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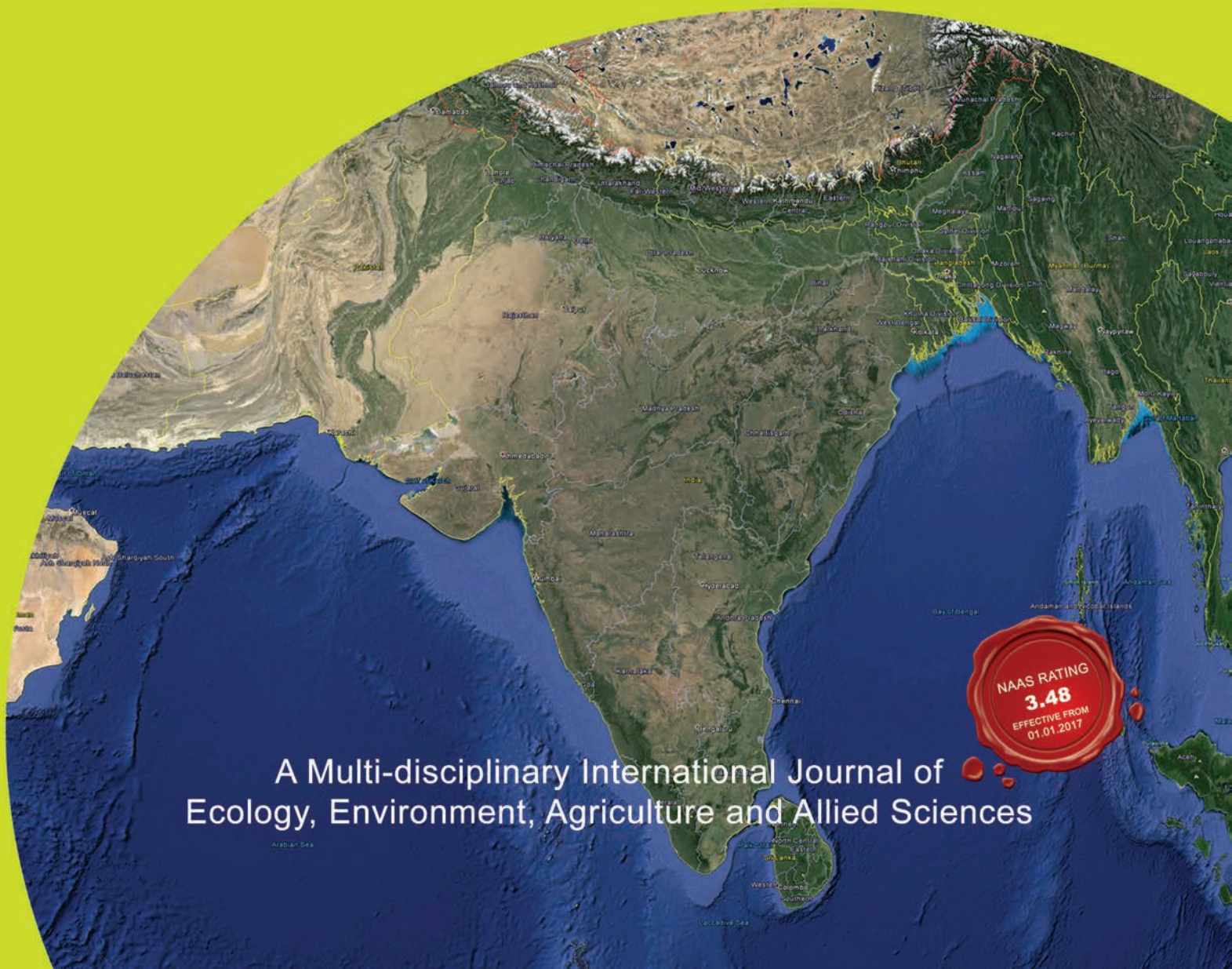

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Vegetation mapping and management strategy of mangroves of Bhitarkanika wildlife sanctuary, Odisha: A remote sensing approach

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ABSTRACT

Mangrove forest of Bhitarkanika constitutes a specialized eco-geographical region enjoying a different ecological status quite distinct from inland forests. In India, the mangroves of Bhitarkanika inhabit a unique and vulnerable ecosystem harbouring very rich floristic composition and occupies second most important mangrove habitat in respect of wider species diversity and quality. In the present report, the status of land use and vegetation regarding their types with dominant species composition, crown density and spatial coverage has been assessed based on the image characteristics of remote sensing satellite data. The multispectral imagery exhibits that the mangrove forest of Bhitarkanika have been subjected to rapid destruction and degradation due to ruthless exploitation, mass encroachment for human habitation and conversion of mangroves to scrubs, agriculture lands, aquaculture sites, mud or tidal flats etc. In view of the importance and uniqueness of the ecosystem, a strategy has been developed for conservation and management of mangroves integrating the resource information generated from satellite data, Survey of India topographical maps and supplementary data. In view of the immense economic potentiality of genetic diversity of mangroves at species and ecosystem level, the establishment of a mangrove genetic resource centre has been prioritized to act as mangrove heritage site in Eastern India.

Key words: Bhitarkanika sanctuary, land use, management strategy, remote sensing, vegetation status

INTRODUCTION

'Mangrove' is a word of African origin, designates an ecosystem formed by the characteristic plant communities in the intertidal region between sea and land of tropical and subtropical coasts, estuaries, deltas, backwaters and lagoons. Being ecologically interesting, strictly habitat specific, highly resourceful, inhabiting vulnerable ecosystem and exhibiting peculiar morphological and anatomical adaptations, mangroves have drawn international attention for study and conservation (Misra and Mishra, 2015). Mangroves are imposing and unique in several aspects because they resist water-logging caused due to periodic submergence by tides, wide fluctuating salinity, high humidity, high solar radiation and strong winds - a combination of characters unfavorable for other plants (Banerjee, 1984).

The mangroves have enormous physical, biological and economic significance and play an important role in maintaining the coastal ecological balance. They have high economic potentiality and utilitarian value at ecosystem and component levels (Banerjee, 1987). The mangroves are considered to be important as they (i) provide a natural barrier against cyclones and storm surges (ii) play an important role in stabilizing the shoreline and

protecting inter-tidal landscape (iii) act against encroachment by sea to control coastal soil erosion (iv) consolidate sediments and mudflats and promote the formation of new islands (v) function as shelter, feeding platform and nursery for many useful plants and animals and represent an ideal breeding ground for a number of threatened animals, birds, estuarine fish, crab and other fauna. Mangroves play a significant role in the economy of the coastal people as they fulfill the fundamental needs such as food, fuel and shelter. Besides, they provide a wide range of goods and services including paper pulp, wood and charcoal production along with support for commercial and subsistence fisheries, salt production and many others (Carugati et al., 2018). The leaf and bark yield tannins, resins and plywood adhesives; flowers of some plants produce nectars and honey and several plant parts act as fodder and traditional medicines (Misra and Mishra, 2015; Carugati et al., 2018).

Distribution of mangrove vegetation in Indian coast is mainly concentrated in the eastern sector. Out of four major Indian estuaries such as Gangetic Sundarbans, the Mahanadi, Brahmani, Baitarani, the Krishna-Godavari and the Kaveri, the Mahanadi deltaic region between Dhamra and Devi river constitutes the second largest mangal formation and harbours the richest biological diversity in terms of species content and quality of mangroves. However, the mangrove vegetation is at present under threats of extinction at an alarming rate due to over-exploitation, habitat destruction through port construction and industrial developments, mass encroachment for habitation and agriculture practice. It has resulted in shrinkage of mangrove vegetation into a fragile state which needs immediate protection and conservation.

ODISHA COAST

Odisha state has a coastline of 480 km long stretching over Baleswar, Bhadrak, Kendrapada, Jagatsinghpur, Puri and Ganjam districts and is interrupted by several rivers and rivulets of which Mahanadi, Brahmani, Baitarani, Budhabalang, Rushikulya and brackish water Chilika lake deserve special mention. This interruption has greatly influenced the coastal vegetation of Odisha to give rise to richest genetic resources of mangrove communities. The tidal and littoral swamp forests of Odisha extend from Chandipur coast in Baleswar district to Gopalpur in Ganjam district either as continuous belt or in scattered patches along the creeks and channels of estuaries. The mangrove forests were confined to erstwhile two places namely Kanika and Kujang ex-zamindari areas of Kendrapada and Jagatsinghpur districts, respectively; the former being situated along the river Dhamara and the latter in the Mahanadi delta. Littoral scrub forest with some specific plants characteristic to deltaic swamps are distributed in salt marshes near Chandipur, Dhamara estuary, Satabhaya, Paradeep, Astaranga, rocky faces of Chilika lake and also a few more localities (Banerjee, 1984).

Compared to the total of 61,294 sq km forest cover in Odisha, about 243 sq. km area is under mangroves, which are quite insignificant (FSI, 2017). However, they enjoy quite a divergent status and constitute a distinct and special type of forests among themselves. Interestingly, the flora is very rich and maximum numbers of mangrove species occur in Odisha coast in comparison to Sundarbans, Godavari, Cauvery and Andaman and Nicobar Islands (Banerjee, 1987). Occurrence of *Avicennia marina var. acutissima*, *Rhizophora stylosa*, *Sonneratia griffithii* and *Heritiera kanikensis* are new records for India and are of considerable phyto-geographical significance (Banerjee and Das, 1972; Banerjee, 1984 and 1987). However, *Nypa fruticans*, common in the Sundarbans and Andaman-Nicobar islands, reported by Haines (1921-25) from Mahanadi delta has been disappeared in due course from Odisha coast.

BHITARKANIKA: AT A GLANCE

Lying between 20° 28’ to 20° 50’ N latitude and 86° 38’ to 87° 10’ E longitude, the study area comprises of Bhitarkanika wildlife sanctuary and its neighborhood in Kendrapada district, which forms major part of mangrove forests of Odisha, India (Fig. 1). The sanctuary is bounded by Dhamara river in the north, the Hansua in the

west and the Bay of Bengal in the east and south. The river Dhamara (the confluence of Brahmani and Baitarani) in combination with Maipura, the tributary of Brahmani, constitutes the true arcuate delta criss-crossed by creeks and channels in Odisha coast. The landmass is about 2 to 10 m above mean sea level and is interrupted by a large number of meandering creeks and channels with mudflats/ tidal flats which provides an ideal niche for the formation of mangrove ecosystem. Bhitarkanika region is mostly covered with sediments of flood plain deposits. The soils are mostly clayed loam and highly slimy due to regular inundation through tidal action of the sea. The surface soil is composed of silt loam and clayey loam and about 3-4 m in depth. It has typical coastal tropical monsoon climate and average annual rainfall is about 1350 mm. The major rainy months are from July to September. The temperature varies between 10 - 45° C and humidity is high throughout the year (75 to 95%). Its prone to severe cyclonic storms almost every year during April to June and October to November.

Bhitarkanika was declared as wildlife sanctuary in 1975 to protect salt water crocodiles. The sanctuary covers 672 sq. km, out of which the core area of 145 sq. km has been notified in 1998 as National Park (Mohanty et al., 2004). The whole area including Gahirmatha coast in eastern flank of the sanctuary, functioning as a marine sanctuary since 1997 to protect olive ridley sea turtle. It has been accorded a wetland of international importance by its recognition as a Ramsar site in 2002 covering an area of 650 sq. km.

Bhitarkanika of Mahanadi delta in Odisha represents one of the finest patches of mangrove forest along the east-coast of India after Sundarbans and Andaman and Nicobar Islands. Compared to Sundarbans, the India's largest tract of mangrove forest, Bhitarkanika represents a wider species

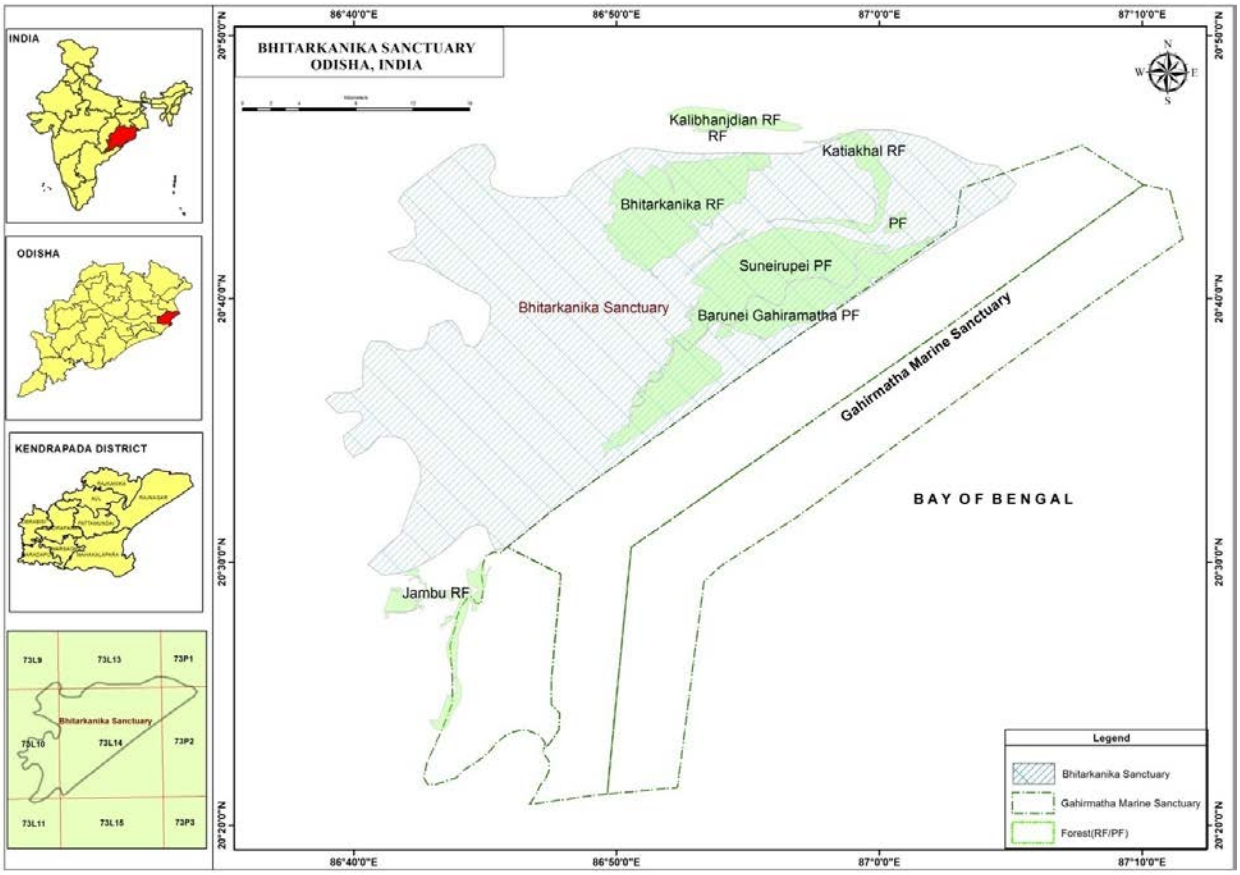

Fig. 1. Location map of Bhitarkanika wildlife sanctuary, Odisha

diversity of mangrove elements comprising of 62 species of vascular plants against 58 species in Sundarbans and out of a total recorded 64 species in India (Banerjee, 1987). The mangrove species are mostly concentrated along the network of creeks and channels and extend from the sheltered bay to the elevated banks of the upper riparian zone, where the composition of the mangrove community is high due the presence of semi-mangals and transitional mangals. Though several reports on the floristic and vegetational studies of mangroves of Odisha coast are available (Banerjee, 1984; Banerjee and Rao, 1985 and 1990; Choudhury, 1984; ORSAC, 1994; Roy, 1989; SAC, 2010). There is no/ very meager information pertaining to the conservation and management plan concerning multi-thematic approach using remote sensing technique.

DATA USED

Indian Remote Sensing Satellite F.C.C. imageries of IRS 1B LISS-II of 1995 and 1997 and IRS Resourcesat-1 LISS-IV of 2012 with 5.8 m spatial resolution in 1: 50,000 scales were referred for the study (Fig. 2). Image interpretation was carried out and the information was updated with available data to determine the status of land use/ vegetation types, crown density and spatial coverage under each type. Based on the image elements such as tone, texture, pattern, location and species association, an interpretation key has been developed (Table 1). Intensive ground truth was performed in the sampling sites of each vegetation/ land use category and in doubtful areas, and the ecological information with respect to floristic composition, crown density and species dominance in each category delineated on the map were collected and confirmed on the spot. Further, an exploration trip was undertaken for survey and

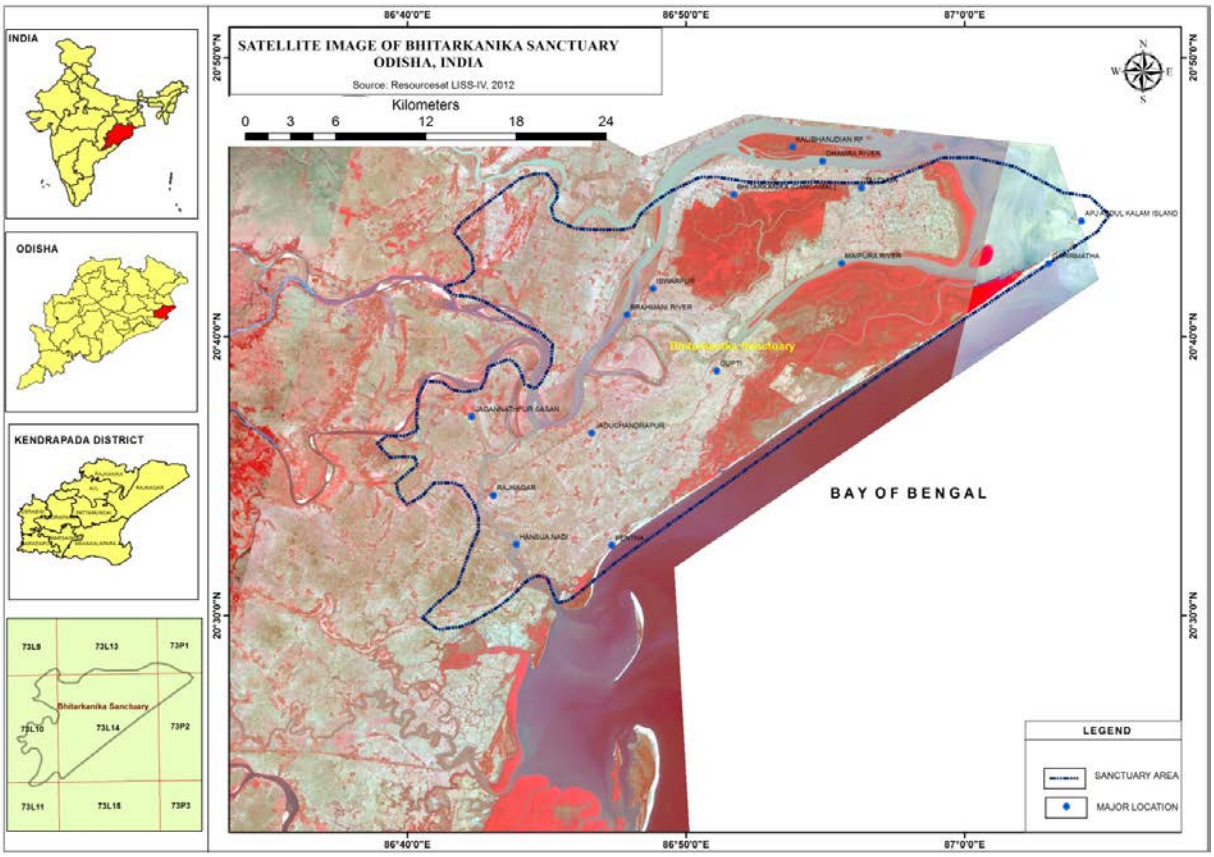

Fig. 2. Satellite image of Bhitarkanika wildlife sanctuary

germplasm collection of medicinal and aromatic plants and crop wild relatives during March, 2013. Survey of India topographical maps in 1: 50,000 scales were used in the field for locating for ground truth areas and to correlate the ground information with satellite images. Thematic information on environmental parameters such as physiography, soil types and surface texture, salinity, slope erosion status etc were collected with respect to each land use category from secondary sources and confirmed on the spot. The areal extent under each vegetation/ land use class was calculated and recorded. Integrating all resource parameters into the account, a general strategy was developed for conservation and management of mangroves of Bhitarkanika and adjoining regions.

Table 1. Interpretation key for vegetation mapping

Vegetation/ land use	Density (canopy %)	Tone	Texture	Pattern	Location	Dominant species
Dense mangrove	> 40	Bright red	Smooth	Contiguous	Intertidal/ silted creeks	*Sonneratia apetala, Avicennia marina, Ceriops tagal, Rhizophora apiculata, R. mucronata, Brownlowia tersa, Heritiera fomes, H. littoralis, Kandelia candel*
Open mangrove	10-40	Medium red	Smooth-medium	Contiguous to non-contiguous	Fringes of creeks/ islands	*Avicennia alba, A. officinalis, Aegiceras corniculatum, Bruguiera gymnorrhiza, Cerbera manghas, Ceriops decandra, Excoecaria agallocha, Phoenix paludosa*
Degraded Mangrove/ scattered scrub	< 10	Reddish brown	Medium-coarse	Frequent openings	Disturbed sites	*Stunted growth of Caesalpinia nuga, Phonix paludosa, Acanthus ilicifolius, Sarcolobus carinatus, Tamarix dioica, T. ericoides, Clerodendrum inerme, Intsia bijuga, Salvadora persica*
Mud flat/ tidal flat	< 10	Light grey	Coarse	Patchy	Estuaries/ sea water intrusions	*Acanthus ilicifolius, Ammania baccifera, Acrostichum aureum, Sueda maritima Myriostachya wightiana, Salicornia brachiata, Sesuvium portulacastrum, Porteresia coarctata, Scirpus littoralis*
Sand/ Bar	< 10	White/ (brown tinge)	Smooth	Narrow strips	Elevated foreshore	*Pandanus tectorius, Spinifex littoreus, Hydrophyllax maritima, Bulbostylis barbata, Ipomoea pescaprae, Cyperus arinarius, Zoisia pungens*
Agriculture land	-	White	Smooth	-	Encroachments and settlements	*Oryza sativa* and horticultural crops; field bunds: *Heliotropium curassavicum, Carissa spinarum, Hemidesmus indicus, Launea sarmentosa, Pandanus tectorius*
River/ creeks	-	Blue	Smooth	Dendritic	Low lying channels	Nil

LAND USE/ VEGETATION TYPES

Based on the vegetation density, degree of deforestation, physiography and overall spectral signature, eight vegetation or land cover types were identified in the mangrove forests of Bhitarkanika. The thematic details in respect of each land cover/ vegetation category are discussed below.

Dense mangrove forest

Occupying an area of 134 sq. km, the dense mangroves are mainly confined to the inner estuarine banks particularly in the central zone of Bhitarkanika, Satabhaya, Kalibhanjadian Reserve Forest, Suneirupei Protected Forest and south of Talchua point. The vegetation density is more than

40 per cent tree canopy cover and the trees attain maximum height of 25 m. The formation of two distinct tiers of canopy with stratified foliage density is the characteristic feature of this type. These might be the factors where the chlorophyll absorption is high resulting in dark red tone, smooth textural value and contiguous pattern. Species such as *Avicennia marina, Brownlowia tersa, Ceriops tagal, Heritiera fomes, H. littoralis, Kandelia candel, Rhizophora apiculata, R. mucronata, Sonneratia apetala* and *Xylocarpus moluccensis* constitute the dominant trees of top storey. The small trees, large shrubs and lianas form the second storey of which *Kandelia candel, Hibiscus tiliaceus, Bruguiera gymnorrhiza, Cynometra iripa, Flagellaria indica* and *Phoenix paludosa* are predominant. In this forest type, the soils are rich in humus and low to moderately saline. The soil texture is silty clay-loam and the slope is 1-3% with slight erosion status.

Open mangrove forest

This type of forest spreads over an area of 2.25 sq. km. This is mostly found along the fringes of defunct creeks, in small islands and forest peripheries where the vegetation density is less than 40 per cent canopy cover. The plant growth is stunted, uneven and the height of the trees reaches up 5 m. The floristic composition is very poor compared to the dense forests. Stunted growth of trees such as *Avicennia alba, A. officinalis, Aegiceras corniculatum, Bruguiera gymnorrhiza, Cerbera manghas, Ceriops decandra, Excoecaria agallocha, Phoenix paludosa, Salvadora persica* in association with shrubs like *Acanthus ilicifolius, Phoenix paludosa, Thespesia populneoides, Aegialitis rotundifolia* and *Sarcolobus carinatus* are found to occur in this type. The soil texture is silty loam with medium salinity content. The slope is 1-3% with moderate to severe erosion status.

Degraded mangrove forest/ scrub

Spreading over an area of 21.06 sq. km., this kind of vegetation is found as secluded patches inside the Satabhaya forest, Suneirupei forests, Gopalpur P.F. and Bhitarkanika R.F. where over-exploitation and encroachment are prevalent. The vegetation density is less than 10 per cent canopy cover and plants reach a height 1-3 ft. At many places, the stands become discontinuous and almost barren. The species like *Azima tetracantha, Caesalpinia nuga, Phonix paludosa, Acanthus ilicifolius, Sarcolobus carinatus, Tamarix dioica, T. ericoides, Clerodendrum inerme, Intsia bijuga, Salvadora persica, Derris trifoliata, Pandanus tectorius* and *Colubrina asiatica* are the dominant elements of this vegetation type. The texture of soils is clay loam to sandy loam. The slope of landform is 1-3% with severe erosion status.

Mud flat/ tidal flat

Salt marsh/mud flats are wide expanse of fine grained soft materials consisting of clay, silt, ooze etc and cover an area of 48.43 sq. km. These are highly rich in nutrients, thus support the growth of tidal marsh vegetation. Mud flats are inundated/ submerged during daily low/high tides and are found mostly in estuarine areas of composite delta fronts of Maipura and Dhamra rivers. These are formed due to high outflow and deposition of sediments carried away by rivers from the catchment. At many places, these tidal/mud flats are vegetated with scanty patches of a number of species such as *Acanthus ilicifolius, Ammania baccifera, Acrostichum aureum, Myriostachya wightiana, Porteresia coarctata, Phoenix paludosa, Salicornia brachiata, Sesuvium portulacastrum, Sueda maritima, S. nudiflora, Scirpus littoralis, Cyperus malaccensis* etc. Vast patches of tidal or mud flats along the river Dhamara, at the confluence of the river Baitarani and along the sea front from Dhamara estuary to Balimunda are being reclaimed for agriculture and shrimp culture purposes. The soil texture is silty-clay with very high saline content. The slope is 0-1% with very severe erosion.

Sand/ bar

Covering an area of 5.06 sq. km., these temporary marine deposits of varying width along the foreshore are formed in shallow epi-continental areas as a thin narrow strip by the action of low tide waves and currents. Their extent is increasing day by day, restricting the flow of water to sea through the channels. These sandy beaches along Gahirmatha and Satabhaya offer suitable habitat for mass nesting

of Olive Ridley sea turtle, *Lepidochelys olivacea*, an endangered animal species. The elevated foreshore of the beach at few places is occupied with a thin cover of vegetation composed of species such as *Azima tetracantha, Bulbostylis barbata, Cyperus arenarius, Hydrophyllax maritima, Ipomoea pescaprae, Pandanus tectorius, Pedalium murex, Sesuvium portulacastrum, Spinifex littoreus* and *Zoisia pungens* etc. The soil texture is sandy with high salinity in the beach areas. The slope of landform is 0-3% and erosion status is very severe.

Agricultural land

These lands presently under paddy cultivation which were once occupied with mangroves of various species. But over the years, due to over-exploitation and subsequent mass encroachment by the local inhabitants, the area was converted to the agricultural land. The texture of surface soil is clay loam or sandy loam with low salinity and the slope of landform is 1-2% with slight erosion status.

CONSERVATION AND MANAGEMENT

On account of immense biotic interference and multiple uses of mangrove species, the genetic resources are under threats of extinction. Apart from the natural threats such as cyclones and floods, the Bhitarkanika mangrove ecosystem suffers from rapid destruction and degradation due to over-exploitation, mass encroachment for human habitation and conversion of mangroves to agriculture lands, aquaculture sites and mud or tidal flats. The hectic search for new land for paddy cultivation and shrimp culture are the two major factors at present which brought once luxuriant mangrove vegetation to almost a disaster. Besides this, the mangroves of Odisha have not received adequate attention and remain totally ignored and neglected. As per remote sensing mapping estimates, it is revealed that the interesting plant communities have reached a fragile state causing a great shrinkage in the density and area and the spatial distribution of mangrove cover in Odisha for different years is indicated in Table 2.

Table 2. Distribution of mangrove vegetation in Odisha coast

Period	Area (Sq. km)	Mapping source	Data used
1972-75	234	NRSA	LANDSAT-1 MSS
1980	227	NRSA	LANDSAT-1 MSS
1984	218.75	ORSAC	MKF-6 (SALYUT-7)
1985	217.12	ORSAC	LANDSAT TM
1989	210.93 207	ORSAC/ NRSA NRSA	IRS – 1A KATE-140 pan photo
1993	199.19	ORSAC	IRS- 1B
1995	195	FSI	IRS-1B LISS-2
1996	239	ORSAC/ SAC	IRS- 1B LISS-2
1997	211	FSI	IRS-1B LISS-2
1999	215	FSI	IRS-1C/1D LISS-3
2001	219	FSI	IRS-1C/1D LISS-3
2003	203	FSI	IRS-1D LISS-3
2005	217	FSI	IRS-1D LISS-3
2009	221	FSI	IRS-P6 LISS-3
2010	233	SAC, ISRO	IRS-P6 LISS-3
2011	222	FSI	IRS-P6 LISS-3 and A-WiFS
2013	213	FSI	IRS-P6 LISS-3 IRS-Resourcesat II LISS III
2015	231	FSI	IRS-P6 LISS-3 IRS-Resourcesat II LISS III
2017	243	FSI	IRS-P6 LISS-3 IRS-Resourcesat II LISS III

The mangrove ecosystem rehabilitation programmes are being carried out world-wide for three reasons: conservation of ecosystem with their biological diversity, multiple use systems for high sustainable yield and protection of coastal areas. In this context, a strategy has been developed for conservation and management of the mangroves of Bhitarkanika by integration of major resource

parameters such as landuse pattern, vegetation cover and density, soil types and texture, salinity, slope and erosion status (Table 3). The information on the vegetation cover and density with land use pattern, slope or erosion status of wetlands of Odisha including mangroves of Bhitarkanika were interpreted from spectral data in conjunction with topographical maps and ground truth whereas other resource parameters such as soil texture, salinity, tidal inundation etc were obtained from field verification and supplementary data (Chari and Mitra, 1989; ORSAC, 1996, 1998; SAC, 2010).

Table 3. Strategy for conservation and management of mangroves of Bhitarkanika

Present land use	Vegetation density	Soil texture	Salinity	Slope (%)	Erosion status	Area (sq. km)	Proposed plan
Dense mangrove forest	>40%	Silty clay-loam	High to medium	2-3	Slight	126	Core zone
-do-	>40%	Silty clay-loam	High	1-2	Slight to moderate	8	Research zone
Open mangrove forest	10-40%	Clay-loam	Medium	1-3	Moderate to severe	2.25	Re-establishment zone
Degraded mangrove or scrub	<10%	Sandy loam	Low to medium	1-3	Severe	21.06	Re-establishment zone
Mud flat or tidal flat	-	Silty clay	Very high	0-1	Very severe (inundated)	48.43	Re-establishment zone
Sand per bar	-	Sandy	High	0-2	Very severe	5.06	Re-establishment zone
Agriculture land (encroached)	-	Sandy-loam	Low	1-2	Slight	82	Agro-forestry zone
Rivers/ Creeks/ Camp sites	-	-	-	-	-	-	Eco-tourism zone

The entire area was divided into five different zones, each with distinct objectives, activity and management plan, which were based on the latest land use pattern, vegetation status with crown density, soil type or texture, slope and erosion status (Fig. 3). The zones are described below.

Core zone

The inner dense forest of Bhitarkanika wildlife sanctuary and adjoining regions with its rich biological diversity comprises the core zone which occupies an area of 126 sq. km. This zone represents the closed high forest community due to its thick crown and stratified foliage density. Thus, the forests of this zone are to be provided adequate protection from biotic interference and there will be no activity of any sort of entry into the area. This may be a protected habitat, the conservation and management may be left to the nature alone.

