed that when the eggs were treated with either freshwater or seawater slightly alters the nymphal development gets altered. But it was more pronounced when the eggs were treated with freshwater alone.

The survival rate of *D. cingulatus* differs from first instar to fifth instar. Death of the insects was mainly due to environmental changes, hormonal change and starvation. Survival rate of *D. cingulatus* was 100% in T_6 category. Among the six categories, increased sea water concentration had no effect on the survival rate of the nymphs. The results showed that the treatment of either fresh or sea water increased the nymphal total survival rate (Table 2). The results showed that treatment of water (either fresh water or marine water) enhanced the nymphal survival rate. Females were larger in size than males. Seawater at 100 (0.55), 75 (0.52%) and 50 (0.63%) slightly enhanced the female sex ratio, rather than

Table - 1: Impact of sea water treatment (T_1 to T_6) on the nymphal developmental periods (days) of red cotton bug, *Dysdercus cingulatus*

Treatments	Nymphal stages					
	I	II	III	IV	V	Total
T_1	4.0 ± 0.0	4.1 ± 0.1	4.4 ± 0.1	4.7 ± 0.2	5.2 ± 0.3	20.1 ± 0.2^{a}
T_2	5.4 ± 0.1	4.2 ± 0.1	5.8 ± 0.1	5.0 ± 0.1	4.2 ± 0.1	24.2 ± 0.4^{b}
T_3	4.3 ± 0.1	5.1 ± 0.1	4.0 ± 0.0	4.5 ± 0.1	3.3 ± 0.1	22.5 ± 0.2^{bc}
T_4	4.2 ± 0.1	5.1 ± 0.1	4.6 ± 0.1	5.0 ± 0.0	4.7 ± 0.1	22.7 ± 0.1^{bcd}
T_5	5.4 ± 0.1	4.0 ± 0.0	5.1 ± 0.1	4.4 ± 0.1	4.9 ± 0.1	22.7 ± 0.2^{bcde}
T_6	4.0 ± 0.0	5.3 ± 0.3	5.5 ± 0.5	5.5 ± 0.3	4.0 ± 0.0	22.5 ± 0.5^{bcdef}

Mean ± SE, followed by same alphabets is statistically insignificant at 5% level ; Analyses was carried between T_1 - T_2, T_3, T_4, T_5 and T_6; T_2 to T_3, T_4, T_5 and T_6; T_3 to T_4, T_5 and T_6; T_4 to T_5 and T_6; T_5 to T_6

Table - 2: Effect of sea water treatment (T_1 and T_6) on the nymphal survival rate (%) of red cotton bug, *Dysdercus cingulatus*

	Nymphal stages					
Treatments	I	II	III	IV	V	Total
T_1	85.0	100.0	100.0	88.2	100.00	94.2^{a}
T_2	83.9	96.2	100.0	100.0	88.0	95.4^{ab}
T_3	86.2	100.0	100.0	100.0	100.0	96.9^{bc}
T_4	100.0	88.2	100.0	100.0	100.0	97.4^{bcd}
T_5	100.0	100.0	98.0	100.0	100.0	99.6^{bcde}
T_6	100.0	100.0	100.0	100.0	100.0	100.0^{bcdef}

Mean value followed by same alphabets is statistically insignificant at 5% level ; Analyses was carried between T_1 to T_2, T_3, T_4, T_5 and T_6; T_2 to T_3, T_4, T_5 and T_6; T_3 to T_4, T_5 and T_6; T_4 to T_5 and T_6; T_5 to T_6

Table - 3: Impact of seawater treatment (T_1 to T_6) on the reproductive biology of red cotton bug, *D. cingulatus*

