ISSN 2449-8866
2(1) 2016

Volume 2
Number 1
January-March 2016

Current Life Sciences

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Current Life Sciences

ISSN 2449-8866

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ISSN 2449-8866

Current
Life Sciences

Research Article

Response of mycorrhizal inoculations on *Dipterocarpus retusus* seedlings in nursery

Ashwani Tapwal[1]*, Rajesh Kumar[2], Devopod Borah[2]

[1] Himalayan Forest Research Institute, Conifer Campus, Panthaghati, Shimla, Himachal Pradesh, 171013, India
[2] Rain Forest Research Institute, P.B. 136, Jorhat, Assam, 785001, India
*Corresponding author: Ashwani Tapwal; Tel. +91 177 2816114; e-mail: ashwanitapwal@gmail.com

Received: 05 October 2015; **Revised submission:** 02 December 2015; **Accepted:** 16 December 2015

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ABSTRACT

Dipterocarpus retusus is one of important tree species among dipterocarps of northeast India and known to have both ectomycorrhizal and endomycorrhizal associations. Under favorable conditions the mycorrhizal fungi present in soil develop symbiotic association with fine roots of trees. It is well known fact that mycorrhizal fungi help the plants for better establishment, growth and protecttion from pathogen attack. In present investigations, mass inoculum of dominant ectomycorrhizal and endomycorrhizal fungi was prepared and applied in nursery bags sown with germinating seeds. Observations on growth characters and mycorrhizal colonization were made at the interval of three months. The results revealed that irrespective of the type of mycorrhizal inoculation, growth of seedlings increased significantly as compared to control. Maximum growth was observed for the seedlings inoculated with ectomycorrhiza alone, followed in dual inoculations (ecto- and endomycorrhizae), seedlings inoculated with endomycorrhizal fungi and minimum in control.

Keywords: Ectomycorrhiza; Endomycorrhiza; *Russula*; *Glomus*; Nursery trials.

1. INTRODUCTION

Trees usually have perennial root system containing roots of different types and ages. Roots not only fix the plant to substratum but also supply it with much needed water and mineral salts. The rhizosphere of plants holds diverse microbiota representing saprophytic, parasitic and symbiotic microorganisms. Mycorrhizae are the symbiotic association between specialized root inhabiting fungi and the roots of living plants [1] and can be defined as ‘fungus roots’ [2]. Mycorrhizae play a significant role in plant nutrition, growth improvement, successful afforestation, reforestation, biocontrol of pathogens and land reclamation programmes [3, 4]. The mycorrhizal fungi can play an important role in the process of plant adaptation when transplanted to new habitats and also induce plant tolerance to biotic and abiotic stresses, disease resistance, tolerance to heavy metal stress etc. [5-8]. Increased survival and growth were also observed in micropropagated plants inoculated with mycorrhizal fungi [9]. In temperate and boreal forests, up to 95% of the short roots form ectomycorrhizae [10]. Ectomycorrhizae have a helpful impact on plant growth in natural and agroforestry ecosystems.

Dipterocarpaceae, to which *Dipterocarpus retusus* belongs, is a tree family that dominates the rain forests in South and Southeast Asia. Most of Dipterocarps occur in evergreen and well-drained tropical rain forests of the Indo-Malayan region and most of them are equipped with winged seeds which aid during wind dispersal [11]. It is one of the major timber yielding family in the forests of Southeast and occupy key canopy strata of the forest [12]. The members of dipterocarpaceae are source of valuable timber and a number of non-timber forest products like oils, nuts, and resins [13]. The roots of dipterocarps are known to be associated with ectomycorrhizal [14, 15] as well as endomycorrhizal fungi [16-18]. Raj and Chandrashekar [19] studied the association of mycorrhizal fungi with endemic dipterocarps of Sharavathi valley forest, Karnataka region and isolated thirty-six species of endomycorrhizal fungi. Among them, *Glomus* was represented by twenty species, *Acaulospora* by eight, *Scutellospora* by four, *Gigaspora* and *Entrophospora* by only two species each. The root colonization ranged from 84% to 92%. Under favorable conditions mycorrhizal fungi present in the soil, colonize the dipterocarp seedlings and improve seedling establishment and performance. Several species of ectomycorrhizal fungi are known to be associated with dipterocarps belonging to Amanitaceae, Boletaceae, Russulaceae and Thelephoraceae [20, 21]. Considering the importance of *D. retusus* in northeastern India, the present investigations were carried out to study the effect of ectomycorrhizal and endomycorrhizal inoculations on the growth of *D. retusus* seedlings under net house conditions.

2. MATERIALS AND METHODS

Diversity of ectomycorrhizal and endomycorrhizal fungi associated with dipterocarps was done earlier by the authors [22, 23].

2.1. Mass inoculum production of mycobiont

Pure culture of dominant ectomycorrhizal fungus (*Russula amoena*) was raised on PDA and mass inoculum was prepared on wheat grains [24]. The AM spores were collected by wet sieving and decanting technique of Gerdemann and Nicolson [25] and Singh and Tiwari [26] from the rhizosphere soil of *D. retusus* and mass inoculum of dominant species (*Glomus* spp.) was raised with living host (wheat) in earthen pots.

2.2. Seed sowing and mycorrhizal inoculation

Nursery bags (20 x 21 cm) filled with sieved and fumigated soil, were sown with freshly collected seeds of *D. retusus*. At the time of seed sowing the nursery bags were inoculated with mycorrhizal fungi (wheat spawn 2g/bag; 50 AM spores/ bag) and placed in agro shed nets. Four sets of experiments were laid: (i) inoculated with ectomycorrhizal fungi, (ii) inoculated with both ecto and endomycorrhizal fungi, (iii) inoculated with endomycorrhizal fungi, (iv) control (not inoculated).

2.3. Observations in nursery

At the interval of three months, the plants were observed for growth parameters like shoot height, collar diameter, root and shoot volume, root and shoot fresh and dry weight and % mycorrhizal colonization. The comparisons were made with control and among treatments.

2.4. Analysis of mycorrhizal association

The percentage of EcM infection was calculated by using the following formula [27]:

EcM association (%) = (Total number of infected root tips / Total number of root tips studied) x 100

AM colonization was studied by rapid clearing and staining method of Phillips and Hayman [28]. The percentage mycorrhizal root colonization was determined by following formula:

AM colonization (%) = (Total number of infected root segments / Total number of root segments examined) x 100

3. RESULTS

3.1. Mycorrhizal colonization of *D. retusus* seedlings in nursery

Mass inoculum of AM and EcM was raised *in vivo* and *in vitro* respectively (Fig. 1A, B) and applied at the time of seed sowing. Five seedlings from each treatment were uprooted at the interval of three months and observed for growth and mycorrhizal colonization. Significant increase in root/shoot biomass and mycorrhizal colonization was recorded in inoculated seedlings (Table 1; Fig. 1C, D). The seedlings inoculated with EcM alone had recorded 40.6% colonization after three months, which gradually increase to 54.4%, 65.41% and 70.1% in six, nine and twelve months respectively. Similarly the seedlings inoculated with AM fungi alone, have recorded root colonization of 19.69%, 31.94%, 43.02% and 49.74% respectively in three, six, nine and twelve months with spore population ranging between 33-81 spores/50 g soil. While the seedlings inoculated with EcM+AM, most of the short roots have EcM association and negligible AM colonization with spore population of 14, 22, 37 and 42 spores/50 g soil respectively in three, six, nine and twelve month old seedlings. None of the mycorrhizal roots was seen with both type of mycorrhizal association. The seedlings have exhibited 36.13% mycorrhizal colonization in three months and 45.64%, 51.23% and 58.79% colonization in six, nine and twelve month old seedlings respectively.

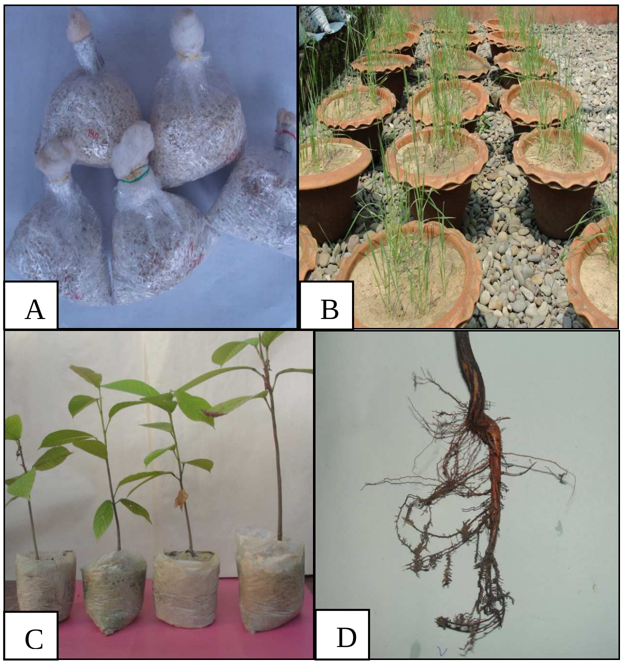

Fig. 1. A. Mass inoculum of EcM fungus; B. Mass inoculum of AM fungi; C. Six month old seedlings (control, EcM+AM, AM, EcM respectively); D. EcM colonization in roots.