Research zone

This is an isolated dense forest zone in the north of the sanctuary covering an area of 8 sq. km in Kalibhanjadian R.F., which may serve as a bench mark for future studies. The forest profile has three tiers of plant strata comprising of trees in the upper,

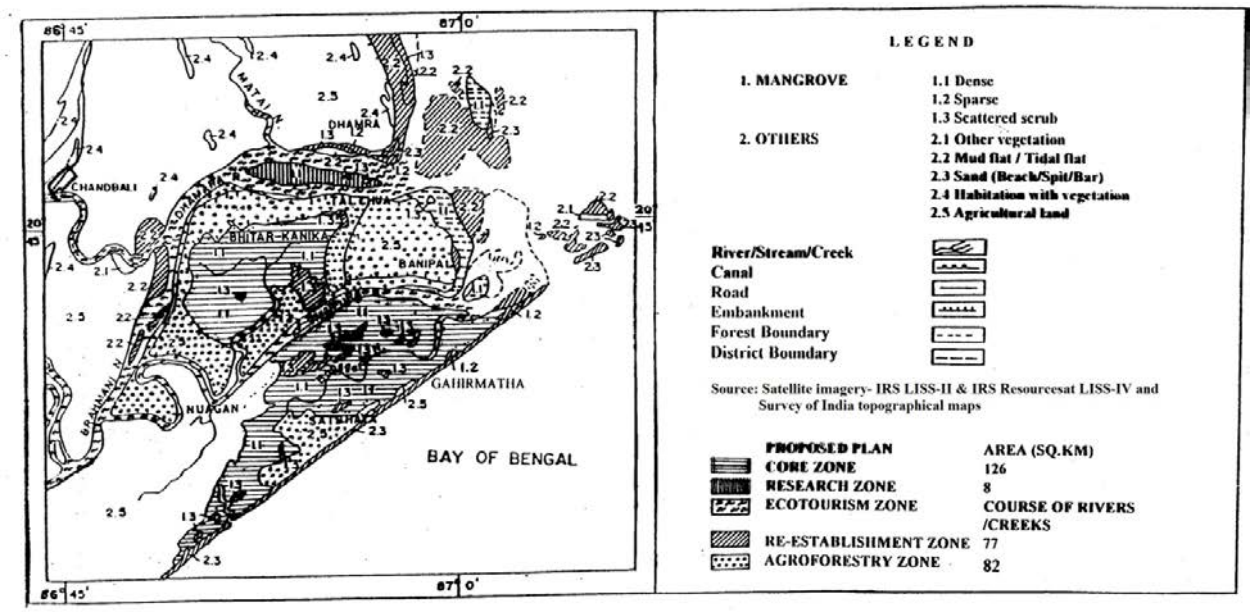

Fig. 3. Strategy for conservation and management of mangroves of Bhitarkanika wildlife sanctuary

shrubs and climbers in the middle and herbs in the ground tier. The area will be solely used for taking up research work on different aspects. Suitable institution are to be entrusted for conducting basic research on biodiversity assessment, germplasm conservation and propagation of vulnerable and rare plants such as *Rhizophora stylosa, Sonneratia griffithii, Cerbera manghas, Heritiera littoralis, Avicennia marina var. acutissima and introduction of Nypa fruticans, Acanthus volubilis and Lumnitzera racemosa*. Based on the limits of salinity tolerance of different species, large scale experiments may be undertaken for natural or artificial regeneration for different environmental conditions. The other parameters on functional dynamics such as productivity, tropic relationship, energy flow, nutrient cycling and overall generation of scientific data base may be included. Such studies would help us in understanding the relative importance of various components of ecosystem.

Re-establishment zone

All activities relating to regeneration and rehabilitation of mangroves may be taken up in degraded and unstocked mangrove areas such as mangrove scrubs, salt marshes, intertidal flats or mud flats, encroachments and other suitable locations. Since most of the mangrove species are viable to natural regeneration rather than artificial felling, hence the natural soil condition of the lands and tidal inundation should be the prime criteria to be considered before preceding the plantation programme. Revegetation of non-mangrove species in these degraded areas may cause unusual hazards and thus the ecological condition may disappear. Therefore, the mangrove species best suited to different site conditions and plants of wide salinity tolerance may be selected for revegetation. The source of plantation may be either from naturally grown seedlings or from mature propagules/ seeds. These degraded mangrove sites may act as congenial habitat for plant regeneration because the soils are rich in nutrients needed for the plant growth.

Eco-tourism zone

The eco-tourism zone may be open to the visitors who are interested in boating, wildlife and nature studies. The tourists may be allowed to have only guided tours in this area and all the rivers, nalas, major creeks, guest houses, rest sheds, observatories watch towers and related facilities may be included in this zone.

Agro-forestry zone

The encroachment area presently under seasonal agriculture inside the mangrove forest belts may be considered as agro-forestry zone which in turn may be used for agriculture and forestry purposes to provide suitable alternatives for the livelihood of the local people for production of food grains, timer, fuel wood, fodder etc with a view to reduce their dependence on the mangrove forests. In the peripheral areas along river banks and seaward fringes, artificial plantations of *Casuarina equisetifolia, Calophyllum inophyllum, Anacadium occidentale* and *Barringtonia acutangula* may show promising success. Silviculture practice of many economically important trees may be carried out to get maximum benefit from this ecosystem. Adequate environmental awareness should also be generated among the local people about the potentiality of the forest and not to exploit the mangrove trees for fuel and other purposes.

Besides this, the mangrove forests of Bhitarkanika need urgent protection from Government agencies like that of Sundarbans in West Bengal. Immediate steps are to be taken for formation of a Mangrove Development Board by the State Government which should give priority to protect and conserve the fast disappearing vegetation. Unless very stringent measures are taken to protect and maintain this precious ecosystem, the mangroves will be completely wiped out within few decades resulting in serious ecological imbalance and loss of genetic diversity. Therefore, conservation of mangrove ecosystem is necessary not only for the sake of preserving natural environment for their intrinsic value and for conservation of genetic diversity but also for gaining a better understanding of the coastal dynamics which may play a protective and productive role in the Bhitarkanika mangrove belt.

ECONOMIC IMPORTANCE

The mangrove forests have enormous economic potentiality and utilitarian value at ecosystem and component levels. The mangrove ecosystem acts as a coastal stabilizer, barrier and protective green belt to disperse the energy of cyclones, tidal bores, winds and storms in general. It functions as a feeding ground and nursery for many useful plants and animals such as providing shelter to seedlings of many species and representing an ideal breeding ground for a number of fishes, crocodiles and prawn fauna. Innumerable pneumatophores, stilt roots and stem buttresses of mangrove trees or shrubs act as substratum for a number of fish food organisms during high tides. Besides these, mangroves serve useful purposes in the coastal region viz. i) afford vegetation cover in the critical intertidal zone that would not exist otherwise and plays a crucial role in cushioning impacts of tides and fury of strong sea winds ii) prevents soil erosion iii) even though at lesser rate they produce detritus and nutrients and iv) consolidate sediments, mud banks and mud flats which promote the formation of permanent islands and significantly create a habitat suitable for colonization by animals.

Because of varying species composition and degrees of genetic diversity, the uses made of mangrove products and of the ecosystem as a whole vary from place to place. Like the terrestrial tropical rain forests, mangals play a significant role in rural economy providing a wide variety of goods and services including timber and fire wood production, support for commercial and substance fisheries, aquaculture, salt production and many others. The mangrove tree wood is highly prized for fuel wood, charcoal production and valuable timbers. The leaves and barks yield various extractives such as tannins and resins. Quite a good number of mangrove elements are economically important as sources of construction materials, edible fruits, pot herbs, fibres, pulps for paper, perfumes, fodder and in traditional medicines. The soil is best used as a fertilizer. The flowers of *Aegiceras corniculatum, Ceriops decandra, Sonneratia apetala, Brownlowia tersa, Avicennia alba* and *A. officinalis* produce profuse nectar and thus these plants act as excellent bee forage. About 25-30 quintal of honey is collected annually from the Bhitarkanika wildlife sanctuary area alone. The stem and leaves of *Phoenix paludasa* is used for roofing and thatching of houses and manufacture of ropes and brooms by the local inhabitants. The

species like *Phragmites karka, Porteresia coarctata* and *Myriostachya wightiana* are good source of fodder for local cattle. On the sea-ward fringe, beach and dune fixing plants like *Ipomoea pescaprae, Sesuvium portulacastrum, Salicornia brachiata, Spinifex littoreus* and *Zoisia pungens* perform the useful function of consolidating the sandy sea front. On the shallow water mass where salinity is low, *Porteresia coarctata* (=*Oryza coarctata*) is tolerant of some degree of water salinity and it has been domesticated or hybridized with *Oryza sativa* to produce cultivated varieties of rice for cultivation at salinity affected soils. High grade of tannin can be extracted from the bark of *Brugueria sexangula, Rhizophora mucronata, R. apiculata, Sonneratia apetala, S. caseolaris, Aegiceras corniculatum, Kandelia candel, Xylocarpus granatum* etc. The leaves of *Flagellaria indica* and *Myriostachya wightiana* are extensively used for basket making by local people (Misra and Mishra, 2015).

MANGROVE GENETIC RESOURCE CENTRE: AN URGENT NEED OF THE DAY

Mangrove ecosystems are reservoirs of plant and animal species and many biological aspects are still imperfectly known and not fully understood. The plant resources not only dominate the habitat and characterize the ecosystem, but also provide economic resource, which has been widely and variously used by the coastal inhabitants since ages. A number of mangrove plants are used as medicines in traditional healthcare and also as antimicrobial and antiviral agents. Many fungal endophytes isolated from mangrove species have produced some bio-active metabolites of pharmaceutical and industrial importance.

Mangrove genetic resources have been the subject of interest for plant taxonomists, ecologists, physiologists, biochemists, geneticists and breeders. Mangroves of Bhitarkanika region of Odisha coast harbor many plant genetic resources of wild relatives such as *Porteresia coarctata* (Fig. 4), *Canavalia maritima, Hibiscus tiliaceus* (Fig. 5), *Phoenix paludosa, Polyalthia korintii, Vigna trilobata* etc. have shown importance with stress tolerant genes and form the wild gene pool for crop improvement studies. Rare or endangered medicinal spp. like *Mucuna gigantea* (Fig. 6), *Cerbera odollam* (Fig. 7), *Salvadora persica, Xylocarpus granatum* and other important species like *Acanthus ilicifolius, Bruguiera parviflora, Caesalpinia nuga, Ceriops tagal, Excoecaria agallocha, Salicornia brachiata* and *Tylophora tenuis* represent the untapped wild species for production of new bioactive compounds of pharmaceutical importance. Bio-prospecting of mangrove ecosystem to conduct crop improvement programme along with isolation of high valued products like drugs, enzymes, microbial bio-fertilizers, bio-feed products of industrial utility is the need of the day. Besides, systematic research should be carried out for survey and inventorisation of plant genetic resources associated with mangrove gene pool at macro-, micro- and molecular level. There is an urgent need to collect, characterize, multiply and conserve the plant genetic resources and disseminate the scientific information about mangroves for education, research and promoting awareness among students, teachers, nature lovers, forest officials and general public (FSI, 2017; Carugati et al., 2018). Even now our studies on the mangroves of Odisha coast are far from adequate (SAC, 2010; Misra and Mishra, 2015). In view of this, Bhitarkanika mangrove forest in Odisha has a great potential for establishment of a mangrove genetic resource center to act as mangrove heritage site in Eastern India.

CONCLUSION

Indian Remote Sensing Satellite data was very much useful for assessing the vegetation status of mangrove vegetation with their dominant species composition, density and spatial distribution. The multispectral imagery showed that the mangrove forests of Bhitarkanika and its neighborhood was deteriorated to a great extent, mainly due to over exploitation, mass encroachment, reclamation for agriculture and lack of management. In this context, a general management strategy has been developed for Bhitarkanika Mangrove biodiversity using remote sensing technique and supplementary/ ancillary data. In view of the enormous economic potentiality of genetic diversity of mangroves at species and ecosystem level, the establishment of a mangrove genetic resource centre has been prioritized to act as mangrove heritage site in Eastern India.

Fig. 4. *Porteresia coarctata*, a wild relative of paddy occurs on mud flat of mangroves

Fig. 5. *Hibiscus tiliaceus*, a crop wild relative in Bhitarkanika mangrove forest of mangroves

Fig. 6. *Mucuna gigantea*, an endangered medicinal plant found in Dhamara river bank of mangroves

Fig. 7. *Cerbera odollam* a vulnerable medicinal plant in Dangmal mangrove area of mangroves

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REFERENCES

Banerjee, L.K. 1984. Vegetation of Bhitarkanika Wildlife Sanctuary in Cuttack district Orissa. *J. Econ. Tax. Bot.* **5** (5): 1065-1079.

Banerjee, L.K. 1987. Comparative study on mangroves of Sundarbans and that of the Mahanadi delta in Eastern India. *J. Econ. Tax. Bot.* **9** (1): 119-131.

Banerjee, L.K. and Das, G.C. 1972. New distributional records from Orissa coast. *Bull. Bot. Surv. India* **14** (1-4): 184-186.

Banerjee, L.K. and Rao, T.A. 1985. Mangals of Mahanadi Delta, Cuttack district, Orissa state, India. In: V. Krishnamurty (ed.) *Proc. All India Symp. Mar. Plants*, Dona Paula, Goa, India, pp. 137-152.

Banerjee, L.K. and Rao, T.A. 1990. *Mangroves of Orissa Coast and their Ecology*. Bishen Singh and Mahendrapal Singh, Dehra Dun, India, pp. 28-32.

Carugati, L., Gatto, B., Rastelli, E., Martire, M.L., Coral, C., Greco, S. and Danovaro, R. 2018. Impact of

mangrove forests degradation on biodiversity and ecosystem functioning. *Sci. Report* **8**: 13298.

Chari, K.N. and Mitra, M.K. 1989. *Mangrove Swamps of Orissa Coast (A Reconnaissance Study)*. Directorate of Soil Conservation, Govt. of Orissa, Bhubaneswar, pp. 1-104.

Choudhury, B.P. 1984. A glimpse into vegetation of Bhitarkanika wildlife sanctuary.*Indian Bot. Reporter* **3** (2): 121-124.

FSI. 2017. *India State of Forest Report-2017*. Forest Survey of India, Dehradun. Ministry of Envioronment, Forests and Climate Change, Government of India.

Haines, H.H. 1921-25. *The Botany of Bihar and Orissa*. Vol. 3. Adlard and Son and West Newman Ltd., London, pp. 1-883.

Misra, R.C. and Mishra, R.K. 2015. Mangroves of Odisha coast: An ecological perspective. In: H.K. Sahu, J. Sethy, and R.K. Mishra (eds.) *Biodiversity Conservation, Research and Management.* Himalaya Publishing House, New Delhi, pp. 95-101.

Mohanty, S.C., Kar, C.S., Kar, S.K. and Singh, L.A.K. 2004. *Wild Orissa-2004*. Wildlife Organisation, Forest Department, Government of Odisha, Bhubaneswar, pp. 1-82.

ORSAC. 1994. *MARSIS Newsletter, 2.* Orissa Remote Sensing Application Centre, Department of Science and Technology, Government of Orissa, Bhubaneswar, pp. 1-8.

ORSAC. 1996. *Wetlands of Orissa, Scientific Note: ORSAC/RSAM-SAC/RSAG/WLM/PR/96.* Orissa Remote Sensing Application Centre, Bhubaneswar and Space Applications Centre, Ahmedabad, pp. 1-68.

ORSAC. 1998. *Report on Coastal Wetland and Shoreline Change Mapping.* Orissa Remote Sensing Application Centre, Bhubaneswar and Space Applications Centre, Ahmedabad, pp. 1-54.

Roy, P.S. 1989. Mangrove vegetation stratification using Salyut 7 photographs. *Geocarto Int.* **3**: 31-47.

SAC. 2010. *National Wetland Atlas: Orissa,* SAC/EPSA/AFEG/NWIA/ATLAS/28/2010, Space Applications Centre, ISRO, Ahmadabad, India, p. 204.

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Rickettsial diseases in animals and humans:Indian scenario

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ABSTRACT

Rickettsia are obligate intracellular organisms, associated with number of diseases in humans and animals. Although Rickettsial diseases are highly prevalent in India, they are grossly under-reported. These diseases are showing an upward trend in India, with increased reports in the last decade, especially Canine Rickettsiosis and Bovine anaplasmosis in animals, while scrub typhus, endemic typhus, and epidemic typhus are important emerging or re-emerging zoonoses in human being. Regardless of the emerging scenario of Rickettsial diseases, there are a very few systematic studies on epidemiology of these pathogens.

Key words: Anaplasma, Ehrlichia, endemic typhus, epidemic typhus, Rickettsia, scrub typhus

INTRODUCTION

Rickettsia as prokaryotes, are obligate intracellular organisms, classified under Phylum – *Proteobacteria*, Class - *Alphaproteobacteria* and Family - *Rickettsiaceae*. These are included under unculturables as cannot be grown on artificial media. However, these organisms can be grown in embryonated eggs through yolk sac or artificially grown cell culture (Cox 1938; Cicuttin et al., 2015). In size, they are smaller than bacteria, while larger than virus. They contain both DNA and RNA as genetic material and multiply by binary fission. Some important genus under this family, which are important for animals and humans, are *Ehrlichia, Anaplasma, Neorickettsia, Orientia, Rickettsia* (typhus and spotted fever groups).

Coxiella and *Bartonella* were previously placed among Rickettsial pathogens are now placed under separate family. Unlike Rickettsials which require vectors for transmission, *Coxiella* is transmitted principally through aerosol route, although can be maintained and transmitted through tick vectors (Van den Brom et al., 2015). Both *Coxiella* and *Bartonella*, were previously being isolated as other Rickettsials, while can now be isolated by direct inoculation into suitable artificial media (Omsland et al., 2009; Chaudhry et al., 2012). The present study includes important rickettsial diseases of animals and human in India.

RICKETTSIAL DISEASES OF HUMAN AND ANIMALS

Some of the important Rickettsial pathogens causing disease in human and animals are mentioned below:

Ehrlichia

Important species of *Ehrlichia* causing disease in animals and human are *E. canis* (canine rickettsiosis), *E. ewingii* (canine granulocytic ehrlichiosis), *E. ruminatum* (heart water disease in cattle), *E. chaffensis* (human monocytic ehrlichiosis) and *E. muris*. Recently a new species of *Ehrlichia* was reported from haemolymph of Brazilian *Rhipicephalus (Boophilus) microplus* ticks known as *E. mineirensis* (Cabezas-Cruz et al., 2013).

Canine rickettsiosis

This disease is known by several synonyms, viz. canine ehrlichiosis, canine haemorrhagic fever, canine typhus, tropical canine pancytopaenia, canine monocytic ehrlichiosis, etc. Dogs and cats are the two principal hosts to be infected. German shepherd shows a greater susceptibility to this infection. The agent is mainly transmitted by brown dog tick (*Rhipicephalus sanguineus*) (Ferrolho et al., 2016). Besides that, iatrogenic transmission has also been observed, where the agent is reported to be transmitted through blood transfusion from infected canine to healthy ones (CFSPH, 2013). Most of the cases occur during spring and summer period of the year and the disease is widely prevalent in tropical and sub-tropical countries (Dantas-Torres et al., 2018). Based on clinical symptoms, the disease may be classified as acute, chronic or sub-clinical disease (Buhles et al., 1974). The pathogen infects monocytes in peripheral blood and subsequently throughout body (Rikihisa et al., 1992). Thrombocytopenia occurs due to consumption of platelet, immune mediate destruction of platelets, sequestering of platelets, decrease bone marrow production (Sosa-Gutierrez et al., 2013). The pathogen is having zoonotic potential and main cause of Venezuelan human ehrlichiosis (Unver et al., 2001).

The first case was reported at Punjab in India during 1992 (Juyal et al., 1992). Then subsequent cases were reported from Tamil Nadu (Lakshmanan et al., 2007), Punjab (Singla et al., 2011), Haryana and Delhi (Dhankar et al., 2011), Mumabi (Rani et al., 2011), Punjab (Wise and Tarlinton, 2012), West Bengal (Das and Konar, 2013), Assam, Nagaland, Jammu and Kashmir and Uttar Pradesh (Mittal et al., 2017), and Gujarat (Bhadesiya and Rayal, 2015).

Most of the studies conducted in India were performed using microscopic detection of pathogen in blood or buffy coat smears (Lakshmanan et al., 2007; Dhankar et al., 2011; Das and Konar, 2013; Milanjeet et al., 2014), serologic detection using ELISA (Singla et al., 2011; Wise and Tarlinton, 2012; Bhadesiya and Raval, 2017), PCR based assay targeting 16s rRNA gene (Lakshmanan et al., 2007; Milanjeet et al., 2014) or combination of these assays (Lakshmanan et al. 2007; Milanjeet et al., 2014; Mittal et al., 2017). Indirect florescent antibody test (IFAT) is considered as the gold standard for detection of antibodies against *E. canis* (Waner et al., 2000). A number of studies have been conducted in India. But most of the study pertains to a limited geographical area, resulting under-reporting of the disease in India. However, an extensive study has been conducted in dog covering different agro-climatic zone in India (Mittal et al., 2017).

Canine granulocytic ehrlichiosis

Canine granulocytic ehrlichiosis (CGE) is caused by *E. ewingii*, transmitted by vector lone star ticks (*Amblyomma americanum*). As the name mentioned, the agent is observed in the granulocytes especially in neutrophills, whereas canine monocytic ehrlichisos is observed in monocytes. In dog it is associated with polyarthritis, along with non-specific symptoms like fever, vomiting, lethargy, etc. The pathogen is having zoonotic potential and causes similar infection to that of human monocytic ehrlichiosis, especially in immunocompromised individuals (Weese and Fulford, 2010). Scanty reports are available on the pathogen in India (Das and Konar, 2013).

Heart water disease

Heart water disease is also known as Cowdriosis or Nintas. It is caused by *Ehrlichia ruminatum*.The agent was previously known as *Cowdria ruminatum*. The pathogen is transmitted by vector bont long tick (*Ambylomma*) through saliva or regurgitated gut content. It commonly affects cattle, sheep, goat, antelopes, buffalo and more commonly seen in young animals. The disease is more commonly found in exotic breeds while indigenous cattle are highly resistant.

The disease is characterised by accumulation of fluid around heart and lungs of animals due to increased vascular permeability which results in muffled heart sound. On post-mortem examination presence of straw coloured fluid around heart which clots on exposure to air due to high fibrinogen

content. Neurological signs like tremors and head pressing are also observed along with respiratory signs like coughing and nasal discharge. Other clinical signs such as fever and petechiae on mucous membrane may be there. This disease is mainly found in Sub-Saharan Africa and West-Indian Island (Zanzibar, Madagascar, Saotome, Mauritius and Reunion) (OIE, 2009). However, the disease is not reported from India (OIE, 2005).

Human monocytic ehrlichiosis

Human monocytic ehrlichiosis (HME) is caused by *E. chaffensis,* which primarily infects monocytes and macrophages. First human case was reported in 1986 (Maeda et al., 1987). The disease is characterised by non-specific symptoms like fever, headache and myalgia. The agent is principally transmitted by lone star tick (*Amblyomma americanum*). Alternatively, *Ixodes pacificus* and *Dermacentor variabilis* have also been incriminated as vector (Steiert and Gilfoy, 2002; Paddock and Childs, 2003). White tailed deer and dogs are considered as most important reservoir. Besides, the agent has also been reported in opposums, foxes, wolves, raccoons, voles, coyotes, and goats (Dawson et al., 1994a,b; Paddock and Childs, 2003).

As reported by CDC, incidence of HME is increasing since the year of first reporting. Number of cases reported in 2016 was 1377 as compared to 200 in 2000. Most of the cases are reported during summer months due to increased activity of lone star ticks during the period. The disease is mostly prevalent in south-eastern and south-central United States, followed by Eastern Coast extending westward to Texas, and the prevalence rate corresponds to distribution of vector (CDC, 2018). The agent is not reported from India.

E. muris

E. muris has been implicated to cause severe infection in wild mice, most commonly associated with hepatomegaly and splenomegaly. *Haemaphysalis flava* has been implicated as vector associated with transmission of the agent. Although human infections has not been reported so far, the human infections associated with *E. muris* like pathogen has been reported (Castillo et al., 2015; Johnson et al., 2015).

Anaplasma

The important species of *Anaplasma* are *Anaplasma marginale* (bovine anaplasmosis), *A. phagocytophilum* (canine ehrlichiosis), *A. platys* (canine ehrlichiosis), *A. centrale* (cattle), *A. ovis* (Sheep, deer, goat), and *A. caudatum* (cattle). The Anaplasmosis in different species are described here under:

Bovine anaplasmosis

Bovine anaplasmosis is also known as *Gall Sickness* as the organ gall bladder is most commonly affected. *Anaplasma marginale, A. centrale,* and *A. caudatum* are the common agents associated with bovine anaplasmosis. Among cattle, *Bos indicus* is less likely to be infected, due to innate resistance and low tick infestation as compared to *Bos taurus* (Bock et al., 1997; Jonsson et al., 2008). Tropical cattle tick (*Boophilus microplus) is most commonly associated with transmission of the agent, as high prevalence has been reported from the geographical regions, which are endemic to the tick.* Besides, at least 20 different species of tick has been involved in transmission of the agent (Futse et al., 2003; Aubry and Geale, 2011). *A. marginale* is distributed in wide geographical area in tropical and subtropical regions of the New World, Europe, Africa, Asia and Australia (Aubry and Geale, 2011).

Inverse age resistance phenomenon is observed in bovine anaplasmosis, where calves and adults are equally prone to infection, but calves are more resistant to disease as compared to adults. Calves less than one year usually exhibit sub-clinical form, while in 1-2 year aged group the disease is moderately severe, while in older cattle the disease is severe and fatal (Aubry and Geale, 2011). The disease is commonly observed as per-acute or acute form. In per-acute form death occurs within a few hours of appearance of clinical sign. While in acute condition, common clinical manifestations are anaemia, decreased milk production, in-appetence, rapid breathing, brown colouration of urine,

and pale and yellow discolouration of mucous membrane. Abortion is observed in case of pregnant animals. Macrocytic normo-chromic anaemia is one of the persistent clinical features observed, which occurs due to destruction of infected and non-infected erythrocytes due to immune mediated phagocytosis. Indigenous breeds are reported to be resistant compared to exotic breeds (Sharma et al., 2013).

Anaplasmosis is reported to be hyper-endemic in developing countries (Rodríguez et al., 2009; Kumar et al., 2015), especially in tropical and sub-tropical countries (CABI, 2018). In India, bovine anaplasmosis has been reported from several states viz. Karnataka (Muraleedharan et al., 2005), Tamil Nadu (Arunkumar et al., 2013; Velusamy et al., 2014), Kerala (Nair et al., 2013), Haryana (Kumar et al., 2015), Punjab (Sharma et al., 2015). In the recent past, there is increase in reports of bovine anaplasmosis, and the disease is considered to be emerging in India (Kumar et al., 2015). In field settings most of the cases are diagnosed on the basis of microscopy. However due to poor sensitivity of microscopy (~30%), may result in non-detection of clinical cases.

Canine anaplasmosis

Causative agents associated with canine anaplasmosis are *Anaplasma phagocytophillus* and *A. platys*. *Anaplasma phagocytophillus* is associated with canine granulocytic anaplasmosis lameness, which is many times confused with Lyme disease (Dumler et al., 2001). The pathogen is having zoonotic significance, and in humans it is associated with human granulocytic anaplasmosis. Common clinical symptoms are fever, headache, myalgia, chills, loss of appetite, cough, and diarrhoea (Bakken and Dumler, 2008). *Ixodes ricinus* is the vector usually involved in transmission of this disease (Stuen et al., 2013).

Anaplasma platys is associated with infectious canine cyclic thrombocytopenia, where the clinical signs are fever, lethargy, anorexia, pale mucous membranes, petechiae and lymphadenomegaly (Matei et al., 2016; Huber et al., 2017).

There are scanty reports, though the pathogen is prevalent in India. In North-Eastern part of India, 4.71% of infection has been detected in dogs due to *A. phagocytophilum*. Rate of infection was higher in case of pet dogs (6.09%) as compared to stray dogs (Borthakur et. al., 2014). Twenty seven cases of *A. platys* have been reported at Indian Veterinary Research Institute poly clinics. The cases reported were in co-infection with *E. canis*, *Babesia gibsoni and B. canis* (Kumar and Varshney, 2007). Besides that *A. platys has* also been reported from Delhi, Maharashtra and Goa (Rani et al., 2011; Wise and Tarlinton, 2012).

Neorickettsia

Important species included under the genus *Neorickettsia* are *N. risticii* (Potomac horse fever), *N. helminthoeca* (Salmon poisoning) and *N. elokominica* (Elokomin fluke fever). The different diseases due to Neorickettsia are described here under:

Potomac horse fever

Potomac Horse Fever is caused by *Neorickettsia risticii*, otherwise known as *Ehrlichia risticii*. The disease is also known as Shasta fever or Equine monocytic ehrlichiosis. As the name indicates, the disease was first recognised in the horses at Potomac River, Washington in 1980 (Whitlock et al., 1984). Freshwater snails act as vector for the pathogen. While, trematodes, *Acanthatrium oregonense* released from the snails are also involved in transmission of disease. Globally the disease is being reported from North and South America, Europe and India (Rikihisa et al., 2005). The disease is mainly observed during July to Septembers and associated with pastures bordering creeks or rivers (Baird and Arroyo, 2013).

The pathogen is often associated with infection of enterocytes of the small and large intestine resulting in acute enterocolitis syndrome, characterised by mild colic, fever and diarrhoea, along with leucopenia and thrombocytopenia. In pregnant mares, the pathogen is often associated with abortion. Rikihisa et al. (2005) reported the disease condition in India however, there is no

literature regarding presence of the pathogen in the country.

Salmon poisoning

Salmon poisoning is caused by *N. helminthoeca* and the principal susceptible host is dog. A classical life cycle of *N. helminthoeca* involves "snail-fish-dog" cycle. Fluke *Nanophyetus salmincola* is the vector involved in this transmission is (Headley et al., 2011). Ingestion of uncooked food acts as source of disease (Millemann and Knapp, 1970). Clinical signs appear 5–7 days after eating infected fish and persist for 7–10 days. In untreated animals case fatality rate can go up to 90%. The pathogen mainly affects the lymphoid tissues and intestines resulting in enlargement of the G.I. lymph follicles, lymph nodes, tonsils, thymus and spleen. Salmon poisoning is endemic in United States of America, British Columbia and Canada (Booth et al., 1984; Rikihisa et al., 2005; Gorham and Foreyt, 2006). So far, there is no report of this disease from India.

Elokomin fluke fever

Elokomin fluke fever is caused by *N. elokominica*, a similar disease to Salmon poisoning, but it involves wide range of host species viz. canids, ferrets, bears and raccoons (The Merck Veterinary Manual, 2016).

Orientia

There are two species of genus *Orientia*, viz. *O. tsutsugamushi* and *O. chuto*. *Orientia tsutsugamushi* is classically associated with scrub typhus, whereas *O. chuto* is being recently isolated in Dubai from an Australian tourist exhibiting symptoms of fever, myalgia, rash and eschar (Izzard et al., 2010; Taylor et al., 2015). Scrub typhus is also known as Rural Typhus, Hairy Mite Fever, Keelani Fever, Japanese Fever and Chigger borne typhus. Globally spread of scrub typhus has been described in terms of tsutsugamushi triangle. The triangle, in west extends up to Pakistan and Afghanistan, in east it extends up to Northern Japan and Far eastern Russia, while in south eastern it extends up to Northern part of Australia (Sharma et al., 2010). Globally around 1 billion population are at risk, while annually around 1 million cases are reported across globe (Sharma et al., 2010).

As the name indicates, 'Tsutsuga' means small and dangerous, and 'Mushi' means creature. Larval stages of Trombiculid mites (*Leptotrombidium deliense* and *L. akamushi*) act as vector for scrub typhus (Kelly et al., 2015). Scrub means a type of vegetation like abandoned plantation, rice field, forest clearing and river bank which acts as mite Island and serves as endemic foci for the vector. Wild rodents acts as natural hosts to Scrub Typhus, which acts as asymptomatic reservoir of the pathogen and helps in establishments of diseases in different foci, as they migrate along with pathogen (Kelly et al., 2015). Most of the cases of scrub typhus occur after July and before February i.e. during monsoon and post-monsoon period, which is associated with increased incidence of rain and exposure to rural people occurs due to harvesting in field during this period. While, increase in incidence during post monsoon period, occurs due to increased scrub vegetation (Tshokey et al., 2016).

Most common characteristic sign associated with scrub typhus is eschar, found at the site of bite, but absence of eschar does not rule out absence of infection. Scrub typhus is associated with non-specific clinical signs, which include fever, headache, myalgia, dry cough, and GI disturbance (Devine, 2003; Peter et al., 2015). While scrub typhus is associated with life threatening complications like renal failure, meningitis, myocarditis, pneumonia, multi organ failure etc. (Peter et al., 2015; Taylor et al., 2015).

