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HOLISTIC SURVEY ON DAMSELFLY (ANISOPTERA : ODONATA)DIVERSITY IN RICE ECOSYSTEM OF EASTERN INDIA

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ABSTRACT: *This study highlights the richness of Damselfly (Anisoptera: Odonata) fauna associated with rice ecosystems in Eastern India.. Sampling of the Damselfly community was conducted during 2010-14 to determine species composition, abundance and distribution in 3 different habitats of rice fields which were selected at 60 m (Chakdaha), 600 m (Cooch Behar) and 1250 m (Kalimpong) respectively. Each location was surveyed at a biweekly interval after transplanting of rice plants and about 10 species of Damselfly were recorded as insect predators in rice crops of Eastern India. General morphology, biology, ecology, behavior of the Damselfly are being highlighted in the present investigation. After comparing different body parts, double branching keys are prepared for their easy identification. The studies of their diversity showed that maximum and minimum value of both Simpson and Shannon-Weiner index were at the flowering and the vegetative stage of crop respectively. The value of Margalef index and Menhinck index also indicated that the highest value in reproductive stage of rice crop. The studies on Evenness index designated that the value of E_1, E_2 and E_3 were influenced by species richness and not evenness. Consequently the influence of fertilizer on the incidence of Damselfly in rice ecosystem showed that there was a remarkable increase of population where high doses of nitrogen (120 kg/ha) were applied followed by the use of mix fertilizer(120:60:60 N:P:K). Although the plot receiving high doses of phosphate @ 60 kg/ha exhibited increase in the level of Damselfly population but the distribution was least in the field where potassium fertilizer was used in both kharif (rainy) and rabi (winter) season during 2010 to 2014.The sampling of Damselfly population on weed, ratoon rice, rice fallow land exhibited that the bund weed provided resting site for damselfly. The colonization and succession of Damselfly species in the rice field habitat showed a uniform pattern in relation to the growth stage of rice crop. At the end of study, the relevance of Damselfly biosystematics in the context on bio diversities has been given in its legitimate status as bio control agent of rice insect pests in Eastern India.*

KEYWORDS- Damselfly, Rice , Predator, naiad, Diversity, Insect pests ,

INTRODUCTION

Damsel flies belong to the order Odonata , suborder Anisoptera of class Insecta an elegant group of insect usually found near water bodies. The Damsel-flies differ from the Dragon-flies in that the two pairs of wings are similar in form and are either folded parallel with the abdomen when at rest or up tilted in resting position . Emiliyamma *et al.* 2005[1] reported that about 7000 species of Odonata belonging to 630 genera and 28 families are recorded from world over. Prasad and Varshney (1995)[2] listed altogether 499 species of dragonflies and damselflies from India. India supports 500 species and subspecies ,which is just slightly more than 50% species subspecies

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recorded in the continental South Asia. These 500 species and subspecies are distributed among 140 genera, 17 families and 3 suborders. The comparative study on predator biodiversity with other parts of India showed that out of 85 species of Odonata , reported from rice ecosystem of India 31 species recorded from West Bengal(Kakkassery, 2004,[3] Mitra, 2006[4], Satpathi and Sarkar 2009[5], Satpathi 2010[6]).

The Odonata is appropriately named as it derives its name from the Greek word "Odonto" meaning tooth and it refers to the strong teeth found on the mandibles of most adults. The head is transverse, each eye being borne by lateral prolongation of the head. Venation of the wings of damselflies are identical to that of the dragonflies. The females possess an ovipositor by means of which the eggs are placed inside the stems of aquatic plants, sometimes beneath the surface of the water. They were found near the margins of streams and ponds, in which the immature stages were passed. The naiads (larvae) of damsel-flies have three plate-like tracheal gills at the caudal end of the body. Generally damselflies are considered as beneficial insect. Adult damselflies capture different types of insects including midges, mosquitoes, small moths of yellow stem bore and leaf folder, and they hold the prey in their legs and eat either while they are flying with the speed up to 50 km per hour or resting on nearby vegetation(Mitra 2006[4],Satpathi 2010[7])