Table 1. Colonization of *D. retusus* seedling by mycorrhizal fungi in nursery.

Age of seedling	Treatment	Short roots (No.)	Non-mycorrhizal roots (No.)	Non-mycorrhizal roots (%)	Mycorrhizal roots (No)	EcM/ *AM (%)	AM spores/ 50 g of soil
3 month	Control	116	116	100.00	0	0.00	0.00
	EcM	133	79	59.40	54	40.60	0.00
	EcM + AM	119	76	63.87	43	36.13	14.00
	AM	127	102	80.31	25	19.69	33.00
6 month	Control	132	132	100.00	0	0.00	0.00
	EcM	182	83	45.60	99	54.40	0.00
	EcM + AM	149	81	54.36	68	45.64	22.00
	AM	144	98	68.06	46	31.94	47.00
9 month	Control	158	158	100.00	0	0.00	0.00
	EcM	185	64	34.59	121	65.41	0.00
	EcM + AM	162	79	48.77	83	51.23	37.00
	AM	172	98	56.98	74	43.02	64.00
12 month	Control	169	169	100.00	0	0.00	0.00
	EcM	194	58	29.90	136	70.10	0.00
	EcM + AM	165	68	41.21	97	58.79	42.00
	AM	189	95	50.26	94	49.74	81.00

Table 2. Effect of mycorrhizal inoculations on shoot growth of *D. retusus.*

Growth parameter	Treatment	Age of seedling			
		3 month	6 month	9 month	12 month
Increase in shoot height (%)	EcM	16.67	14.44	10.01	10.04
	AM	6.25	8.52	7.00	7.77
	EcM + AM	7.69	10.82	8.76	8.01
SEm± = 0.23, CD (p=0.05)= 0.69					
Increase in shoot volume (%)	EcM	23.75	22.97	18.60	17.01
	AM	15.28	14.24	12.82	10.46
	EcM + AM	17.94	16.93	13.55	11.73
SEm± = 0.08, CD (p=0.05)= 0.24					
Increase in shoot fresh weight (%)	EcM	24.64	23.15	16.61	19.32
	AM	15.23	14.13	11.06	12.22
	EcM + AM	18.56	18.02	13.32	13.04
SEm± = 0.10, CD (p=0.05)= 0.30					
Increase in shoot dry weight (%)	EcM	16.03	15.68	17.47	17.87
	AM	12.25	11.93	12.93	13.93
	EcM + AM	15.01	14.62	13.33	15.16
SEm± = 0.04, CD (p=0.05)= 0.13					
Increase in shoot collar diameter (%)	EcM	15.26	14.14	11.14	10.61
	AM	13.65	12.57	9.55	8.93
	EcM + AM	14.91	13.74	10.33	9.43
SEm± = 0.02, CD (p=0.05)= 0.07					

3.2. Effect of mycorrhizal inoculations on the shoot growth of *D. retusus* in nursery

The selected shoot growth parameters exhibited significant increase over control irrespective of the treatment. Invariably a significant increase in growth of seedlings inoculated with ectomycorrhizal fungi was observed, followed by seedlings with dual inoculations (EcM+AM fungi) and minimum for the seedlings inoculated with AM fungi only (Table 2). The differences in growth increment were also significant among the treatments. Since the growth was recorded at the interval of three months, the increase in growth from 0-3, 3-6, 6-9 and 9-12 month interval was also significant for all treatments with few exceptions.

Data analysis on shoot height revealed a significant increase over control in all treatments [SEm± = 0.23, CD (p=0.05) = 0.69]. The seedlings inoculated with EcM alone has recorded maximum increase in shoot height (10.04-16.67%) followed by seedlings inoculated with EcM+AM (7.69-8.01%) and minimum in seedlings inoculated with AM alone (6.25-7.77%). Similarly the shoot volume has also recorded maximum increase in the seedlings inoculated with EcM (17.01-23.75%), followed by the seedlings inoculated with EcM+AM (11.73-17.94%) and minimum in the seedlings inoculated with AM (10.46-15.28%). All of the treatments were found statistically significant in comparison to control [SEm± = 0.08, CD (p=0.05) = 0.24]. Likewise the shoot fresh weight has recorded significant increase over control [SEm± = 0.10, CD (p=0.05) = 0.30]. Maximum increase of shoot fresh weight was recorded for EcM inoculated seedlings (16.61-24.64%) followed by EcM+AM inoculated seedlings (13.04-18.56%) and minimum by AM inoculated seedlings (11.06-15.23%). Accordingly the dry shoot weight was also highest for EcM inoculated seedlings (15.68-17.87%) followed by EcM+AM inoculated seedlings (13.33-15.16%) and least in AM inoculated seedlings (11.93-13.93%). All the treatments were statistically significant in comparison to control [SEm± = 0.04, CD (p=0.05) = 0.13]. Although the visible increase in collar diameter was very less but it was statistically significant [SEm± = 0.02, CD (p=0.05) = 0.07]. Like other treatments, the increase in collar diameter was maximum for the seedlings inoculated with EcM (10.61-15.26%), followed by EcM + AM (9.43-14.91%) and minimum for seedlings inoculated with AM (8.93-13.65%).

3.3. Effect of mycorrhizal inoculations on the root growth of *D. retusus* in nursery

The results pertaining the effect of mycorrhizal inoculations on the root growth of *D. retusus* seedlings are presented in Table 3. In coherence to shoot growth, a significant growth in root biomass was also recorded in comparison to its respective control. Highest increase in root length was recorded (16.95-27.88%) for the seedlings inoculated with EcM followed by seedlings inoculated with EcM+AM (14.42-24.24%) and lowest (12.23-21.05%) for the seedlings inoculated with AM alone. The increase in growth was significant among all treatments and with its respective control [SEm± = 0.08, CD (p=0.05) = 0.24]. In similar trend the increase in root volume was also significant in comparison to control [SEm± = 0.04, CD (p=0.05)= 0.13]. The increase in root volume was maximum for the seedlings inoculated with EcM (13.81-24.42%) followed by the seedlings inoculated with EcM+AM (12.18-23.53%) and minimum for the seedlings inoculated with AM only (10.68-19.75%). Similarly the increase in root fresh weight was maximum for the seedlings inoculated with EcM (12.04-26.81%) followed by seedlings inoculated with EcM+AM (11.00-24.72%) and minimum for seedlings inoculated with AM (9.74-21.57%). All of the treatments were significant in respect to control [SEm± = 0.05, CD (p=0.05)= 0.16]. Likewise significant increase was recorded for root dry weight [SEm± = 0.03, CD (p=0.05)= 0.08]. It was maximum for the seedlings inoculated with EcM (10.93-21.82%) followed by the seedlings inoculated with EcM+AM (8.81-20.83%) and seedlings inoculated with AM (7.72-19.82%) with reference to control.

Table 3. Effect of mycorrhizal inoculations on root growth of *D. retusus.*

Growth parameter	Treatment	Age of seedling			
		3 month	**6 month**	**9 month**	**12 month**
Increase in root length (%)	EcM	27.88	25.17	16.79	16.95
	AM	21.05	22.69	13.85	12.23
	EcM + AM	24.24	23.95	14.07	14.42
SEm± = 0.08, CD (p=0.05)= 0.24					
Increase in root volume (%)	EcM	24.42	23.26	13.81	14.83
	AM	19.75	20.48	10.68	11.84
	EcM + AM	23.53	22.81	12.18	13.96
SEm± = 0.04, CD (p=0.05)= 0.13					
Increase in root fresh weight (%)	EcM	26.81	29.58	12.14	12.04
	AM	21.57	24.15	9.74	10.37
	EcM + AM	24.72	25.93	11.24	11.00
SEm± = 0.05, CD (p=0.05)= 0.16					
Increase in root dry weight (%)	EcM	18.67	21.82	10.93	14.76
	AM	14.05	19.82	7.72	11.23
	EcM + AM	16.83	20.83	8.81	13.32
SEm± = 0.03, CD (p=0.05)= 0.08					

4. DISCUSSION

Earlier the dipterocarps were known as ectomycorrhizal [27, 29], but some studies also revealed AM colonization [30, 31]. Natarajan et al. [32] has reported the species of *Amanita*, *Boletus*, and *Russula* as ectomycorrhizal associates of Dipterocarpaceae. Shi et al. [16] have recorded *Acaulospora* and *Glomus* as dominant genera associated with different dipterocarp species with varying rates of colonization. Comparable to earlier studies, we got *Russula amoena* as dominant ectomycorrhizal fungus and *Glomus* species as dominant AM fungi associated with *D. retusus*, mass inoculum of these fungi was prepared and applied at the time of seed sowing in nursery bags filled with sterilized soil. In favorable environmental conditions, the fungi grow, multiply and make symbiotic association with roots of growing seedlings. Maximum mycorrhizal colonization and increase in root/shoot growth was recorded for the seedlings inoculated with EcM, followed in dual inoculations, seedlings inoculated with AM alone and least in control. This may be due to the formation of symbiotic association among the roots of *D. retusus* seedling and mycorrhizal inoculum incorporated in the nursery bags. The mycorrhizal fungi have helped the seedlings for better nutrient uptake and resulted in increased growth over control. Several nursery experiments revealed that mycorrhizae improve dipterocarp seedling growth and nutrient uptake [33-35].