In India scrub typhus is most common zoonotic Rickettsial infection. The disease has been reported from almost all the states from India. While scrub typhus is mostly prevalent in Shivalik Ranges i.e. from Himalayan foothills of Kashmir to Assam, Vindhya ranges and Satpura in Central India, and Decan Plateau in Southern India. As per recently published studies, it is one of the most common agent associated with pyrexia of unknown origin cases in India (Kumar et al., 2014a; Sinha et al., 2014; Morch et al., 2017; Giri et al., 2018;

Rawat et al., 2018).

Rickettsia

Rickettsia is one of the important genus under family *Rickettsiaceae*, because of its public health importance. Based on the clinical disease, Rickettsials are classically divided into two groups, Typhus group and Spotted fever group. Important species under Typhus group are *R. typhi* (endemic typhus), *R. prowazekii* (epidemic typhus). While, important species of spotted fever group are *R. rickettsii* (Rocky mountain spotted fever), *R. conorii* (Indian tick typhus), *R. africae* (African tick typhus), *R. akari* (Rickattsial pox), *R. australis* (Queensland tick typhus), and *R. felis* (cat flea rickettsiosis). Some of the above mentioned Rickettsial diseases, important in context to India, are discussed below:

Endemic typhus

Endemic typhus is known by several names, viz. Murine typhus, Urban typhus, Shop typhus, Flea Borne Typhus. Rats of the genus *Rattus rattus, R. norvegicus, R. exulans* act as a natural host but don't show any symptoms. Along with rats, shrews and skunks also act as host. Rat flea (*Xenopsylla cheopis*) and rat louse (*Polyplax spinulosa*) involved in transmission of disease. Besides, *Ctenocephalidis felis* (Cat flea) and *Leptopsylla segnis* (mouse flea) may also act as a vector. Source of infection are inhalation of infected flea faeces, contamination with conjunctiva, swatting of flea while feeding or scratching of the site after bite. Life cycle of the pathogen involves rat-flea-rat, and humans get infected due to accidental exposure (Eisen and Gage, 2012).

The pathogen affects vascular endothelial cells resulting in obliterative thrombo vasculitis and perivascular nodules. The disease is associated with non-specific clinical symptoms viz. fever, headache, and rash on trunk and extremities. However complications are observed in some cases with involvement of liver, kidney, lung, and brain (Peniche Lara et al., 2012). The disease is reported from almost all the countries except Antarctica. However murine typhus is more prevalent in south-east Asian region (Carr et al., 2014; van der Vaart et al., 2014). In India cases are reported from Uttar Pradesh, Karnataka, West Bengal, Andhra Pradesh, Madhya Pradesh, and Kashmir (Rahi et al., 2016; MoHFW, 2016).

Epidemic typhus

Epidemic Typhus is also known as Jail Fever, Urban Fever, Louse-borne Typhus, etc. As the synonym '*Louse borne Typhus*' indicates, human body louse acts as vector for the pathogen, and in winter season along with overcrowding helps in spreading of the disease (Raoult and Houhamdi, 2007). The only animal reported to be the reservoir for the disease is flying squirrel, *Glaucomys volans volans* (Bozeman et al., 1975).

Clinical signs associated with the disease are characterized by fever, myalgia, headache, arthralagia and appearance of characteristic rash, which begins in trunk region, spreading centrifugally. A recrudescent form of disease is observed in epidemic typhus, known as Brill-Zinsser disease, which is a milder form of disease and observed in case of immune-depressed individuals (Green et al., 1990).

In India, epidemic typhus is endemic in Northern part of the country, across Himalayan hills to Kullu valley (MoHFW, 2016). However a very few case reports are available in India, notably from Karnataka (Vivek et al., 2016).

Indian tick typhus

Indian Tick Typhus which is also known as Boutonesee Fever, Israeli Spotted Fever and Mediterranean Spotted Fever. Vector responsible for transmitting the disease is *Riphicephalus sanguineus*. It has a wide host range which includes wild rodents, sheep and goats, non- human primates. Up to 80% of Dogs are found to be serologically positive. But clinical signs are not evident in case of animals.

Clinical signs are observed in case of humans' starts with small red dish shaped ulcer is observed at the site of bite of tick along with localized lymphadenitis, at the site of bite. Fever persists for 5-7 days. Myalgia and arthralgia are also

commonly observed clinical symptoms (Raoult and Rovery, 2007).Complication may occur in some cases, resulting neurological symptoms and multi-organ failure.

In India, the disease has been reported from Haryana, Himachal Pradesh, Maharastra, and Delhi (Padbidri et al., 1984; Mahajan et al., 2007; Chaudhry et al., 2009; Kumar et al., 2014b; Gupta and Singh, 2014; Nigam et al., 2016).

CONCLUSION

In the present analysis it was observed that Rickettsial diseases are showing an upward trend in India, with increased reports in the recent past, especially Canine Rickettsiosis and Bovine anaplasmosis in animals, while scrub typhus, endemic typhus, and epidemic typhus are important emerging or re-emerging zoonoses in cases of human. However diseases like Canine Granulocytic Ehrilichiosis, Canine Anaplasmosis, Endemic Typhus, and Indian Tick Typhus although prevalent in India, are grossly under reported. Hence, studies should be conducted all over India, for estimating actual burden of the disease in the country. Along with it an epidemiological approach should be adopted in the studies for better assessment of vector dynamics and unknown reservoirs in domestic and wildlife settings especially for zoonotic pathogens,

REFERENCES

Arunkumar, S. and Nagarajan, K. 2013. A study on prevalence status of Anaplasma marginale infection among cattle population of Kancheepuram and in and around Chennai districts of Tamil Nadu. *Int. J. Food Agric. Vet. Sci.* **3**(1):155-157.

Aubry, P. and Geale, D.W. 2011. A review of bovine anaplasmosis. *Transbound. Emerg. Dis*. **58** (1): 1-30.

Baird, J.D. and Arroyo, L.G. 2013. Historical aspects of Potomac horse fever in Ontario (1924–2010). *Can. Vet. J*. **54**(6): 565.

Bakken, J.S. and Dumler, S. 2008. Human granulocytic anaplasmosis. *Infect. Dis. Clin. North Am.* **22**(3): 433-448.

Bhadesiya, C.M. and Raval, S.K. 2015. Hematobiochemical changes in ehrlichiosis in dogs of Anand region, Gujarat. *Vet. World* **8**(6): 713.

Bock, R.E., De Vos, A.J., Kingston, T.G. and McLellan, D.J. 1997. Effect of breed of cattle on innate resistance to infection with *Babesia bovis*, *B. bigemina* and *Anaplasma marginale*. *Austr. Vet. J*. **75**(5): 337-340.

Booth, A.J., Stogdale, L. and Grigor, J.A. 1984. Salmon poisoning disease in dogs on southern Vancouver Island. *Can. Vet. J*. **25**(1): 2.

Borthakur, S.K., Deka, D.K., Bhattacharjee, K. and Sarmah, P.C. 2014. Seroprevalence of canine dirofilariosis, granulocytic anaplasmosis and lyme borreliosis of public health importance in dogs from India's North East. *Vet. World* **7**(9): 665-667.

Bozeman, F.M., Masiello, S.A., Williams, M.S. and Elisberg, B.L. 1975. Epidemic typhus rickettsiae isolated from flying squirrels. *Nature* **255** (5509): 545.

Buhles Jr, W.C., Huxsoll, D.L. and Ristic, M. 1974. Tropical canine pancytopenia: Clinical, hematologic, and serologic response of dogs to *Ehrlichia canis* infection, tetracycline therapy, and challenge inoculation. *J. Infect. Dis.* **130**(4): 357-367.

Cabezas-Cruz, A., Vancová, M., Zweygarth, E., Ribeiro, M.F.B., Grubhoffer, L. and Passos, L.M.F. 2013. Ultrastructure of *Ehrlichia mineirensis*, a new member of the *Ehrlichia genus*. *Vet. Microbiol*. **167** (3-4): 455-458.

CABI. 2018. Anaplasmosis. Datasheet, Centre for Agriculture and Bioscience International. Available at: https://www.cabi.org/isc/datasheet/94682

Carr, S.B., Bergamo, D.F., Emmanuel, P.J. and Ferreira, J.A. 2014. Murine typhus as a cause of cognitive impairment: case report and a review of the literature. *Pediatric Neurol.* **50**(3): 265-268.

Castillo, C.G., Eremeeva, M.E., Paskewitz, S.M., Sloan, L.M., Lee, X., Irwin, W.E., Tonsberg, S. and Pritt, B.S. 2015. Detection of human pathogenic *Ehrlichia muris*-like agent in *Peromyscus leucopus*. *Ticks Tick-borne Dis*. **6**(2): 155-157.

CDC. 2018. *Ehrlichiosis, Epidemiology and Statistics.* Centre for Disease Control, Available at: https://www.cdc.gov/ehrlichiosis/stats/index.html

CFSPH. 2013. Ehrlichiosis and anaplasmosis: zoonotic species. The Centre for Food Security and Public Health.

Chaudhry, D., Garg, A., Singh, I., Tandon, C. and Saini, R., 2009. Rickettsial diseases in Haryana: not an uncommon entity. *J. Assoc. Physicians India* **57**(4): 334-337.

Chaudhry, R., Mukherjee, A. and Menon, V. 2012. Isolation and characterization of Bartonella sp. from optic neuritis patients. *Indian J. Med. Res.* **136**(6): 985.

Cicuttin, G.L., De Salvo, M.N., Rosa, I.L. and Dohmen, F.G. 2015. Isolation of *Rickettsia massiliae* from *Rhipicephalus sanguineus* ticks, Buenos Aires (Argentina). *J. Parasitol.* **101**(6): 711-712.

Cox, H.R. 1938. Use of yolk sac of developing chick embryo as medium for growing rickettsiae of Rocky Mountain spotted fever and typhus groups. *Public Health Rep.* **1896-1970**: 2241-2247.

Dantas-Torres, F., da Silva, Y.Y., de Oliveira, Miranda, D.E., da Silva, Sales, K.G., Figueredo, L.A., Otranto, D. 2018. Ehrlichia spp. infection in rural dogs from remote indigenous villages in north-eastern Brazil. *Parasit. Vectors* **11**(1): 139.

Das, M. and Konar, S. 2013. Clinical and hematological study of canine Ehrlichiosis with other hemoprotozoan parasites in Kolkata, West Bengal, India. *Asian Pacific J. Trop. Biomed.* **3**(11): 913.

Dawson, J.E., Childs, J.E., Biggie, K.L., Moore, C., Stallknecht, D., Shaddock, J., Bouseman, J., Hofmeister, E. and Olson, J.G. 1994a. White-tailed deer as a potential reservoir of Ehrlichia spp. *J. Wildlife Dis.* **30**(2): 162-168.

Dawson, J.E., Stallknecht, D.E., Howerth, E.W., Warner, C., Biggie, K., Davidson, W.R., Lockhart, J.M., Nettles, V.F., Olson, J.G. and Childs, J.E. 1994b. Susceptibility of white-tailed deer (*Odocoileus virginianus*) to infection with *Ehrlichia chaffeensis*, the etiologic agent of human ehrlichiosis. *J. Clin. Microbiol.* **32**(11): 2725-2728.

Devine, J. 2003. A review of scrub typhus management in 2000-2001 and implications for soldiers. *J. Rural Remote Environ. Health* **2**(1): 14-20.

Dhankar, S., Sharma, R.D. and Jindal, N. 2011. Some epidemiological observations on canine ehrlichiosis in Haryana and Delhi states. *Haryana Vet.* **50**: 9-14.

Dumler, J.S., Barbet, A.F., Bekker, C.P., Dasch, G.A., Palmer, G.H., Ray, S.C., Rikihisa, Y. and Rurangirwa, F.R. 2001. Reorganization of genera in the families Rickettsiaceae and Anaplasmataceae in the order Rickettsiales: unification of some species of Ehrlichia with Anaplasma, Cowdria with Ehrlichia and Ehrlichia with Neorickettsia, descriptions of six new species combinations and designation of Ehrlichia equi and HGE agent'as subjective synonyms of *Ehrlichia phagocytophila*. *Int. J. Syst. Evol. Microbiol.* **51**(6): 2145-2165.

Eisen, R.J. and Gage, K.L. 2012. Transmission of flea-borne zoonotic agents. *Annu. Rev. Entomol.* **57**: 61-82.

Ferrolho, J., Simpson, J., Hawes, P., Zweygarth, E. and Bell-Sakyi, L. 2016. Growth of *Ehrlichia canis*, the causative agent of canine monocytic ehrlichiosis, in vector and non-vector ixodid tick cell lines. *Ticks Tick-Borne Dis.* **7**(4): 631-637.

Futse, J.E., Ueti, M.W., Knowles, D.P. and Palmer, G.H. 2003. Transmission of *Anaplasma marginale* by *Boophilus microplus*: retention of vector competence in the absence of vector-pathogen interaction. *J. Clin. Microbiol.* **41**(8): 3829-3834.

Giri, P.P., Roy, J. and Saha, A. 2018. Scrub typhus–A major cause of pediatric intensive care admission and multiple organ dysfunction syndrome: A single-center experience from India. *Indian J. Crit. Care Med.* **22**(2): 107.

Gorham, J.R. and Foreyt, W.J. 2006. Salmon poisoning disease. In: C.E. Green (Ed.), *Infectious Diseases of the Dog and Cat*, third edn. Saunders-Elsevier, Saint Louis, USA, pp. 198–203.

Green, C.R., Fishbein, D. and Gleiberman, I. 1990. Brill-Zinsser: still with us. *JAMA* **264**(14): 1811-1812.

Gupta, R. and Singh, V. 2014. Indian tick typhus–an uncommon cause of hepatitis: a case report. *J. Clin. Diagn. Res.* **8**(5): MD01.

Headley, S.A., Scorpio, D.G., Vidotto, O. and Dumler, J.S. 2011. *Neorickettsia helminthoeca* and salmon poisoning disease: a review. *Vet. J.* **187**(2): 165-173.

Huber, D., Reil, I., Duvnjak, S., Jurković, D., Lukačević, D., Pilat, M., Beck, A., Mihaljević, Ž., Vojta, L., Polkinghorne, A. and Beck, R. 2017. Molecular detection of *Anaplasma platys*, *Anaplasma phagocytophilum* and Wolbachia sp. but not *Ehrlichia canis* in Croatian dogs. *Parasitol. Res.* **116**(11): 3019-3026.

Izzard, L., Fuller, A., Blacksell, S.D., Paris, D.H., Richards, A.L., Aukkanit, N., Nguyen, C., Jiang, J., Fenwick, S., Day, N.P. and Graves, S. 2010. Isolation of a novel Orientia species (*O. chuto* sp. nov.) from a patient infected in Dubai. *J. Clin. Microbiol.* **48**(12): 4404-4409.

Johnson, D.K.H., Schiffman, E.K., Davis, J.P., Neitzel, D.F., Sloan, L.M., Nicholson, W.L., Fritsche, T.R., Steward, C.R., Ray, J.A., Miller, T.K. and Feist, M.A. 2015. Human infection with *Ehrlichia muris*–like pathogen, United States, 2007–2013. *Emerg. Infect. Dis.* **21**(10): 1794.

Johnsson, N.N., Bock, R.E. and Jorgensen, W.K. 2008. Productivity and health effects of anaplasmosis and babesiosis on *Bos indicus* cattle and their crosses, and the effects of differing intensity of tick control in Australia. *Vet. Parasitol*. **155** (1-2): 1-9.

Juyal, P.D., Sandhu, B.S., Kalra, I.S. and Sood, N. 1992. *Ehrlichia canis* and *Hepatozoon canis* in naturally infected dogs in Punjab. *J. Vet. Parasitol.* **6**: 21-26.

Kelly, D.J., Foley, D.H. and Richards, A.L. 2015. A spatiotemporal database to track human scrub typhus using the VectorMap application. *PLoS Negl. Trop. Dis.* **9**(12): p.e0004161.

Kumar, A. and Varshney, J.P. 2007. Clinico-haematological and biochemical investigations in dogs concurrently infected with *Anaplasma platys* and other blood parasites. *J. Vet. Parasitol.* **21**(1): 43-45.

Kumar, M., Singh, R. and Yadav, M. 2014a. Indian tick typhus presenting with gangrene: A case report from an urban slum of Delhi. *Indian J. Pediatrics* **81**(1): 95-97.

Kumar, T., Sindhu, N., Charaya, G., Kumar, A., Kumar, P., Chandratere, G., Agnihotri, D. and Khurana, R. 2015. Emerging status of anaplasmosis in cattle in Hisar. *Vet. World* **8**(6): 768.

Kumar, V., Kumar, V., Yadav, A.K., Iyengar, S., Bhalla, A., Sharma, N., Aggarwal, R., Jain, S. and Jha, V. 2014b. Scrub typhus is an under-recognized cause of acute febrile illness with acute kidney injury in India. *PLoS Negl. Trop. Dis.* **8**(1): e2605.

Lakshmanan, B., John, L., Gomathinayagam, S. and Dhinakarraj, G. 2007. Molecular detection of *Ehrlichia canis* from blood of naturally infected dogs in India. *Vet. Arhiv* **77**(4): 307.

Maeda, K., Markowitz, N., Hawley, R.C., Ristic, M., Cox, D. and McDade, J.E. 1987. Human infection with *Ehrlichia canis*, a leukocytic rickettsia. *New England J. Med.* **316**(14): 853-856.

Mahajan, S.K., Kashyap, R., Sankhyan, N., Sharma, V., Rolain, J.M., Prasher, B.S. and Raoult, D. 2007. Spotted fever group rickettsioses in Himachal Pradesh. *JAPI* **55**: 868-870.

Matei, I.A., D'Amico, G., Yao, P.K., Ionică, A.M., Kanyari, P.W., Daskalaki, A.A., Dumitrache, M.O., Sándor, A.D., Gherman, C.M., Qablan, M. and Modrý, D. 2016. Molecular detection of *Anaplasma platys* infection in free-roaming dogs and ticks from Kenya and Ivory Coast. *Parasit. Vectors* **9**(1): 157.

Milanjeet, H.S., Singh, N.K., Singh, N.D., Singh, C. and Rath, S.S. 2014. Molecular prevalence and risk factors for the occurrence of canine monocytic ehrlichiosis. *Vet. Med.* **59**(3): 129-136.

Millemann, R.E. and Knapp, S.E. 1970. Biology of *Nanophyetus salmincola* and salmon poisoning disease. Academic Press.

Mittal, M., Kundu, K., Chakravarti, S., Mohapatra, J.K., Nehra, K., Sinha, V.K., Sanjeeth, B.S., Churamani, C.P. and Kumar, A. 2017. Canine Monocytic Ehrlichiosis among working dogs of organised kennels in India: A comprehensive analyses of clinico-pathology, serological and molecular epidemiological approach. *Prev. Vet. Med.* **147**: 26-33.

MoHFW. 2016. Zoonotic Diseases of Public Health Importance. Ministry of Health and Family Welfare

Mørch, K., Manoharan, A., Chandy, S., Chacko, N., Alvarez-Uria, G., Patil, S., Henry, A., Nesaraj, J., Kuriakose, C., Singh, A. and Kurian, S. 2017. Acute undifferentiated fever in India: a multicentre study of aetiology and diagnostic accuracy. *BMC Infect. Dis.* **17**(1): 665.

Muraleedharan, K., Ziauddin, K.S., Hussain, P.M., Pattabyatappa, B., Mallikarjun, G.B. and Seshadri, S.J. 2005. Incidence of Anaplasma sp., Babesia sp. and Trypanosoma sp. in cattle of Karnataka. *J. Vet. Parasitol.* **19**: 135-137.

Nair, A.S., Ravindran, R., Lakshmanan, B., Sreekumar, C., Kumar, S.S., Raju, R., Tresamol, P.V., Vimalkumar, M.B. and Saseendranath, M.R. 2013. Bovine carriers of *Anaplasma marginale* and *Anaplasma bovis* in South India. *Trop. Biomed.* **30**(1): 105-112.

Nigam, G., Sureshbabu, S., Patras, E., Peter, S. and Sobhana, C. 2016. Meningoencephalitis, myositis, and rash-neurological presentation of Indian tick typhus. *J. Neurosci. Rural Pract.* **7**(3): 476.

OIE. 2005. Handistatus, World Animal Health Publication and Handistatus II (data set for 2004). Office International des Epizooties, Paris, France.

OIE. 2009. Heartwater – cowdriosis. World Organisation for Animal Health, Paris, France.

Omsland, A., Cockrell, D.C., Howe, D., Fischer, E.R., Virtaneva, K., Sturdevant, D.E., Porcella, S.F. and Heinzen, R.A. 2009. Host cell-free growth of the Q fever bacterium *Coxiella burnetii*. *PNAS* **106**(11): 4430-4434.

Padbidri, V.S., Rodrigues, J.J., Shetty, P.S., Joshi, M.V., Rao, B.L. and Shukla, R.N. 1984. Tick-borne rickettsioses in Pune district, Maharashtra, India. *Int. J. Zoonoses* **11**: 45–52.

Paddock, C.D. and Childs, J.E. 2003. *Ehrlichia chaffeensis*: a prototypical emerging pathogen. *Clin. Microbiol. Rev.* **16**: 37–64.

Peniche Lara, G., Dzul-Rosado, K.R., Zavala Velázquez, J.E. and Zavala-Castro, J. 2012. Murine Typhus: Clinical and epidemiological aspects. *Colomb. Med.* **43**(2): 175-180.

Peter, J.V., Sudarsan, T.I., Prakash, J.A.J. and Varghese, G.M. 2015. Severe scrub typhus infection: clinical features, diagnostic challenges and management. *World J. Crit. Care Med.* **4**(3): 244.

Rahi, M., Gupte, M.D., Bhargava, A., Varghese, G.M. and Arora, R. 2016. DHR-ICMR Guidelines for diagnosis and management of Rickettsial diseases in India. In: *Rickettsiales*. Springer, Cham, pp. 125-133

Rani, P.A.M.A., Irwin, P.J., Coleman, G.T., Gatne, M. and Traub, R.J. 2011. A survey of canine tick-borne diseases in India. *Parasit. Vectors* **4**(1): 141.

Raoult, D. and Houhamdi, L. 2007. Louse-borne epidemic typhus. In: *Rickettsial Diseases*. CRC Press, pp. 63-74

Raoult, D. and Rovery, C. 2007. Rickettsia conorii infections (Mediterranean spotted fever, Israeli spotted fever, Indian tick typhus, Astrakhan fever). In: *Rickettsial Diseases*. CRC Press, pp. 137-150

Rawat, V., Singh, R.K. Kumar, A., Saxena, S.R., Varshney, U. and Kumar, M. 2018. Epidemiological, clinical and laboratory profile of scrub typhus cases detected by serology and RT-PCR in Kumaon, Uttarakhand: a hospital-based study. *Trop. Doct.* **48**(2): 103-106.

Rikihisa, Y., Dumler, J.S. and Dasch, G.A. Genus III. Neorickettsia. In: Brenner D J, Krieg N R, Staley J T, eds. 2005. The Proteobacteria, Part C The Alpha-, Beta-, Delta-, and Epsilonproteobacteria. In: *Bergey's Manual® of Systematic Bacteriology*. 2nd ed. vol. 2, New York, Springer 2005, pp. 132–137.

Rikihisa, Y., Ewing, S.A., Fox, J.C., Siregar, A.G., Pasaribu, F.H. and Malole, M.B. 1992. Analyses of *Ehrlichia canis* and a canine granulocytic Ehrlichia infection. *J. Clin. Microbiol.* **30**(1):143-148.

Rodríguez, S.D., Ortiz, M.Á.G., Ocampo, R.J. and Murguía, C.A.V. 2009. Molecular epidemiology of bovine anaplasmosis with a particular focus in Mexico. *Infect. Genet. Evol.* **9**(6): 1092-1101.

Sharma, A., Singla, L.D., Kaur, P. and Bal, M.S. 2015. PCR and ELISA vis-à-vis microscopy for detection of bovine anaplasmosis: A study on associated risk of an upcoming problem in North India. *Scientific World J. Article* ID 352519

Sharma, A., Singla, L.D., Kaur, P., Bal, M.S., Batth, B.K. and Juyal, P.D. 2013. Prevalence and haemato-biochemical profile of *Anaplasma marginale* infection in dairy animals of Punjab (India). *Asian. Pac. J. Trop. Med.* **6**(2): 139-44.

Sharma, P., Kakkar, R., Kaore, S.N., Yadav, V.K. and Sharma, R. 2010. Geographical distribution, effect of season and life cycle of scrub typhus. *JK Sci.* **12**(2): 63.

Singla, L.D., Singh, H., Kaur, P., Singh, N.D., Singh, N.K. and Juyal, P.D. 2011. Serodetection of *Ehrlichia canis* infection in dogs from Ludhiana district of Punjab, India. *J. Parasit. Dis.* **35**(2): 195-198.

Sinha, P., Gupta, S., Dawra, R. and Rijhawan, P. 2014. Recent outbreak of scrub typhus in North Western part of India. *Indian J. Med. Microbiol.* **32**(3): 247.

Sosa-Gutierrez, C.G., Quintero Martinez, M.T., Gaxiola Camacho, S.M., Cota Guajardo, S., Esteve-Gassent, M.D. and Gordillo-Pérez, M.G. 2013. Frequency and clinical epidemiology of canine monocytic ehrlichiosis in dogs infested with ticks from Sinaloa, Mexico. *J. Vet. Med.* 2013.

Steiert, J.G. and Gilfoy, F. 2002. Infection rates of *Amblyomma americanum* and *Dermacentor variabilis* by *Ehrlichia chaffeensis* and *Ehrlichia ewingii* in southwest Missouri. *Vector Borne Zoonotic Dis.* **2**:53–60.

Stuen, S., Granquist, E.G. and Silaghi, C. 2013. *Anaplasma phagocytophilum*—a widespread multi-host pathogen with highly adaptive strategies. *Front. Cell Infect. Microbiol.* **3**: 31.

Taylor, A.J., Paris, D.H. and Newton, P.N. 2015. A systematic review of mortality from untreated scrub typhus (*Orientia tsutsugamushi*). *PLoS Negl. Trop. Dis.* **9**(8): e0003971.

The Merck Veterinary Manual. 2018. "Salmon Poisoning Disease and Elokomin Fluke Fever". https://www.msdvetmanual.com/dog-owners/disorders-affecting-multiple-body-systems-of-dogs/salmon-

poisoning-disease-and-elokomin-fluke-fever-in-dogs. Retrieved: 29: 8: 2018.

Tshokey, T., Choden, T. and Sharma, R. 2016. Scrub typhus in Bhutan: a synthesis of data from 2009 to 2014. *WHO South East Asia J. Public Health* **5**(2): 117.

Unver, A., Perez, M., Orellana, N., Huang, H. and Rikihisa, Y. 2001. Molecular and antigenic comparison of *Ehrlichia canis* isolates from dogs, ticks, and a human in Venezuela. *J. Clin. Microbiol*. **39**(8): 2788-2793.

Van den Brom, R., Engelen, E., Roest, H.I.J., van der Hoek, W. and Vellema, P. 2015. *Coxiella burnetii* infections in sheep or goats: an opinionated review. *Vet. Microbiol.* **181**(1): 119-129.

Van der Vaart, T.W., van Thiel, P.P., Juffermans, N.P., van Vugt, M., Geerlings, S.E., Grobusch, M.P. and Goorhuis, A. 2014. Severe murine typhus with pulmonary system involvement. *Emerg. Infect. Dis.* **20**(8): 1375.

Velusamy, R., Rani, N., Ponnudurai, G., Harikrishnan, T.J., Anna, T., Arunachalam, K., Senthilvel, K. and Anbarasi, P. 2014. Influence of season, age and breed on prevalence of haemoprotozoan diseases in cattle of Tamil Nadu, India. *Vet. World* **7**(8): 574-578.

Vivek, K., Anwar, Q. and Shampure, S. 2016. Atypical presentation of epidemic typhus in South India: A case report. *Int. J. Infect. Dis*. **45**: 193.

Waner, T., Strenger, C. and Keysary, A. 2000. Comparison of a clinic-based ELISA test kit with the immunofluorescence test for the assay of *Ehrlichia canis* antibodies in dogs. *J. Vet. Diagn. Invest*. **12**(3): 240-244.

Weese, J.S. and Fulford, M., eds., 2010. *Companion animal zoonoses*. John Wiley and Sons.

Whitlock, R.H., Palmer, J.E., Benson, C.E., Acland, H.M., Jenny, A. and Ristic, M. 1984. Potomac horse fever: clinical characteristics and diagnostic features. In: Proc. Ann. Meeting American Association of Veterinary Laboratory Diagnosticians, USA.

Wise, A.E. and Tarlinton, R.E. 2012. Seroprevalence of vectorborne diseases in free-roaming dogs in Goa, India. *Vet. Rec.* **170**(3): 76.

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Correlation analysis of forage production of sorghum, cowpea and rice-bean under varying seed rates of intercrops

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ABSTRACT

A field experiment was conducted at Forage Agronomy Block of Instructional Dairy Farm at G.B. Pant University of Agriculture and Technology, Pantnagar, Uttarakhand during *kharif* 2011 to find out the correlation between growth, yields and quality parameters of legumes (cowpea: *Vigna unguiculata* L. var. UPC-5286 and rice-bean: *Vigna umbellate* L. var. RB-1) and sorghum (*Sorgum bicolar* L. Moench, var. Pant chari-5) crops in intercrops. Overall, intercropping system reduced the growth parameters of crops than sole stand. The correlation studies indicated that association between growth parameters and yield as well as quality was positive and significant, except land equivalent ratio which negatively correlated with growth, yield and quality parameters.

Key words: Correlation, cowpea, growth parameters, intercropping, rice bean, sorghum

INTRODUCTION

Traditionally, intercropping is used by marginal farmers to increase the density of their produce and stability. However, with rapid increase in population and reduction in cultivated areas, intercropping plays crucial role in intensifying land use. The fodder legumes which are mostly removed for fodder at 55 days stage leave biologically fixed nitrogen available in the soil for the sorghum plant without further competing for light or for other resources. It is accounted for total N accumulation of 61-77% in cowpea (*Vigna unguiculata* L.) and 58-78% in soybean (*Glycine max*. L.), respectively (Ofori et al., 1987; Ahmad et al., 2008).

Among *kharif* cereal forage crops, sorghum possesses a wide range of ecological adaptability for its xerophytic characteristics. It is fed to almost every class of livestock. It has higher green forage yield (35-70 t ha^{-1}) and dry fodder yield (10.2 t ha^{-1}). However, the fodder is poor in quality due to low protein content (0.69 t ha^{-1}; Hingra et al., 1995). Legumes have long been recognized as important components of intercropping situations. Among the fodder legume crops, cowpea is commonly grown with maize and sorghum in *kharif*. Being deep rooted crop and slow growing in early growth stage, the rapidly growing crops like sorghum and maize due to their shallow roots utilize the natural resources more efficiently (Willey et al., 1981). Cowpea enhances fodder productivity (25-45 t ha^{-1} green forage yield), improves nutritive value of fodder (crude protein) more than 20% (Solaiman, 2007). Rice-bean (*Vigna umbellate* L.) is another forage legume crop intercropped with sorghum in rainy season. Rice-bean is reported to produce 3000 kg seed ha^{-1}, up to 0.8 t ha^{-1} (Mukherjee et al., 1980) dry herbage to meet scarcity of green forage during lean periods and can supply green fodder yield 15-30 t ha^{-1} (ICAR, 2011).

Increased intercrop competition from 1: 1 to 1: 2 ratio of fodder cowpea and fodder sorghum, plant height, green fodder yield and dry fodder yield of sorghum reduced owing to increased population

pressure of legume in the system (Gumaste, 1990). Intercropping system has an important role in profitability and sustainability in crop production for low-input agricultural systems especially in arid and semi-arid regions (Yildirim and Ekinci, 2017), efficient use of resources (Knudsen et al., 2004), reducing damage caused by pests, diseases and weeds and improvement of forage quality through complementary effects of two or more crops grown simultaneously on the same area of land (Bingol et al., 2007). Singh and Jadhav (2003) reported the higher values of plant height, leaf area and leaf area index under sole sorghum as compared to sorghum intercropped with groundnut, soybean and pigeon pea. The seed proportions of sorghum and rice-bean significantly affected the sorghum plant height, number of leaves of sorghum and rice-bean plants, green and dry matter yields (Ayub et al., 2004).

There has been little or no information on correlation analysis on intercrop of crops, although, Bello et al. (2010) reported the significant and positive correlation of green yield per ha with D50F tassel and PH l maize. A positive association between crude protein content, dry matter yield and protein yield has been found under intercropping of sorghum with cowpea (Ram and Singh, 2003a, b). Based on two years study, Singh (2009) concluded that sweet sorghum intercropped with phillipesara receiving nitrogen 50 per cent through inorganic fertilizer and 50 per cent through vermicompost sustain higher fodder and stalk equivalent yield, quality such as total crude protein, digestibility, and improves soil fertility. Significant positive correlation between yield and all growth parameters of sweet sorghum was noticed. Also there is a report of positive and significant effects on grain yield of rice in intercrop with cassava (Okonji et al., 2013).