MATERIALS AND METHODS

The regional studies on Damselfly diversity in rice crops were conducted in both southern and northern part of West Bengal in Eastern India during 2010 to 2014. In southern part the field trials were conducted at Regional Research Station, Chakdaha located between 20.50°-24.50° North latitude and 86.0°-89.0° East longitude with a mean sea level rise of 9.75 m. Normal rainfall ranges between 1271 mm to 1800 mm, maximum and minimum temperature varies between 20.4°C to 37.0°C and 9.0°C to 27.4°C respectively. The survey study was conducted at Coach Behar(600m altitude from sea level) and Kalimpong((1250m altitude from sea level) in Terai and Hill zone of northern part of West Bengal respectively, which is located between 20°31' and 27°31' North latitudes and between 87°9´ and 88°53´ East longitude. The hill zone in general consists of steep hills, which is a part of the Himalayan mountain range. The mountain spars of the Himalayas rises up from the plains to an altitude of 600 to 1900 meters above the mean sea level in the zone. Climate varies greatly from one place to another due to difference in altitudes. The average rainfall of hill zone varies from 2,500 to 3,000 mm, of which 80% is received during June to September. Rainfall is not certain from November to March. The average maximum and minimum temperature round the year records 20°C and 2°C respectively. The relative humidity varies from 70 to 80% depending on the locality and season of the year.

The Damselfly species inhabiting the rice field proper as well as weed habitat, ratoon crop and rice fallow were sampled at seven days after land preparation . The insect within the enclosed space; on rice plants, weeds and water/ground surface were collected by the sweep net, and flushed into a container for further studying in laboratory. In order to ensure a uniform capture efficiency using the sweep net, usage time per sample was increased with increasing growth and age of the rice plant. Damselflies collected in sweeps were immediately sprayed with chloroform and put either into labeled plastic containers or kept in insect box after drying in a dehydrator at 60°C for 72 hours. The Damselfly species in the rice field bunds were sampled by taking 10 sweeps from

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the weeds while walking along a bund transect (one sweep/m) at each of five randomly selected locations (using numbered paper slots) on each sampling day. The intensity of population were in the range of 1 /m^2 area was low whereas 1 to 4/m^2 , more than 5/m^2 area were medium (+ +)and high (+ + +) respectively. A total of 104 sweep net samples were collected during the entire study period at weekly intervals from the rice field.. The sampling was done in the forenoon from 8 to11 a. m. and in the afternoon from 4 to 6 p.m.

The Damselfly species were collected from the rice fields were identified and classified into the smallest possible taxa using available keys and guides for the different taxa. Heinrichs, E. A., Barrion and Litsinger (1994)[8] were used as a reference for rice pests and their predators. The Odonata were identified using key of de Fonseka (1997)[9]. Some of the insect predators were confirmed by the experts of Zoological Survey of India, Kolkata. Comparing different body parts the double branching keys were prepared for easy identification of Damslfly species. Each key begin with a couplet (a pair of alternative) and each of which leads to another couplet. Finally the reader reaches the specific identity of specimen.

Biodiversity indices such as richness indices, diversity indices like Simpson index, Shannon's index, evenness index etc. were used to estimate the diversity of insects in given habitat (Ludwig and Reynoids, 1988)[10]. Predator diversity analyzed through Simpson index (Simpson, 1949)[11] and Shannon-Weiner index (Shannon, 1948)[12], while abundance of species in each sample was assessed through Berger-Parker Dominance index (Southwood, 1978)[13]. To study the effects of fertilizer a field trials was conducted at the Regional Research sub-station, Chakdaha, under Bidhan Chandra Krishi Viswavidyalaya during 2010-14. The high yielding locally adopted variety Swarna (MTU-7029) and IET-4786 were planted on *Kharif* (rainy) and *Rabi* (winter) season respectively in each year supplemented with different doses of fertilizers in a randomized block design with three replications. Observations were recorded randomly from 10 hills/plot at 7 days interval starting from 15 days after transplanting. The plots were treated with combination of 3 levels of nitrogen viz. 0, 60, 120 kg/ha, 3 levels of Phosphate and potash viz. 0, 30, 60 kg/ha. along with a mix fertilizer N:P:K (120:60:60) and spacing (15x10 cm). In each of the observation10 hills were thoroughly examined walking in zigzag manner at random in each plot.

Data obtained on the abundance of Damselfly from the rice and non-rice habitats were compared using Means and Standard Error values (SE at 95% confidence limits). The arthropod diversity and species richness in the rice field proper and the bunds were compared using ecological indices reviewed by Magurran (1988)[14], calculated separately for different species on each sampling day. The mean values of the two indices obtained for *kharif* and *rabi* seasons were statistically analyzed using the SAS nested GLM Procedure . Using the pooled data from the two seasons, the diversity of Damselfly at the three major growth stages of the rice crop (vegetative, reproductive, ripening) and on harvest (fallow period) was analyzed using the SAS Nested GLM Procedure.