Dual inoculation of *D. retusus* seedlings exhibited maximum EcM colonization in comparison to AM colonization. It was also observed that the growth was more than the seedlings inoculated with AM alone, but less that seedlings inoculated with EcM alone. Like Dipterocarps, the Eukalypts are also known to have dual mycorrhizal (EcM and AM) association [36]. Gange et al. [37] observed that dual inoculation of *Eucalyptus urophylla* reduced tree growth for some period in the early stages when inoculated with AM fungi and no effects of EcM inoculation on tree growth. In North America alone 2 billlion tree seedlings are grown annually in nurseries for artificial regeneration programmes. They recorded dramatic improvements in survival and growth of various pines species inoculated with ectomycorrhizal fungi [38]. The ectomycorrhizal association increases the surface area of the roots and facilitate better intake of nutrients like nitrogen, phosphorus and potassium from the rhizosphere soil [39]. *D. retusus* is one of important tree species of northeast India and by efficiently utilizing the mycorrhizal technology in nursery, the seedling establishment and performance can be increased during field transplantations.

AUTHORS CONTRIBUTION

AT: Overall design and execution of research work and paper writing; RK: Layout of nursery experiment and observations; DB: Data collection from trials. The final manuscript has been read and approved by both authors.

TRANSPARENCY DECLARATION

The authors declare no conflicts of interest.

ACKNOWLEDGEMENTS

The authors are gratefully acknowledged to Indian Council of Forestry Research and Education (ICFRE) for funding the research project: No-RFRI-13/2008-09/FP.

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ISSN 2449-8866

Current
Life Sciences

Research Article

Diversity of herpetofaunal community in Kuldiha wildlife sanctuary, Odisha, India

Srustidhar Rout[1], Biswajit Baruah[1], Nirlipta Mishra[2], Taranisen Panda[3]*

[1] Department of Wildlife & Biodiversity Conservation, North Orissa University, Takatpur, Baripada - 757003, Odisha, India
[2] Department of Zoology, Chandbali College, Chandbali, 756133, Bhadrak, Odisha, India
[3] Department of Botany, Chandbali College, Chandbali, 756133, Bhadrak, Odisha, India
*Corresponding author: Taranisen Panda, e-mail: taranisenpanda@yahoo.co.in

Received: 23 September 2015; **Revised submission:** 06 December 2015; **Accepted:** 27 December 2015

ABSTRACT

The diversity and distribution of reptiles and amphibians was studied in Kuldiha Wildlife Sanctuary of Odisha, India. Data on the herpeto-faunal population was collected from all the possible microhabitat sites of the sanctuary following standard procedure. One amphibian species (*Polypedates maculatus*), two lizard species *Cosymbotus platyurus* and *Cyrtodactylus nebulosa* and two species of snake (*Ahaetulla nasutus isabalinus* and *Lycodon aulicus*) were recorded for the first time. *Duttaphrynus melanostictus*, and *Psammophilus dorsalis* were the dominant species among the anurans and lizards respectively. *Ptyas mucosa*, *Xenochropis piscator* and *Lycodon aulicus* were the common snakes found throughout the sanctuary. The chelonian diversity was poor in comparison to the other reptiles groups. Kuldiha forest habitat is under threat due to anthropogenic activities like firewood collection and grazing pressure by cattle and goats. Awareness prog-rammes are needed in order to make people acquainted with herpetofauna and their importance for a balanced ecosystem.

Keywords: Herpetofauna; Reptiles; Amphibians; Kuldiha wildlife sanctuary; Odisha.

1. INTRODUCTION

In many ecosystems of India the reptiles and amphibians exist with great diversity of habitats and microhabitats such as deserts, grasslands, forests, oceans, hills, agro-ecosystems and even in our houses. More than 518 species of reptiles [1] and 314 species of amphibians [2] are found in India. According to IUCN criteria 57% of the amphibians in India are 'threatened' [3]. The prevailing climate, availability of food, moisture, microhabitat and human interference influence the herpetofaunal community in a particular area [4]. Habitat destruc-tion and the resulting fragmentation of population are the most important factors affecting amphibian populations [5]. The Kuldiha Wildlife Sanctuary is located in the Nilgiri Civil Sub Division of Balasore (Wildlife) division bordering to Mayurbhanj district and the area lies between 21˚-20´ to 21˚-30´N and 86˚-30´ to 86˚-45´E and covers an area of 272.75 km^2. The sanctuary harbour mainly three types of forests: northern tropical semi evergreen forest, peninsular (coastal) sal forest and moist mixed deciduous forest [6]. The area exhibits a high level of heterogeneity in vegetation both at the local and landscape level, strongly influenced by the topo-graphic complexity. Investigations of herpetofaunal species are receiving considerable attention because of the proposed role of reptiles as indicators of ecosystem deterioration [7]. In this context, documentation on herpetological species of Kuldiha Wildlife Sanctuary has been poorly studied and described [8, 9]. The present investigation focuses on the diversity and distribution of herpetological species along with their threats and conservation in Kuldiha Wildlife Sanctuary of Odisha

2. MATERIALS AND METHODS

The current study was carried out during March 2009 - August 2009 in Kuldiha Wildlife Sanctuary to assess herpetofaunal diversity and to evaluate the effects of human interferences. The surveys were carried out in all available microhabitats; mainly in leaf litter, under rocks, fallen and decaying logs, tree bark, grass clumps, on shrubs (plants > 1 m and < 7 m in height), on herbs (plants < 1 m in height), in tree holes and alongside forest trials and streams utilising the visual encounter methodology [10], during both day and night surveys. Specimens were captured by hand, or with the aid of blowpipes and snake hooks. With the aid of coloured field guides locals of Kuldiha Wildlife Sanctuary were interviewed to explore their knowledge of local herpetofaunal diversity. Specimens were euthanized in the field by immersion of dilute Chlorobutanol, fixed in 10% buffered formalin and stored in 70% ethanol. The different recorded species were identified taxonomically according to Smith [11], Schleich and Kastle [12], Das [13, 14], Dutta [15] and David and Vogel [16].

3. RESULTS AND DISCUSSION

A total of five amphibian species were observed from which four species were documented previously [8, 9], and one species (*Polypedates maculatus*) was reported for the first time (Table 1). Out of the 15 lizard species, two species (*Hemidactylus platyurus and Geckoella nebulosa*) have not been recorded previously; the remaining 13 species were documented previously [8, 9]. Although 25 species of snakes were observed previously, two newly recorded species i.e. *Ahaetulla nasutus isabalinus* and *Lycodon aulicus* were documented in the present investigation. According to Daniel [17], Whitaker and Captain [18] the common green whip snake *Ahaetulla nasutus isabalinus* is a peninsular species, widely distributed except in the northwest and much of the Gangetic basin. This species has been reported in Kuldiha Wildlife Sanctuary. During the survey period no turtles and tortoises were observed through direct observation. However, two species i.e. *Chitra indica* (Gray, 1830) and *Lissemys punctata* (Lacépède, 1788) were domesticcated by the local people (secondary source). Of the anurans *Duttaphrynus melanostictus* and *Hoplobatrachus tigerina* were the abundant species in the forested areas of the sanctuary. *Duttaphrynus melanostictus* is cosmopolitan in distribution [15] and is known to occur in a variety of habitats, especially in disturbed areas [19]. *Psammophilus dorsalis* was the most abundant lizard species encountered. In case of snakes *Xenochropis piscator, Ptyas mucosa* and *Lycodon aulicus* were frequent throughout the sanctuary. *Xenochrophis piscator* is one of the most common snakes in India [17, 20-21]; it is also found to be the most relatively abundant snake at Kuldiha. *Xenochrophis piscator* and *Naja naja* were more likely to create human-snake conflict in the study area. In most cases, non-venomous snakes were found to be the victims in the human-snake conflict, as most of the people unable to distinguish between venomous and non-venomous snakes. Lack of awareness was the main reason for the killing of snakes [21]. But the chelonian diversity is poor in comparison to the other reptile groups. The distribution pattern of herpetofauna was widely varied among different habitat types of Kuldiha. In most cases, physiological constraints have confined the amphibians to moist habitats, added to which their dispersal capacity and strong site fidelity have further restrained them [22-24].

Kuldiha Wildlife Sanctuary being blessed with tropical dry forests provides shelter for the living treasure of nature is under threat due to anthropogenic activities [25]. In the Sanctuary, poaching takes place almost any time during the year and is conducted by local ethnic people and neighbourhoods nearby as well as professional hunters and trappers coming from the other provinces. Therefore, uncontrolled hunting was identified as one of the most important threat to the larger snakes, turtles.