MATERIALS AND METHODS

The experiment was conducted at Forage Agronomy block of Instructional Dairy Farm, Nagla of the Govind Ballabh Pant University of Agriculture and Technology, Pantnagar, Uttarakhand, India in *kharif* 2011. Soil of the experimental field was rich in organic carbon (8.48 g kg^{-1}), medium in available nitrogen (278.48 kg ha^{-1}), available phosphorus (27.70 kg ha^{-1}) and available potassium (232.8 kg ha^{-1}) with neutral in reaction (pH: 7.6). The experiment was laid out in randomized block design consisting of 11 treatments (sole sorghum, sole cowpea, sole rice bean, sorghum + cowpea and rice bean intercropped each with 25, 50, 75 and 100 % seed rates) with 4 replications. The recommended application of fertilizers (N and P_2O_5) was 120 and 60 kg ha^{-1} for sole sorghum, 20 and 60 kg ha^{-1} for sole legumes and 80 and 60 kg ha^{-1} for intercropping system, respectively. In sole sorghum, two third nitrogen and all phosphorus were applied as basal and remaining one third nitrogen was top dressed at 30 DAS. In legume crops, whole nitrogen along with phosphorus was applied as basal. The source of nitrogen and phosphorus were urea and single super phosphate (SSP). Sole and intercrops were sown on June 8, 2011 and harvested at 112 days after sowing.

The statistical analysis of data were appropriate to randomized block design (Cochran and Cox, 1966). Correlation coefficient analysis (Dewey and Lu, 1959) was based on data collected randomly and was carried out to find out the association between plant growth, yield and quality characters using Pearson's correlation at P = 0.05.

RESULTS AND DISCUSSION

The simple correlation coefficient analysis carried out in this study for establishing the extent and cause of association between growth, yield and quality parameters of sorghum and legumes intercropped.

Correlation between growth parameters and green forage yield of sorghum

The correlation for sorghum growth parameters was found to have positive correlation among them and with green fodder yield of

sorghum, excluding land equivalent ratio (LER), which was negatively correlated with all the growth parameters and yield. The positive association between mentioned parameters was significant, except number of plants with total dry weight, in which their correlation was positive, but not significant (Table 1).

Cowpea

The linear correlation coefficient between cowpea growth parameters such as plant height, number of plants per meter row length, total dry weight, dry matter (DM) yield, crude protein (CP) content, land equivalent ratio and sorghum equivalent yield with green fodder yield was positive, except LER with fodder yield of cowpea. This, positive association between mentioned parameters was positively significant, excluding plant height with number of plant, total dry weight, DM yield, CP content and sorghum equivalent yield, number of plant with total dry weight and green fodder yield, total dry weight with DM yield, CP content, sorghum equivalent yield and green fodder yield, DM with green fodder yield and finally sorghum equivalent yield with green fodder yield which were positively associated but statistically there was no significant difference among them. The only exception was LER that was negatively correlated with all the other parameters (Table 1).

Rice-bean

The linear positive correlation between growth parameters and green fodder yield of rice bean were positive. These positive correlations were significant among plant height with number of plants, total DM accumulation, DM yield and sorghum equivalent yield; number of plants and sorghum equivalent yield; DM yield with CP content, sorghum equivalent yield and green fodder yield; CP content with green fodder yield (Table 1).

The correlation studies of sorghum, cowpea and rice bean growth parameters with their green forage yield in Table 1 found positive, but in case of sorghum, the growth parameters were significantly positive with CP content and yield. It might be attributed to the fact that increase in plant population, there will be increase in plant height and accumulation of more dry matter in plant parts, which enhance the total dry weight and ultimately green and DM yield would be improved. The positive correlation of plant growth parameters with CP content may be due to sorghum associated legumes which contribute biologically fixed nitrogen to sorghum and enhance nitrogen availability and uptake resulted in improvement of CP content in sorghum. The negative correlation of LER with all other parameters, could be attributed to reduction of yields in intercropping system compared to sole crops. It was in conformity with the findings of Singh (2009) who noticed that various growth parameters and nutrient content per uptake had positively correlated with DM accumulation and yield of sorghum stalk. The positive association between CP content, DM yield and protein yield of sorghum and cowpea was also noticed by Ram and Singh (2003b). Similarly, reports of positive and significant correlation between yield factors of cowpea to that of cowpea and maize (Maurice et al., 2010).

Correlation between yield and quality parameters of Sorghum

The correlations between CP yield, digestible DM, digestible DM yield, DM yield and green forage yield of sorghum were positively correlated. These positive associations were significant between CP yield and digestible DM yield, DM yield and green forage yield; digestible DM yield with DM yield and green forage yield, and DM yield with green forage yield, however, the correlation was not significant with the remaining parameters but maintained positive association (Table 2).

Table 1. Correlation coefficient between growth parameters and green fodder yield of sorghum, cowpea and ricebean plants grown in intercrop

Characters	PH (cm)	NP m RL^{-1}	TDW (g 0.5m RL^{-1})	DMY (q ha^{-1})	CPC (%)	LER	GFY(q ha^{-1})
Plant height (cm) (PH)	-	.850**	.755**	.9328**	.922**	-.534	.937**
Number of plants/m row length (NP mRL^{-1})	-	-	.478	.834**	.791**	-.853	.806**
Total dry weight (g 0.5^{-1} m row length) (TDWg 0.5 mRL^{-1})	-	-	-	.766**	.742**	-.254	.775**
Dry matter yield (q ha^{-1}) (DMY)	-	-	-	-	.988**	-.667	.969**
Crude protein content % (CPC)	-	-	-	-	-	-.607	.948**
Land equivalent ratio (LER)	-	-	-	-	-	-	-.623
Green fodder yield (q ha^{-1})	-	-	-	-	-	-	-

Correlation Coefficient between growth parameters and green fodder yield of cowpea

Characters	PH (cm)	NP mRL^{-1}	TDW (g 0.5 mRL^{-1})	DMY (q ha^{-1})	CPC %	LER	SEY (q ha^{-1})	GFY (q ha^{-1})
Plant height (cm) (PH)	-	0.505	0.510	0.168	0.316	-0.389	0.031	0.715**
Number of plants/m row length (NP mRL^{-1})	-	-	0.541	0.902**	0.893**	-0.410	0.791**	0.516
Total dry weight (g $0.5m^{-1}$ row length) (TDWg $0.5mRL^{-1}$)	-	-	-	0.591**	0.413	-0.168	0.464	0.157
Dry matter yield (q ha^{-1}) (DMY)	-	-	-	-	0.903**	-0.249	0.952**	0.282
Crude protein content (CPC)	-	-	-	-	-	-0.641	0.932**	0.636**
Land equivalent ratio (LER)	-	-	-	-	-	-	-0.397	-0.913
Sorghum Equivalent yield (q ha^{-1}) (SEY)	-	-	-	-	-	-	-	0.351
Green fodder yield (q ha^{-1}) (GFY)	-	-	-	-	-	-	-	-

Correlation Coefficient studies among growth parameters and with green fodder yield of rice-bean

Characters	PH (cm)	NP mRL^{-1}	TDW (g 0.5 mRL^{-1})	DMY (q ha^{-1})	CPC %	LER	SEY (q ha^{-1})	GFY (q ha^{-1})
Plant height (cm) (PH)	-	0.797**	0.683**	0.738**	0.545	-0.012	0.726**	0.543
Number of plants m^{-1} row length (NP mRL^{-1})	-	-	0.379	0.406	0.023	-0.551	0.803**	0.067
Total dry weight (g 0.5 m^{-1} row length) (TDW g 0.5 mRL^{-1})	-	-	-	0.180	0.511	-0.206	0.039	0.347

Dry matter yield (q ha^{-1}) (DMY)	-	-	-	-	0.648**	-0.338	0.739**	0.750**
Crude protein content % (CPC)	-	-	-	-	-	-0.820	0.298	0.975**
Land equivalent ratio (LER)	-	-	-	-	-	-	-0.203	-0.777
Sorghum equivalent yield (q ha^{-1}) (SEY)	-	-	-	-	-	-	-	0.441
Green fodder yield (q ha^{-1}) (GFY)	-	-	-	-	-	-	-	-

**Level of significant at n-2 degree of freedom at 5% in "r" table is 0.6215 for sorghum plants
** Table value of r = 0.5822, significant at 5% and (n-2 degree of freedom) for cowpea plants
** Table value of r = 0.5822, significant at 5% and (n-2 degree of freedom) for rice-bean plants

Table 2. Correlation coefficient between quality parameters and fodder yield of sorghum, cowpea and rice-bean plants grown in intercrop

Correlation coefficient between quality parameters and fodder yield of sorghum					
Characters	CPY	DDM	DDMY	DMY	GFY
Crude protein yield (CPY)	-	0.003	0.983**	0.988**	0.948**
Digestible dry matter (DDM)	-	-	0.107	0.046	0.062
Digestible dry matter yield (DDMY)	-	-	-	0.988**	0.961**
Dry matter yield (DMY)	-	-	-	-	0.969**
Green forage yield (GFY)	-	-	-	-	-
Correlation Coefficient between quality parameters and fodder yield of cowpea					
Characters	CPC	CPY	DDMY	DMY	GFY
Crude protein content (CPC)	-	0.565	0.119	0.155	0.916**
Crude protein yield (CPY)	-	-	0.886**	0.903**	0.636
Digestible dry matter yield (DDMY)	-	-	-	0.999**	0.246
Dry matter yield (DMY)	-	-	-	-	0.282
Green forage yield (GFY)	-	-	-	-	-
Correlation coefficient between quality parameters and fodder yield of rice-bean					
Characters	CPY	DDM	DDMY	DMY	GFY
Crude protein yield (CPY)	-	0.851	0.704	0.648	0.975**
Digestible dry matter (DDY)	-	-	0.445	0.365	0.822
Digestible dry matter yield (DDMY)	-	-	-	0.996**	0.796
Dry matter yield (DMY)	-	-	-	-	0.75
Green forage yield (GFY)	-	-	-	-	-

** Table value of r = 0.666, significant at 5% and (n-2 degree of freedom: 7) for sorghum plants
** Table value of r = 0.8782, significant at 5% and (n-2 degree of freedom: 3) for cowpea plants
** Table value of r = 0.8782, significant at 5% and (n-2 degree of freedom: 3) for rice-bean plants and Cowpea

The correlation between quality and yield of cowpea indicated the positive correlation between CP content, CP yield, digestible DM yield, DM yield and green forage yield. These positive correlations were significant between CP content and green forage yield; CP yield with digestible DM yield and DM yield, and digestible DM yield with DM yield, but maintained positive correlation with other parameters, though there were not significant correlation (Table 2).

Rice-bean

There was positive correlation between quality and yield of rice-bean parameters such as CP yield, digestible DM, digestible DM yield, DM yield and green forage yield. Among the parameters, CP yield with green forage yield and digestible DM yield with DM yield significantly correlated, whereas, the remaining parameters maintained positive association, although there were not significant associations (Table 2).

Generally, the positive correlation between quality and yield parameters of forage crops indicated that there are direct relationship between quality and yields. It was evident that increase in productivity of green forage yield caused in enhancing the DM yield, digestible DM, digestible DM yield and CP yield. The present findings are in conformity with the findings of Mittal and Moore (2009) who observed significant positive association between green and DM yield of cowpea. Maurice et al. (2010) reported that the positive and significant correlation existed between all the yield attributes of cowpea, as well as between cowpea and maize yields. Sanderson et al. (1994) found that *in vitro* digestibility and CP of sorghum were positively correlated, but the yield of forage sorghum was negatively associated with CP.

CONCLUSION

On the basis of the present investigation, the correlation studies indicated the positive and significant association between growth parameters with yield as well as yield with quality parameters of fodder crops, except for land equivalent ratio, which was negatively correlated with growth yield parameters.

REFERENCES

Ahmad, A.A., Ahmad, R., Mahmood, N. and Tanveer, A. 2007. Performance of forage sorghum intercropped with forage legumes under different planting patterns. *Pak. J. Bot.* **39**(2): 431-439.

Ayub, M., Tanveer, A., Nadeem, M.A. and Shah, S.M.A. 2004. Studies on the fodder yield and quality of sorghum grown alone and in mixture with rice-bean. *Pak. J. Life Soc. Sci.* **2**(1): 46-48.

Bello, O.B., Abdulmaliq, S.Y., Afolabi, M.S. and Lge, S.A. 2010. Correlation and path coefficient analysis of yield and agronomic characters among open pollinated maize varieties and their F1 hybrids in a diallel cross. *Afr. J. Biotechnol.* **9** (18): 2633-2639.

Bingol, N.T., Karsli, M.A., Yilmaz, I.H. and Bolat, D. 2007. The effects of planting time and combination on the nutrient composition and digestible dry matter yield of four mixtures of vetch varieties intercropped with barley. *J. Vet. Anim. Sci.* **31**: 297-302.

Cochran, W.G. and Cox, G.M. 1966. *Experimental Design.* 2nd Edn. John Willey and Sons, Inc., New York.

Dewey, D.R. and Lu, K.H. 1959. A correlation and path coefficient analysis of components of wheat grass seed production. *Agron. J.* **51**: 515-518.

Gumaste, S.K. 1990. *Intercropping Principles and Practices*. University of Agricultural Sciences, Dharwad, pp. 161-164.

Hingra, S.H., Davis, B. and Akhtar, M.J.A. 1995. *Fodder Production*. Food and Agriculture Organization of the United Nations, Rome, pp. 1-8.

ICAR. 2011. *Handbook of Agriculture*. Sixth edn. Indian Council of Agricultural Research, New Delhi, pp. 1354-1355, 1385.

Knudsen, M.T., Hauggaard-Nielsen, H., Jornsgard, B. and Jensen, E.S. 2004. Comparison of inter-specific competition and N use in pea - barley, faba bean – barley and lupin – barley intercrops grown at two temperate locations. *Eur. J. Agron.* **142**: 617-627.

Maurice, G., Albert, N., Isidore, T. and Francois, A.A. 2010. Altering the time of intercropping cowpea relative of maize: A food production strategy to increase crop yield attribution in Adamawa-cameroon. *World J. Agric. Sci.* **6** (5): 473-479.

Mittal, A. and Moore, M. 2009. *Voices from Africa. African farmers and environmentalists speak out against a new green revolution in Africa.* The Oakland Institute, USA, pp. 1-39.

Mukherjee, A.K., Roquib, M.A. and Chatterjee, B.N. 1980. Rice-bean for the scarcity period. *Indian Farming* **30**: 26–28.

Ofori, F., Pate, J.S. and Stern, W.R. 1987. Evaluation of N_2 fixation and nitrogen economy of a maize/cowpea intercrop system using ^{15}N dilution methods. *Plant Soil* **102**: 149-160.

Okonji, C.J., Ajayi, E.O., Okeleye, K.A., Oyekanmi, A.A. and Sakariyawo. S.O. 2013. Correlation analysis of rice (*Oryza sativa* L.) growth, yield and its yield attributes in an intercrop with cassava and melon. *Afr. J. Plant Sci. Biotechnol.* **7**: 27-31.

Ram, S.N. and Singh, B. 2003a. Physiological growth parameters, forage yield and nitrogen uptake of sorghum as influenced with legume intercropping, harvesting time and nitrogen level. *Indian J. Agron.* **48**(1): 38-41.

Ram, S.N. and Singh, B. 2003b. Growth, yield and quality of forage sorghum as affected by intercrop, harvesting time and nitrogen. *Indian J. Dryland Agric Res. Dev.* **18**(2): 167-172.

Sanderson, M.A., Miller, F.R., and Jones, R.M. 1994. *Forage quality and agronomic traits of experimental forage sorghum hybrids*. MP-1759. Texas Agric. Exp. Stn., College Station, TX.

Singh, P.K. and Jadhav, A.S. 2003. Intercropping of sorghum with pigeonpea, groundnut and soybean under varying planting geometry. *Indian J. Dryland Agric. Res. Dev.* **18**(2): 126-129.

Singh, S. 2009. Studies on integrated nutrient management in sweet sorghum and phillipesara intercropping system. PhD Thesis, Govind Ballabh Pant University of Agriculture and Technology, Pantnagar, Uttarakhand, India.

Solaiman, S.G. 2007. Feeding value of seed-harvested cowpea vines for goats. In: *Notes on goats*, Technical Paper No. 7-9, Tuskegee University.

Willey, R.W., Rao, M.R., Reddy, M.S. and Natarajan, M. 1981. Cropping systems with sorghum. In: *Proc. Int. Symp. Sorghum*, 2-7 November, International Crops Research Institute for the Semi-Arid Tropics, Patancheru, Hyderabad, India, pp. 449- 477.

Yildirim, E. and Ekinci, M. 2017. Intercropping systems in sustainable agriculture. *Süleyman Demirel Üniversitesi Ziraat Fakültesi Dergisi* **12** (1): 100-110.

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Effect of different levels of phosphorus and biofertilizers on growth and yield of soybean in Paktia, Afghanistan

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ABSTRACT

A field research was conducted during spring season in 2017 at Paktia province, Afghanistan to find out the effect of different levels of phosphorus and biofertilizers on growth and yield of soybean in Paktia, Afghanistan. The treatments consisted of T_1= recommended K only, T_2 = recommended FYM only, T_3 = recommended NPK only, T_4 = recommended NPK + FYM + PSB and Rhizobium, T_5 = recommended FYM+ PSB and Rhizobium, T_6 = recommended NPK + PSB and Rhizobium, T_7 = 0 % recommended NP + recommended K+ FYM + PSB and Rhizobium, T_8 = 50 % P and N + recommended K + FYM + PSB and Rhizobium. The experiment was laid out in randomized complete block design with three replications. The results of experiment showed that T_4 = recommended NPK + FYM + PSB and Rhizobium recorded significantly higher plant height (40 cm at 60 DAS and 51.47 cm at harvest), number of branches (6.57 at 60 DAS and 8.40 at harvest), number of root nodules (34 at 60 DAS and 58.43 at harvest), number of pods per plant (66.03), number of seeds per pod (2.57), 100 seeds weight (20.33 g), seed yield per plant (20.13 g), seed yield (2490 kg ha^{-1}) and straw yield (4109 kg ha^{-1}) and it was recorded non-significantly higher harvest index (38.20) and significantly higher gross return (1929 US$ ha^{-1}), net return (1067 US$ ha^{-1}) and net benefit cost of ratio (1.36). Based on the result of experiment it is recommended that for the higher yield of soybean the farmer should apply recommended NPK + FYM + PSB and Rhizobium.

Key words: Biofertilizers, phosphorus, soybean growth, yield

INTRODUCTION

Pulses are important food crops as they provide vital proteins and vitamins in an average Afghan diet (Noorzai et al., 2017 a, b). Afghanistan probably is the lowest producer of pulses and imports pulses from neighboring countries. Thus, there is a need to increase the production of pulses to meet the protein and oil requirements of growing population by appropriately manipulating the pulse production technologies.

Soybean (*Glycine max* (L.) Merill) a grain legume is considered as a wonder crop due to its dual qualities viz., high protein (40-43%) and oil content (20%). Soybean being the "Golden Bean" of the 20th century is a species of legume, native to East Asia, widely grown for its edible bean which has numerous uses. The plant is classed as an oilseed rather than a pulse by the Food and Agricultural Organization (FAO). It grows in varied agro-climatic conditions (Rana et al., 2014). It has emerged as one of the important commercial crops in many countries. Due to its worldwide popularity, the international trade of soybean has spreaded globally. Several countries such as Japan, China, Indonesia, Philippines, and European countries are importing soybean to supplement their domestic requirement for human consumption and cattle feed (Geetha and Radder, 2015).

Although, the climate of the country is reasonable for soybean cultivation, but the major

problems are inappropriate cultural practices of the application of phosphorous and biofertilizers, which lead to low yield of soybean.

To solve this problem we tried to find out the proper dose of P and biofertilizers. This crop is recently introduced to country and the country soils are varying from province to province because of heterogeneity nature. In Paktia province, the Nutrition and Education International (NEI) distributed soybean for cultivation to deprive the hunger from the province. While the total amount of P is high in some soils, available P is often limited because soil P not only forms insoluble precipitates with metals such as iron and aluminum in acid soils, and calcium in alkaline soils (Sharpley et al., 1984; Sanyal and De Datta, 1991), but also 50 to 80 percent of the soil P can exist as organic P which is not directly available to plants (Alexander, 1977; Iyamuremye et al., 1996).

MATERIALS AND METHODS

The field experiment was conducted during spring 2017 to study the effect of different levels of phosphorus and biofertilizers on growth and yield of soybean in Syedan village, Gardiz, Paktia, Afghanistan under irrigated condition. The geographical co-ordinates are 37° 16' N latitude and 49° 55' E longitudes with an altitude of 2350 m above mean sea level. It comes under South-eastern Zone of Afghanistan. The soil was clay with pH above 7.0 and low available nitrogen and phosphorous content, but high in available potassium.

The experimental design involved was randomized complete block design with three replications and eight treatments (T_1 = recommended K only, T_2 = recommended FYM only, T_3 = recommended NPK only, T_4 = recommended NPK + FYM + PSB and Rhizobium, T_5 = recommended FYM+ PSB and Rhizobium, T_6 = recommended NPK + PSB and Rhizobium, T_7 = 0 % recommended NP + recommended K+ FYM + PSB and Rhizobium, and T_8 = 50 % P and N + recommended K + FYM.+ PSB and Rhizobium). The recommended fertilizer dose 40:80:25 kg N, P_2O_5 and K_2O kg ha^{-1} in the form of Urea, DAP and MOP and FYM 5 t ha^{-1} was applied. Seeds were treated using Rhizobium and PSB (*Pseudomonas striata*) at the rate of 6 g kg^{-1} of seed. Entire dose of N, P and K as basal were applied at the time of sowing and FYM was applied 10 days before sowing of the crop.

There were 24 experimental plots and each plot was with dimension of 3 m × 5 m. Soybean cultivar 'Stine 3300' was sown on 20 April, 2017 using 60 kg seeds per ha. Two seeds per hill were dibbled 5 cm deep at a spacing 40 cm × 5 cm. The crop was harvested at its physiological maturity. In the experiment all plant samples were taken by randomized uprooting of five plants in both sides of the border rows from each plot. After harvesting the border rows, yield per plot was recorded by taking the weight of the seeds from net plot. The seed yield of net plots is converted to seed yield per hectare and expressed in kg per hectare, in the order to evaluate effect of treatments on growth parameters, yield attributes and yield.

The economic ratio (returns per US dollars invested) was worked out on the basis of existing rates inputs and outputs. The methods outlined by Panse and Sukhatme (1985) was used for the statistical analysis of the data for drawing conclusions on the effect of various treatments on different parameters studied.

RESULTS AND DISCUSSION

Plant height was recorded significantly higher (40 and 51.47 cm at 60 DAS and harvest, respectively) with the application of treatment T_4= RDF + FYM + PSB + Rhizobium (Table 1). It was on par with all the treatments at harvest except T_1 recommended K, but at harvest it was on par with all treatments except of T_1 = recommended K only), at 60 DAS it was recorded non-significantly higher number of branches per plant (6.57). However, at harvest it was recorded significantly higher number of branches per plant (8.40) which was comparable with T_1 = recommended K only. Significantly higher number of nodules was recorded by application of T_4 = recommended NPK + FYM + PSB and Rhizobium (34 at 60 DAS and 66.03 at harvest, but at 60 DAS it was on par with

T_8 = 50% recommended NP + recommended K + FYM + PSB and Rhizobium). Rana et al. (2014) was reported that inoculation of the soybean seeds with rhizobium and PSB resulted in a significant increase in the growth parameters (plant height, dry matter production and number of nodules). Abd-Alla et al. (2001) and Son et al. (2006) found that inoculated soybean seed with *Bradyrhizobium japonicum* and phosphate solubilizing bacteria significantly increased nodulation, seed and biomass yield, nutrient uptake and symbiotic N fixation.

The application of recommended NPK + FYM + PSB and Rhizobium (T_4) was superior to other treatments in yield attributes and yield (Table 2). It had higher number of pods per plant (66.03), number of seeds per pod (2.57), 100 seeds weight (20.33 g), seed yield per plant (20.13 g), seed yield (2490 kg ha^{-1}), straw yield (4109 kg ha^{-1}) and non-significant increase in harvest index (38.20), which agree with Geetha and Radder (2015). Afzal and Bano (2008) also reported a favourable effect of integration of chemical fertilizers, rhizobium and PSB on growth and yield parameters. Integrated nutrient management of inorganic chemical fertilizers along with application of FYM and inoculation with biofertilizers (rhizobium and PSB) produced higher yield (Kumpawat, 2010). Singh and Rai (2004) reported that the highest pods per plant, seeds per pods and 100 seed weight of soybean through the combination of recommended dose of NPK + FYM @ 5 t ha^{-1} + bio-fertilizers.

The experiment revealed that the significant highest gross return (1929 US$ ha^{-1}), net return (1067 US$ ha^{-1}) and net benefit: cost ratio (1.36) was registered due to T_4 = recommended NPK+ FYM + PSB and Rhizobium (Table 3). Rana et al. (2014) also reported that inoculation of the soybean seeds with rhizobium and PSB resulted in a significant increase in the benefit to cost ratio.

Table 1. Effects of different levels of phosphorus and biofertilizers on growth parameters of soybean

Treatments	Plant height (cm)		Number of branches per plant		Number of root nodules per plant	
	At 60 DAS	At harvest	At 60 DAS	At harvest	At 60 DAS	At harvest
T_1= Recommended K only	30.37	47.47	4.87	6.98	13.33	19.67
T_2= Recommended FYM only	32.73	48.03	5.17	7.50	15.00	25.10
T_3= Recommended NPK only	35.67	48.30	5.10	7.70	18.83	30.47
T_4= Recommended NPK + FYM + PSB and Rhizobium	40.00	51.47	6.57	8.40	34.00	58.43
T_5= Recommended FYM + PSB and Rhizobium	35.83	48.57	5.40	7.80	25.17	44.63
T_6= Recommended NPK + PSB and Rhizobium	37.40	49.73	6.37	8.77	29.00	50.37
T_7= 0% Recommended NP + Recommended K + FYM + PSB and Rhizobium	36.10	49.40	5.83	7.83	27.90	46.17
T_8= 50% Recommended NP + Recommended K + FYM + PSB and Rhizobium	36.47	49.60	6.00	8.03	30.17	46.33
SEm±	0.55	1.24	0.37	0.43	1.62	1.64
CD (P=0.05)	1.66	3.76	1.12	1.30	4.91	4.99
CV	2.67	4.38	11.31	9.46	11.59	7.09

Table 2. Effects of different levels of phosphorus and biofertilizers on yield attributes and yields of soybean

Treatment	Number of pods per plant	Number of seeds per pod	Hundred seeds weight (g)	Seed yield per plant (g)	Seed yield (kg ha^{-1})	Straw yield (kg ha^{-1})	Harvest index
T_1= Recommended K only	35.7	2.2	16.3	9.9	1427	2731	34.4
T_2= Recommended FYM only	36.7	2.2	17.3	10.1	1600	2874	35.7
T_3= Recommended NPK only	38.5	2.3	17.7	10.4	1694	2914	36.9
T_4= Recommended NPK + FYM + PSB and Rhizobium	66.0	2.6	20.3	20.1	2490	4109	38.2
T_5= Recommended FYM + PSB and Rhizobium	47.3	2.4	18.3	10.6	1897	3273	37.0
T_6= Recommended NPK + PSB and Rhizobium	52.7	2.5	19.3	16.8	2212	3619	38.0
T_7= 0% Recommended NP + Recommended K + FYM + PSB and Rhizobium	50.9	2.5	18.7	13.2	2035	3433	37.4
T_8= 50% Recommended NP + Recommended K + FYM + PSB and Rhizobium	51.3	2.4	19.3	13.4	2082	3464	37.6
SEm±	0.5	0.1	1.3	0.4	50	283	2.0
CD (P=0.05)	1.55	0.29	3.90	1.06	152	858	5.98
CV	1.87	7.02	12.08	4.63	4.51	14.84	9.25

Table 3. Effects of different levels of phosphorus and biofertilizers on economics of soyabean

Treatment	Gross returns (US$ ha^{-1})	Net returns (US$ ha^{-1})	Net benefit: cost
T_1= Recommended K only	1154	523	0.83
T_2= Recommended FYM only	1270	688	1.18
T_3= Recommended NPK only	1327	566	0.74
T_4= Recommended NPK + FYM + PSB and Rhizobium	1929	1067	1.36
T_5= Recommended FYM + PSB and Rhizobium	1488	856	1.24
T_6= Recommended NPK + PSB and Rhizobium	1709	898	1.11
T_7= 0% Recommended NP + Recommended K + FYM + PSB and Rhizobium	1586	854	1.17
T_8= 50% Recommended NP + Recommended K + FYM + PSB and Rhizobium	1616	820	1.03
SEm±	46.5	46.5	0.06
CD (P=0.05)	141	141	0.19
CV	5.33	10.27	10.11

CONCLUSION

Based on the results obtained, it may be concluded that the application of recommended NPK + FYM + PSB + Rhizobium was recorded significantly higher growth and yield parameters. It was followed by the application of recommended NPK + PSB + Rhizobium and then 50% recommended NP + recommended K + FYM + PSB + Rhizobium during spring season under Paktia, Afghanistan conditions.

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REFERENCES

Abd-Alla, M.H., Omar, S.A. and Omar, S.A. 2001. Survival of rhizobia/bradirhizobia and a rock phosphate solubilizing fungus *Aspergillus niger* on various carriers from some agro-industrial wastes and their effect on nodulation and growth of fababean and soybean. *J. Plant Nutr.* **24**: 261-272.

Afzal, A. and Bano, A. 2008. Rhizobium and phosphate solubilizing bacteria improve the yield and phosphorous uptake in the wheat (*Triticum aestivum*). *Int. J. Agric. Biol.* **10**: 85-88.

Alexander, M. 1977. Solubilization of inorganic phosphorus. In: *Introduction to soil microbiology*, John Wiley and Sons Inc., New York, USA.

Geetha, G.P. and Radder, B.M. 2015. Effect of phosphorus cured with FYM and application of biofertilizers on productivity of soybean (*Glycine max* L.) and phosphorus transformation in soil. *Karnataka J. Agric. Sci.* **28**(3): 414-415.

Iyamuremye, F., Dick, R.P. and Baham, J. 1996. Organic amendments and phosphorus dynamics: II. Distribution of soil phosphorus fractions. *Soil Sci.* **161**: 436-443.

Kumpawat, B.S. 2010. Integrated nutrient management in blackgram (*Vigna mungo*) and its residual effect on succeeding mustard (*Brassica juncea*) crop. *Indian J. Agric. Sci.* **80**(1): 76-79.

Noorzai, A.U. and Choudhary, A.K., 2017b. Influence of summer mungbean genotypes on grain yield and resource-use efficiency in Kandahar province of Afghanistan. *Ann. Agric. Res.* **38**(2): 194-199.

Noorzai, A.U., Choudhary A.K., Bana R.S. and Prasad R. 2017a. Growth behaviour, productivity and profitability of promising mungbean varieties in semi-arid region of Afghanistan. *Ann. Agric. Res.* **38**(1): 78-86

Panse, V.G. and Sukhatme, P.V. 1985. *Statistical Methods for Agricultural Worker*. Indian Council of Agricultural Research, New Delhi, India.

Rana, M., Lahoty, P. and Sharma, N. 2014. Effect of PSB, rhizobium and phosphorous levels on growth parameters and benefit cost ratio of soybean (*Glycine max* (L.) Merr.). *J. Industr. Pollut. Control* **30**(2): 263-266.

Sanyal, S.K. and De Datta, S.K. 1991. Chemistry of phosphorus transformations in soil. *Adv. Soil Sci.* **16**: 1–120.

Sharpley, A.N., Daniel, T., Sims, T., Lemunyon, J., Stevens and Parry, R. 1984. *Agricultural Phosphorus and Eutrophication*. USDA Agricultural Research Service, Beltsville. MD.

Singh, R. and Rai, R.K. 2004. Yield and yield attributes, yield and quality of soybean (*Glycine max*) as influenced by integrated nutrient management. *Indian J. Agron.* **49**(4): 271-274.

Son, T.T.N., Diep, C.N. and Giang, T.T.M. 2006. Effect of bradyrhizobia and phosphate solubilizing bacteria application on soybean in rotational system in the Mekong Delta. *Omonrice* **14**: 48-57.