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RESULTS AND DISCUSSIONS

Damselfly does not prefer to remain with dove and peatfowl's since they are arid zone forms. These insect also do not occur in the selforsts due to lack of under growth. The number of species in the Ganga basin is more than that of other ecosystem in India, due to occurrence huge number of breeding areas and their preys. The double branching keys were prepared for easy identification of Damslfly species in rice ecosystem of Eastern India are as follows:

Order- Odonata
Sub-Order I: Zygoptera (Dragonfly)
Sub-Order II: Anisoptera (Damselfly)
Key to the Sub-Order
1. Wing unequal in size, hind wing broader at the base held horizontally, compound eye close together, ovipositor reduced.....Zygoptera
1'.Wing of equal in size, hind wing narrow at the base held vertically at rest., compound eye widely separated, female with well-developed ovipositor..... .....Anisoptera

Key to the nymphal stage of sub-order
1. Nymph robust with rectal gill.....Dragonfly
1'. Nymph slender with paddle like caudal gill.....Damselfly

Key to the species damselfly (Male)
1. Vertex multicoloured.....2
1'. Vertex unilcoloured.....4
2(1). Abdomen VII to X yellowish.....3
2'. Abdomen VII to X azure blue.....9
3(2). Vertex black, with blue postocular spot, thorax black with blue stripe on dorsum, abdomen I to VI blue or pale green.....*Agriocnemes femina femina* (Brauer) (Fig - 1)
3'. Vertex black with green post ocular spot, thorax black on dorsum with apple green stripe.....*Agriocnemes pygmaea pygmaea* (Rambur) (Fig - 2)
4(1'). Vertex olivaceous.....5
4'. Vertex either blue or metallic red.....8
5(4). Both thorax and abdomen not concolourous with vertex.....6
5'. Thorax and abdomen concolourous with vertex.....7
6(5). Vertex olivaceous, thorax olive green, abdomen uniformly citron yellow……
……*Ceriagrion coromandelium* (Fabricius) (Fig - 3)
6'. Vertex and thorax olivaceous, abdomen olive yellow.....
.....*Ceriagrion glabrum* (Burn) Fig - 4)
7(5'). Head, thorax and abdomen azure blue.....
.....*Pseudoagrion microcephalym* (Rambur) (Fig - 5)
7'. Head, thorax and abdomen olivaceous.....*Ceriagrion olivaceum* (Laid) (Fig - 6)
8(4'). Vertex metallic red, thorax with alternately red and white band, abdomen metallic red with thin segmental band.....*Ceriagrion tenellum* (Burn.) (Fig - 7)

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8'. Vertex blue, thorax with alternately deep & light blue band, abdomen azure blue.....*Ceriagrion azureum* (Selys) (Fig - 8)
9. Vertex and occiput black with blue post ocular spot; thorax bronzed black on dorsum, lateral palest green, abdomen black, but the dorsum of 1 to 2 and 3 to 7 metallic and citron yellow respectively.....*Ischnura senegalensis* (Rambur) (Fig – 9,10)
9'. Vertex and occiput black with blue post ocular spot, thorax bronzed black on dorsum, abdomen 1 and 3 segment red on dorsum 2 black and 6 to 7 bronzed black on dorsum.....*Ischnura aurora aurora* (Brauer) Fig- 11)

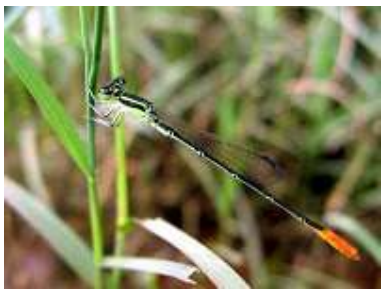

Fig-1 *Agriocnemes femina femina* (Brauer) Fig-2 *Agriocnemis pygmaea* (Rambur) Fig-3 *Ceriagrion coromandelianum* (Fab.)