Table 1. Herpetofaunal diversity of Kuldiha wildlife sanctuary, Odisha, India.

Zoological name	Class, order, family	Place of observation
Duttaphrynus melanostictus (Schneider, 1799)	Amphibia, Anura Bufonidae	This toad was observed in association with anthropogenic or modified/disturbed habitats, near the Jorachowa forest rest house.
Hoplobatrachus tigerina (Daudin, 1802)	Dicroglossidae	The species was encountered from the forest of Jorachowa. A number of this species were calling from nearby pools.
Fejervarya limnocharis (Gravenhorst, 1829)	Dicroglossidae	The species was observed within the field station's compound wall during March and June surveys.
Euphylyctis cyanophlyctis (Schneider, 1799	Dicroglossidae	This frog was commonly found inside the water bodies of the sanctuary.
Polypedates maculatus (Gray, 1830)	Rhacophoridae	The species was caught from a drooping climber near the water body of Purunapani forest.
Calotes versicolor (Daudin, 1802)	Reptilia Squamata (Sauria) Agamidae	Individual of this species were collected from the trees in the Kuldiha forest area.
Calotes rouxii (Duméril & Bibron, 1837)	Agamidae	This species was observed especially in the tree and inside tree holes of the sanctuary but mostly found in Kuldiha and Jorachowa locality.
Psammophilus dorsalis (Gray, 1831)	Agamidae	This species was observed while crossing the main road at morning time just outside the Kuldiha forest area, moving apparently from the forest towards scrub area on the other side of the road.
Sitana ponticeriana (Cuvier, 1829)	Agamidae	The species was encountered on the rock surface besides the forest trail near streamline vegetation.
Eublepharis hardwickii (Gray, 1827)	Eublepharidae	The species was commonly recorded from the side of drain, near Spider cave and near rock field of Purunapani area.
Hemidactylus frenatus (Schelegel, 1836)	Gekkonidae	This gecko was commonly encountered in house and is common throughout the sanctuary.
Hemidactylus brookii (Gray, 1845)	Gekkonidae	This species was collected from the Jorachowa forest area.
*Hemidactylus leschenaultii (*Duméril & Bibron, 1836)	Gekkonidae	The species was encountered on the tree bark near Devigarh hills.
Hemidactylus platyurus (Schneider, 1792)	Gekkonidae	The species was recorded on the tree bark near Devigarh hills and is basking.
Geckoella nebulosa (Beddome,1870)	Gekkonidae	This species collected from the Devigarh hills forest.
Eutropis bibronii (Gray, 1838)	Scincidae	The species was collected from beneath a rock near the top of Sergarh hills.
Eutropis carinata (Schneider, 1801)	Scincidae	The species was recorded from secondary and degraded forest areas as well as roadside and around habitation of Nilgiri hills, Devigarh hills, Purunapani, Kuldiha and Jorachowa. At night individuals were seen roosting on thick bushy plants and in tree holes.
Eutropis macularia (Blyth, 1853)	Scincidae	The species was recorded from leaf litter of dry stream bed of Jorachowa inside secondary forest.
Lygosoma albopunctata (Gray, 1846)	Scincidae	Recorded mostly around the stream near the forest trail and in the bambusetum.
Varanus bengalensis (Daudin, 1802)	Varanidae	This species was encountered while crossing the forest trail in the early morning near the Sergarh hill forest.
Bungarus caeruleus (Schneider, 1801)	Squamata (Serpentes) Elapidae	This species was encountered near human habitation of Kuldiha forest range.
Bungarus fasciatus (Schneider, 1801)	Elapidae	One dead and partly eaten specimen found on the road.

Zoological name	Class, order, family	Place of observation
Naja kaouthia (Lesson, 1831)	Elapidae	The brown variety of this species was observed from Nilgiri forest area during the survey period. The individual had taken refuge under accumulated firewood near habitation at degraded forest edge.
Naja naja (Linnaeus, 1758)	Elapidae	The individual was reported on Devigarh hill from a bamboo thicket area.
Ophiophagus hannah (Cantor, 1836)	Elapidae	One male individual of the species was killed inside the human habitation during day time of Nilgiri area.
Enhydris enhydris (Schneider, 1799)	Homalopsidae	Commonly seen near the drains and wetlands of the sanctuary.
Argyrogena fasciolata (Shaw, 1802	Natricidae	This species was observed near the forest edge of Jodachua.
Amphiesma stolatum (Linnaeus, 1758)	Natricidae	Commonly seen along the wetlands and the drains of the sanctuary.
Ahaetulla nasuta var. isabellinus (Lacepede, 1789)	Natricidae	This species was observed while crossing forest near the Purunapani locality.
Atretium schistosum (Daudin, 1803)	Natricidae	The species was observed while basking on the bank of the stream.
Boiga trigonata (Schneider, 1802)	Natricidae	A female individual was found inside a dry bamboo at 3 ft above the ground in Devigarh hill area. The biotope where the snake was recorded is covered with degraded forest on a low hill with extensive bamboo clump.
Chrysopelea ornata (Shaw, 1802)	Natricidae	This species was sighted while it was basking on the tree.
Dendrelaphis tristis (Daudin, 1803)	Natricidae	One individual was encountered while it was crossing forest near the Devigarh forest edge.
Lycodon aulicus (Linnaeus, 1758)	Natricidae	This species was widely distributed and is recorded from Purunapani and Jorachowa forest area.
Lycodon jara (Shaw, 1802)	Natricidae	This species was observed on the tree near the Sergarh forest edge.
Macropisthodon plumbicolor (Cantor, 1839)	Natricidae	The snake was encountered at 1-2m above ground among woody shrubs of stream side hill slope at Devigarh.
Ptyas mucosa (Linnaeus, 1758)	Natricidae	The species was encountered in Nilgiri, Sergarh and Kuldiha forest area near human habitation.
Xenochrophis piscator (Schneider, 1799)	Natricidae	This species was observed throughout the sanctuary.
Python molurus (Linnaeus, 1758)	Pythonidae	One dead individual, approx. 4m in length was encountered on Sergarh hill area.
Rhinotyphlops acutus (Duméril & Bibron, 1844)	Typhlopidae	One dead individual was observed on the forest of Chandipur.
Typhlops diardii (Schlegel, 1839)	Typhlopidae	The species was recorded from Purunapani forest edge. The individual taken refuse on tree crevice at 25cm above water level of a waterlogged area.
Ramphotyphlops braminus (Daudin, 1803)	Typhlopidae	This species was observed in dead and partly eaten condition on the road near the Kuldiha forest rest house.
Uropeltis ocellata (Beddome, 1863)	Uropeltidae	This species was encountered under the leaf litter.
Trimeresurus gramineus (Shaw, 1802)	Viperidae	One male was encountered while moving on ground on the bank of the stream. The individual was seen coiling among leaf of an overhanging tree branch at 4m above flowing stream water.
Daboia russelii (Shaw & Nodder, 1797)	Viperidae	A single juvenile individual was found under boulders of the forest trail.

Moreover, fire, firewood collection by the local people and grazing pressure by cattle and goats, within the boundaries of the sanctuary also creates threats to the herpetofaunal diversity. In the present period of mass extinction of biodiversity [26, 27] many species of animals, plants, and other organisms are disappearing at an alarming rate, primarily due to human activities such as deforestation [28, 29], fire [30], erosion [31], lack of systematic or scientific understanding [32] and some what may be due to climate change [33]. Additionally, the use of agrochemicals is a great threat to the local biodiversity, especially for the environmentally sensitive amphibians. Habitual overuse of agrochemicals in cultivation can lead to death, malformations, and abnormalities in amphibians [34].

Knowledge of biodiversity and organization of its communities is essential for the development of conservation policies and a sustainable environmental management system. Herpetofauna are the integral part of both terrestrial and aquatic ecosystem and are very sensitive to habitat quality [35]. Consequently, the identification of amphibians and reptiles and the study of their ecological characteristics are decisive for the success of actions directed to biodiversity conservation and resource management strategies [36]. Results of the present study could provide base line information that would fill gaps in understanding these species diversity and distribution patterns. Awareness programmes are needed in order to make people acquainted with herpetofaunal communities and their pivotal role for a balanced ecosystem.

AUTHORS CONTRIBUTION

SDR: Field data collection, compilation of data, collection of references and manuscript preparation; BB: Field data collection, compilation of data; NM: Field data collection, compilation of data, collection of references; TP: Collection of references, manuscript preparation, final editing and checking of manuscript. The final manuscript has been read and approved by all authors.

TRANSPARENCY DECLARATION

The authors declare no conflicts of interest.