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Residual effect of organic nutrient management on yield and economics of greengram in rice-greengram cropping system

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ABSTRACT

Field experiments were carried out at Gadarupasha, Puri, Odisha, India during 2014-15 and 2015-16 to study the effect of different sources of organic manures in comparison with RDF on economics of rice with succeeding greengram. The experiment consisted of twelve treatments, which were laid out in Randomized Block Design. In case of greengram the highest gross return was obtained in 50% RDN from vermicompost + 50% RDN from Dhaincha i.e. Rs. 47945/- which is statically at par with 50% RDN from FYM + 50% RDN from vermicompost. The pooled data revealed that the crop receiving 50% RDN from vermicompost + 50% RDN from Dhaincha recorded highest net return i.e. Rs. 32832/- per ha which was remain at par with 50% RDN from FYM + 50% RDN from vermicompost and significantly higher than other organic sources as sole as well as their combinations. The lowest gross return, net return and return per rupee invested were obtained in control treatment where no fertiliser or organic matter was applied.

Key words: Economics, greengram, Odisha, residual effect

INTRODUCTION

Rice-pulse (Greengram or Blackgram) is the predominant cropping system of major rice growing areas of Odisha. The cropping sequence of rice-pulse is practically feasible, viable, economical, eco-friendly, water saving technology for sustaining soil fertility and rice productivity (Lakshmi et al., 2012). In the recent years, crop productivity has modest increase or stagnated in spite of consumption of increased rate of chemical fertilizers (Brisson et al., 2010; Hawkesford, 2014). As a result, agricultural ecosystems face various situations like chemical nutrient saturation, huge nutrient loss through leaching, run-off, volatization, emissions, and immobilization resulting in low nutrient use efficiency. Benefits of organic manures like farm yard manure (FYM), green manures, Azolla and vermicompost (VC) are well known, but their availability is reducing day by day (Sarangi et al., 2016). These organic manures are not only good sources of nutrients but also improve the physical structure of the soil and economics of the farmer (Alagappan and Venkitaswamy, 2016; Sarangi et al., 2016).

Keeping the above points in view, the present study was undertaken to the effect of organic nutrient management on economics of scented rice and its residual effect on economics of green gram in rice-green gram cropping system.

MATERIALS AND METHODS

A field experiment entitled at Gadarupasha, Gop, Puri, Odisha during 2014-15 and 2015-16. The field is situated at 19° 53’ 27’’ N latitude and 86° 06’ 01’’ E longitude with an average altitude of 2 m above mean sea level. It comes under East and South Eastern Coastal Plain Agro-climatic Zone of Odisha. Field experiment was conducted with 12 treatments and 3 replications. The soil

of the experimental plot was sandy clay loam in texture, acidic in soil reaction with medium level of organic carbon and available nitrogen, but high level of available phosphorus and medium level of potassium. The climate of the area is warm and moist with hot and humid summer and mild winter. The rainfall is monsoonal and unimodal.

The study was conducted on aromatic rice–greengram cropping system where rice-greengram cropping system was follwed. The experiment was carried out in randomized block design to study the organic nutrient management in aromatic rice in kharif 2014 and 2015. Its residual effect on greengram was studied in respective *rabi* seasons. During both the years of experimentation, randomization of treatments in *kharif* and *rabi* season remained the same. All the plots demarcated by 10 cm high ridges on all sides. Adequate numbers of irrigation channels were also constructed to provide irrigation independently to each plot.

Treatment details

T_1: Control [No chemical fertilizer or organic Matter OM)]; T_2: 100% RDN (Recommended dose of nitrogen) from chemical fertilizer (60:30:30); T_3: 100% RDN from farm yard manure (FYM); T_4: 100% RDN from vermicompost (VC); T_5: 100 % RDN from Dhaincha; T_6: 100% RDN from Azolla; T_7: 50% RDN from FYM + 50% RDN from VC; T_8: 50% RDN from FYM + 50% RDN from Dhaincha; T_9: 50% RDN from FYM + 50% RDN from Azolla; T_{10}: 50% RDN from VC + 50% RDN from Dhaincha; T_{11} : 50% RDN from VC + 50% RDN from Azolla; T_{12}: 50% RDN from Dhaincha + 50% RDN from Azolla

Table 1. Nutrient content (%) and quantity of organic material applied during *kharif* experiment

Materials used	Content (%) on dry weight basis			Applied quantity (t ha^{-1})
	N	P_2O_5	K_2O	
Farm yard manure (FYM)	0.48	0.25	0.46	12.5
Vermicompost (VC)	1.20	0.42	0.58	5.0
Green leaf manure (Dhaincha)	0.60	0.10	0.25	10.0
Azolla	0.43	0.20	0.40	14.0

As per the treatment nutrients were applied through inorganic as well as organic sources to rice during *kharif* season. In case of organic sources the nutrients were applied through FYM, vermicompost, green leaf manure (Dhaincha) and *Azolla* as whole as well as their combination as per the treatments. All the organic sources were applied as basal dose to rice at the stage of final land preparation and transplanting. The fertilizers were applied as per recommended dose *viz.* 60 kg N, 30 kg P_2O_5 and 30 kg K_2O ha^{-1}. Half of nitrogen and full amount of phosphorus and potassium were applied in case of inorganic treatment as basal before transplanting and remaining quantity of N was applied in two splits as top dressing *i.e.* 25% of nitrogen was top dressed at 45 days after transplanting (active tillering stage) and rest 25% of nitrogen was top dressed at 75 days after transplanting (panicle initiation stage). The sources of fertilizers were urea for N, single super phosphate (SSP) for P and Muriate of potash (MOP) for K.

Cost of cultivation and gross return were calculated taking into account the prevailing price of inputs and outputs. Net return per hectare and return per rupee invested were also worked out as per the following formula.

Net return = Gross return - Cost of cultivation

$$\text{Return per rupee invested} = \frac{\textit{Gross return}}{\textit{Total Cost of cultivation}}$$

Statistical analysis

The data were analyzed statistically by applying 'analysis of variance' technique for a randomized block design (Cochran and Cox, 1957).

The significance of different sources of variation was tested by error mean square of Fisher Snedecor's 'F' test at probability level of 0.05. Standard error of mean (SEm) was determined in all the cases, while critical difference (CD) at 5% level of significance was estimated only in cases where 'F' test was found significant and provided in the summary tables of the results to compare the difference between the treatment means.

RESULTS AND DISCUSSION

Crop productivity

The seed yield, stick yield and harvest index recorded after harvesting and processing of the crop were presented below.

Seed yield (kg ha^{-1})

The seed yield recorded from each plot at harvest was analyzed statistically and presented in the Table 2. Perusal of seed yield data reflected that residual effect of nutrients management practices of rice had significant effect on seed yield of greengram. As per the pooled data the highest seed yield was produced by 50% RDN from VC + 50% RDN from Dhaincha (946.8 kg ha^{-1}) which remained at par with 50% RDN from FYM + 50% RDN from VC (921.7 kg ha^{-1}) and 50% RDN from FYM + 50% RDN from Dhaincha (898.3 kg ha^{-1}) which significantly differed from other treatments including residual effect from 100% RDN from RDF (670 kg ha^{-1}). The lowest seed yield was observed in control (655 kg ha^{-1}). Similar findings were reported by Mohanty et al. (2015). In continuation to this study, in our earlier report growth and yield attributes also followed similar pattern (Mahunta et al., 2017).

Stick yield (kg ha^{-1})

The stick yield recorded from each plot at harvest was analyzed statistically and presented in the Table 2. Residual effect of nutrient management practices of rice exerted significant effect on stick yield of greengram. Stick yield of greengram followed similar trend as grain yield. As per the pooled data stick yield was found to be highest in 50% RDN from VC+50% RDN from Dhaincha (2786.7 kg ha^{-1}) which was significantly different from all other treatments. The lowest stick yield was observed in control (1558.3 kg ha^{-1}).

Table 2. Residual effect of organic nutrient management in rice on greengram productivity

Treatment	Seed yield (kg ha^{-1})			Stick yield (kg ha^{-1})		
	2015	2016	Pooled	2015	2016	Pooled
T_1 – Control (No fertilizer or OM)	646.7	663.3	655.0	1520.0	1596.7	1558.3
T_2 – 100% RDN from RDF (60:30:30)	653.3	686.7	670.0	1703.3	1836.7	1770.0
T_3 – 100% RDN from FYM (12.5 t ha^{-1})	690.0	693.3	691.7	1913.3	1973.3	1943.3
T_4 – 100% RDN from VC (5 t ha^{-1})	763.3	760.0	761.7	2046.7	2100.0	2073.3
T_5 – 100 % RDN from Dhaincha (10 t ha^{-1})	723.3	756.7	740.0	1996.7	1969.7	1983.2
T_6 – 100% RDN from *Azolla* (14 t ha^{-1})	663.3	670.0	666.7	1860.0	1930.0	1895.0
T_7 – 50% RDN from FYM + 50% RDN from VC	913.3	930.0	921.7	2440.0	2430.0	2435.0
T_8 – 50% RDN from FYM + 50% RDN from Dhaincha	893.3	903.3	898.3	2386.7	2400.0	2393.3
T_9 – 50% RDN from FYM + 50% RDN from *Azolla*	793.3	810.0	801.7	2136.7	2146.7	2141.7
T_{10} – 50% RDN from VC + 50% RDN from Dhaincha	953.3	940.3	946.8	2783.3	2790.0	2786.7
T_{11} – 50% RDN from VC + 50% RDN from *Azolla*	860.0	893.3	876.7	2246.7	2210.0	2228.3
T_{12} –50% RDN from Dhaincha + 50% RDN from *Azolla*	803.3	830.0	816.7	2163.3	2263.3	2213.3
SEm (±)	17.65	17.72	16.73	81.52	79.89	79.19
CD (P=0.05)	51.77	51.96	49.07	239.10	234.31	232.24

OM= Organic material; RDF (Recommended dose of fertilizer) = 60 kg N, 30 kg P_2O_5 and 30 kg K_2O ha^{-1};

RDN (Recommended dose of nitrogen) = 60 kg N ha^{-1}; FYM = Farm yard manure; VC = Vermicompost

Economics of greengram

Economics of greengram under residual effect of different organic nutrient management practices in rice with respect to cost of cultivation, gross return, net return and return per rupee invested were calculated and presented in Table 3.

Cost of cultivation (₹ ha^{-1})

As greengram was grown as residual crop after harvest of rice without any direct application of fertilizer to greengram the cost of cultivation of greengram remained the same for all the treatments during the experimental year, but there was a slight increase (5% approx) in subsequent year due to increase in cost of other variable inputs. The cost of cultivation for greengram is presented Table 3. The cost of cultivation was increased in subsequent years as expected with mean value of ₹15,113 ha^{-1}.

Gross return (₹ ha^{-1})

In residual greengram cultivation, gross return recorded in each plot after harvesting of greengram was analyzed statistically and presented in the Table 3. Organic nutrient management practices showed significant effect on gross return of greengram in both the years. As per the pooled data of 2015 and 2016 the highest gross return was achieved in treatment with 50% RDN from VC + 50% RDN from Dhaincha (₹47,945 ha^{-1}), which was statistically at par with 50% RDN from FYM + 50% RDN from VC (₹46,327 ha^{-1}). The lowest gross return was obtained in control treatment (₹32,918 ha^{-1}). The same trend was observed in both the experimental years.

Net return (₹ ha^{-1})

The net return estimated by subtracting cost of cultivation from gross return recorded in each plot after harvesting of greengram was analyzed statistically and presented in the Table 3. Organic nutrient management practices in *kharif* rice showed significant effect on net return of residual greengram during both the years. The pooled data revealed that the crop receiving 50% RDN from VC + 50% RDN from Dhaincha recorded the highest net return (₹32,832 ha^{-1}), which remained statistically at par with 50% RDN from FYM + 50% RDN from VC (₹31,213 ha^{-1}) and significantly higher than other organic sources as sole and combination of organic sources. The lowest net return was achieved in control (₹17,804 ha^{-1}). Similarly, INM treatment recorded the highest grain yield of 6270 kg ha^{-1} and the higher gross return (1,17,175) and net return (70,690) and which was comparable with 100% RDN through green manure with the grain yield of 5140 kg ha^{-1} and the gross return of 1,15,380 and the net return of 69,340 respectively (Alagappan and Venkitaswamy, 2016).

Return per rupee invested (₹)

Organic nutrient management practices in *kharif* rice exerted significant impact on return per rupee invested of residual greengram during both the years. The return per rupee invested recorded in each plot after harvesting of greengram was analyzed statistically and presented in the Table 3. The return per rupee invested for different nutrient management practices followed the same trend as that of gross return and net return. As per the pooled data analysis the highest return per rupee invested was obtained with 50% RDN from VC + 50% RDN from Dhaincha (₹3.17) which was at par with 50% RDN from FYM + 50% RDN from VC (₹3.07) and 50% RDN from FYM + 50% RDN from Dhaincha (₹2.99) and significantly different from other treatments. Previous reports also found that integrated nutrient management produced the highest return (Lakshmi et al., 2012).

As regards to residual effect of organic nutrient management practices in rice on greengram, the treatment with 50% RDN from VC + 50% RDN from Dhaincha in rice resulted to be the best in terms of economics such as gross return, net return and return per rupee invested for residual greengram. Performance of residual effect of organic sources alone or in combination might be ascribed to prolonged availability of nutrients to the crop as compared to sole fertilizer application.

Table 3. Residual effect of organic nutrient management in rice on economics of greengram

Treatment	Cost of cultivation (₹ ha^{-1})			Gross return (₹ ha^{-1})			Net return (₹ ha^{-1})			Return $rupee^{-1}$ invested (₹)		
	2015	2016	Pooled	2015	2016	Pooled	2015	2016	Pooled	2015	2016	Pooled
T_1 – Control (No Fertilizer or OM)	14890	15337	15113	32485	33350	32918	17595	18014	17804	2.18	2.17	2.18
T_2 – 100% RDN from RDF (60:30:30)	14890	15337	15113	32837	34493	33665	17947	19156	18552	2.21	2.25	2.23
T_3 – 100% RDN from FYM (12.5 t ha^{-1})	14890	15337	15113	34691	34864	34778	19801	19527	19664	2.33	2.27	2.30
T_4 – 100% RDN from VC (5 t ha^{-1})	14890	15337	15113	38371	38210	38291	23481	22873	23177	2.58	2.49	2.53
T_5 – 100 % RDN from Dhaincha (10 t ha^{-1})	14890	15337	15113	36366	38030	37198	21476	22694	22085	2.44	2.48	2.46
T_6 – 100% RDN from *Azolla* (14 t ha^{-1})	14890	15337	15113	33353	33693	33523	18463	18356	18409	2.24	2.20	2.22
T_7 – 50% RDN from FYM + 50% RDN from VC	14890	15337	15113	45911	46743	46327	31021	31406	31213	3.08	3.05	3.07
T_8 – 50% RDN from FYM + 50% RDN from Dhaincha	14890	15337	15113	44905	45407	45156	30015	30070	30043	3.02	2.96	2.99
T_9 – 50% RDN from FYM + 50% RDN from *Azolla*	14890	15337	15113	39880	40715	40298	24990	25378	25184	2.68	2.65	2.67
T_{10} – 50% RDN from VC + 50% RDN from Dhaincha	14890	15337	15113	47945	47946	47945	33055	32609	32832	3.22	3.13	3.17
T_{11} – 50% RDN from VC + 50% RDN from *Azolla*	14890	15337	15113	43225	44888	44056	28335	29551	28943	2.90	2.93	2.91
T_{12} –50% RDN from Dhaincha + 50% RDN from *Azolla*	14890	15337	15113	40383	41726	41055	25493	26390	25941	2.71	2.72	2.72
SEm (±)	-	-	-	880.6	883.8	834.2	880.6	883.8	834.2	0.1	0.1	0.1
CD (P=0.05)	-	-	-	2582.8	2592.2	2446.6	2582.8	2592.2	2446.6	0.2	0.2	0.2

OM= Organic material; RDF (Recommended dose of fertilizer) = 60 kg N, 30 kg P_2O_5 and 30 kg K_2O ha^{-1}; RDN (Recommended dose of nitrogen) = 60 kg N ha^{-1}; FYM = Farm yard manure; VC = Vermicompost

CONCLUSION

From this study, it was concluded that, in case of greengram, the highest gross return was obtained in treatment receiving 50% RDN from vemicompost + 50% RDN from Dhaincha which is statically at par with treatment receiving 50% RDN from FYM+50% RDN from vemicompost. As regards to residual effect of nutrient management practices in rice on greengram, the combination of organic sources (vermicompost + Dhanicha) came to be the best in terms of economics such as gross return, net return and return per rupee invested. The lowest gross return, net return and return per rupee invested were obtained in control treatment where no fertiliser or organic matter was applied.

REFERENCES

Alagappan, S. and Venkitaswamy, R. 2016. Yield and economics of rice-green gram cropping system in relation to site-specific organic nutrient management with different sources of organic manures in comparison with RDF and LNM. *Austr. J. Basic Appl. Sci.* **10**(1): 537-541

Brisson, N., Gate, P., Gouache, D., Charmet, G., Oury, F.X. and Huard, F. 2010. Why are wheat yields stagnating in Europe? A comprehensive data analysis for France. *Field Crops Res.* **119**: 201–212.

Cochran, W.G. and Cox, G.M. 1957. *Experimental Design*, 2nd edn. John Wiley and Sons, New York, pp. 6-11.

Fisher, R.A. 1921. *Statistical method for research works*. Oliver and Boyd and Co. Inc. Endinburgh, UK.

Hawkesford, M.J. 2014. Reducing the reliance on nitrogen fertilizer for wheat production. *J. Cereal Sci.* **59**(3): 276-283.

Lakshmi, C.S.R., Rao, P.C., Sreelatha, T., Madahvi, M., Padmaja, G., Rao, P.V. and Sireesha, A., 2012. Nitrogen use efficiency and production efficiency of rice under rice-pulse cropping system with integrated nutrient management. *J. Rice Res.* **5**(1): 42-45.

Mahunta, R., Barik, A.K. and Roul, P.K. 2017. Residual effect of organic nutrient management in aromatic rice on growth and productivity of greengram. *IOSR J. Agric. Vet. Sci.* **10** (3): 36-39.

Mohanty, T.R., Roul, P.K, Maity, S.K. and Nayak, A. 2015. Productivity and profitability of greengram influenced by rice crop establishment and nutrient management practices in rice-greengram cropping system. *J. Crop Weed* **11** (1): 92-97.

Sarangi, D.R., Sahoo, T.R., Sethy, S., Chourasia, M., Prasad, S.M., Mohanta, R.K. and Sadangi, B.N. 2016. Effect of replacing a part of nitrogenous fertilizer by brown manuring in direct seeded rice: a field study. *Oryza* **53**(2): 226-228.

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Influence of varying phosphorus rates on productivity, resource-use efficiency and profitability of chickpea (*Cicer arietinum* L.) in Ghazni province of Afghanistan

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ABSTRACT

Chickpea (*Cicer arietinum* L.) is one of the major pulse crops having considerable importance as food, feed and fodder. It is responsive to phosphorus (P) application, but no recommendation on P fertilization in chickpea is available for Afghanistan. Thus, to find out the optimum rate of P application in chickpea, a field experiment was conducted during spring season of 2017 at Agronomy Research Farm, Agriculture Faculty of Ghazni University, Ghazni, Afghanistan. It is characterized by cold and semi-arid climate. The experiment was laid out in a randomized complete block design with four replications. The treatments included five P application rates, 0, 15, 30, 45 and 60 kg P_2O_5 ha^{-1}. The results revealed that application of increasing rates of P significantly increased root nodule number, productivity, profitability and resource-use efficiency. With successive increase in levels of P there was a significant increase in root nodule count, grain yield, straw yield, gross returns, net returns, B:C ratio, water-use efficiency, production efficiency, monetary efficiency, total energy output, net energy benefit, energy-use efficiency and energy productivity up to 60 kg P_2O_5. However, maximum root nodule count (27.1), seed yield (2.04 t ha^{-1}), straw yield (4.05 tha^{-1}), grass returns (2,33,941 Afn. ha^{-1}), net returns (1,84,516 Afn. ha^{-1}), benefit: cost ratio (3.84), irrigation water-use efficiency (9.05 kg ha^{-1} mm^{-1}), production efficiency (19.4 kg ha^{-1} day^{-1}), monitory efficiency (1757.3 Afn. ha^{-1} day^{-1}), total energy output (91,360 MJ ha^{-1}), net energy output (79,810 MJ ha^{-1}), energy- use efficiency (7.91) and energy productivity (0.176 kg MJ^{-1}) were recorded with 60 kg P_2O_5 ha^{-1}, which were significantly greater than control, 15 and 30 kg P_2O_5 ha^{-1}, but these parameters were at par with 45 kg P_2O_5 ha^{-1}.

Key words: Chickpea, energy, profitability, production efficiency, resource-use efficiency

INTRODUCTION

Pulses occupy a unique position in farming all over the world. Among the pulse crops chickpea (*Cicer arietinum* L.) is the third most widely grown grain legume in the world after bean and soybean (Dass et al., 1997; Soltani et al., 2006; Dass, 2008). About 70% of world's chickpea production comes from Asia. Chickpea is predominantly grown in cool, dry periods on receding soil moisture. It is known to have originated in western Asia (probably eastern Turkey) (Hussen et al., 2013). It is also a major pulse crop grown in Afghanistan for food and also used as a feed for animals. It is predominantly grown as an irrigated crop though in some parts of the country, it is grown under rainfed conditions also. Chickpea is mostly consumed in the form of processed whole seed (boiled, roasted, parched, fried, steamed, sprouted, etc.). Chickpea is a good source of protein (18–22%), carbohydrate (52–70%), fat (4–10%), minerals (calcium, phosphorus, iron) and vitamins (Dass et al., 2008; Choudhary, 2014).

It is a helpful source of high quality protein in the diets of millions of people in developing countries who cannot afford animal protein for balanced nutrition (Zia Ul-Haq et al., 2007). Grains are also very high in dietary fiber and hence a healthy source of carbohydrates for persons with insulin sensitivity or diabetes (Deppe, 2010). Further, it is an excellent animal feed as its straw has good forage value (Prasad, 2012). As it is used as feed for livestock, thus it has a significant role in farming systems (Singh, 1997). It has multipurpose use and ability to grow under the condition of low fertility and varying conditions of soil and climate (Nawange et al., 2011). Chickpea is not only a source of dietary protein but it also helps to enriches the soil fertility due to its nitrogen fixing capability (Dotaniya et al., 2014).

Among the fertilization especially that of P has a key role on yield of chickpea (Dass et al., 1997; Dass, 2008). In many soil types, P is the most limiting nutrient for the production of crops (Jiang et al., 2006; Pooniya et al., 20015; Rana et al., 2018) that plays primary role in many of the physiological processes. Legumes generally have higher P requirement because the process of symbiotic N fixation consumes a lot of energy (Schulze et al., 2006). Some specific growth factors that have been associated with P are stimulated root development, increased stalk and stem strength, improved flower formation and seed production, more uniform and earlier crop maturity, increased N-fixing capacity of legumes, improvements in crop quality, and increased resistance to plant diseases (Cross and Schlesinger, 1995; Magid et al., 1996; Griffith, 2010). Keeping in view the above facts, there is a great need to increase the productivity of chickpea to meet the nutritional requirement of the growing population. The present investigation was, therefore, undertaken to evaluate the influence of different Prates on productivity, resource-use efficiency and profitability of chickpea in Ghazni province Afghanistan.

MATERIALS AND METHODS

Experimental site

The present investigation was conducted at Research Farm of Agronomy Department, Agriculture Faculty of Ghazni University, during spring season of 2017. Geographically, the experimental field is located at 68° 28' 52" East longitude and 33° 31' 58" North latitude at an elevation of 2204 m above mean sea level.

Climate and soil

The Ghazni province is located in the southeast region of Afghanistan. Climate of the region is transitional between cold semi-arid and warm-summer humid continental climate. It has cold, snowy winters and warm dry summers. Precipitation is low and mostly occurs in winter. Soil of the experimental field was sandy clay loam in texture, low in organic matter and available P (1.0 mg kg^{-1}) having pH (8.5).

Experimental design and treatments

The experiment consisting of five P –rates, viz., 0, 15, 30, 45 and 60 kg P_2O_5 ha^{-1} was laid-out in a randomized complete block design, replicated four times. The whole amount of P was applied basally at the planting time. The P was applied through TSP the recommended dose of N (30 kg h^{-1}) was applied through urea. The half dose of N was given as basal and remaining half dose of N was top-dressed at 30 days after sowing. The local chickpea cultivar (*Waghaznakhud*) was used in this experiment.

Data collection

For root nodule count, five plants were selected randomly from sample row of each plot at maximum flowering stage. They were uprooted carefully with the help of *khurpa* (hoe) for counting the *Rhizobium* inhabited root nodules per plant. The roots of uprooted plants were washed carefully and nodules from the tap and lateral roots were counted and the average values were recorded as nodule number per plant. For yield estimation, the crop was harvested from the net-plot area and the pods were threshed manually. The weight of cleaned seeds was recorded as net-plot yield. The dried stover from each plot was harvested and weighed. Both seed and stover yields were expressed as t ha^{-1}. The gross returns were computed using prevalent market price of the chickpea grains (AFN 105 kg^{-1})

and straw (AFN 5 kg^{-1}) following standard procedure. The net returns were then calculated using respective cost of cultivation. For computing of benefit: cost ratio, the net return was divided with the cost of cultivation. The value so obtained was considered as cost benefit ratio.

The production efficiency (kg ha^{-1} day^{-1}) and monetary efficiency (AFN ha^{-1} day^{-1}) were computed using the following expressions (Kumar et al., 2015):

$$\text{Production efficincy (PE)} = \frac{\text{(Grain yield (kg ha}^{-1}\text{))}}{\text{(Crop duration)}}$$

$$\text{Monetary efficiency (ME)} = \frac{\text{(Net returns (AFN ha}^{-1}\text{))}}{\text{(Crop duration)}}$$

Regarding water-use efficiency (WUE); the seasonal water use (Et) was computed from profile water contribution (CS), effective rainfall (ER) and irrigation water applied (I) using following equation (Choudhary and Suri, 2014):

$$Et = CS + ER + I$$

The profile water contribution (CS) was not taken into consideration in current study. Thus, the effective rainfall and irrigational water use was considered as the seasonal total water use in the present study by taking into account the respective crop growth period by following the procedure as suggested by Choudhary et al. (2009). Water-use efficiency (WUE): The WUE was computed by using following formula (Choudhary et al., 2009):

$$\text{WUE (kg ha}^{-1}\text{ mm}^{-1}) = Y/E_t$$

Where, Y is the economic yield (grain yield in kg ha^{-1}) and TWU refers to total amount of seasonal water used in ha-mm, respectively.

The energy values for input (e.g. machinery, seeds, fertilizer, water, and labour requirements) and outputs (e.g. grain and stover) in different Prates were estimated based on the energy equivalents of the inputs and output (Table 1), the energy calculations like energy-use efficiency (EUE), energy productivity (EP) and net energy were calculated by using the following equation (Patil et al., 2014; Hatirli et al., 2008).

$$\text{Energy use efficiency} = \frac{\text{(Energy output (MJ ha}^{-1}\text{))}}{\text{(Energy input (MJ ha}^{-1}\text{))}}$$

$$\text{Energy productivity} = \frac{\text{(Chickpea grain yield (kg ha}^{-1}\text{))}}{\text{(Total energy input (MJ ha}^{-1}\text{))}}$$

Net energy benefit (MJ ha^{-1}) =

Total energy output (MJ ha^{-1}) – Total energy input (MJ ha^{-1}).

Table 1. Energy equivalents of inputs and outputs in agricultural production for the chickpea under varying phosphorus rates in Ghazni, Afghanistan

Particulars	Unit	Energy equivalent (MJ per unit)	Source
A. Inputs			
1. Human labor (man)	hr	1.96	(Mobtaker et al., 2012)
2. Machinery (tractor)	hr	62.7	(Nabavi-Pelesaraei et al., 2013)
3. Diesel fuel	Liter	56.31	(Barber, 2003)
4. Chemical fertilizers			
(a) Nitrogen (N)	kg	66.1	(Mousavi-Avval et al., 2011)
(b) Phosphate (P_2O_5)	kg	11.15	(Unakitan et al., 2010)
5. Water for irrigation	m^3	1.02	(Hamedani et al., 2011)
6. Seed (chickpea)	kg	25.0	(Thyagaraj, 2013)
B. Outputs			
1. Grain of chickpea	kg	25.0	(Thyagaraj, 2013)
2. Stover of chickpea	kg	10.0	(Thyagaraj, 2013)

Statistical analysis of data

The collected data was analysed statistically by using Fisher's 'analysis of variance techniques' and differences among treatment means were compared using least significant difference test at 5% probability level.

RESULTS AND DISCUSSION

Root nodule count and crop productivity

Data pertaining to *Rhizobium* inhabited root nodule count plant^{-1}at maximum flowering stage as influenced by different P rates is presented in Table 2. The results of the investigation showed the root nodule count plant^{-1}at maximum flowering stage was highest (27.4) when P_2O_5 was applied @ 60 kg ha^{-1} which was significantly higher over the treatments where P_2O_5 was applied @ 0, 15 and 30 kg ha^{-1}, but it was statistically at par with 45 kg P_2O_5 ha^{-1}. Dutta and Bandyopadhyay (2009) reported that in the presence of adequate supply of P, the bacterial cells became motile and flagellate which is the prerequisite for bacterial migration, but in P-deficient soils the infection remains latent leading to the poor nodulation. This might be the possible reason for better nodulation in P applied treatments. These findings are in line with those of Deepali et al. (2003) and Gulpadiya et al. (2014) who also reported enhancement in number of nodules with incremental levels of P.

Data regarding seed yield of chickpea as influenced by different rates of P have been presented in Table 2. The result revealed that seed yield of chickpea improved remarkably due to different P-rates. Application of P @ 60 kg P_2O_5 ha^{-1} resulted in the highest seed yield (2.04 t ha^{-1}) of chickpea. This treatment was significantly better over control, 15 and 30 kg P_2O_5 ha^{-1}, but was at par with 45 kg P_2O_5 ha^{-1}. The fertilization of increasing rates of P significantly increased the seed yield, due to the active biotic role of P in metabolic processes of plants and photosynthesis tended to increase at flowering, fruiting and grain formation which ultimately increased the yield attributes and subsequently the yield (Dass et al., 1997). Similar observations were also noted by Meena et al. (2010), Rathore et al. (2010) and Muhammad et al. (2012), who reported that there was a significant increase in seed yield of chickpea with P application, seed yield increased as P rate increased from 0 to 80 kg P_2O_5ha^{-1}. The highest level of P @ 60 kg P_2O_5 ha^{-1} produced highest straw yield (4.05 t ha^{-1}) of chickpea. This treatment was significantly superior to control, 15 and 30 kg P_2O_5 ha^{-1}, but it was statistically similar with 45 kg P_2O_5 ha^{-1}. This may be due to adequate supply of P_2O_5 that played a vital role in physiological and developmental processes in plant life and the favorable effect of these important nutrients might have accelerated the growth processes that in result increased straw yield of the crop.

Crop profitability

Cost of cultivation (Afn. ha^{-1}) of chickpea increased consistently due to phosphorus-application. Application of P_2O_5 influenced the cost of cultivation due to variable P_2O_5 application (Table 2). The maximum cost of cultivation was recorded with application of 60 kg P_2O_5 ha^{-1} and minimum in control. In the current study, the maximum grass returns (2,33,941 Afn. ha^{-1}) was seen when $P_2O_5$was applied @ 60 kg ha^{-1} which was significantly higher over 0, 15 and 30 kg P_2O_5 ha^{-1}, but it was statistically at par with 40 kg ha^{-1} (Table 2). Net returns data also reveals that the maximum net returns (184516 Afn. ha^{-1}) was obtained when P_2O_5 was applied @ 60 kg ha^{-1} which was significantly higher than the treatments 0, 15 and 30 kg P_2O_5 ha^{-1}, but it was statistically at par with 45 kg P_2O_5 ha^{-1} (Table 2). The higher gross and net returns were mainly due

to higher grain and straw yields of chickpea in the respective application of P_2O_5. Benefit: cost ratio data reveals that the maximum benefit: cost ratio was obtained when P_2O_5 was applied @ 60 kg ha^{-1} which was significantly higher over 0 and 15 kg P_2O_5 ha^{-1}, and at par with 30 and 45 kg P_2O_5 ha^{-1}. The similar findings have also been reported by Kumar et al. (2017) who reported that application of 60 kg P_2O_5 ha^{-1} and 25 kg ha^{-1} sulphur recorded the highest net return and B:C ratio.

Resource-use efficiency

Data pertaining to irrigation water-use efficiency (IWUE), production efficiency and monetary efficiency as influenced by different P_2O_5 rates are presented in Table 3. During the study period the water-use was same in all the treatments. The significantly higher IWUE was registered with 60 kg P_2O_5 ha^{-1} than 0, 15 and 30 kg P_2O_5 ha^{-1}. But, the difference between 60 and 45 kg ha^{-1} P_2O_5 application was non-significant (Table 3). The higher IWUE at 60 kg ha^{-1} P_2O_5 application was mainly due to higher grain yield as amount of irrigation water used for each treatment was equal.