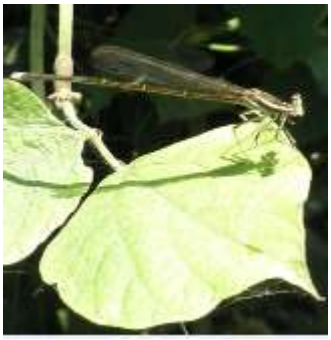


Fig-4 *Ceriagrion glabrum* (Burn) Fig-5 *Pseudagrion microcephalum* (Rambur Fig -6 *Ceriagrion olivaceum* (Laid)



Fig-7 *Ceriagrion tenellum* (Burn.) Fig-8 *Ceriagrion azureum* (Selys.) Fig-9 *Ischnura senegalensis*(Rambur)

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Fig-10 *Ischnura senegalensis*(Rambur) Fig -11 *Ischnura aurora aurora* (Brauer) Fig-12 *Ischnura aurora aurora* (Brauer)

Adults of 10 damselfly recorded in rice ecosystem usually captured different types of insect including gall midge adult small moths of rice stem borer(Fig10), leaf folder adults of plant hopper and leaf hopper(Fig -2). They hold their prey in their legs and eat either while on flying or resting on weeds or ratoon rice plant or rice fallow (Fig-9). Some cannibalism was also found among themselves when the sufficient foods were not available in the rice field. Initially the active stout adult chase the comparatively weaker individual of the same or different species. They immediately cut the thin neck after capturing their prey. Therefore the Damselfly species could be considered as general predator as it had no specification for selection of prey. Adult Damselfly normally fly below the rice canopy searching for flying insect as well as hoppers on rice plant. The nymphs hunt by stealth, creeping around very slowly on the bottom of the mass of water in which they live or a water vegetation (weed).The population of 10 species damselfly are more frequent in rice field of which *Ceriagrion coromandelianum* (Fabricius), *Ischnura aurora aurora* (Brauer) and *Pseudagrion microcephalum* (Rambur) were more predominent in the plains upto 600 m altitude of West Bengal.

Mating and egg laying

Most of Damselfly spent a part of their life cycle in fresh water ecosystem. Usually mating takes place during flight. The male curls its abdomen downwards to transfer the sperms from genital pore to the accessory genetalia present on the ventral side of the abdominal segments 2 and 3 (Fig-13). During this process first eggs were laid in or near fresh water, depending on whether the female possesses a complete ovipositor or not. The eggs were deposited by these matured female in the tissues of plants (endophytic) or in floating debris by means of robust ovipositor but quite a number of species oviposit in the aerial part of plant(Fig14). Female used a number of distinct method for egg laying in weed and ratoon crop in rice field. The fallow land could not provide the suitable environment for survival of these predators. During off season when the rice crops were harvested the female inserted their eggs either in to the stem of water weed or submerged ratoon plant(Fig14).. Developmental time dependent on the temperature of the water in which the nymph lived as long as adequate food was available.

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Fig-13 Mating Stage *Agriocnemes femina femina* (Brauer)

Fig-14 Eggs are laid in submerged plant tissue

Nymphal development

In rice field the development of damselfly *viz*. *Ceriagrion coromandelianum* (Fab.), *Ischnura aurora aurora* (Brauer), *Agriocnemis femina* (Brauer), *Ceriagrion tenellum* (Brun), *Ceriagrion glabrum* (Burn.), *Ceriagrion olivaceum* (Laidlow), *Ceriagrion azureum* (Selys), *Agriocnemis pygmaea pygmaea* (Rambur), *Pseudagrion microcephalum* (Rambur) of Coengrionidae usually takes about 28 to 30 days during June to September in eastern India. As soon as the naiad or larva matured the nymph crawled up out of water and emerged as an adult with functional wing. Some of the adults stay close to the emergency site, while others may fly extreme distances in flock. The rice fields were ideal wetland for most of the damselfly which did not require extensive areas of open water. Both adult and nymphs are predator, mainly catching other insects in air and water respectively. The nymphs of these Damselfly fed almost any kind of insect that is small enough for them to handle. The nymphs buried them beneath the weed, loose gravel mud, ratoon effectively concealed themselves from passing prey. When suitable prey came they used their killer mask or modified lower lip of their mouthparts. During rest this mask covered the other mouthpart like mask. The labium of the nymph was long and hinged with 2 inward pointing claws on the end. As and when the prey came close it shoots the labium forwarded very rapidly. The claws of the front pair of leg used to pull the prey inside the face. Damselfly nymphs were very slim, while dragonfly nymphs are more heavily built. Damselfly nymphs could be recognized by three external gills while dragonfly nymphs lack these external gills instead they had gill in the rear end of gut (rectum). They had special tricks that helped them to be escaped from their enemies. If the damselfly nymph grabbed by a leg, it could break at weak point at the base of the femur. The action shoot them away forward from possible danger. The damselfly nymphs were voracious carnivores. aquatic and also climbed up rice stems to search for hopper nymphs.