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ISSN 2449-8866

Current
Life Sciences

Research Article

Efficacy of entomopathogenic fungi on *Craspedonta leayana*, a serious insect pest of *Gmelina arborea*

Raja Rishi*, Shailesh Pandey, Rajib Kumar Borah, Rajesh Kumar, Nizara Borthakur

Forest Protection Division, Rain Forest Research Institute, Jorhat - 785 001, Assam, India
*Corresponding author: Raja Rishi; e-mail: rajappanrajarishi@rediffmail.com

Received: 20 November 2015; **Revised submission:** 31 December 2015; **Accepted:** 05 January 2016

ABSTRACT

The chrysomelid beetle, *Craspedonta leayana* Latr., is the most destructive defoliator of *Gmelina arborea* Roxb. In North East India, severe outbreaks were recorded from April to October in *G. arborea* nurseries and plantations. The trees were completely defoliated during May to September. Considering the importance of the tree species, an attempt was made to manage this menace using entomopathogenic fungi (EPF). A total of five fungal isolates were recovered from the infected cadavers of *Galleria mellonella* through insect bait method. The fungal isolates were identified as *Beauveria bassiana*, *Fusarium* sp., *Metarhizium anisopliae*, *Paecilomyces* sp., and *Verticillium lecanii*. One way analysis of variance revealed significant differences ($P<0.05$) among EPF in causing the III instar larval mortality of *C. leayana*. Highest spore concentration 2.4 x 10^{10} spores/ml of *B. bassiana*, *M. anisopliae*, *V. lecanii*, *Paecilomyces* sp., and *Fusarium* sp. were found to cause percent mortality of 100, 88, 54, 47.8 and 31 in laboratory condition, respectively, and 90, 50, 29, 28 and 2 in field condition, respectively. *B. bassiana* and *M. anisopliae* were found more effective, in both laboratory as well as in field conditions, but significant differences were observed in their efficacy. The result of the present study indicates: the field application of *B. bassiana* is an effective management approach to combat *C. leayana*.

Keywords: *Beauveria bassiana*; *Metarhizium anisopliae;* Entomopathogenic fungi; *Verticillium lecanii.*

1. INTRODUCTION

Gmelina arborea Roxb. is an important tree species of commercial value planted in large scale in North East India by the forest department and private owners. It is an indigenous fast growing tree species native to South Asia from Pakistan to Myanmar and Sri Lanka and has been widely planted in Southeast Asia, tropical Africa and America. It grows well with teak and number of other forest ecosystem [1, 2]. The wood is having an excellent timber value and also useful for pulp and paper industries. It is considered to be a good fodder as well as medicinal plant and used for various diseases like gonorrhea, cough etc. It is also useful for match boxes splints. During our pest survey during 2011-2014 in North-East India, *C. leayana* was found to be the major defoliator of *G. arborea* plantations. Earlier, about 34 insect pests mostly defoliators were reported on this tree species from Kerala, India [3]. Integrated pest management (IPM) is a suitable multidisciplinary methodology to adopt for pest management that is practical, effective, economical and protective of both public health and environment [4]. The effective utilization of EPF to manage a variety of insect pests of agricultural and horticultural importance was attempted by many researchers [5, 6]. *Brachymeria excarinata* (parasitoid) and *B. bassiana* (EPF) were found effective against *C. leayana* [7]. Keeping in mind the serious nature of pest incidence, an attempt was made to evaluate the native entomopathogenic fungi against *C. leayana* in laboratory and field conditions.

2. MATERIALS AND METHODS

2.1. Entomopathogenic fungi trapping

Soil samples were collected from various land use systems and subjected to insect bait method using *Galleria mellonella* [8]. Infested cadavers of *G. mellonella* were collected in clean and surface sterilized plastic containers and stored at 4^0C till further use. The fungi were isolated from the infected cadavers were subcultured in Sabouraud Dextrose Agar medium (SDA) and pure cultures were obtained and maintained in refrigerated condition.

2.2. Conidial suspension preparation

Fungal isolates were grown in SDA at 28^0C for 8-10 days. Spores were harvested by scrapping the media surface and aqueous solutions were prepared. The spore suspensions were then filtered through several layers of muslin cloth to remove mycelial mats. The concentration of spores in the final suspension was determined by haemocytometry [9].

2.3. Dilution, counting and estimation of spore concentration

One ml of the purified EPF suspension was diluted with water containing 0.1% wetting agent (Tween-80). The spores were counted in about 25 of 1/400 mm^2 using a haemocytometer. Spore suspensions of desired concentration were prepared from the stock with suitable dilution with sterilized distilled water. If the number of spores counted from 25 of 1/400 mm^2 is X and the original dilution is 100 times, then the spores/ml was calculated as follows:

Spores in 1 Sq.mm = $(X \times 400) / 25$

To calculate the spores in 1 cu.mm, the depth of the suspension in between the haemocytometer and the cover slip, which is 0.1 mm or the depth factor, is 10.

Spores in 1ml = $(X \times 400 \times 10 \times 1000) / 25$

Taking into consideration the dilution factor:

Spores in 1 ml = $(X \times 400 \times 10 \times 1000 \times 100 \times 10) / 25$

Then the concentration will be $X \times 10^{10}$ spores/ml.

2.4. Bioefficacy of EPF isolates

Third instar larvae of *C. leayana* were used for conducting bioassay studies. Five fungal isolates, viz., *B. bassiana*, *Fusarium* sp., *M. anisopliae, Paecilomyces* sp., and *V. lecanii* with four spore concentrations, viz., 2.4 x 10^{10}, 2.4 x 10^8, 2.4 x 10^6 and 2.4 x 10^4 spores/ml were tested against *C. leayana* in laboratory condition. Healthy third instar larvae of *C. leayana* reared in the laboratory were surface sterilized with 1-5% sodium hypochlorite and released to feed on the fungus treated leaves of *G. arborea*. Twenty larvae were used per replication and five replications were maintained for each concentration. Larvae sprayed with only distilled water was served as control. Larval mortality was recorded at every 48 h interval and recording of data was concluded on the seventh day of the experiment. Likewise, in the field testing, foliar spray of five isolates, viz., *B. bassiana, M. anisopliae, V. lecanii*, *Paecilomyces* sp., and *Fusarium* sp. with all the four concentrations, viz., 2.4 x 10^{10}, 2.4 x 10^8, 2.4 x 10^6 and 2.4 x 10^4 spores/ml was done and the healthy III instar larvae of *C. leayana were* released onto the treated *G. arborea* seedlings. The mortality was observed up to 7 days after spraying of spores suspensions. The data on percent mortality were subjected to Analysis of Variance (ANOVA) using SPSS version 16.

3. RESULTS AND DISCUSSION

A total of five fungal isolates were recovered from the infected cadavers of *G. mellonella* and identified as *B. bassiana*, *Fusarium* sp., *M. anisopliae*, *Paecilomyces* sp., and *V. lecanii* on the basis of microscopic and colony characteristics. Significant differences among the EPF were observed in causing the larval mortality at different concentrations ($P < 0.05$). The highest spore concentration

2.4×10^{10} spores/ml of *B. bassiana*, *M. anisopliae, V. lecanii, Paecilomyces* sp., and *Fusarium* sp., were found to cause percent mortality of 100, 88, 54, 47.8 and 31 respectively after 7 days (Table 1). All the isolates were found significantly different from each other at the highest concentrations, i.e. 2.4×10^{10} and 2.4×10^{8} spores/ml. No significant difference was found in the effect of *V. lecanii* and *Paecilomyces* sp. in causing the larval mortality at 2.4×10^{6} and 2.4×10^{4} spores/ml concentrations. Significant differences were observed among the EPF isolates under field conditions ($P < 0.05$), where the highest spore concentration of 2.4×10^{10} spores/ml of *B. bassiana*, *M. anisopliae, V. lecanii, Paecilomyces* sp., and *Fusarium* sp., were found to cause percent mortality of 90, 50, 29, 28 and 2 respectively (Table 2). No significant differences were observed in the efficacy of *V. lecanii* and *Paecilomyces* sp. with the rest of the spore concentrations tested. *Fusarium* species was found to be not effective, i.e. similar to the control. The data shows an increase in the III instar larval mortality with an increase of EPF concentration. *B. bassiana* was found to be more virulent than *M. anisopliae* under laboratory and field conditions.

Similar observation was recorded with *B. bassiana* at the concentration of 1×10^{5} spores/ml causing mortality in the *Myllocerus viridanas* on Teak in Kerala [10]. Similarly, high mortality due to *B. bassiana* on the shot hole borer, *Euwallacea fornicates* infesting tea in South India was also reported [11]. EPF are reported effective against several insect pests of various economically important agricultural crops. EPF was found highly effective against mites *Isaria fumosorosea* [12, 13]. *B. bassiana* was found effective in controlling *Helicoverpa armigera*, a major pest of tomato [14]. *B. bassiana* was also reported to cause 88.68 percent mortality of *Dicladispa armigera* on rice and also found effective against *Spilarctia oblique* [15, 16].

Table 1. Effect of different concentrations of entomopathogens (EPF) on the larval mortality percentage of *C. leayana* in laboratory condition after 7 days.