Production efficiency data revealed that maximum production efficiency (19.4 kg ha^{-1} day^{-1}) was seen when P_2O_5 was applied @ 60 kg ha^{-1} which was significantly higher over the treatments that included 0, 10 and 30 kg P_2O_5 ha^{-1}, but it was statistically at par with 45 kg P_2O_5 ha^{-1}. Monetary efficiency of chickpea under various rates of P application are given in Table 2. Results showed that application of 60 kg P_2O_5 ha^{-1} resulted in significantly higher monitory efficiency (1757 Afn. ha^{-1} day^{-1}) compared to 0, 15 and 30 kg P_2O_5 ha^{-1}. But the difference between 60 and 45 kg ha^{-1} P_2O_5 application was non-significant. Higher production efficiency (PE) and monetary efficiency in increasing rates of P was due to significantly higher grain yield, at increasing rates of P.

Energy relations of chickpea under different rates of P are given in (Table 4). Results indicate that less input energy was utilized for the control treatment than other treatments. With increasing P_2O_5 rates, input energy increased. High total energy output of 91,360 MJ ha^{-1} was produced by 60 kg P_2O_5 ha^{-1} and this was significantly superior over 0, 15 and 30 kg P_2O_5 ha^{-1}, but it was statistically at par with the 45 kg P_2O_5 ha^{-1}. The net energy output was significantly higher for the 60 kg ha^{-1} (79,810 MJ ha^{-1}) compared to 0, 15 and 30 kg P_2O_5 ha^{-1}. But the difference between 60 and 45 kg P_2O_5 ha^{-1} was non-significant. Again, 60 kg ha^{-1} P_2O_5 application showed significantly higher energy-use efficiency of 7.91 than control treatment and 15 kg ha^{-1} P_2O_5. But it was at par with the 30 and 45 kg P_2O_5 ha^{-1}. The trend in energy productivity was similar to the energy-use efficiency with 60 kg ha^{-1} P_2O_5 application recording significantly higher energy productivity (0.176 kg MJ^{-1}) compared to the control and 15 kg ha^{-1} P_2O_5 application.

CONCLUSION

Chickpea is a legume crop mostly grown in irrigated and also rainfed areas in some parts of Afghanistan. It is mostly consumed in the form of processed whole seed (boiled, roasted, parched, fried, steamed, sprouted, etc.). Phosphorus plays a key role in many of the physiological processes, such as the utilization of sugar and starch, photosynthesis, energy storage and transfer. Legumes generally have higher P requirement because the process of symbiotic nitrogen (N) fixation consumes a lot of energy. After going through the finding of the present study, it was concluded that the root nodules count, profitability, production efficiency and resource-use efficiency of chickpea consecutively improved with increasing P rates; and highest P rate of 60 kg P_2O_5 ha^{-1}resulted in maximum gross and net returns ha^{-1}. Therefore, it is suggested to farming community at Ghazni province that chickpea should be fertilized with 60 kg P_2O_5 ha^{-1} for higher yield, profit and resource-use efficiency.

Table 2. Effect of different P rates on number of nodules per plant, productivity and profitability of chickpea

P- rates (kg P_2O_5 ha^{-1})	Nodules $plant^{-1}$ Seed yield (t ha^{-1})	Crop productivity			Crop profitability			
		Straw yield (t ha^{-1})		Cost of cultivation (Afn. ha^{-1})	Gross return (Afn. ha^{-1})	Net return (Afn. ha^{-1})	B: C ratio	
Control	14.8	1.66	3.31		44,225	1,90,365	1,46,140	3.30
15	18.1	1.73	3.57		45,525	1,99,775	1,54,250	3.39
30	24	1.83	3.64		46,825	2,10,449	1,63,624	3.49
45	25.4	1.99	3.85		48,125	2,28,520	1,80,395	3.75
60	27.1	2.04	4.05		49,425	2,33,941	1,84,516	3.84
SEm (±)	0.81	0.06	0.13		-	6,555	6,555	0.13
CD (P=0.05)	2.49	0.19	0.39		-	20,198	20,198	0.40

Table 3. Effect of different P rates on efficiency of water-use, production and monetary efficiency of chickpea

P- rates (kg P_2O_5 ha^{-1})	Water use (mm ha^{-1})	Water-use efficiency (kg ha^{-1} mm^{-1})	Production efficiency (kg ha^{-1} day^{-1})	Monetary efficiency (Afn. ha^{-1} day^{-1})
Control	225	7.36	15.4	1392
15	225	7.70	16.5	1469
30	225	8.14	17.4	1558
45	225	8.86	19.0	1718
60	225	9.05	19.4	1757
SEm (±)	-	0.27	0.58	62.4
CD (P=0.05)	-	0.83	1.78	192.3

Table 4. Effect of different P rates on total energy output, net energy benefit, energy-use efficiency and energy productivity of chickpea

P- rates (kg P_2O_5 ha^{-1})	Total energy input (MJ ha^{-1})	Total energy output (MJ ha^{-1})	Net energy benefit (MJ $ha^{-1)}$	Energy-use efficiency	Energy productivity (kg MJ^{-1})
Control	10,881	74,528	63,647	6.85	0.152
15	11,048	79,001	67,953	7.15	0.157
30	11,216	82,139	70,924	7.32	0.163
45	11,383	88,362	76,979	7.76	0.175
60	11,550	91,360	79,810	7.91	0.176
SEm (±)	-	2,205	2,205	0.20	0.006
CD (P=0.05)	-	6,795	6,795	0.60	0.017

REFERENCES

Barber, A.A. 2003. *Case Study of Total Energy and Carbon Indicator for New Zealand Arable and Outdoor Vegetable Production*. Agricultural engineering consultant Agril Lnk. New Zealand Ltd.

Choudhary, A.K. 2014. *Agronomy of Pulse and Oilseed Crops.* Indian Agricultural Research Institute, New Delhi, India.

Choudhary, A.K. and Suri, V.K., 2014. Scaling-up of pulse production under frontline demonstration technology transfer program in Himachal Himalayas, India. *Commun. Soil Sci. Pl. Anal*. **45**(14): 1934-48.

Choudhary, A.K., Yadav, D.S. and Singh, A., 2009. Technological and extension yield gaps in oilseeds in Mandi district of Himachal Pradesh. *Indian J. Soil Conserv*. **37**(3): 224-229.

Cross, A.F. and Schlesinger, W.H. 1995. A literature review and evaluation of the Hedley fractionation scheme: applications to the biogeochemical cycle of soil phosphorus in natural ecosystems. *Geoderma* **64**: 197-214.

Dass, A. 2008. Effect of agronomic factors on nutrient content and uptake, dry matter accumulation and yield of chickpea under on-farm conditions. *Int. J. Agric. Sci.* **4**(1): 83-87.

Dass, A., Kharwara, P.C. and Rana, S.S. 1997. Response of gram varieties to sowing dates and phosphorus under on-farm condtions. *Himachal J. Agric. Res.* **23**: 112-115

Deepali, P., Singh, J.P., Namita, K. and Dwivedi, G.K. 2003. Response of vasicular arbuscular mycorrhizae (VAM), rhizobium and phosphorus sources on nodulation, growth and yield of pea variety vl-7. *Ind. Crop Res*. **25** (2): 333-336.

Deppe, C. 2010. *The Resilient Gardener*. Chelsea Green, p. 241.

Dotaniya, M.L., Meena, V.D. and Das, H. 2014. Chromium toxicity on seed germination, root elongation and coleoptile growth of pigeon pea (*Cajanus cajan*). *Legume Res*. **37**(2): 225-227.

Dutta, D. and Bandyopadhyay, P. 2009. Performance of chickpea (*Cicer arientinum* L.) to application of phosphorus and bio-fertilizer in laterite soil. *Arch. Agron. Soil Sci.* **55**: 147-155.

Griffith, B. 2010. *Efficient Fertilizer Use-Phosphorus*. The Efficient Fertilizer Use Manual, pp. 1-7.

Gulpadiya ,V.K. and Chhonkar, D.S. 2014. Effect of phosphorus on growth, productivity and economics of chickpea varieties. *Ann. Plant Soil Res.* **16**: 334-37.

Hamedani, S.R., Keyhani, A. and Alimardani, R. 2011. Energy use patterns and econometric models of grape production in Hamedan province of Iran. *Energy* **36**: 6345- 6351.

Hatirli, S.A., Ozkan, B. and Fert, C. 2008. Energy inputs and crop yield relationship in greenhouse tomato production. *Renew Energy* **31**: 427–438.

Hussen, S., Yirga, F. and Tibebu, F. 2013. Effect of Phosphorus fertilizer on yield and yield components of chickpea (*Cicer arietinum*) at Kelemeda, South Wollo, Ethiopia. *Int. J. Soil Crop Sci.* **1**(1): 1-4

Jiang, D., Hengsdijk, H., Dai, T.B., de Boer, W., Jing, Q. and Cao, W.X. 2006. Long term effect of manure and inorganic fertilizer on yield and soil fertility for a winter wheat- maize system in Jiangsu, China. *Pedosphere* **16**: 25-32.

Kumar, A., Choudhary, A.K. and Suri, V.K. 2015. Influence of AM-fungi and applied phosphorus on growth indices, production efficiency, phosphorus-use efficiency and fruit-succulence in okra (*Abelmoschus esculentus*)-pea (*Pisum sativum*) cropping system in an acid Alfisol. *Indian J. Agric. Sci.* **85**(8): 1030-1037.

Kumar, P., Prajapat, O.P. and Parihar, R. 2017. Effect of different levels of phosphorus, sulphur and cultivars on growth and economics of chickpea (*Cicer arietinum* L). *Int. J. Farm Sci.* **7**(2): 57-59.

Magid, J., Tiessen, H. and Condron, L.M. 1996. Dynamics of organic phosphorus under natural and agricultural ecosystems. In: A. Piccolo (ed.) *Humic Substances in Terrestrial Ecosystems*. Elsevier, Amsterdam, pp. 429-466.

Meena, B.L., Pareek, B.L., Kumar, R. and Singh, A.K. 2010. Response of moth bean (*Vignaa contifolia*) cultivars on different levels of phosphorus. *Environ. Ecol*. **28**: 2614-2617.

Mobtaker, H.G. ,2012. Application of Data envelopment analysis (DEA) to improve cost efficiency of alfalfa production in Iran. *Int. J. Environ. Sci.* **2**(4): 2367-2377.

Mousavi-Avval, S.H., Rafiee, S., Jafari, A. and Mohammadi, A. 2011. Optimization of energy consumption for soybean production using Data Envelopment Analysis (DEA) approach. *Appl. Energy* **16**: 84-89.

Nabavi-Pelesaraei, A., Shaker-Koohi, S. and Dehpour, M.B. 2013. Modeling and optimization of energy inputs and greenhouse gas emissions

for eggplant production using artificial neural network and multi-objective genetic algorithm. *Int. J. Adv. Biol. Biomed. Res.* **1**(11): 1478-1489.

Nawange, D.D., Yadav, A.S. and Singh, R.V. 2011. Effect of phosphorus and sulphur application on growth, yield attributes and yield of chickpea (*Cicer arietinum* L.). *Legume Res.* **34**: 48-50.

Patil, S.L., Mishra, P.K., Loganandhan, N., Ramesha, M.N. and Math, S.K.N. 2014. Energy, economics, and water use efficiency of chickpea (*Cicer arietinum* L.) cultivars in vertisols of semi-arid tropics, India. *Curr. Sci*. **107**(4): 656-664.

Pooniya, V., Choudhary, A. K., Dass, A.,Bana, R.S., Rana, K.S., Rana D.S. Tyagi, V.K. and Pooniya, M.M. 2015. Improved crop management practices for sustainable pulse production: A Indian Perspective. *Indian J. Agric. Sci*. **85** (6): 747-758.

Prasad, R. 2012. *Textbook of Field Crops Production*, Vol. 1. Indian Council of Agricultural Research, New Delhi, pp. 320-321.

Rana, D.S., Dass, A., Rajanna, G.A and Choudhary, A.K. 2018. Fertilizer phosphorus solubility effects on Indian mustard–maize and wheat–soybean cropping systems productivity. *Agron. J.* **110** (6): 2608-2618.

Rathore, D.S., Purohit, H.S. and Yadav, B.L. 2010. Integrated phosphorus management on yield and nutrient uptake of urdbean under rainfed conditions of Southern Rajasthan. *J. Food Legumes* **23**: 128-131.

Schulze, J., Temple, G., Temple, S.J., Beschow, H. and Vance. C.P. 2006. Nitrogen fixation by white lupin under phosphorus deficiency. *Ann. Bot.* **98**: 731-740.

Singh, K.B. 1997. Chickpea (*Cicer arietinum* L). *Field Crops Res.* **53**: 161-170.

Soltani, A., Robertson, M.J., Mohammad-Nejad, Y. and Rahemi- Karizaki, A. 2006. Modeling chickpea growth and development: leaf production and senescence. *Field Crops Res.* **99**(1): 14-23.

Thyagaraj, C.R. 2012. Enhancing energy use efficiency through conservation. In: training course on '*Conservation Agriculture Strategies for Resource Conservation and Mitigation of Climate Change*', CRIDA Hyderabad, pp. 229–240.

Unakitan, G., Hurma, H. and Yilmaz, F. 2010 . An analysis of energy use efficiency of canola production in Turkey. *Energy* **35**: 3623- 3627.

Zia Ul-Haq, M., Iqbal, S., Ahmad, S., Imran, M., Niaz, A. and Bhanger, M.I. 2007. Nutritional and compositional study of Desi chickpea (*Cicer arietinum* L.) cultivars grown in Punjab, Pakistan. *Food Chem.* **105**: 1357-1363.

Zohary, D. and Maria, H. 2000. *Domestication of Plants in the Old* World (3rd edn), Oxford University Press, p. 110.

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Studies on variability, heritability and genetic advance for quantitative and qualitative traits in cashew (*Anacardium occidentale* L.)

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ABSTRACT

Clonal planting materials of 25 cashew varieties were studied for their variability, heritability and genetic advance for qualitative and quantitative traits in cashew. Results revealed that variety, Vengurla-7 was the most vigorous, but dwarf in stature, and hence this cultivar can be used for high density planting. Chintamani-1 variety exhibited superiority in respect to floral traits like number of total laterals per m^2, flowering laterals per m^2, number of staminate flowers and total flowers per panicle. Bhubaneswar-1 variety recorded the highest number of perfect flowers per panicle, sex ratio, number of nuts per panicle and total soluble solid. Dhana and Jharagram-1 variety recorded the shortest and longest duration of flowering (89.5 vs. 150.5 days), respectively. Nut weight and kernel weight were recorded the maximum in Vengurla-7. The maximum shelling percentage (32.76%) was recorded in variety Kanaka. Among the evaluated varieties, BPP-8 recorded the maximum number of nuts per m^2; mean annual nut yield (16.75 kg per plant) and cumulative nut yield (56.27 kg per plant). Studies on genetic variability revealed that characters like sex ratio, yield per plant, nuts per panicle and nuts per m had high heritability and high genetic advance together with high genotypic coefficient of variation (GCV). Thus, these traits should be selected for cashew crop improvement. In the traits plant height, nut weight, trunk girth, canopy spread (E-W), total laterals per m^2, flowering laterals per m^2, flowering duration, kernel weight and apple weight showed high heritability, moderate genetic advance and moderate GCV, indicating improvement of these characters would be expected.

Key words: Cashew, heritability, morpho-economic traits, qualitative traits, variability

INTRODUCTION

Cashew, an important commercial plantation crop of India, is widely cultivated in states like Kerala, Tamil Nadu, Maharashtra, Goa, Karnataka, Andhra Pradesh, Orissa, West Bengal and North Eastern states. Presently, area under cashew is about 10.41 lakh ha with the total raw nut production of 7.79 lakh metric tons and productivity of 753 kg ha^{-1} (Hubballi, 2018). Odisha is the third largest producer of cashew nut in the country covering a total cashew area of 1.83 lakh ha with annual nut production of 0.93 lakh ton. Productivity of cashew nut in Odisha is only 513 kg ha^{-1} for which the cashew processing industry is facing a shortfall of 35,000 metric tons raw cashew nut per annum. One of the reasons of wide gap between the present level of productivity and potential productivity (2.0 ton ha^{-1}) of cashew nut in the country as well as in the state is use of traditional varieties with low yield potential.

So, crop improvement through breeding is one of the tools to address the issue of its low productivity.

Cashew is a highly cross pollinated crop, as a result large variations are observed among the quantitative and qualitative traits. Available genetic variability and inheritance of desirable traits decide the success of any breeding programme. Therefore, studies on genetic parameters become highly indispensible for an effective crop improvement programme (Hore et al., 2015; Bhoomika and Sudha Rani, 2018). So, an effort has been made to understand the variable and heritable traits of cashew, which can be utilized to formulate an effective breeding programme.

MATERIALS AND METHODS

A field experiment was laid out in 2008 using clonal planting materials of 25 released cashew varieties collected from different co-operating centres of All India Coordinated Research Projects on Cashew, India (Table 1). The grafted plants were planted at a spacing of 7.5 m × 7.5 m following randomized block design having six plants per treatment replicated twice.

The study was undertaken at Cashew Research Station, Ranasinghpur during the fruiting season 2016-17 (10 year old plants) with an objective to study variability, heritability and genetic advance in cashew. Observations on vegetative, yield and yield attributing traits were recorded as per the standard descriptor of cashew (Swamy et al., 1998). Statistical procedures were followed for analysis of variance and covariance (Panse and Sukhatme, 1954; Singh and Choudhury, 1985).

Table 1. Details of source of collection of cashew varieties used in the study

Sl.	Name of the cashew types	Sources of collection
1.	BPP-4, BPP-6, BPP-8	Cashew Research Station (CRS), Bapatla, Andhra Pradesh
2.	Bhubaneswar-1	Cashew Research Station (CRS), Bhubaneswar, Odisha
3.	Chintamani-1, Ullal-1, Ullal-3, Ullal-4	Cashew Research Station (CRS), Hogalagere, Karnataka
4.	Jhargram-1	Cashew Research Station (CRS), Jharagram, West Bengal
5.	Madakkathara-1, Madakkathara-2, K-22-1, Dhana, Kanaka, Priyanka, Amrutha, UN-50	Cashew Research Station (CRS), Madakkathara, Kerala
6.	Vengurla-1, Vengurla-4, Vengurla-6, Vengurla-7	Regional Fruit Research Station (RFRS), Vengurle, Maharashtra
7.	VRI-3	Regional Research Station (RFRS), Vridhachalam, Tamil Nadu
8.	Bhaskara, NRCC Sel-2	Directorate of Cashew Research Puttur (DCR), Karnataka
9.	Goa-1	ICAR Research Complex for Goa, Ela, Old Goa.

RESULTS AND DISCUSSION

Results on performance of twenty five cashew varieties are presented in Table 2 and 3, which revealed that among the tested varieties, Vengurla-7 recorded the maximum for the vegetative parameters like tree height (5.45 m), trunk girth (84.05 cm) and canopy spread in North-South direction (8.75 m); while canopy spread in East-West direction was recorded maximum in variety, BPP-8 (8.75 m). Cashew varieties such as K22-1 (4.20 m) and VRI-3 (4.25 m) recorded the minimum plant height among the evaluated cashew varieties, indicating their suitability for high density planting (Hore et al., 2015; Malhotra et al., 2016). The number of total laterals m^{-2} ranged from the minimum 16.37 in Bhubaneswar-1 to the maximum 29.50 in Chintamani-1. Similar variation in vegetative growth parameters among cashew varieties were also reported previously by various workers from different locations across India (Hanumanthappa et al., 2014; Tripathy et al., 2015).

Table 2. Mean of vegetative and yield attributing traits of twenty five cashew varieties

Sl. No.	Varieties	Plant height (m)	Trunk girth (cm)	Canopy spread (m)		Total laterals m^{-2}	Number of flowering laterals m^{-2}	Nuts per panicle	Number of nuts m^{-2}	Nut weight (g)	Kernel weight (g)	Shelling (%)
				(E-W)	(N-S)							
1	BPP-4	4.55	58.65	6.42	6.45	21.00	19.37	5.5	41.75	7.20	2.04	28.31
2	BPP-6	4.90	66.90	7.60	6.65	24.50	23.50	7.5	36.50	6.45	1.85	28.56
3	BPP-8	5.25	71.80	8.75	6.85	28.25	25.50	6.0	46.00	9.30	2.66	28.68
4	Bhubaneswar-1	4.53	62.30	5.95	6.30	16.37	14.00	9.0	25.62	6.45	1.97	30.59
5	Chintamani-1	5.35	73.55	8.35	7.15	29.50	28.87	4.5	15.25	7.10	2.13	30.02
6	Jhargram-1	5.25	71.80	8.25	7.75	23.00	20.87	1.0	3.50	6.80	2.05	30.25
7	Madakkathara-1	4.75	67.25	6.30	6.65	27.75	23.12	7.5	34.87	7.30	2.37	32.40
8	Madakkathara-2	4.35	52.75	5.60	5.50	24.25	24.87	3.0	13.50	6.90	2.08	30.19
9	K-22-1	4.20	61.95	5.95	5.70	28.50	28.00	4.5	15.75	6.40	1.99	31.08
10	Dhana	4.75	68.90	6.60	7.30	28.75	27.87	3.0	14.50	7.40	2.09	28.25
11	Kanaka	5.00	70.55	6.55	6.00	20.87	18.75	3.0	21.37	5.70	1.87	32.76
12	Priyanka	4.85	63.10	7.62	7.55	19.00	18.37	1.5	9.12	9.45	2.78	29.42
13	Amrutha	4.25	54.70	5.45	6.45	26.25	25.87	3.5	13.75	6.95	2.10	30.13
14	Vengurla-1	4.95	62.50	7.25	7.15	24.00	21.87	3.5	17.75	6.95	2.12	30.45
15	Vengurla-4	4.75	61.40	6.20	6.50	21.00	19.12	5.5	26.50	7.35	2.20	29.87
16	Vengurla-6	4.85	60.25	6.80	6.65	22.00	24.87	7.5	21.62	8.95	2.62	29.28
17	Vengurla-7	5.45	84.05	8.70	9.47	21.00	20.12	3.5	17.75	9.60	3.02	31.38
18	VRI-3	4.25	53.00	5.75	5.80	22.25	21.62	5.5	37.87	7.05	2.34	28.14
19	NRCC Sel-2	4.68	62.15	8.05	6.60	19.25	17.50	4.0	26.50	8.55	2.51	29.29
20	Ullal-1	4.75	69.00	6.60	7.00	28.87	24.25	2.5	25.50	7.10	2.13	30.10
21	Ullal-3	4.80	53.30	6.30	6.40	20.62	20.50	4.0	23.12	8.15	2.20	26.97
22	Ullal-4	4.55	57.85	6.10	7.15	19.75	15.25	5.0	24.75	8.15	2.54	31.20
23	UN-50	4.95	65.60	6.40	5.60	20.50	17.87	2.0	25.37	8.20	2.38	29.12
24	Goa-1	4.65	67.35	6.45	6.65	23.00	20.25	5.5	34.87	7.55	2.45	32.39
25	Bhaskara	4.65	69.75	7.50	6.55	16.62	16.50	6.0	34.37	7.15	2.16	30.31
SEm (±)		0.15	1.26	0.16	0.21	1.52	1.61	0.47	1.43	0.17	0.05	0.34
CD (5 %)		0.46	3.70	0.47	0.63	4.44	4.72	1.39	4.19	0.49	0.15	0.99

Table 3. Mean of nut yield (kg per plant) and quality traits of twenty five cashew varieties

Sl. No.	Varieties	Annual nut yield (kg per plant)	Cumulative nut yield (kg per plant)	Apple colour	Apple weight (g)	TSS (°Brix)	Acidity (%)
1	BPP-4	13.77	31.21	Yellow	35.60	10.08	0.15
2	BPP-6	6.45	28.18	Yellow	42.27	10.63	0.14
3	BPP-8	16.75	56.27	Yellow	60.00	9.96	0.19
4	Bhubaneswar-1	9.45	30.67	Red	39.95	12.75	0.20
5	Chintamani-1	6.70	21.19	Reddish Yellow	39.30	11.80	0.15
6	Jhargram-1	1.60	9.95	Yellow	54.80	12.10	0.14
7	Madakkathara-1	13.97	35.95	Yellow	47.00	11.75	0.20
8	Madakkathara-2	2.57	14.05	Red	34.10	10.40	0.19
9	K-22-1	7.42	20.74	Red	51.75	10.05	0.11
10	Dhana	9.55	31.91	Yellow	52.50	10.59	0.16
11	Kanaka	6.27	24.88	Yellow	65.50	11.38	0.21
12	Priyanka	2.37	12.82	Reddish Orange	98.42	9.18	0.16
13	Amrutha	4.45	16.27	Yellow	37.80	11.90	0.21
14	Vengurla-1	5.32	18.33	Reddish yellow	38.20	10.64	0.19
15	Vengurla-4	12.15	33.04	Red	57.60	10.84	0.22
16	Vengurla-6	13.27	31.24	Yellow	69.70	9.51	0.17
17	Vengurla-7	12.8	46.96	Yellow	56.50	11.01	0.19
18	VRI-3	9.22	25.57	Red	34.30	10.75	0.18
19	NRCC Sel-2	11.30	31.38	Red	74.35	10.09	0.17
20	Ullal-1	6.30	17.82	Yellow	44.15	11.54	0.16
21	Ullal-3	5.10	21.19	Red	48.15	10.81	0.19
22	Ullal-4	6.50	20.68	Yellow	54.40	12.31	0.19
23	UN-50	6.95	16.78	Reddish yellow	52.55	10.46	0.19
24	Goa-1	9.15	24.73	Yellow	69.30	10.95	0.13
25	Bhaskara	13.10	38.38	Orange	65.20	10.53	0.16
SEm (±)		0.46	-	-	2.47	0.48	0.01
CD (5 %)		1.36	-	-	7.21	1.42	0.04

Number of flowering laterals per m^2 was recorded the maximum in var. Chintamani-1 (28.87), whereas the maximum number of nuts panicle^{-1} was recorded in Bhubaneswar-1 (9.0). Average number of nuts per m^2 ranged from 3.5 in Jharagram-1 to 46.0 in BPP-8. According to Poduval (2015) number of nuts per m^2 contributes towards total nut yield per plant in var. H-255 in West Bengal. The nut weight (g) varied from 5.7 in Kanaka to 9.6 in Vengurla-7. More than 8.0 g nut weight was recorded in BPP-8, Vengurla-6, Priyanka, NRCC Sel-2, Ullal-3, Ullal-4 and UN-50. Similar variations in nut weight of different cashew types was also reported by Tripathy et al. (2015) and Gajbhiye et al. (2015). It is also revealed that the kernel weight in most of the varieties was more than 2 g and the maximum kernel weight was recorded in variety Vengurla-7 (3.02 g). Among the tested varieties highest shelling (%) was recorded in variety Kanaka (32.76) followed by Goa-1 (32.39) and Madakkathara-1 (32.40). Similar variations in shelling percentage have been reported by Gajbhiye et al. (2015) and Poduval (2015). The tested varieties also revealed significant variations for mean annual nut yield (kg per plant) as well as cumulative nut yield per plant during the period of investigation (Table 3). The highest nut yield was recorded in var. BPP-8 (16.75 kg per plant) while that of the lowest in var. Jharagram-1 (1.60 kg per plant) at the 7th harvest. Cashew varieties which recorded > 10 kg annual nut yield per plant at 7th harvest (10 year old plants) were NRCC Sel-2 (11.30), Vengurla-4 (12.15), Vengurla-7 (12.80), Bhaskara (13.10), Vengurla-6 (13.27), BPP-4 (13.77) and Madakkathara-1 (13.97). Hence, these varieties have the potential of producing higher nut yield than rest of the tested varieties. Cumulative nut yield per plant for 7th harvest was also recorded the maximum for the above mentioned varieties during the study (Table 3). Tripathy et al. (2015) reported similar variations in nut yield of different cashew types under Odisha conditions.

Variety, Dhana recorded the shortest duration of flowering (89.5 days) while Jharagram-1 had the longest duration of flowering (150.5 days). Nut weight and kernel weight were found the maximum in Vengurla-7. The highest shelling percentage was recorded in var. Kanaka. Among the evaluated varieties, BPP-8 recorded the maximum number of nuts per m^2, mean annual nut yield (16.75 kg per plant) as well as cumulative nut yield (56.27 kg per plant). Similar variations were also reported with respect to vegetative characters, yield attributes, nut yield and biochemical parameters (Anand et al., 2015; Gajbhiye et al., 2015; Lakshmana et al., 2015). Wide variations were observed for various physico-chemical parameters of cashew apple such as colour, weight, TSS (°brix) and acidity (%). The acidity percentage in different cashew varieties ranged from 0.11 (K-22-1) to 0.22 (Vengurla-4). The range for different characters among the varieties and superior varieties for different quantitative and qualitative characters are explained in Table 4.

Analysis of variance for all quantitative traits under study revealed significant variations among the twenty five genotypes. The co-efficient of variation, heritability and genetic advance estimated for different characters are presented in Table 5. Wide difference in coefficient of variation both at phenotypic (PCV) and genotypic (GCV) levels in most of the characters confirmed existence of genetic variability in the tested cashew genotypes (Table 5). Although all the component traits recorded higher value for PCV than GCV, but the difference was very narrow. This implies that component traits were least affected by environment. During evaluation, it was observed that the estimates of PCV varied from 4.77% for shelling percentage to 65.22% for sex ratio. The estimates of GCV also showed a similar trend and recorded minimum for shelling percentage (2.87) and maximum for sex ratio (63.64%). High magnitude of PCV as well as GCV were observed for the quantitative traits like sex ratio, nuts per panicle, nuts per m^2 and nut yield per plant. This indicates relatively higher contribution of these characters towards genetic variability in cashew. Rest of the quantitative traits like plant height, trunk girth, canopy spread (both in East-West and North-South direction), flowering laterals per m^2, total laterals per m^2, flowering duration, kernel weight,

nut weight and acidity recorded moderate PCV as well as GCV. The present study revealed that lot of variability exists for the quantitative traits of cashew that can be effectively exploited by simple selection method in crop improvement programme. Similar results were also reported earlier by Lenka et al. (2001), Dashmohapatra et al. (2012) and Mohapatra et al. (2018).

Table 4. Promising cashew varieties in relation to specific quantitative and qualitative traits

Sl. No.	Characters	Range of traits with varieties
1	Plant height (m)	4.20 (K-22-1) - 5.45 (Vengurla-7)
2	Trunk girth (cm)	52.75 (Madakkathara-2) - 84.05 (Vengurla -7)
3	Canopy spread (E-W)(m)	5.45 (Amrutha) - 8.75 (BPP-8)
4	Canopy spread (N-S)(m)	5.50 (Madakkathara-2) - 9.47 (Vengurla-7)
5	Flowering laterals per m^2	14.00 (Bhubaneswar-1) - 28.87 (Chintamani-1)
6	Total laterals per m^2	16.37 (Bhubaneswar-1) - 29.50 (Chintamani-1)
7	Flowering duration (days)	89.5 (Dhana) - 150.5 (Jhargram-1)
8	Sex ratio	0.05 (Chintamani-1 and Vengurla-1) - 0.46 (Bhubaneswar-1 and Kanaka)
9	Nuts per panicle	1.00 (Jhargram-1) - 9.00 (Bhubaneswar-1)
10	Nuts per m^2	3.50 (Jhargram-1) - 46.00 (BPP-8)
11	Nut weight (g)	5.70 (Kanaka) - 9.60 (Vengurla-7)
12	Kernel weight (g)	1.85 (BPP-6) - 3.02 (Vengurla-7)
13	Shelling percentage	28.14(VRI-3) - 32.76 (Kanaka)
14	Nut yield (kg per plant)	1.60 (Jhargram-1)- 16.75 (BPP-8)
15	Cumulative nut yield	9.95 (Jhargram-1) - 56.27 (BPP-8)
16	Apple weight (g)	34.10 (Madakkathara-2) - 98.42 (Priyanka)
17	TSS (°Brix)	9.18 (Priyanka) - 12.75 (Bhubaneswar-1)
18	Acidity (%)	0.11(K-22-1) - 0.22 (Vengurla-4)

Table 5. Genetic parameters of different component characters in cashew

Sl. No.	Characters	PCV (%)	GCV (%)	Heritability (Broad sense)	Genetic advance	Genetic advance (% of mean)
1	Plant height (m)	6.96	6.12	77.28	0.45	9.47
2	Trunk girth (cm)	11.50	11.33	97.06	12.65	19.64
3	Canopy spread (E-W)(m)	14.26	13.98	96.04	1.66	24.10
4	Canopy spread (N-S)(m)	12.27	11.84	93.08	1.35	20.10
5	Flowering laterals per m^2	18.74	17.17	83.94	5.97	27.68
6	Total laterals per m^2	16.86	15.51	84.65	5.80	25.15
7	Flowering duration (days)	13.04	12.80	96.42	25.36	22.12
8	Sex ratio	65.22	63.64	95.22	0.23	109.30
9	Nuts per panicle	44.24	42.98	94.41	3.35	73.50
10	Nuts per m^2	47.05	46.65	98.32	20.61	81.42
11	Kernel weight (g)	12.94	12.75	97.03	0.50	22.10
12	Nut weight (g)	13.53	13.34	97.18	1.74	23.15
13	Shelling percentage	4.77	2.87	36.19	0.91	3.04
14	Nut yield (kg per plant)	47.75	47.44	98.68	7.05	82.93
15	Apple weight (g)	28.68	28.30	97.36	26.01	49.14
16	TSS (°Brix)	9.01	7.83	75.41	1.30	11.96
17	Acidity (%)	15.60	13.05	70.04	0.03	19.23

The heritability estimates depend upon the amount of genetic variation in the population and the environmental conditions under which the population is evaluated. The heritability estimates ranged from 36.19% in shelling percentage to 98.68% in nut yield indicating varied seasonal effect on character expression. However, the relatively high estimates of heritability (>80%) was obtained for all the quantitative traits except plant height (77.28%), TSS (75.41%), acidity (70.04%) and shelling percentage (36.19%). Heritability is one of the factors influencing genetic gain under selection. Heritability estimates along with genetic gain is more reliable in predicting the effect of selection. Expected genetic advance for different traits expressed as percentage of population mean ranged from 3.04 in shelling percentage to 109.3% in sex ratio at 5% selection intensity. The genetic advance as percentage of mean was higher for sex ratio, nuts per panicle, nuts per m^2 and nut yield (>70%) indicating the predominance of additive gene effects. They can be taken as unit characters for effective selection. Low genetic gain was obtained for rest of the characters. High heritability (>90%) with moderate genetic advance was recorded for the characters like trunk girth, flowering duration, nuts per m^2 and apple weight. This indicates that these characters are governed by both additive and non- additive gene action, while high heritability with low genetic advance indicates non-additive gene action only. Sharma et al. (2011), Dasmohapathra et al. (2012) and Sethi et al. (2016) reported similar findings in cashew.