Distribution of Damselfly species in Eastern India

Damselfly usually prefer moist humid condition and distributed throughout rice growing areas in Eastern India. Although the rice is grown up to 1500 m altitude in hilly areas but the damselfly could not build up their population due to lack of sufficient water in the field. The distribution of damselfly species in different altitudes are given in table-1

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Table- 1 Distribution of Damselfly species in different altitude of Eastern India during 2010-14

SL .No.	Scientific name of the Damselfly	Stage	Pop^n/ mt^2 at different altitudes from sea level		
			60m	600mt	1250mt
1	*Agriocnemis femina femina* (Brauer)	N, A	+	+	-
2	*Agriocnemis pygmaea* (Rambur)	N,A	+	+	-
3	*Ceriagrion azureum* (Selys)	A	+	+	-
4	*Ceriagrion coromandelianum* (Fabricius)	N,A	+ +	+	-
5	*Ceriagrion glabrum* (Burn.)	A	+	+	-
6	*Ceriagrion olivaceum* (Laidlow)	N,A	+	+	-
7	*Ceriagrion tenellum* (Brun)	A	+	+	-
8	*Ischnura aurora aurora* (Brauer)	N,A	++	+	-
9	*Ischnura senegalensis* (Rambur)	N,A	++	+	-
10	*Pseudagrion microcephalum* (Rambur)	A	+ +	+	-

+ = Low = Less than 1/m^2, + + = Medium = 1 to 4/m^2, + + + = High = More than 5/m^2, N=Naiad, A=Adult

It is evident from the table-1 that only 2 species of *Agriocneme* spp, 5 species of *Ceriagrion* spp, 2 species of *Ischnura* spp and 1 species of *Ceriagrion*sp were recorded from rice ecosystem in eastern India and the result support the observation of Emiliyama *et al.* (2005) who recorded that 10, 8, 11 and 5 species of *Agriocnemes* spp, *Ceriagrion* spp, *Ischnura* spp. and *Ceriagrion* spp from India.

Species diversity:

An investigation was made to find out the crop stage wise diversification of Damselfly and found that they were more diverse during flowering and ripening stages of crop respectively as given in table-2.

Table-2 Diversity indices of Damselfly in three different stages of rice crop in Eastern India during 2010-14

Crop stage	**Total abundance**	**No of sp**	**Population range/sweep**	**Simpson Index(D)**	**Shannon-Weiner Index(H´)**	**Berger-Parker Index(h)**	**Dominant Species**
Vegetative	41	10	2-5	9.259	2.157	0.121	*Ischnura aurora aurora*
Flowering	28	10	2-10	12.658	2.239	0.357	*Ischnura aurora aurora*
Reproductive	32	10	2-4	11.627	2.223	0.125	*Ischnura aurora aurora*

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The data in table-2 showed that Simpson index of diversity (D) for damselfly had the highest value at ripening stage (D =12.658) and lowest value at vegetative stage (D = 9.259). The highest and lowest value indicate maximum and minimum species diversity during that period. Shannon-Weiner index (H') indicated the combined effect of species richness and evenness on species diversity. The highest species diversity for damselfly (H' = 2.239) was also found in flowering stage of the crop .

Fig 15Vegetative stage of rice plant

Fig-16 Prof. C.R. Satpathi estimating the

Damselfly population in rice field

Berger-Parker index had the maximum value for damselfly (0.357) at flowering stage of crop indicating most abundant species constituted 35.7% of total population count respectively.

This result is in consonance with the view of Kandibane *et al.* (2005)[15] who stated that the species of damselfly preferred tillering stage of crop because the canopy of rice crop covered the entire surface area to create a favorable microclimate for the abundance of damselfly species.

From the result it is concluded that the species richness diversity of Damselfly increased from vegetative to flowering stage followed by sudden decline with maturity of crop. The result is in agreement with the view of Bambaradeniya and Edirisinghe (2008[16]) who stated that the species richness diversity of terrestrial arthropods increased gradually with the crop age. The mean species diversity of terrestrial arthropod of vegetative, reproductive and ripening were significantly different and the highest diversity was recorded during the reproductive stage. The early colonization and build up of arthropod communities observed in the field proper were similar to those recorded by Heong *et al.* (1991)[17] and Schoenly *et al.* (1996)[18] where pest phytophages increased in number faster than predator. The dominance of predators during ripening stage of crop can be attributed to an increase in their abundance of prey.