Entomopathogens	2.4×10^{10} spores/ml	2.4×10^{8} spores/ml	2.4×10^{6} spores/ml	2.4×10^{4} spores/ml
B. bassiana	100^{a}	100^{a}	99.4 ± 0.54^{a}	98.6 ± 1.34^{a}
M. anisopliae	88 ± 0.70^{b}	85 ± 1.00^{b}	79.6 ± 2.88^{b}	72 ± 2.00^{b}
V. lecanii	54 ± 1.00^{c}	50.4 ± 0.54^{c}	42.2 ± 1.48^{c}	39.2 ± 0.70^{c}
Paecilomyces sp.	47.8 ± 1.30^{d}	44.8 ± 1.09^{d}	40.8 ± 1.30^{c}	38.4 ± 2.30^{c}
Fusarium sp.	31 ± 1.73^{e}	26.2 ± 0.83^{e}	23.4 ± 1.34^{d}	16.4 ± 0.54^{d}
Control	0.0^{f}	0.0^{f}	0.0^{e}	0.0^{e}

In the column, values having the same letter are not statistically different ($P < 0.05$) according to Duncan's multiple range test.

Table 2. Effect of different concentrations of entomopathogens (EPF) on the larval mortality percentage of *C. leayana* in field condition after 7 days.

Entomopathogens	2.4×10^{10} spores/ml	2.4×10^{8} spores/ml	2.4×10^{6} spores/ml	2.4×10^{4} spores/ml
B. bassiana	90 ± 0.70^{a}	82.2 ± 2.04^{a}	59.6 ± 1.14^{a}	40.8 ± 1.30^{a}
M. anisopliae	50 ± 1.22^{b}	40 ± 1.22^{b}	33.6 ± 1.51^{b}	26 ± 0.70^{b}
V. lecanii	29 ± 1.87^{c}	21.6 ± 1.14^{c}	13.2 ± 0.83^{c}	8.2 ± 0.70^{c}
Paecilomyces sp.	28 ± 0.70^{c}	20 ± 0.70^{c}	11.2 ± 0.83^{c}	6.2 ± 0.83^{c}
Fusarium sp.	2.0 ± 0.54^{d}	1.8 ± 0.83^{d}	1.2 ± 0.44^{d}	1.0 ± 1.00^{d}
Control	0.0^{e}	0.0^{e}	0.0^{e}	0.0^{e}

In the column, values having the same letter are not statistically different ($P < 0.05$) according to Duncan's multiple range test.

Very limited reports are available in the management of pest on forestry tree species. *B. bassiana* was reported as an important biocontrol agent to control *Hypsiphylla robusta*, a serious pest of *Toona ciliate* and *Sweietenia macrophylla* in Uttar Pradesh, India [17]. *B. bassiana* as a promising biocontrol agent on the bark feeding borer, *Indarbela quadrinotata* on *Casuarina equisetifolia* was earlier reported [18]. The efficacy and persistence of *B.bassiana* on the diamond back moth larvae (*Plutella xylostella)* was studied [19]. Therefore, the EPF have demonstrated considerable potential in pest control especially within IPM programs. Furthermore, their restricted host ranges allow for control of insect pests with limited harm to non target organisms including predators, parasites, and other beneficial microbes. Therefore, non hazardous and environmental friendly nature of EPF, makes them suitable choices for pest management.

4. CONCLUSIONS

B. bassiana and *M. anisopliae* with the higher concentrations 2.4×10^{10} and 2.4×10^{8} spores/ml were found effective and resulting considerable larval mortality of *C. leayana* in laboratory as well as in field condition. Therefore, *B. bassiana* can be considered as a potential candidate for inclusion in ecofriendly pest management of *C. leayana* on *G. arborea*. Future research should focus on the formulation development of effective EPFs, to target the key insect pest of economically important tree species. Furthermore, awareness programmes for the effective utilization of bio-pesticides should be carried out for the benefit of end users.

AUTHORS CONTRIBUTION

Conception and design: RR; Development of methodology: RR, SP, RK; Acquisition of data: NB, RR; Analysis and interpretation of data writing, review and/or revision of the manuscript, administrative, technical or material support: RR, RKB; Study supervision: RR. The final manuscript has been read and approved by all authors.

ACKNOWLEDGEMENT

The authors are thankful to the Director, Rain Forest Research Institute, Jorhat for providing the laboratory facilities. Financial support for this work by the Indian Council of Forestry Research and Education, Dehradun, India, is gratefully acknowledged.

TRANSPARENCY DECLARATION

The authors declare no conflicts of interest.

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ISSN 2449-8866

Current
Life Sciences

Research Article

Preliminary study of avifauna diversity of Utkal University Campus, Bhubaneswar, Odisha, India

Pooja Pattnaik[1], Manika Das[1], Siba Prasad Parida[2]*

[1]P.G. Department of Zoology, Utkal University, Vani Vihar, Bhubaneswar, Odisha, India
[2]Regional Museum of Natural History, RRL, Acharya Vihar, Bhubaneswar, Odisha, India
*Corresponding author: Dr. Siba Prasad Parida; email: paridasp@gmail.com

Received: 07 December 2015; **Revised submission:** 19 February 2016; **Accepted:** 24 February 2016

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ABSTRACT

Utkal University Campus, Vani Vihar, Bhubaneswar is a vast area of 400 acre land located in temple city, Bhubaneswar. The campus is a good habitat of different species of birds due to its plenty vegetation. A one year survey of the avifauna present in this campus revealed the presence of 63 species of birds belonging to 12 orders. Of these 48 species were resident and 15 species were migrant. One endangered species Green sandpiper, four species Black kite, Black shoulder kite, Shikra and Eurasian scoop owl are under the appendix of CITES and 54 species are protected under schedule-IV of the WPA, 1972. Being the first avifauna survey of this site, the present study indicates that the campus of Utkal University is sufficiently rich in avian species diversity.

Keywords: Avifauna diversity; Survey; Habitat; Endangered; Checklist.

1. INTRODUCTION

Birds have always fascinated man for their ability to fly in air and for their exquisite colouration. They have their functional role in ecosystem as potential pollinators and scavengers, indeed rightly called bioindicators [1]. As far as bird diversity is concerned, India is a blessed country having more than 1300 species which is over 13% of the world bird species [2, 3]. But unfortunately India is third among the countries having the largest number of threatened and rare bird species followed by Brazil and Indonesia [4]. Continued degradation of forest, habitat loss and urbanization are the major threats for avian diversity in Northeast India [5]. Odisha being a state of India, is the place where resides more than 541 species of birds.

The distribution and occurrence of avifauna co-relate well with the vegetation patterns of the area which is of great significance [6]. The vegetation found in Utkal University Campus mainly consists of large number of tall trees viz., *Magnolia champaca* (L.), *Aegle marmelos* (L.), *Neolamarckia cadamba* (Roxb.), *Mangifera indica* (L.), *Mimusops elengi* (L.) etc. which provide food as well as nesting and breeding sites for many bird species [7]. Campus also contains two water bodies (Talapadeswari pond and Oxidation pond) which attract many resident and migratory birds every year. Besides tall trees, shrubs and grasses also add to the diversity of bird habitat in the campus.

Since no one has conducted satisfactory work regarding the diversity of avifauna of this campus, thus the present study is focused on preparing the checklist of birds and their status. This will provide baseline information for future in depth studies.

2. MATERIALS AND METHODS

2.1 Study area

Utkal University (20°18’14” N and 85°50’23” E) established in the year 1943, is the seventeenth oldest University in India. Its present campus at Vani Vihar is located on a sprawling 400 acre area in Bhubaneswar beside the National Highway No. 5, connecting Kolkata and Chennai. The University campus is nestled with academic buildings, university hostels, temple, pond, sports ground and barren lands. The entire campus is criss-crossed with good networks of roads which is tree lined.

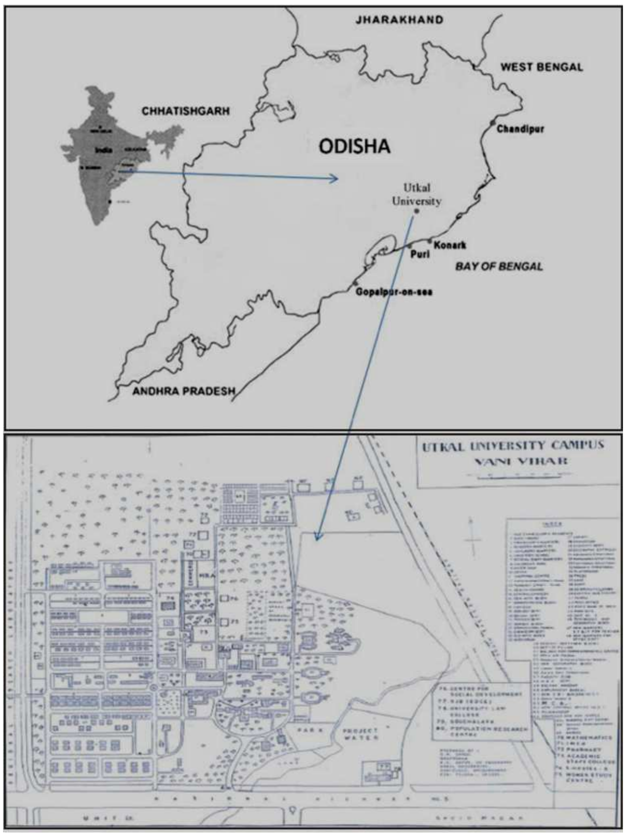

Figure 1. Map of Utkal University Campus, represents the studied area.