CONCLUSION

Evaluation of twenty five released cashew varieties revealed that var. Vengurla-7 was the most vigorous plant, while Chintamani-1 produced

the maximum vegetative as well as reproductive shoot. Nut weights as well as kernel weight were the highest in var. Vengurla-7 while variety, BPP-8 recorded the maximum nut per plant at 7th harvest. High magnitude of phenotypic coefficient of variation as well as genotypic coefficient of variation were observed for the quantitative traits like sex ratio, nuts per panicle, nuts per m^2 and nut yield per plant. This indicates relatively higher contribution of these characters towards genetic variability in cashew. The genetic advance as per cent of mean was higher for sex ratio, nuts per panicle, nuts per m^2 and nut yield (>70%) indicating the predominance of additive gene effects. They can also be taken as unit characters for effective selection.

REFERENCES

Anand, A., Sahu, G.S. and Mishra, N. 2015. Physico-chemical characteristics of cashew. *Res. J. Agric. Sci.* **6**(3): 656-658.

Bhoomika, H.R. and Sudha Rani, N. 2018. Problems and prospects of cashew cultivation in India - An overview. *Int. J. Curr. Microbiol. App. Sci.* **7**(10): 3687-3694.

Dasmohapatra, R., Rath, S. and Pattnaik, A.K. 2012. Variability, heritability and genetic advances for morphological and yield traits in Cashew. *Environ. Ecol.* **30**(3): 982-984.

Gajbhiye, R.C., Pawar, S.N., Salvi, S.P. and Zote, V.K. 2015. Early performance of cashew (*Anacardium occidentale* L.) genotypes under Konkan region of Maharashtra. *J. Indian Soc. Coastal Agric. Res.* **33**(2): 58-61.

Hanumanthappa, M., Patil, R.S., Sudhir Kamath, K.V., Vinod V.R, Dhananjaya, B. and Shankar, M. 2014. Performance of different cashew cultivars in coastal Karnataka. *Environ. Ecol.* **32**(3): 891-895.

Hore, J.K., Murmu, D.K., Chattopadhyay, N. and Alam, K. 2015. Evaluation of cashew germplasms in West Bengal. *Acta Hort.* **1080**: 135-141.

Hubballi, V.N. 2018, Cashew developmentEncashing Technological innovations for production and processing of cashew, In: Souvenir of National Conference on Cashew,12th to 14th February 2018 at Bhubaneswar, Odisha.

Lakshmana, J.V., Rangaswamy, S.D. and Chandrappa, H. 2015. Performance of cashew cultivars under coastal zone of Karnataka. *Acta Hort.* **1080**: 193-196.

Lenka, P.C., Mohapatra, K.C., Dash, S. and Mishra, N.K. 2001. Genetic variability and character association in cashew. *Hort. J.* **14**(2): 105110.

Malhotra, S.K., Hubballi, N., Venkatesh and Guruprasad, T.R. 2016. *Cashew: Production, Processing and Utilization of By-products*. Directorate of Cashew nut and Cocoa Development, Cochin, Kerala, India.

Mohapatra, M., Dash, D.K., Tripathy, P., Sethi, K., Dash, M. and Roy, A. 2018. Studies on variability, heritability and genetic advance in cashew (*Anacardium occidentale* L.). *Trends Biosci.* **11**(2): 120-125.

Panse, V.G. and Sukhatme, P.V. 1954. *Statistical Methods of Agricultural Work*. Indian Council of Agricultural Research, Publications, New Delhi.

Poduval, M. 2015. Performance of cashew (*Anacardium occidentale* L.) cultivars under red and laterite zone of West Bengal. *Acta Hort.* **1080**: 157-163.

Sethi, K., Tripathy, P. and Mohapatra, K.C. 2016. Variability and heritability of important quantitative characters in cashew (*Anacardium occidentale* L.). *Environ. Ecol.* **34** (4): 1795-1798.

Sharma, D., Sahu, K.R. and Nanda, H.C. 2011. Studies on component of variability and genetic divergence in cashew. *J. Agric. Issu.* **16** (1 and 2): 47-51.

Singh, R.K. and Choudhury, B.C. 1985. *Biometrical Techniques in Genetics and Plant Breeding*. International Bioscience Publications, India, pp. 63-68.

Swamy, K.K.M., Bhaskar Rao, E.V.V. and Bhat, M.G. 1998. *Catalogue of Minimum Descriptors of Cashew Germplasm-II*. ICAR-National Research Centre for Cashew, Puttur, Karnataka, India.

Tripathy, P., Sethi, K. and Mukherjee, S.K. 2015. Evaluation of released cashew varieties under Odisha condition. *Int. J. Bioresour. Stress Manage.* **6**(5): 566-571.

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Response of growth and yield of cucumber (*Cucumis sativus* L.) to staking and plant spacing under protected culture

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ABSTRACT

The study was performed in Ghazni University Agriculture faculty farm, south-east region of Afghanistan, to determine the effect of staking and plant spacing on the growth and yield of cucumber. Staked and non-staked crops and three plant spacing (60 cm × 20 cm, 60 cm × 30 cm and 60 cm × 40 cm) were evaluated. The study was conducted as a 2 × 3 factorial randomized block design with five replications. Treatment means were separated using least significant difference (LSD=0.05). The result generated from the study showed that staking had no significant effect on weight of fruits, but showed significant effect on number of branches, number of leaves and vine length decreased as the plant spacing increased from 60 cm × 20 cm to 60 cm × 30 cm. The closest plant spacing (60 cm × 20 cm) recorded the highest value in all the parameters assessed in this trial except for number of flowers, days to 50% flowering, length of fruit and weight of fruit. The staked treatment constantly performed better with higher values than the non-staked treatment except for the flowers and number of non-marketable fruits. Hence for maximum production of cucumber staking and closer plant spacing should be adopted.

Key words: Staking, plant spacing, growth, yield

INTRODUCTION

Cucumber (*Cucumis sativus* L.) is an important vegetable and one of the most popular members of the Cucurbitaceae family (Lower and Edwards, 1986; Thoa, 1998). It is a major vegetable crop worldwide. Cucumber is the fourth most important vegetable crop after tomato, cabbage, and onion (Tatlioglu, 1993). Although its calorie and nutritional value is very low, it is a primary source of vitamins and minerals in the human diet (Mah, 1989). In addition to its delicious taste and fairly good caloric value, it has high medicinal value for human beings. It is well known for natural diuretic and thus can serve as an active drug for secreting and promoting flow of urine. Due to high content of potassium (50-80 mg per 100 g), cucumber can highly be useful for both high and low blood pressure (Kashif et al., 2008).

Compared with othercrops, cucumber reaches harvest stage rapidly. The cucumber fruit products are used not only for fresh consumptionand culinary purpose, but also for salad and pickling (Kadans, 1979). Cucumber is good for diabetic patients as it contains low sugar and help in the burning of excess fat in the body. The epicarp of cucumber is used or mixed with pomade or cream to control oily or fatty face (Hardy and Rowell, 2002). With these potential attributes of cucumber, the production of the crop is still mainly in the hands of peasant farmers in Afghanistan especially in Ghazni city who lack information in some important cultural practices such as staking and right spacing for optimum yield of the crop. These farmers allow the vines to trail on the ground leading to the production of fruits with yellow bellies, overcrowding of the vines and subsequent attack by mold due to high humidity. Studies has shown that cucumber appropriately

spaced and staked show enormous disparity and differences with the both un-staked and un-spaced, as a result of avoiding competition, overcrowding and correct exposure of cucumber leaves to sunlight for effective photosynthetic activities, that will enhance fruit yield. Elsewhere, staking of cucumber has been found to help optimize yields for harvest of pickling cucumber. Higher fruit yield was observed on trellis treatment than for the non-trellised treatment (Hardy and Rowell, 2002; Hirata and Tilato, 2000; Nelson, 2005) reported increase in fruit yield as plant density increased. The present investigation shows the effect of plant spacing and staking on the growth and yield of cucumber grown in Ghazni University Agriculture faculty farm (GUAFF).

Protected cultivation or greenhouse cultivation is the most contemporary approach to produce mainly horticultural crops qualitatively and quantitatively and has spread extensively over the world in the last few decades. Protected cultivation also known as controlled environment agriculture (CEA) is highly productive, conservative of water and land and also protective of the environment (Jensen, 2002). The technology involves the cultivation of crops in a controlled environment wherein the factors like the temperature, humidity, light, soil, water, fertilizers etc. are manipulated to attain maximum produce as well as allow a regular supply of them even during off-season. By adopting protected cultivation technology, the growers can look forward to a better and additional remuneration forhigh yield andgood quality produce.

MATERIALS AND METHODS

Site location

Ghazni is located in the southeast region of Afghanistan. The study was conducted in Ghazni University Agriculture faculty farm, near to Unit mountain, Ghazni, Afghanistan during the period from June to October, 2018. The day temperatureof experimental area is 15-20°C and receives an annual rainfall of 400- 450 mm. The soil is sandy loam, low in organic matter content having approximately pH 7.5 (Hamayoun et al., 2018).

Field management and experimental design

The experimental field was clear of its natural weeds, the debris burnt and the field bed was divided into plots (3 m × 4 m). The experiment was conducted as 2 × 3 (FRBD) with five replications. Treatments (staked, unstaked) and three-plant spacing (60 cm × 20 cm; 60 cm × 30 cm and 60 cm × 40 cm) were used for the study. Two seeds of cucumber were planted per hole at a depth of about 2 cm and later thinned down to one plant per stand, two weeks after germination. NPK fertilizer at the rate of 102 kg NPK per ha was applied as a blanket treatment to all the plots, using broadcasting method two weeks after germination. Weeds were manually controlled and the crop was sprayed with wood ash at 4th and 5^{h} week after planting to protect the crop against cucumber beetle, Zonocerusvariegates and lady beetle identified in the locality. Parameters evaluated were number of branches, number of leaves, leaf area, vine length, number of flowers, days to 50% flowering, number of fruits, length of fruits, number of non-marketable and marketable fruits and weight of fruits. All data generated during the experiment were subjected to statistical analysis using the procedure outlined by Steel and Torrie (1980) for a factorial experiment in randomized complete block design and the means were separated by the least significance difference at 5% alpha level.

RESULTS AND DISCUSSION

The staked cucumber plants produced more number of leaves than the unstaked treatment and they were statistically similar (Table 1), showing that staking treatments has no significant effect on the number of leaves. The resultalso shows that the number of leaves was not significantly affected by plant spacing. Though the number of leaves decreased as plant spacing increased from 60 cm × 20 cm to 60 cm × 30 cm, but increased in 60 cm × 40 cm, the least value was recorded in 60 cm × 30 cm, while the closest plant spacing (60 cm × 20 cm) produced the highest number of leaves. The leaf area (Table 1) value in staked cucumber was found to be higher than the unstaked plants. The value was decreased, as the plant spacing increased.

Table 1. Response of growth and yield of cucumber (*Cucumis sativus* L.) to staking and plant spacing under protected culture

Plant spacing (cm)				
Plant spacing (cm)	60 × 20	60 × 30	60 × 40	Mean
Staked	68.70	55.55	42.55	55.6
Number of leaves unstaked	47.55	45.75	65.30	52.9
	Mean	58.1	50.7	53.9
Staked	157.91	134.02	134.89	142.3
Leaf area (cm^2) unstaked	126.54	147.49	138.20	137.4
Mean	142.2	140.8	136.55	

LSD 0.05 (Number of leaves)	LSD 0.05 (leaf area)
Staking= NS	Spacing=NS
Spacing=NS, Staking x Spacing=N	Staking=NS
Interaction	Spacing × Interaction=NS

Table 2. Response of branches, vine length, number of flowers, days to 50 % flowering to stalking and plant spacing

Plant spacing (cm)				
Staking	60 × 20	60 × 30	60 × 40	Mean
Staked	6.80	4.10	5.75	5.6
Branches unstaked	3.70	3.30	4.50	3.8
Mean	5.3	3.7	5.1	
Staked	131.37	110.25	125.05	122.2
Vine length unstaked	24.45	16.35	13.75	18.2
Mean	121.5	97.9	104.8	
Staked	24.45	16.35	13.75	18.2
Number of flowers untaked	15.80	24.10	17.45	19.1
Mean	20.1	20.2	15.6	
Staked	40.25	46.30	43.70	43.42
Days to 50 % flowering unstaked	43.70	40.35	42.25	42.10
Mean	41.98	43.33	42.98	
LSD 0.05 Staking = NS Spacing = NS Staking × Spacing = NS	LSD 0.05 (Vine length) Staking = NS Spacing = NS Staking × Spacing = NS	LSD 0.05 (Days to 50 % Anthesis) Staking = NS Spacing = NS Staking × Spacing = NS	LSD 0.05 (Number of Flowers) Staking = NS Spacing = NS Staking × Spacing = NS	

Table 3. Response of length of fruit, marketable fruit, non-marketable fruit and weight of fruit to stalking and plant spacing

Plant spacing (cm)				
Staking	60 × 20	60 × 30	60 × 40	Mean
Staked	46.40	22.40	14.00	27.6
Number of fruits unstaked	18.60	17.40	21.20	19.1
Mean	32.5	19.90	17.6	
Staked	21.36	22.07	20.76	21.4
length of fruit (cm) unstaked	20.10	20.74	21.40	20.7
Mean	20.8	21.4	21.1	20.7
Staked	3.40	2.80	1.80	2.7
Number of non-marketable fruit unstaked	3.80	3.80	4.60	4.1
Mean	3.6	3.3	3.2	
Staked	43.40	20.60	12.80	25.6
Number of marketable fruit unstaked	16.40	16.80	18.00	17.1
Mean	29.9	18.7	15.4	
Staked	0.34	0.37	0.33	0.4
Weight of fruit (kg) unstaked	0.31	0.38	0.34	0.4
Mean	0.3	0.4	0.3	
LSD 0.05 (number of fruit) Spacing = 8.34 Staking =6.81 Spacing × Staking =5.8 LSD 0.05 (marketable fruit) Spacing = 8.87 Staking =7.24 Spacing × Staking =5.13	LSD 0.05 (length of fruit Staking= NS Spacing=NS Spacing × Staking =NS	LSD 0.05 (weight of fruit Spacing = 0.02 Staking =NS Spacing × Staking =NS	LSD 0.05 (nun-marketable fruit) Spacing = NS Staking =NS Spacing × Staking =NS	

The closest plant spacing (60 cm × 20 cm) recorded the highest value of leaf area and both the staking and plant spacing showed no significant effect on the leaf area value of the cucumber plant. The values recorded for number of branches, vine length, number of flowers and days to 50% flowering showed that staking and plant spacing treatments have no significant effect on all these parameters assessed. However, the result (Table 2) showed that higher values are recorded in staked plants than the unstaked ones. The effect of plant spacing however does not follow this trend, the number of branches and vine length decreased in 60 cm × 30 cm spacing and increased in 60 cm × 40 cm plant spacing. The number of flowers and 50% flowers increased as plant spacing increased, but decreased in the widest space, 60 cm × 40 cm.

The results of the field trial showed that staking and plant spacing had effect on the vegetative growth of cucumber, although all the parameters measured for vegetative growth were non-significant at P=0.05. The number of leaves, branches and vine length decreased as the plant spacing increased from 50 cm × 30 cm to 50 cm × 40 cm,

but not beyond 60 cm × 30 cm. There was also a decrease in leaf area as the plant spacing increased from 60 cm × 20 cm to 60 cm × 40 cm. The closest plant spacing 60 cm × 20 cm produced the highest number of branches, leaves, and leaf area and vine length. The number of branches, number of leaves, vine length and leaf area were higher in the staked than the non-staked treatment. This may suggest that the leaves on the staked plants were all exposed to greater light interception leading to a higher accumulation of photosynthesis for vegetative growth. Hanna and Adams (1991) reported that staking cucumber increased the fruit yield because of better light interception. The number of days to 50% flowering was higher in the staked than the non-staked treatment. This agrees with the findings of Jansen (1985) who observed that staking prolongs vegetative growth and delays fruit formation. The non-staked treatment consistently produced lower values in all the vegetative parameters evaluated except in the number of flowers.

The results of variables of fruit parameters presented in Table 3 showed that staked plants produced higher values than the unstaked plants except in weight of fruit where their fruit yield are equal and in non-marketable fruit, where staked value is less than unstaked. Table 3 also showed that staking has significant (p=0.05) effect on the number of fruits and number of marketable fruits but showed no effect on length of fruit, number of non-marketable fruits, and weight of fruit. The value recorded for number of fruits, number of non-marketable fruits and number of marketable fruits decreased as plant spacing increased. The widest plant spacing produced the least value in number of fruits, non-marketable and marketable fruits. The plant spacing of 60 cm × 30 cm produced the highest length of fruit and fruit weight. Also significant differences between plant spacing was observed in the number of fruits and staking × spacing interaction was significant at P=0.05. However, the value obtained in 60 cm × 30 cm and 60 cm × 40 cm spacing was statistically similar.

The result of number of marketable fruits also showed significant differences among the treatments in both staking and plant spacing treatments (Table 3) and staking × plant spacing interaction was equally significant at P=0.05. The effect of 60 cm × 30 cm and 60 cm × 40 cm spacing was similar. Staking treatment had no significant effect on the weight of fruit, while plant spacing showed significant effect on the weight of fruit, however the effect of the closest (50 cm × 30 cm) and widest (60 cm × 40 cm plant spacing were statistically similar and their interaction (staking × plant spacing) had no significant effect on the weight of fruit.

The closest plant spacing (50 cm × 30 cm) produced the highest number of fruit, number of marketable and non-marketable fruits, while length of fruit and weight of fruit was highest at 50 cm × 40 cm. Gebologu and Saglam (1999) reported the highest fruit yield in 20 cm, the closest plant spacing used. While Quian (2000) observed that the closest plant spacing gave the highest early yield. Jacques et al. (2002) reported that the number of fruit decreased as the plant density changed from four to ten plants per meter square. However, the observations made in the trial is contrary to the findings of Phamthic (1991), Jonathan et al. (1996) and Paulo et al. (2003), who obtained highest yield at higher plant spacing. The yield parameters assessed were found to be higher on the staked plants than that vine grown on the ground. The result agreed with the findings of Hardy and Rowell (2002), who observed that the yield of super select cucumbers were higher for the trellised treatment than the non-trellised treatment. Hanna and Adams (1991) reported that staked cucumber gave an average marketable yield of 25 ton per acre as against 16.4 tons per acre of the non-staked cucumber. While Jansen (1985) concluded that staked cucumber produced fruits that double the quantity of the crops on the ground. The number of non-marketable fruit was higher in the non-staked than the staked treatment. This could be attributed to the poor quality in the color of the fruit, reduced length of fruit and development of yellow bellies on the fruits, which predisposes them to spoilage. Hanna and Adams (1991) reported that staking brings about an increase in color quality, fruit length and sugar content of the fruits.

Also Hardy and Rowell (2002) affirmed that staking improves the color and lowers the incidence of yellow bellies in cucumber. The non-staked treatment consistently gave the least values in all the yield parameters evaluated except in the number of non-marketable fruits.

CONCLUSION

The result showed that staking and plant spacing treatment had effect on the vegetative growth and yield of cucumber. The non-staked treatment consistently gave least values in all the vegetative and yield parameters measured except in the number of flowers and number of non-marketable fruits respectively, while the closer plant spacing produced the highest values virtually in all the parameters assessed in this trial. The result, therefore, suggest that the vegetable farmers who have the intention of producing high quality cucumber fruit from the agro-ecological zone understudy should adopt staking and use a plant spacing of 50 cm × 30 cm for the maximum production.

REFERENCES

Ardy, C. and Rowell, B. 2002. Trellising slicing cucumber. *Western Kenturcky Hort. Bull*. **3**: 15-18.

Gebologu, N. and Saglam, R. 1999. The effect of different of different spacing and mulching materials on the yield and fruit quality of pickling cucumber. *ISHS Acta Hort.* **11**: 579.

Gomez, K. H. and Gomez, A. A. 1984. Statistical Procedures for Agricultural Research.

Hamayoun, H. and Saravaiya, S.N. 2018. Influence of nitrogen and plant spacing on growth and yield characteristics of lettuce (*Lactuca sativa* L.). *e-planet* **16** (1): 9-18.

Hanna, H.Y. and Adams, A.J.1991. Staking fresh market cucumber gives higher yields. A long term research report pro-society. *Proc. Fla. State Hort. Soc.* **104**: 237-240.

Hardy, C. and Rowell, B. 2002. Trellising slicing cucumber. *Western Kenturcky Hort. Bull*. **3**:15-18.

Hirata, S.L. and Tilato, R. 2002. Comparative cost of Teepee-trellised vs non-trellised cucumber production. *Economic information report EL* **95**(1): 40-46.

Jacques, L.S., Jeronimo, L.A. and Aron, B.H. 2002. Dry matter accumulation and partitioning of pickling cucumber plants under different plants densities. *Clientia Rural, Santa Maria*. **32**(1): 3-41.

Jansen, D.Y. 1985. Trellised cukes yield more cucumbers. *Hort. Bull.* **5**: 13-18.

Jensen M. H. 2002. Controlled environment agriculture in deserts tropics and temperate regions- A world review. *Acta Hort.* **578**: 19-25.

Jonathan, R.S. and Todd.C.W.1996. Optimum density of determinate and normal pickling cucumbers harvested onceover. *Hort. Sci.* **10** (3): 151-155.

Kadans, J.M. 1979. Encyclopedia of Medical Foods. Thorns Pub. Ltd., Willing Borough, North

Kashif, W., Kamran, Q.M. and Jilani, M.S. 2008. Effect of different nitrogen levels on growth and yield of cucumber (*Cucumis sativus* L.). *J. Agric. Res.* **46**(3): 259-266.

Lower, R. L. and Edwards, M. D. 1986. Cucumber breeding. In: M.J. Basset (ed.) *Breeding Vegetables Crops*. AVI Publishing Co., Westport, Connecticut USA, pp. 173-203.

Mah, S.Y..1989. An effective fungicide for the control of downy mildew on cucumber. *MAPPS Newsletter,* **12**(4): 40.

Nelson, H. 2005. Effect of population density on fruits and seeds production in muskmelon. *Acta Hort*. **38**(3): 15-28.

Paulo, S., Lima, S., Jailton, F.R., Jaedson, C.A.M. and Jaeverson D.A.S. 2003. Plant density and fruit density of muskmelon. *Rer. Bras Frutic* **25**

Phamthic, K. T. 1991. Effect of spacing and pruning on the yield of cucumber. *Hort. Sci.* **36**(2): 230-235.

Quian, H. 2000. Effect of pruning and spacing on yield and quality of cucumber. *Hort. Sci*. **36**(2): 274-278.

Tatlioglu, T. 1993. Cucumber (*Cucumis sativus* L.). In: *Genetic Improvement of Vegetable Crops*. Pergamon Press, Oxford, pp. 197-227.

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Management of fruit and shoot borer, (*Leucinodes orbonalis)* in brinjal

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ABSTRACT

The experiment was carried out during *rabi* 2015-16. Five crops viz. maize, sesamum, broad bean, niger and buckwheat were used as border crop in brinjal field. It was compared with alternate spray of dimethoate (0.05%) and lambda cyhalothrin (0.005%). Dimethoate was sprayed at 80 and 100 DAT and lambda cyhalothrin was sprayed at 90 and 110 DAT. Lowest incidence in brinjal was recorded in alternate spray of chemical pesticides. Amongst the different crop used as border crop, maize as border crop recorded significantly lower incidence of *L. orbonalis* than the other border crops. Farmers can adopt the practice of intercropping with maize to reduce the population of fruit borer and shoot borer of brinjal.

Key words: Dimethoate, intercropping, *Leucinodes orbonalis*, lambda cyhalothrin, *Solanum melongena*

INTRODUCTION

Brinjal or egg plant *(Solanum melongena* L, $2n = 2x = 24$) is an important solanaceous vegetable crop in many countries particularly India, Japan, Indonesia, China, Bulgaria, Italy, France, USA and several African countries. It is one of the most important vegetable crops in Africa, probably the fourth one after tomato, onion and okra (Grubben and Denton, 2004). Fruits are rich in essential vitamins and minerals, which are good for health (Fayemi, 1999; Yahia et al., 2011). India produces almost thirteen per cent of world's vegetable output occupying second position in brinjal production. India accounts for about 8.7 million MTs with an area of 0.53 million hectares under cultivation.

In West Bengal total area under brinjal production is 161 thousand ha, and the total production is 2965 MT (NHPD, 2015). Amongst the insect pests of egg plant, the shoot and fruit borer (*Leucinodes orbonalis* Guen.) is the most serious insect pest and is responsible for severe damage to fruit and at severity yield loss reached to 20-70% (FMANR, 1996; Degri et al., 2013; Degri, 2014; Greene et al., 2018).

Farmers currently use pesticides heavily, and borer is vulnerable to sprays for a few hours before it bores into the plant, forcing farmers to spray insecticides as often as every 2-3 days intervals (AVRDC, 2018). Heavy use of synthetic pesticides leads to environmental pollution and poses problem for human health. Effect of intercropping on pest problems have been studied or reviewed by many authors (Vandermeer, 1989; Prasad et al., 2007; Hailu et al., 2018; Liu et al., 2018). Intercropping practice is of economic benefit and one of the best cultural practices that have potential of reducing insect pest infestation by increasing crop diversity (Willey, 1985; Trenbath, 1993; Prasad et al., 2007; Hailu et al., 2018).

To study the influence of intercropping; an experiment was carried out during *rabi,* 2015-16. Five crops viz. maize, sesamum, broad bean, niger and buck wheat, were used as border crop in brinjal field in reducing the incidence and damage of fruit and shoot borer in brinjal.

MATERIAL AND METHODS

The experiment was conducted at College Farm, College of Post Graduate Studies, Barapani

under Central Agricultural University, Imphal, Manipur in the year 2015-16. The main aim of the study was to assess the influence of trap cropping/ mixed cropping/ intercropping of different crops on brinjal (egg plant) on the level of incidence and damage of fruit and shoot borer (*Leucinodes orbonalis*). Observations were recorded on twenty randomly tagged plants in each treatment of brinjal in which maize, sesamum, broad bean, niger and buck wheat were used as border crops.

The crop was transplanted on 30 days after sowing at 60 × 60 cm spacing with each plot measuring 4 m^2. The intercrops-maize, sesamum, broad bean, niger and buck wheat were sown twenty days prior to transplantation of brinjal in the field. It was compared with alternate spray of dimethoate (0.05%) and lambda cyhalothrin (0.005%). Dimethoate was sprayed at 80 and 100 DAT and lambda cyhalothrin was sprayed at 90 and 110 DAT. The incidence of *Leucinodes orbonalis* in shoot was recorded from twenty randomly selected plants in each treatment and fruit damages were recorded as number of infested fruit in twenty randomly selected fruit in each plot. Observations were converted into percent infestation. Both the observations were converted into per cent infestation. The values were expressed as means ± standard error of means.

Table 1. Brinjal shoot and fruit borer, *Leucinodes orbonalis* infestation in different border cropped in brinjal field in Meghalaya

Treatment	Per cent damage by *Leucinodes orbonalis*													
	90 DAT		100 DAT		110 DAT		120 DAT		130 DAT		140 DAT		Mean	
	Shoot	Fruit	Shoot	Fruit	Shoot	Fruit	Shoot	Fruit	Shoot	Fruit	Shoot	Fruit	Shoot	Fruit
Maize	3.33 (10.47)	3.33 (10.47)	3.33 (10.47)	5 (12.92)	3.33 (10.47)	6.67 (15)	1.67 (7.49)	10 (18.44)	1.67 (7.49)	11.67 (20)	1.67 (7.49)	13.33 (21.39)	2.50 (9.10)	8.33 (16.74)
Sesamum	3.33 (10.47)	6.67 (15)	3.33 (10.47)	10 (18.44)	3.33 (10.47)	10 (18.44)	3.33 (10.47)	15 (22.79)	5.00 (12.92)	13.33 (21.39)	3.33 (10.47)	18.33 (25.33)	3.61 (10.94)	12.22 (20.44)
Niger	3.33 (10.47)	8.33 (16.74)	3.33 (10.47)	16.67 (4.12)	5.00 (12.92)	13.33 (21.39)	3.33 (10.47)	16.67 (24.12)	5.00 (12.92)	16.67 (24.12)	3.33 (10.47)	13.33 (21.39)	3.89 (11.39)	14.17 (21.97)
Buck-Wheat	3.33 (10.47)	8.33 (16.74)	5.00 (12.92)	10 (18.44)	3.33 (10.47)	8.33 (16.74)	15 (22.79)	13.33 (21.39)	5.00 (12.92)	16.67 (24.12)	5.00 (12.92)	20 (26.56)	4.17 (11.83)	12.78 (20.96)
Broad bean	3.33 (10.47)	6.67 (15)	3.33 (10.47)	8.33 (16.74)	3.33 (10.47)	6.67 (15)	3.33 (10.47)	11.67 (20)	5.00 (12.92)	16.67 (24.12)	3.33 (10.47)	20 (26.56)	3.61 (10.94)	11.67 (20)
Chemical	1.67 (7.49)	3.33 (10.47)	1.67 (7.49)	5.00 (12.92)	1.67 (7.49)	1.67 (7.49)	1.67 (7.49)	3.33 (10.47)	0.00	3.33 (10.47)	0.00	1.67 (7.49)	1.39 (6.80)	3.06 (3.19)
Control	3.33 (10.47)	10 (18.44)	3.33 (10.47)	10 (18.44)	3.33 (10.47)	15 (22.79)	3.33 (10.47)	16.67 (24.12)	5.00 (12.92)	16.67 (24.12)	5.00 (12.92)	18.33 (25.33)	3.89 (11.39)	14.45 (22.38)
SEd(±)	6.09	3.79	5.32	2.89	7.49	3.57	5.79	2.81	2.30	3.04	3.64	3.94	1.32	7.1
$CD_{0.05}$	NS	NS	NS	6.30	NS	7.75	NS	6.13	5.01	6.63	7.93	8.59	NS	13.91

RESULTS AND DISCUSSION

The incidence of *Leucinodes orbonalis* in shoot was recorded from twenty randomly selected plants in each plot and fruit damages were recorded as number of infested fruit in twenty randomly selected fruit in each plot. Lowest incidence of pest was recorded in alternate spray of chemical pesticides (dimethoate (0.05%) and lambda cyhalothrin (0.005%) i.e., 1.39 per cent shoot and 3.05 per cent fruit infestation. Among the different crop used as border crop, maize as border crop recorded significantly lower incidence of *L. orbonalis* (2.50 per cent shoot and 8.30 per cent fruit infestation) than the other crops. Incidence of *L. orbonalis* in the plots with sesamum, niger, broad

bean and buck wheat were comparable with untreated control. In another study, Prasad et al. (2007) found that roselle and sowa as intercrop in brinjal were effective in reducing the shoot damage to the extent of 65 and 63.3%, respectively over brinjal (sole), followed by marigold and maize. Similarly, Hailu et al. (2018) observed the benefit of intercropping in brinjal than the sole crop.