Extend of diversity indices of damselfly in rice ecosystem of WestBengal

The extend of diversity of damselfly was also varied in different crop stages which can be calculated by Richness index, Hill diversity No and Evenness indices(E´) as given in table-3

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Table-3 **Parameter and indices to express the extend of diversity insect predator in rice ecosystem of West Bengal**

Crop stage	**No of species**	**Richness index**		**Hill diversity No**		**Evenness indices(E´)**				
		Margalef Index(R_1)	**Menhinick Index(R_2)**	**N_1**	**N_2**	**E_1**	**E_2**	**E_3**	**E_4**	**E_5**
Vegetative	10	2.425	1.502	8.64	9.21	0.93	0.86	0.84	1.00	1.00
Flowering	10	2.702	1.890	9.38	12.61	0.97	0.94	0.93	1.00	1.00
Reproductive	10	2.597	1.768	9.23	11.54	0.96	0.92	0.91	1.00	1.00

Here both Margalf index (R_1) and Menhinick index (R_2) had the maximum value (R_1 = 2.702, R_2 = 1.890) and minimum value (R_1 = 2.425, R_2 = 1.502) for damselfly in flowering and vegetative stage of the crop respectively. The Hill's diversity number i.e. measures the effective number of species present in a sample which is used to determine the degree to which proportional abundances are distributed among the species. In case of damselfly the species richness number was 10, of which number of abundant (N_1) and most abundant (N_2) regardless of crop stages, were 8.64 and 12.61 respectively.

The evenness index reaches its maximum when all the 10 species of damselfly are equally abundant. Here the value of evenness indices ranges between 0.84 to 0.97 irrespective to the stages of crop. Therefore it may be concluded that species was equally abandoned which do not diverge from evenness. Data showed that E_1, E_2 and E_3 are strongly influenced by species richness whereas E_4 and E_5 are not influenced by species richness.

Relative composition of Damselfly in different habitat of rice ecosystem in eastern India

Damselfly population also varied with the presence green vegetation along with the water logged condition which prove a suitable microclimate for their growth and development. The population fluctuation of 4 different habitats in rice ecosystem of Eastern India are given in table-4

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Table-4 Relative composition (Number/m^2 area) of Damselfly in ratoon crop, weed habitat, rice fallow land and rice habitat during 2010.-14

	Weed habitat/m^2		Ratoon/m^2		Rice fellowland/m^2		Rice habitat/m^2	
	Actual No.	TR No± SEm	Actual No.	TR No±SEm	Actual No.	TR No±	Actual No.	TR No±
	0.747	5.058, ±0.078	1.30	6.596, ±0.068	0.024	1.548, ±0.054	2.662	9.258, ±0.055

TR No= Transformed value

weeds provided resting site of damselfly. The result of the present study shows that the abundance of damselfly 0.747/m^2 , 1.30/ m^2 , 0.24/ m^2 and 2.662/m^2 in weed habitat, Ratoon, Rice fellow land and Rice habitat respectively. The results support the observation of Bambaradeniya and Edirsinghe (2000)[16] who reported that partial and intense slashing of weed cover in bunds during the vegetative and mature stage of rice crop resulted in a reduction in density of pests and predator. Haq and Karim (1991)[19] also reported that transplanted aman (July-December) ratoon rice harbored more insect pests and predator than ratoon rice crops at other time of the year in Bangladesh. The study highlighted that a percent of total predator population survived on natural ratoon crops developed lowland areas after harvesting the main crop in the month of November. The insect predator which was recorded from fallow land required no green vegetation and for the most part stay on ground.

Effect of different chemical fertilizers used by the farmers on abundance of Damselfly in rice fields

The rice crop during the period of its growth and development absorbed different nutrients from the soil. The actual amount of nitrogen, phosphate and potash required to be added to the soil would depend upon the ability of the soil to supply that particular nutrients from the region of West Bengal and total removed by the crop. Nitrogen augments plant growth rates leading to softer tissue which ultimately help quicker penetration by stem borer and hopper pests. Phosphorous also tends to increase some borer pests whereas potassium suppress all the pest by lowering level of amino acid, sugar, and also make thicken cell wall. On the other hand the application of nitrogen fertilizer substantially reduced mirid bug, whereas increased the population of damselfly and coccinellid beetle. The effect of different doses of fertilizers on abundance of damselfly was recorded during rainy season of 2010-14 as given in table- 5.