Parameters	Treatments					
	T_1	T_2	T_3	T_4	T_5	T_6
Preoviposition period (days)	5.3 ± 0.4^{a}	5.5 ±0.4^{ab}	5.9 ± 0.1^{abc}	6.3 ± 0.3^{cd}	8.3 ± 0.2^{e}	7.0 ± 0.0^{df}
Oviposition period (days)	9.0 ± 1.9^{a}	6.5 ± 0.1^{b}	7.7 ± 1.1	6.9 ± 1.0	6.5 ± 1.5	5.0 ± 1.8
Fecundity (no./female)	163.3 ± 0.6^{a}	135.2 ± 1.5^{b}	115.5 ± 2.1^{bc}	112.4 ± 0.9^{bcd}	105.4 ± 2.7^{e}	104.5 ± 1.3^{ef}
Incubation (days)	6.15 ± 0.5^{a}	4.34 ± 0.1^{b}	5.81 ± 0.6^{c}	6.83 ± 0.4^{ad}	6.42 ± 0.3^{ade}	7.34 ±0.2^{f}
Hatchability (%)	100.0 ± 0.0^{a}	77.51± 3.5^{ab}	72.56 ± 0.6^{c}	70.32 ± 2.9^{d}	51.13± 1.1^{e}	8.97± 1.5^{f}
Postoviposition period (days)	6.5 ± 0.9^{a}	19.5 ± 0.6^{b}	18.8 ± 1.2^{c}	12.6 ± 1.3^{d}	10.2 ± 1.3^{e}	4.0 ± 0.1^{f}

Mean ± SE, followed by same alphabets is statistically insignificant at 5% level ; Analyses was carried between T_1 to T_2, T_3, T_4, T_5 and T_6; T_2 to T_3, T_4, T_5 and T_6; T_3 to T_4, T_5 and T_6; T_4 to T_5 and T_6; T_5 to T_6

control (0.47) and fresh water treatment (0.50). However, male biased sex ratio is a common phenomenon in *Dysdercus cingulatus* (Carrol *et al.*, 1997).

It has been suggested by Stadler *et al.* (1987), Kohno and Thingam (2004) that the time of reproduction, nymphal development, migration and diapauses of *Dysdercus* species depend on the diet and abiotic factors. Results reveal, irrespective of the categories, the females lived longer than males (Fig. 1). Freshwater at 100% (T_6), 75% (T_5) and 50% (T_4) and seawater at 100% (T_2) and 75% (T_3) treatments significantly ($p<0.05$) enhanced the male (4 to 8 days) and female (2 to 14 days) adult longevities respectively. Among the treatments, seawater and fresh water at 75: 25 ratio has greater impact than other treatments. More studies are necessary to confirm the present observation. The most characteristic attribute of sea water is its salinity. About 73 elements are known to be present in seawater. The salinity of the sea water is a measure of the total quantity of salts present in it (Balakrihnan Nair and Thampy, 1980; Bann and Field, 2010). This study clearly shows that salinity is known to affect the reproduction of *D. cingulatus*. In many forms the salinity range for reproduction is narrower than that for other functions. Reduction in reproductive performance has been reported in certain freshwater animals. Reproductive biology of *Dysdercus cingulatus* was related to mating, nutrition, crowding (Odhiambo and Arora, 1973; Kohno and Thingam, 2004) and matting partner (Sahayaraj and Ilyaraja, 2008).

In the control category (T_1) preoviposition period was shorter than the oviposition period and postoviposition period. Oviposition period was highly reduced when the egg was flooded in seawater alone (5.0). It gradually increased while sea water proportion was decreased. However, no distinct difference was observed between controls (9.0 days) and freshwater alone treated category (8.5 days). Freshwater treatment remarkably prolonged the postoviposition period (19.5 days) more than in the other categories. It was three times longer than that is the control category. At the same time, sea water reduced post oviposition period (4.0 days) distinctly. Kasule (1991) reported that *Dysdercus fasciatus* Sign and *Dysdercus cardinalis* Gerst egg size increased with maternal age advanced in both species. It was found that water stress affected oviposition and subsequent egg survival but not pine sawfly *Neodiprion fulviceps* and *N. autumnalis* (Wagner and Frantz, 1990) and meat ants (*Iridomyrmex purpureus*) (Bann and Field, 2010) development or survival. Hemipteran insects lay eggs in a cyclic order. Generally, the egg cycles and their duration are not recognized with the parameters of fecundity. In *Dysdercus cingulatus* five gonadotrophic cycles were recorded in the mated female which was completed in a month. In control category (T_1), the number of eggs laid per female was 163.3. In tap water treated category (T_2), it was reduced to 135.2 eggs. In the rest of the categories, with the increasing concentration of sea water, the egg laying capacity of the female was gradually decreased. Through aerophyle, water enters into the porous layer called the trabecaular layer and subsequently reaches the developing embryo.

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