2.2. Methods

The study was carried out for a period of one year from February 2014 to February 2015. Point count method and digital method were followed to record the bird species. Bird were observed using binocular (Canon 10x X 50x) and photographs were taken by using digital camera (Canon SX160, 16 Mpx). Then the identification of birds was carried out with the help of field guides [4, 8]. The survey was carried out regularly during the most active period of the day i.e., in the morning from 6.00 am to 8.00 am. And casual observations were made whenever possible.

Based on the frequency of field observation, abundance of birds was categorized as Very Common (VC), Common (C), Uncommon (UN) and Rare (R). According to the migratory behavior, status of birds was categorized as Residental (RS), Local Migrant (LM), Migratory (M) and Winter Visitors (WV). The birds were also classified on the basis of their food habits such as Carnivorous (C), Frugivorous (F), Grainivorous (G), Insectivorous (I), Nectarivorous (N), Omnivorous (O) and Piscivorous (P).

Any schedule of the Wildlife (Protection) Act, 1972 of Government of India is protected (WPA) [9]. IUCN threatened category (Version-3.1, 2001): Least Concerned (LC), Near Threatened (NT), Vulnerable (VU), Endangered (EN), Critically Endanger (CE), Extinct in Wild (EW), Extinct (EX). CITES (Convention on International Trade in Endangered Species of Wild Fauna and Flora): Appendix-I (APP. I), Appendix-II (APP. II), Appendix-III (APP. III), NY- Not yet studied/comes under any of 3 appendices of CITES (I, II, III).

3. RESULTS

The study reveals an investigation of the campus birds where the occurrence of 63 species of birds belonging to 31 families and 12 orders. Out of 12 orders, 30 species belong to order Passeriformes; 7 species to Coraciiformes; 8 species to Charadriiformes; 3 species each to order Piciformes, Cuculiformes, Ciconiiformes, Falconiformes; 2 species to order Columbiformes and 1 species each to order Psittaciformes, Pelecaniformes, Podicipediformes and Strigiformes.

4. DISCUSSION

The highest bird diversity is due to more diversity of plant which provides more choice for the food as well as nesting and breeding sites [10, 11]. Birds are key species in an agricultural ecosystem for maintaining the ecological balance

[6]. Birds providing important ecosystem service like pest control, pollination and seed dispersal [1, 12].

The results obtained from the present study shows out of the total bird species recorded, 46.03% were insectivorous, 12.69% were omnivorous, 12.69% were piscivorous, 11.11% were carnivorous, 9.52% were frugivorous, 4.76% were graminivorous, and only 3.17% were nectarivorous.

High percentage of insectivorous birds shows that the campus has sufficient insect species. The percentage composition of different bird groups shows the rich and diversified habits the campus harbors.

Cattle Egrets, Black Drogo were present in great numbers over the entire study area. It seems that they are the most conspicuous birds in this campus. Yellow wagtail, Citrine Wagtail, Gray Wagtail, Large pied Wagtail, White Wagtail were mainly found in Oxidation pond. Green Sandpiper (Endangered species according to IUCN) has been identified for the first time in Utkal University Campus. Winter visitors like Little ringed Plover, Wood Sandpiper, Green Sandpiper, White-breasted Waterhen, Small blue Kingfishers were only observed during winter season around the waterbodies. Bronze-winged Jacana, Little Cormorant, Little Grebe were more abundant in rainy and winter season when the waterbodies were full of water, but gradually their number decrease towards summer when ponds become dry.

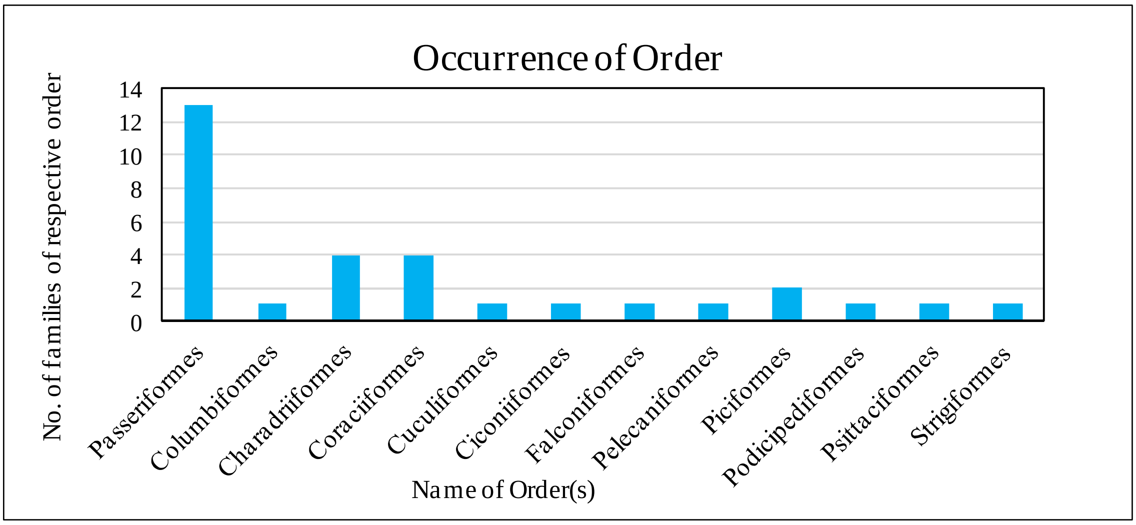

Figure 2. Representing Occurrence of order(s) with respect to belonging families of birds.

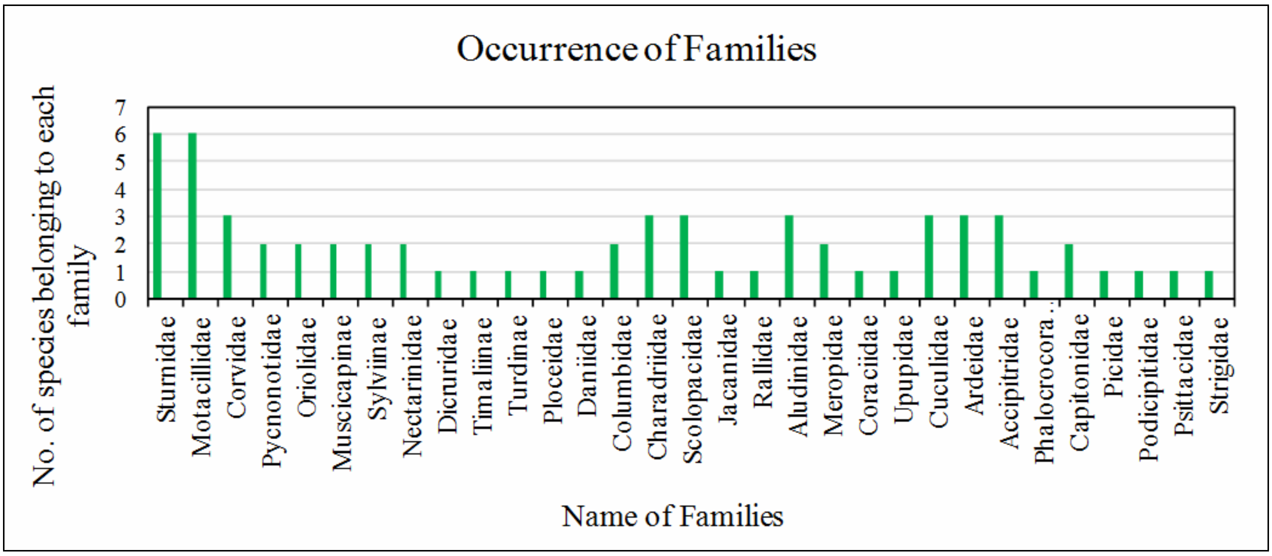

Figure 3. Representing occurrence of families with respect to belonging the species of birds.

Table 1. Checklist of birds of Utkal University Campus, Bhubaneswar, India.