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Table-5 Effect of different doses of fertilizer on incidence of damselfly in rice ecosystem of West Bengal during rainy season 2010-14

SL No	Treatments	Crop stage			Mean
		Vegetative	Flowering	Reproductive	
T_1	Nitrogen 120 kg ha^{-1}	4.33(12.08)	4.00(11.61)	3.66(1.11)	3.33
T_2	Nitrogen 60 kg ha^{-1}	2.66 (9.48)	2.33(8.87)	2.00(8.23)	1.99
T_3	Phosphate 60 kg ha^{-1}	3.66(11.11)	3.33(10.60)	3.00(10.06)	2.66
T_4	Phosphate 30 kg ha^{-}	3.00(10.06)	2.66(9.48)	2.33(8.87)	2.33
T_5	Potash 60 kg ha^{-1}	1.66(7.51)	1.33(6.75)	1.33(6.75)	1.11
T_6	Potash 30 kg ha^{-1}	2.00(8.23)	1.66(7.51)	1.66(7.51)	1.44
T_7	N : P : K (120 : 60 : 60),	4.00(11.61)	3.66(11.11)	3.33(10.60)	2.99
T_8	Control	2.33(8.87)	2.00(8.23)	1.66(7.51)	1.66
	SEm±	0.14	0.15	0.16	
	CD at 5%	0.41	0.44	0.48	

Figures in the parenthesis are arc sine transformed values;

After application of high doses of fertilizer there was remarkable increase of damselfly on vegetative stage, flowering and reproduction stage in treatment where high doses of nitrogen (120 kg/ha) was used. The average number of adults varied 3.66 to 4.33 adult/m^2. The treatment was followed by normal doses N:P:K (80:60:30) with 3.33 to 4.00 adult/m^2, and phosphate 60 kg/ha with 3.00 to 3.66 adults/m^2. The least effective fertilizer was high dosage potassium fertilizer @ 60 kg/ha followed by low dosage of potassium fertilizer @ 30 kg/ha as given in Table- 5. Identical trend of population was also recorded in winter season as given in table-6

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Table-6 Effect of different doses of fertilizer on incidence of damselfly in rice ecosystem of West Bengal during winter season 2010-14

SL No	Treatments	Crop stage			Mean
		Vegetative	Flowering	Reproductive	
T_1	Nitrogen 120 kg ha^{-1}	4.66(12.53)	4.00(11.61)	3.66(11.11)	4.10
T_2	Nitrogen 60 kg ha^{-1}	3.66(11.11)	3.00(10.06)	2.66(9.48)	3.10
T_3	Phosphate 60 kg ha^{-1}	4.33(12.08)	3.66(11.11)	3.00(10.06)	3.66
T_4	Phosphate 30 kg ha^{-}	4.00(11.61)	3.33(10.60)	2.66(9.48)	3.33
T_5	Potash 60 kg ha^{-1}	2.33(8.87)	2.00(8.23)	1.66(7.51)	1.99
T_6	Potash 30 kg ha^{-1}	3.00(10.06)	2.33(8.87)	2.00(8.23)	2.44
T_7	N : P : K (120 : 60 : 60),	4.33(12.08)	3.66(11.11)	3.33(10.60)	3.77
T_8	Control	3.33(10.60)	2.66(9.48)	2.33(8.87)	2.77
	SEm±	0.11	0.14	0.14	
	CD at 5%	0.34	0.42	0.42	

Figures in the parenthesis are arc sine transformed values

The results indicated significant differences among the treatments after application of different types and level of fertilizers where Nitrogen @ 120 kg/ha recorded significantly higher population of Damselfly (4.10/m^2) followed by mix fertilizer (3.77/m^2), phosphate @ 60 kg/ha (3.66/m^2), phosphate @ 30 kg/ha (3.33/m^2), nitrogen @ 60 kg/ha (3.10/m^2), potassium fertilizer @ 60 kg/ha (1.99/m^2) and potassium @ 30 kg/ha during 2010-14. Among the three different stage intensity of population was high in vegetative stage and then gradually declined with the maturity crop.

Collonisation and Succession of Damselfly with respect to pest and environment.

The colonization and succession of Damselfly fauna in the rice field habitat was observed to follow a uniform pattern in relation to the growth stage of rice crop as well as the different phases in the rice field . In the early stage the pest phytophagous was increased in number faster than predator. The dominance of predator during the flowering stage of crop can be attributed to an increase in relation to an abundance of their prey. During the early stage the wide gap between plant to plant provides innumerable richness of Daselfly(Fig15). Ripening of rice crop remove insect pests resulting in the reduction of Damselflyr population(Fig-16). The observation were similar to the record of Heong *et al.* (1991)[17] and Schoenly *et al.* (1996)[18] where pest phytophages increased in number faster than predator. . After rice establishment both pest and predator species colonize and over time progressively increase in diversity. The rice field predator is one of the important component of that biodiversity (Altieri and Nicholl, 1999)[20]. Their communities may vary with the environment crop stage and cultivation practices. Rice field often support high level predator biodiversity, which play an important role in the agricultural productivity of these system. . The observation was agreement with Thorbek and Bilde (2004)[21] who reported that adjacent, less

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disturbed, refuge areas are colonized by predators following husbandry event, demostrating significant special dynamics among farmland arthropod. Abundance of predator could show a shift seasonally and geographically, but a few species of predator have been shown to highly impact on pest population. Simultaneously with the terrestrial predator 10 species of aquatic predators were recorded in vegetative stage. Which peaked to same in flowering followed by sudden disappeared at the ripening stage of crop. Although 10 species of aquatic(naiad) and terrestrial(adult) insect predators were found to survive on ratoon as well as in aquatic weed but they could not survive in fallow land. This is confirmation with the previous study of Haq and Karim (1990)[19] who reported that transplanted amon ratoon rice (July to Dec.) harbored more insect predator than ratoon rice crop at other time of year in Bangladesh. Numerically 10 predators were recorded as terrestrial or aquatic predator of rice pests but all of them did not have direct relation with pest incidence indicating generalistic nature of their predation. The predators are certainly conspicuous forms, and sometime confused with pests.

It is not uncommon more than 5to10% of the adults of rice yellow stem borer and leaf folder consumed by Damselfly(Fig10) . Naiads live on the surface of the water in rice field. When the stem borer, leaf folder and case worm larvae attempt to disperse, many use the water and are attacked by this aquatic predators. The natural balance between insect pests and their natural enemies is often disturbed by indiscriminate use of chemical insecticides.

Relative Ranking of Damselfly as predator in rice ecosystem of Eastern India

The study could be used to provide initial guidance before embarking on a much more comprehensive study of predator importance in a particular area. The ranking chart in the present investigation give a current of predator importance. Their validity will increase over time and they will need to be updated periodically. Four consecutive years survey across the 3 regions at 3 different attitude could give a comprehensive idea about the status of the Damselfly. These estimates were cross checked with the ranking given by progressive farmers and friends who could rank. About50 insect predators under 7 different orders were ranked, on the basis of general survey the peak period of appearances and found that the highest number of predators belong to the order Coleoptera (17 species) followed by Hemiptera (13species), Odonata (10species), Hymenoptera (3), Neuroptera (2), Orthoptera (1) and Dermaptera (1) respectively. From the ranking it was also specified that *Ischnura aurora aurora* (Brauer), *Ischnura senegalensis* (Rambur), *Agriocnemis pygmaea* (Rambur) ,*Agriocnemes femina femina* (Brau,*Ceriagrion coromandelianum* (Fab.) occupied 8ht, 16th , 18$^{t.}$h, 28th and 36th position on the arbitrary list prepared for listing major predators in rice ecosystem of Eastern India during2010-2014

CONCLUSION

From the overall results of the experiment it is to be concluded that rice crop being a relatively short duration annual crop harbored number of Damselflies which are most important group of biological control organisms in Eastern India. The composition structure of Damselfly communities in rice ecosystems are characterized by both terrestrial and aquatic. Damselfly appear numerically dominant due to their typical biological attributes of short life cycle. Their predation scarcely reflected on pest management to any great extent due to their omnivorous habit.

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The studies of different diversity index showed that Damselflies are specific to particular growth stage of crop. The species richness diversity of this predator increased from vegetative to flowering stage followed by sudden decline with the maturity of crop. The value of Margalef index and Menhinick index also indicates that the Damselflies were more diverse in flowering stage of crop whereas it was least in vegetative stage of crop. The effect of different fertilizers on incidence of Damselfly indicates that the application of high doses of Nitrogen and Phosphate in rice field enhances to build up their population both in vegetative an flowering stage of the crop. The studies on colonization and succession of Damselfly in the rice field indicates that it follows an uniform pattern in relation to growth stage as well different phases in the rice field. The relative ranking chart of 50 important predator in rice ecosystem of exhibited that *Ischnura aurora aurora* (Brauer), *Ischnura senegalensis* (Rambur), *Agriocnemis pygmaea* (Rambur) could be placed 8th 16th and 18th position respectively in Eastern India.

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