Sl No Common Name	Scientific Name	Abundance	Feeding habit	Status	Protection Status		
					WPA. India	IUCN	CITES
Order: Passeriformes							
Family: Sturnidae							
1. Common Myna	*Acridotheres tristis*	VC	O	RS	Sch. IV	LC	NY
2. Jungle Myna	*Acridotheres fuscus*	UN	O	RS	Sch. IV	LC	NY
3. Asian pied Starling	*Sturnus contra*	VC	I	RS	Sch. IV	LC	NY
4. Brahminy Starling	*Sturnus pagodarum*	UN	C	LM	Sch. IV	LC	NY
5. Grey headed Starling	*Sturnus malabaricus*	UN	I	LM	Sch. IV		
6. Rosy Starling	*Sturnus roseus*	R	I	WV	Sch. IV		
Family: Motacillidae							
7. Yellow Wagtail	*Motacilla flava*	C	I	M	Sch. IV	LC	NY
8. Grey Wagtail	*Motacilla cinerea*	C	I	WV	Sch. IV		
9. Citrine Wagtail	*Motacilla citreola*	UN	I	M	Sch. IV	LC	NY
10. White Wagtail	*Motacilla alba*	UN	I	M	Sch. IV	LC	NY
11. Large pied Wagtail	*Motacilla maderaspatensis*	C	I	LM	Sch. IV		
12. Olive backed Pipit	*Anthus bodgsoni*	UN	I	LM	Sch. IV		
Family: Corvidae							
13. Common Crow	*Corvus splendens*	VC	O	RS	Sch. V	LC	NY
14. Jungle Crow	*Corvus macrorhynchos*	C	O	RS	Sch. IV	LC	NY
15. Indian Treepie	*Dendrocitta vagabunda*	C	O	RS	Sch. IV		
Family: Pycnonotidae							
16. Red Vented Bulbul	*Pycnonotus cafer*	VC	F	RS	Sch. IV	LC	NY
17. Red Whiskered Bulbul	*Pycnonotus jocosus*	C	F	RS	Sch. IV	LC	NY
Family: Oriolidae							
18. Black naped Oriole	*Oriolus chinensis*	UN	O	LM	Sch. IV	LC	NY
19. Eurasian golden Oriole	*Oriolus oriolus*	C	O	RS	Sch. IV	LC	NY
Family: Muscicapinae							
20. Slaty backed Flycatcher	*Ficedula bodgsonii*	UN	I	RS	Sch. IV		
21. Spotted Flycatcher	*Muscicapa striata*	UN	I	LM	Sch. IV		
Family: Sylviinae							
22. Willow Warbler	*Phylloscopus trochilus*	C	I	RS			
23. Yellowish bellied bush Warbler	*Cettia acanthizoides*	UN	I	RS			
Family: Nectarinidae							
24. Loten's Sunbird	*Nectarinia lotenia*	UN	I,F,N	RS	Sch. IV		
25. Purple rumped Sunbird	*Nectarinia zeylonica*	C	I,F,N	RS	Sch. IV	LC	NY
Family: Dicruridae							
26. Black Drongo	*Dicrurus macrocercus*	VC	C	RS	Sch. IV	LC	NY
Family: Timaliinae							
27. Jungle Babbler	*Turdoides striatus*	VC	I	RS	Sch. IV	LC	NY
Family: Turdinae							
28. Oriental magpie Robin	*Copsychus saularis*	VC	I	RS	Sch. IV	LC	NY
Family: Ploceidae							
29. House Sparrow	*Passer domesticus*	UN	I,G	RS			

Sl No Common Name	Scientific Name	Abundance	Feeding habit	Status	Protection Status		
					WPA. India	IUCN	CITES
Family: Daniidae							
30. Brown Shrike	*Lanius cristatus*	C	I	M	Sch. IV	LC	NY
Order: Columbiformes							
Family: Columbidae							
31. Blue rock Pigeon	*Columba livia*	VC	F,G	RS		LC	NY
32. Spotted Dove	*Streptopelia chinensis*	C	F,G	RS	Sch. IV	LC	NY
Order: Charadriiformes							
Family: Charadriidae							
33. Little ringed Plover	*Charadrius dubius*	R	I	RS	Sch. IV		
34. Yellow wattled Lapwing	*Vanellus malabaricus*	UN	I	RS	Sch. IV	LC	NY
35. Red wattled Lapwing	*Vanellus indicus*	C	I	RS	Sch. IV	LC	NY
Family: Scolopacidae							
36. Common Sandpiper	*Actitis hypoleucos*	C	I	WV	Sch. IV		
37. Green Sandpiper	*Tringa ochropus*	R	I	WV	Sch. IV	EN	
38. Wood Sandpiper	*Tringa glareola*	R	I	M	Sch. IV	LC	NY
Family: Jacanidae							
39. Bronze winged Jacana	*Metopidius indicus*	UN	O	RS	Sch. IV	LC	NY
Family: Rallidae							
40. White breasted Waterhen	*Amauronis phoenicurus*	C	I	RS	Sch. IV	LC	NY
Order: Coraciiformes							
Family: Aludinidae							
41. White breasted Kingfisher	*Halcyon smyrnensis*	C	P	RS	Sch. IV	LC	NY
42. Lesser pied Kingfisher	*Ceryle rudis*	UN	P	RS	Sch. IV	LC	NY
43. Small blue Kingfisher	*Alcedo atthis*	R	P	RS	Sch. IV		
Family: Meropidae							
44. Blue tailed Bee eater	*Merops philippinus*	VC	I	RS			
45. Small Bee eater	*Merops orientalis*	C	I	RS	Sch. IV	LC	NY
Family: Coraciidae							
46. Indian Roller	*Coracias benghalensis*	UN	I	RS	Sch. IV	LC	NY
Order: Coraciiformes							
Family: Upupidae							
47. Common Hoopoe	*Upapa epops*	R	I	RS	Sch. IV	LC	NY
Order: Cuculiformes							
Family: Cuculidae							
48. Asian Koel	*Eudynamys scolopacea*	VC	F,I	RS	Sch. IV	LC	NY
49. Greater Coucal	*Centropus sinesis*	C	I	RS	Sch. IV	LC	NY
50. Brainfever bird	*Heirococcyx varius*	UN	C	RS	Sch. IV		
Order: Ciconiiformes							
Family: Ardeidae							
51. Indian pond Heron	*Ardeola grayii*	C	P	RS	Sch. IV	LC	NY
52. Cattle Egret	*Bubulcus ibis*	VC	P	RS	Sch. IV	LC	NY
53. Little Egret	*Egretta garzetta*	UN	P	RS	Sch. IV	LC	NY

Sl No Common Name	Scientific Name	Abundance	Feeding habit	Status	Protection Status		
					WPA. India	IUCN	CITES
Order: Falconiformes							
Family: Accipitridae							
54. Black Kite	*Milvus migrans*	C	C	RS	Sch. IV	LC	APP. II
55. Black shouldered Kite	*Elanus caeruleus*	UN	C	RS	Sch. IV	LC	APP. II
56. Shikra	*Accipiter badius*	C	C	RS	Sch. IV	LC	APP. II
Order: Pelecaniformes							
Family: Phalocrocoracidae							
57. Little Cormorant	*Phalacrocorax niger*	UN	P	RS	Sch. IV	LC	NY
Order: Piciformes							
Family: Capitonidae							
58. Brown headed Barbet	*Megalaima zeylanica*	C	F	RS	Sch. IV	LC	NY
59. Coppersmith Barbet	*Megalaima haemacephala*	UN	F	RS	Sch. IV	LC	NY
Family: Picidae							
60. Lesser golden backed Woodpecker	*Dinopium benghalense*	C	I	RS	Sch. IV	LC	NY
Order: Podicipediformes							
Family: Podicipitidae							
61. Little Grebe	*Tachybaptus ruficollis*	R	P	RS	Sch. IV	LC	NY
Order: Psittaciformes							
Family: Psittacidae							
62. Rose ringed Parakeet	*Psittacula krameri*	C	F	RS	Sch. IV	LC	NY
Order: Strigiformes							
Family: Strigidae							
63. Eurasian scops Owl	*Otus scops*	C	C	RS	Sch. IV		APP. II

Elanus caeruleus *Otus scops* *Accipiter badius* *Milvus migrans*

Figure 4. Representing the CITES Appendix-II avifauna in the campus.

Among the non-passerines maximum richness is represented by the order Charadriiformes (3 families, 8 species) and order Coraciiformes (4 families, 7 species). Two families Sturnidae and Motacillidae show the highest species richness (6 species) within the campus.

Under protection status Common Crow (*Corvus splendens*) comes under Schedule-V of the Wildlife (Protection) Act, 1972 and rest of bird species come under Schedule-IV of the same Act [9]. According to the status list of IUCN, Green Sandpiper (*Tringa ochropus*) comes under endangered (EN) whereas remaining bird species comes under Least Concerned (LC) category [6]. Only four species of birds, Black Kite (*Milvus migrans*), Black shouldered Kite (*Elanus caeruleus*), Shikra (*Accipiter badius*), Eurasian scops Owl (*Otus scops*), were enlisted in Appendix-II of CITES [7].

5. CONCLUSIONS

Utkal University campus is sufficiently rich in bird species diversity having 63 species of birds belonging to 12 orders, 31 families and 62 species. This checklist of birds is the result of survey of one year from February 2014 to February 2015. Further extensive surveys of this area will undoubtedly reveal the existence of many more species than what is known today.

AUTHORS CONTRIBUTION

PP and MD: Field study, data record, compilation of data, collection of references and manuscript preparation. SPP: Field identification, data record, compilation of data, collection of references, final editing and checking of manuscript. The final manuscript has been read and approved by all authors.

ACKNOWLEDGEMENT

PP and MD are grateful to Dr. Siba Prasad Parida for guidance in field study and field identification and Ar Shakti Nanda for the photographic documentation.

TRANSPARENCY DECLARATION

The authors declare no conflicts of interest.

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