CONCLUSION

The results indicate that intercropping has significant influence on brinjal in reducing the incidence and damage of the fruit and shoot borer. Damage in the intercrop was significantly lower from that of the plant in the sole crop. There was also significant yield advantage of intercropping in brinjal with maize. Incidence of insect pest in the plots with sesamum, niger, broad bean and buck wheat were comparable with untreated control. It is therefore recommended that farmers in this agro ecological region can adopt the practice of intercropping in brinjal with maize to minimize fruit and shoot borer infestation and increase its production.

REFERENCES

AVRDC. 2018. *The World Vegetable Center,* Asian Vegetable Research and Development Center. https://avrdc.org/

Degri, M.M., Sharah, H.A. and Dauda, Z. 2013. Effects of intercropping pattern and planting date on the performance of two cowpea varieties in Dalwa, Maiduguri, Nigeria. *Global J. Biosci. Biotechnol.* **2**: 480-484.

Degri, M.M. 2014. The effect of spacing of egg plant (*Solanum melongena* L.) (Solanaceae) on shoot and fruit borer (*Leucinodes orbonalis* Guen.) Lepidoptera: Pyralidae) infestation in the dry Savanna zone of Nigeria. *Agric. Biol. J. North Am.* **5**: 10-14.

Fayemi, P.O. 1999. *Nigerian Vegetables*. Heineman Educational Books PLC, Nigeria.

FMANR. 1996. *A guide to insect pests of Nigerian crops: identification, biology and control*. Federal Ministry of Agriculture and Natural Resources, Nigeria, Natural Resources Institute, UK.

Greene, J.K., Baum, J.A., Benson, E.P., Bundy, C.S., Jones, W.A., Kennedy, G.G., McPherson, J.E., Musser, F.R., Reay-Jones, F.P., Toews, M.D. and Walgenbach, J.F. 2018. General Insect Management. In: *Invasive Stink Bugs and Related Species (Pentatomoidea) Biology, Higher Systematics, Semiochemistry, and Management*. Routledge, pp. 727-728.

Grubben, G.J.H. and Denton, D.A. 2004. *Plant Resources of Tropical Africa, vegetables.* PROTA Foundation, Wageningen, Netherlands. Blacklings Publishers Leiden, Netherlands, pp. 1-668.

Hailu, G., Niassy, S., Zeyaur, K.R., Ochatum, N. and Subramanian, S. 2018. Maize–legume intercropping and push–pull for management of fall armyworm, stemborers, and striga in Uganda. *Agron. J.* **110**: 1-10.

Liu, J.L., Ren, W., Zhao, W.Z. and Li, F.R. 2018. Cropping systems alter the biodiversity of ground and soil-dwelling herbivorous and predatory arthropods in a desert agroecosystem: Implications for pest biocontrol. *Agric. Ecosyst. Environ* **266**: 109-121.

NHPD. 2015. Horticultural Statistics at a Glance 2015. National Horticulture Production Database. Ministry of Agriculture, Government of India, pp. 1-464. Available at http://nhb.gov.in/areapro/horst_galance

Prasad, G.S., Jayakumar, V, Bhagwat, V.R. and Subba Rayudu, B. 2007. Intercropping in brinjal: a prospectful component for the management of fruit and shoot borer, *Leucinodes orbonalis* Guenee (Pyralidae: Lepidoptera). *Veg. Sci.* **34**(2): 189-191.

Trenbath, B.R. 1993. Intercropping for the management of pests and diseases. *Field Crop Res.* **34**(3-4): 381-405.

Vandermeer, J. 1989. *The Ecology of Intercropping.* Cambridge University Press, Cambridge, pp. 1-273.

Willey, R.W. 1985. Evaluation and presentation of intercropping advantages. *Exp. Agric.* **21**: 119-133.

Yahia, E.M., Ornelas-Paz, J.D.J. and Gonzalez-Aguilar, G.A., 2011. Nutritional and health-promoting properties of tropical and subtropical fruits. In: *Postharvest Biology and Technology of Tropical and Subtropical Fruits: Fundamental Issues*, pp. 21-78.

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Ichthyofaunal diversity in Ansupa lake, Cuttack, Odisha, India

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ABSTRACT

Ansupa Lake is the largest freshwater lake of Odisha. An ichthyofaunal inventory was carried out in Ansupa Lake during January-September, 2015 to generate the present ichthyofaunal diversity. A total of 33 species belonging to 8 order, 18 families and 28 genera were recorded, where Perciformes was the most dominant order with 12 species. Cypriniformes was the second dominant order with 11 species, followed by Siluriformes (n=4), Osteoglossiformes (n=2), Beloniformes (n=1), Cyprinidontiformes (n=1), Synbranchiformes (n=1) and Tetradontiformes (n=1). Among the 33 recorded fishes, 29 species come under the least concern (LC) category, one species under data deficient (DD) and two species comes under near threatened (NT) category.

Key words: Ansupa lake, conservation status, diversity, fish

INTRODUCTION

The wellbeing of an aquatic ecosystem is assessed by its biodiversity. In aquatic ecosystems understanding of fish species diversity is complicated due to the existence of several factors and their combinations. Factors like the quality of fish resources, emigration, reproductive potential, physical and chemical characteristics of the aquatic environment are mainly responsible for the diversity and richness of species in aquatic systems. Fishes are the most diverse and abundant vertebrate in the world, which constitute about half of the total number of vertebrates in the world (Ghorbani et al., 2013). Fishes are regarded as the keystone species as their presence can determine the abundance and distribution of other organisms. They are also considered as excellent indicators of the water quality and presence of a particular species indicates about the habitat quality in which they occur. Being good source of food, protein value and significant economic importance, they have great prominence in the life of humans in many nations.

There are 27997 species of fishes belonging to 4494 genera under 515 families found all over the world (Nelson, 2006). In the Indian region, 1570 speciesare known to be marine (Kar, 2003) and 1027 species are known to be freshwater inhabitants (Gopi et al., 2017). Odisha represents 186 species of freshwater fishes belonging to 11 orders, 33 families and 96 genera. Being the large freshwater lake of Odisha, Ansupa acts as a significant resource for the livelihood of villagers inhabited around the lake. Previous studies on the Ichthyofaunal diversity in Ansupa lake carried out by Sarkar et al. (2015) with record of 28 fish species belonging to 7 orders and by Das (2008), who reported a total of 24 fish species. To get a clear picture, the present study was carried out in Ansupa lake, to reveal the current status of Ichthyofaunal diversity.

MATERIALS AND METHODS

Ansupa Lake is the largest freshwater lake of Odisha spreading over an area of 382 acres. It is formed as a part of the river Mahanadi in the Banki block of Cuttack district lying in Athgarh Forest Division, within 20^0 26′ 28.43″ to 20^0 28′ 34.44″ latitude and 85^0 35′ 56.74″ to 85^0 36′ 30.01″ longitude. The surroundings of the lake is broadly undulating plain with isolated hill ranges such as Saranda (124 m) on the west, Bishnupur (65 m) on the East, Dhangarh (160 m) on the North and Betlapahara (105 m) on the Northwest and the dissected valleys. The lake is connected with Mahanadi in its Southern side with a channel known as Kabulanala through which flood water of Mahanadi enters the lake. To the southwest lake is connected by another channel known as Huluhulanala, which transverse through the borders of some of the village Kantapahara and Ghodabasa. The length of Ansupa lake is about 3 kilometres and breadth varies from 250 m to 500 m. The lake is surrounded by Malbiharpur, Ostia, Subarnapur and Anandapur villages. The lake has assumed international importance, as it is a home to several migratory as well as residential birds.

Das (2008) and Sarkar et al. (2015) revealed 24 and 28 species of fishes in Ansupa in their respective findings. There was considerable variation among the species reported. Thus, the present study was conducted to elucidate the ichthyofaunal diversity of Ansupa lake which may vary from time to time.

The present study was carried out from January to September, 2015. Information regarding the availability of fishes was collected through discussion with local fishermen, fish markets in nearby villages and by monthly survey in early morning (6 am to 7 am), when fishes were captured by the local fisherman community at the respective study area.

The fishes were collected by the fisherman and local people by operating various nets like gill nets, cast nets, hook nets, drag nets, and locally used indigenous box traps. Fresh fish samples were photographed with the help of Nikon D3200 and Canon Camera. Some fish samples were preserved in 70% alcohol for further identification. Fishes were identified with the help of taxonomic keys from standard literature (Day, 1878; Talwar and Jhingran, 1991, 1992; Jayaram, 2013; Mohanty et al., 2015; Mogalekar and Canciyal, 2018).

RESULTS AND DISCUSSION

The study revealed presence of 33 species belonging to 8 orders, 18 families and 28 genera (Table 1; Fig. 1-28). Among the 33 species, Perciformes was the most dominant order with 12 species belonging to 7 families (Table 1). Cypriniformes was the second dominant order with 11 species belonging to 2 families, whereas, Cyprinidae with 10 species was the dominant family in the study area. Siluriformes represented by 4 species belonging to 4 families, whereas, Beloniformes, Cyprinidontiformes, Synbranchiformes and Tetradontiformes orders were represented by 1 species and 1 family. In a related study, Pati (2008) recorded 43 fish species belonging to 21 families. He further reported that among major carps, rohu (*Labeo rohita*) showed the maximum representation in the drag net catch followed by *Catla catla*, *Cirrihinus mrigala* and *Labeo calbasu*. Overall species compositions revealed the dominance of predatory and weed fishes in the fish fauna (Pati, 2008).

Out of the 33 fish species recorded from Ansupa lake, 32 species come under the IUCN Red List of threatened category. Among them 29 species come under the *least concern* (LC) category, one species under *data deficient* (DD), namely *Anabas testudineus* (Bloch, 1792) and two species comes under *near threatened* (NT) category namely *Chitala chitala* (Hamilton, 1822) and *Wallagoattu* (Bloch and Schneider, 1801).

Table 1. Checklist of recorded fish species from Ansupa Lake during the present study

Sl.	Order name	Family and Scientific name	Vernacular name/ Local name	Conservation status
1	**Beloniformes**	**Belonidae**		
		Xenentodon cancila (Hamilton,1822)	Freshwater gar fish	LC
2	**Cypriniformes**	**Cyprinidae**		
		Catla catla (Hamilton,1822)	Catla	LC
		Labeo rohita (Hamilton, 1822)	Rohu	LC
		Cirrihinus mrigala (Hamilton, 1822)	Mrigal	LC
		Labeo calbasu (Hamilton, 1822)	Kalbasu/Orange Finlabeo	LC
		Systomus sarana (Hamilton, 1822)	Olive Barb	LC
		Puntius sophore (Hamilton, 1822)	Pool Barb	LC
		Cirrhinus reba (Hamilton, 1822)	Reba carp	LC
		Pethia phutunio (Hamilton, 1822)	Spotted sail barb	LC
		Rasbora daniconius (Hamilton, 1822)	Slender Barb, BlacklineRasbora	LC
		Amblypharyngodon mola (Hamilton,1822)	Molacarplet	LC
		Cobitidae		
		Lepidocephalichthys guntea (Hamilton,1822)	Guntea loach	LC
3	**Cyprinidontiformes**	**Poeciliidae**		
		Gambusia affinis (Baird and Girard, 1853)	Mosquitofish	LC
4	**Osteoglossiformes**	**Notopteridae**		
		Notopterus notopterus (Pallas, 1769)	Bronze feather back	LC
		Chitala chitala (Hamilton, 1822)	Clown knifefish	NT
5	**Perciformes**	**Channidae**		
		Channa marulius (Hamilton,1822)	Great snakehead	LC
		Channa orientalis (Bloch and Schneider,1801)	Walking snakehead	NE
		Channa punctata (Bloch,1793)	Spotted snakehead	LC

		Channa striata (Bloch,1793)	Common snakehead/ Striped snakehead	LC
		Ambassidae		
		Chanda nama (Hamilton,1822)	Elongate glass-perchlet	LC
		Parambassis ranga (Hamilton,1822)	Indian Glassy fish	LC
		Osphronemidae		
		Colisa fasciatus (Bloch and Schneider,1801)	Giant gourami	LC
		Trichogaster lalius (Hamilton,1822)	Dwarf gourami	LC
		Gobiidae		
.		*Glossogobius giuris* (Hamilton,1822)	Tank goby	LC
		Badidae		
.		*Badis badis* (Hamilton,1822)	Badis/Dwarf chameleon fish	LC
		Nandidae		
.		*Nandus nandus* (Hamilton,1822)	Gangetic leaf fish	LC
		Anabantidae		
		Anabas testudineus (Bloch, 1792)	Climbing Perch	DD
5	**Siluriformes**	**Heteropneustidae**		
		Heteropneustes fossilis (Bloch,1794)	Stinging catfish	LC
		Clariidae		
		Clarias batrachus (Linnaeus, 1758)	Walking catfish	LC
		Siluridae		
		Walla goattu (Bloch and Schneider,1801)	Wallago	NT
		Bagridae		
		Mystus tengara (Hamilton,1822)	Tengara catfish	LC
6	**Synbranchiformes**	**Mastacembelidae**		
		Macrognathus pancalus (Hamilton,1822)	Barred spiny eel	LC
7	**Tetradontiformes**	**Tetraodontidae**		
		Tetraodon cutcutia (Hamilton,1822)	Ocellated puffer fish	LC

DD: data deficient; LC: least concern; NE: not evaluated; NT: near threatened.

Fig. 1. *Trichogaster lalius*

Fig. 2. *Amblypharyngodon mola*

Fig. 3. *Channa striata*

Fig. 4. *Channa marulius*

Fig. 5. *Labeo rohit*a

Fig. 6. *Systomus sarana*

Fig. 7. *Heteropneustes fossilis*

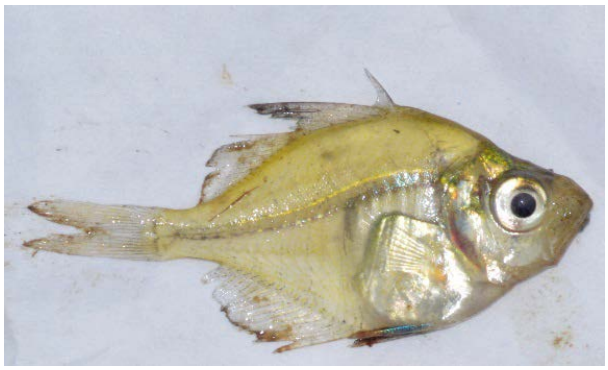

Fig. 8. *Chanda nama*

Fig. 9. *Xenentodon cancila*

Fig. 10. *Wallago attu*

Fig. 11. *Glossogobius giuris*

Fig. 12. *Catla catla*

Fig. 13. *Cirrhinus reba*

Fig. 14. *Rasbora daniconius*

Fig. 15. *Labeo calbasu*

Fig. 16. *Mystus tengara*

Fig. 17. *Gambusia affinis*

Fig. 18. *Macrognathus pancalus*

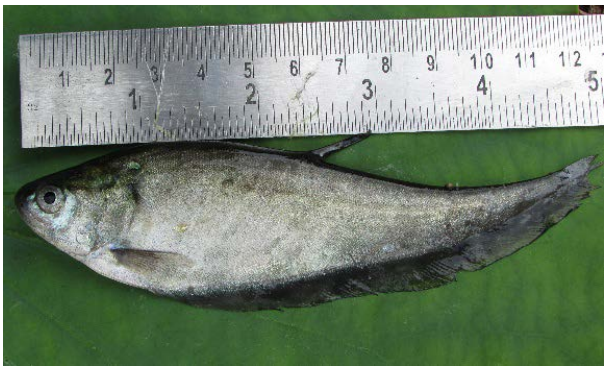

Fig. 19. *Notopterus notopterus*

Fig. 20. *Cirrihinus mrigala*

Fig. 21. *Nandus nandus*

Fig. 22. *Puntius sophore*

Fig. 23. *Pethia phutunio*

Fig. 24. *Badis badis*

Fig. 25. *Tetraodon cutcutia*

Fig. 26. *Lepidocephalichthys guntea*

Fig. 27. Ansupa Lake

Ansupa lake exists as a natural resource, creating distinct economic opportunities to a range of lake users such as forest users in the upstream, irrigation water users in the valley floor, community drinking water users in the settlements both in the upstream and the valley floor, boat operators, tourism entrepreneurs operating hotels and restaurants in and around the lake shore. The lake continues to exist as a common pool resource (Pattanaik et al., 2004). However, because of various environmental degradations and anthropogenic activities, such as siltation due to exploitation of vegetation from nearby hills, poor system in inlet and outlet mechanism of water flow and increasing eutrophication, the condition of the lake has been deteriorated day by day. Thus, the rich floral and faunal diversity of lake is in significant threat and in imminent danger of being diminished. From the present scenario, there is an immediate need to take significant conservation measures and long-term monitoring on floral and faunal composition of the lake, to conserve the glorified diversity of the Ansupa lake.

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REFERENCES

Das, C.R. 2008. Integrated sustainable environmental conservation and restoration of largest fresh water Ansupa Lake, a famous wetland of Orissa. In: M. Sengupta and R. Dalwani (eds.), *Proceedings of the 12th World Lake Conference*, pp. 1571-1577.

Day, F. 1878. The fishes of India, being a natural history of the fishes known to inhabit the seas and freshwaters of India, Burma and Ceylon. Dawson, London **1**: 778; 2:195 plates; reprint 1958.

Ghorbani, R., Abbasi, F., Molaei, M. and Naeimi, A. 2013. Identification and distribution of fish fauna in Kaboodval Stream (Golestan Province, Iran). *World J. Fish Mar. Sci*. **5**(5): 467-473.

Gopi, K.C., Mishra, S.S. and Kosygin, L. 2017. Pisces. Chapter 33. In: K. Chandra, K.C. Gopi, D.V. Rao, K. Valarmathi and J.R.B. Alfred (Eds.) *Current Status of Freshwater Faunal Diversity in India*. Zoological Survey of India, Kolkata, India, pp. 527–570.

Jayaram, K.C. 2013. *The Freshwater Fishes of the Indian Region*. Narendra Publishing House, New Delhi, pp. 1-551.

Kar, D. 2003. Fishes of barak drainage, Mizoram and Tripura. In: A. Kumar, C.P. Bohra and L.K. Singh (eds) *Environment, Pollution and Management*. APH Publishing Corporation, New Delhi, India, pp. 203–211.

Mogalekar, H.S. and Canciyal, J. 2018. Freshwater fishes of Orissa. *Indian J. Fish.* **6**(1): 587–598.

Mohanty, S.K., Mishra, S.S., Khan, M., Mohanty, R.K., Mohapatra, A. and Pattnaik, A.K. 2015. Ichthyofaunal diversity of Chilika Lake, Odisha, India: an inventory, assessment ofbiodiversity status and comprehensive systematic checklist (1916–2014). *Check List* **11**(6): 1817.

Nelson, J.S. 2006. *Fishes of the World*, 4th edn. John Wiley and Sons Inc, p. 601.

Pati, D.K. 2008. Present status of fish and fishery in Ansupa Lake, Orissa. *J. Inland Fish. Soc. India* **40**(2): 83-84.

Pattanaik, C., Swain, D., Choudhury, S.B. and Das, R. 2004. Conservation and restoration of wetlands in India: A strategic approach for sustainable management. In: *International Conference on'Conservation, Restoration and Management of Lakes and Coastal wetlands'*, Bhubaneswar).

Sarkar, S.D., Ekka, A., Sahoo, A.K., Roshith, C.M., Lianthuamluaia, Roychowdhury, A. 2015. Role of flood plain wetlands in supporting livelihood: A case study of Ansupa Lake in Odisha. *J. Environ. Sci. Comp. Sci. Eng. Technol. Sec. A* **4**: 819-826.

Talwar, P.K. and Jhingran, A.G. 1991. *Inland Fishes of India*. Oxford and IBH Publishing Co-Pvt. Ltd., New Delhi, p. 1158.

Talwar, P.K. and Jhingran, A.G. 1992. *Inland Fishes of India and Adjacent Countries*, Vol. 2. A.A. Balkenma/Rotterdam, Calcutta, India.

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Bird diversity of Mundali area (Mahanadi river) under Cuttack Forest Division, Odisha, India

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ABSTRACT

The bird diversity study of Mundali area in Cuttack Forest Division of Cuttack District, Odisha was carried out from June 2016 to January 2017. During the study, a total of 185 species of birds belonging to 58 families and 20 orders were recorded. Out of 185 species a total 48% (n=88) species resident birds, 46% (n=85) species winter visitors, 4% (n=8) species passage visitors and 2% (n=4) species summer visitors were recorded in the study area. According to frequency of sighting of birds 96 species (53%) were common, 43 species (23%) were uncommon and 28 species (15%) were rare and 18 species (10%) were occasional recorded from the study area.

Key words: Avifauna, Cuttack Forest Division, diversity, Mundali area, Odisha

INTRODUCTION

In Odisha bird life is very rich, with 524 species reported till now (Inskipp, 2014), including historical records, primarily those by Valentine Ball (Ball, 1877, 1878). For Odisha, several studies describe the distribution, behaviour, check list and ecology of birds like Mukherjee (1952), Singh (1993), Acharya and Kar (1996), Acharya et al. (1999), Kar et al. (1999), Sahu and Kar (2000), Sahu and Rout (2005), Gopi et al. (2007a,b), and Pradhan et al. (2014). Many other recent works also report about the richness in avian diversity in protected areas of Odisha (Sahu et al., 2012; Palei et al., 2011, 2012a, b, 2014a, b, c; Palei et al., 2015; Palei et al., 2017; Rajguru, 2017). However, many areas are still unexplored like Mundali area of Mahanadi river. The bird diversity of this protected area is still unknown. The aim of this study is to present a list of the bird species of scientifically explored of this area.

MATERIAL AND METHODS

The former capital and the second largest city in the eastern Indian state of Odisha is best known either for its natural heritage, biodiversity and the largest river of Odisha "Mahanadi". The name Cuttack is derived form of "Katak" which figuratively means, 'The Fort', lies between 20° 30´ N and 85° 49´ E and covers an area of 398 km². The city is located at an elevation of 36 meters above the mean sea level. The physiography of Cuttack elucidates that the city is situated at the apex of the delta formed by Mahanadi and Kathajodi, the two important rivers flowing through the territory. The city has a tropical climate and experiences about 144.39 cm of rainfall during the monsoons. The Mahanadi river delta in Cuttack district starts from Jobra (20° 28´ N, 85° 54´ E) to Mundali (20° 26´ N, 85° 40´ E) having semi-urban forest patches and all the Mahanadi and Kathajodi river beds are included in the study area and comprises Cuttack Forest Division.

Observations were made, usually for a full day between the months of June 2016 to January 2017. Regular surveys were done by walking on fixed routes throughout the study area. Observations were made in the morning and afternoon, depending on the light condition. Recordings were not made at

the time of heavy rains. Surveys were conducted twice a week. Birds were observed using 7 × 50 and 7 × 42 binoculars and identified. At each site birds were counted using a binocular before moving to the next point as rapidly as possible without disturbing the birds. We observed details on habitat type, season and status (resident/ migrant). In case of doubtful identification, photographs were taken and the species is identified later by consulting experts. The abundance status of birds are categorized into Common (Com) - seen on most of the visits, uncommon (Un Com) - seen on a few visits and Rare (Ra) - Seen once or twice, local movement (LM) and migrants (M). Some birds are resident and their residential status is classified into resident (R) and they are also included.

RESULTS AND DISCUSSION

During the study, we observed 185 species of birds belonging to 58 families and 20 orders from Mundali area of Cuttack Forest Division. Table 1 depicts detail status, scientific and common names of birds, which shows that the area shows that high diversity of birds. Accipitridae (14), Anatidae (11), Ardeidae (10), Scolopacidae (9), Motacillidae (8), Sylvidae (7), Muscicapidae (7), Charadriidae (7), Sturnidae (6), Alaudidae (5), Cuculidae(5), Estrildidae (5), Laridae (5), Columbidae (5), Strigidae (4), Rallidae (4), Phasianidae(3), Psittacidae (3), Phalacrocoracidae (3), Corvidae (3), Lanidae (3), Campephagidae(3), Pycnonotidae (3), Hirundinidae (3), Cisticolidae (3), Turnicidae (2), Burhinidae (2), Jacanidae (2), Ciconiidae (2), Caprimulgidae (2), Picidae (2), Halcyonidae (2), Megalaimidae (2), Meropidae (2), Nectariniidae (2), Passeridae (2), Oriolidae (2), Monarchidae (2), Dendrocygnidae (1), Podicipedidae (1), Threskiornithidae (1), Anhingidae (1), Falconidae (1), Recurvirostridae (1), Glareolidae (1), Tytonidae (1), Upupidae (1), Coraciidae (1), Apodidae (1), Alcedinidae(1), Cerylidae (1), Aegithinidae (1), Artamidae (1), Dicruridae (1), Pellorneidae (1),

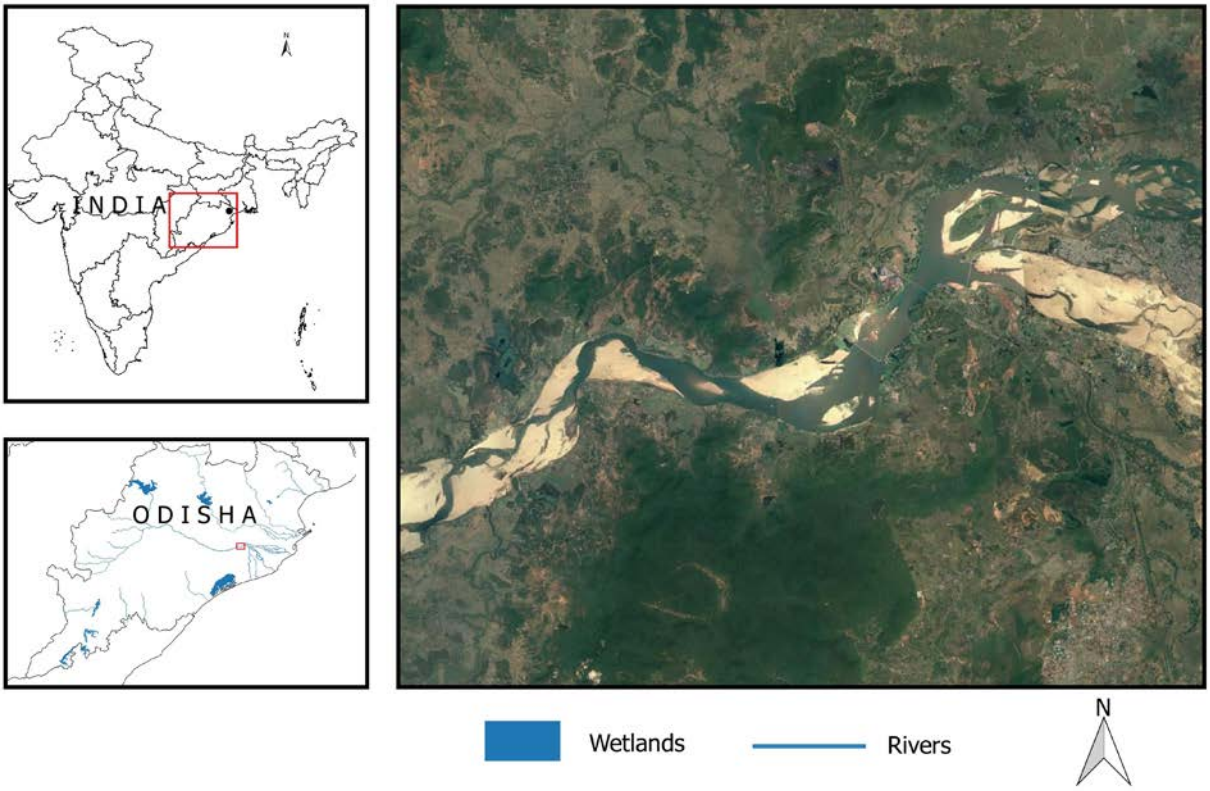

Fig. 1. Location map Mundali area of (Mahanadi River) under Cuttack Forest Division, Odisha, India

Leiothrichidae (1), Irenidae (1) and Dicacidae (1) species were recorded during the study area.

According to frequency of sighting of birds, 96 species (52%) were common, 43 species (23%) were uncommon and 28 species (15%) were rare and 18 species (10%) were occasional as recorded from Mundali area during the study period (Fig. 2). During the migratory status out of 185 species a total 48% (n=88) species resident bird, 46% (n=85) species were winter visitor, 4% (n=8) species were passage visitor and 2% (n=4) species summer visitor recorded to the study area. Some migratory birds were recorded in the study area namely Ruddy shelduck *Tadorna ferruginea,* Cotton pigmy goose *Nettapus coromandelianus,* Gadwall *Anas strepera*, Bar headed goose *Anser indicus,* Eurasian Wigeon *Anas Penelope*, Spot bellied duck *Anas poecilorhyncha*, Northern Shoveler *Anas clypeata*, Northern Pintail *Anas acuta,* Common Teal *Anas crecca*, Red crested pochard *Netta rufina,* Tufted Duck *Aythya fuligula* recorded in the study area. Besides these, birds prey species were recorded during the study area namely Black Winged Kite *Elanus caeruleus,* Black kite *Milvus migrans,* Black eared kite *Milvus ineatus,* White bellied Sea eagle *Haliaeetus leucogaster,* Greater Spotted eagle *Clanga clanga,* Brahminy kite *Haliastur Indus,* Osprey *Pandion haliaetus,* Short toed snake eagle *Circaetus gallicus,* Crested Hawk eagle *Nisaetus cirrhatus,* Crested Serpent eagle *Spilornis cheela,* Booted eagle *Hieraaetus pennatus,* White eyed buzzard *Butastur teesa,* Crested Goshawk *Accipiter trivirgatus and* Shikra *Accipiter badiu* recorded during the Mundali area.

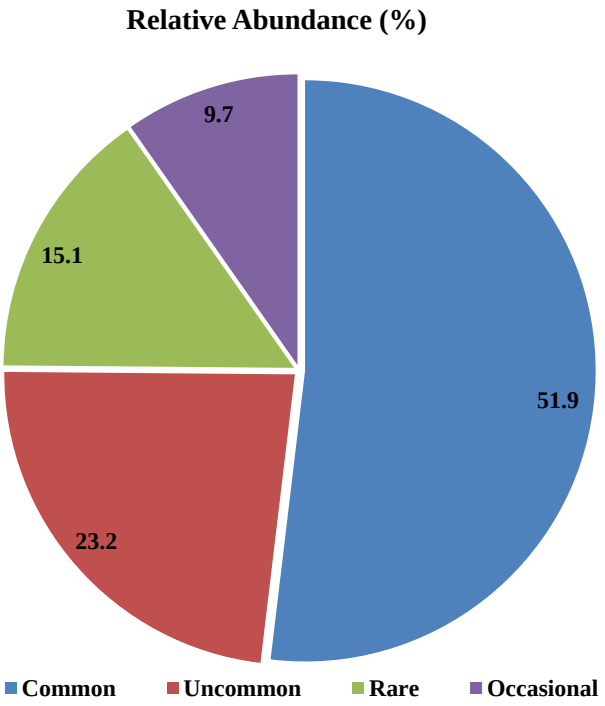

Fig. 2. Relative abundance of bird species in percentage in Mundali area of Mahanadi River under Cuttack Forest Division, Odisha, India.

Table 1. Checklist of birds recorded in Mahanadi River (Mundali area) under Cuttack Forest Division, with their residential and breeding status

Sl	Family	Common Name	*Scientific Name*	Abundance	Migratory status
		Order: Galliformes			
1	Phasianidae	Grey francolin	*Francolinus pondicerianus*	C	R
2		Red Jungle Fowl	*Gallus gallus*	UC	R
3		Indian Peafowl	*Pavo cristatus*	C	R
		Order: Anseriformes			
4	Dendrocygnidae	Lesser Whistling Duck	*Dendrocygna javanica*	C	SV
5	Anatidae	Ruddy shelduck	*Tadorna ferruginea*	C	WV
6		Cotton pigmy goose	*Nettapus coromandelianus*	UC	SV
7		Gadwall	*Anas strepera*	C	WV
8		Bar headed goose	*Anser indicus*	R	WV
9		Eurasian Wigeon	*Anas penelope*	R	WV
10		Spot bellied duck	*Anas poecilorhyncha*	C	R
11		Northern Shoveler	*Anas clypeata*	R	WV
12		Northern Pintail	*Anas acuta*	C	WV
13		Common Teal	*Anas crecca*	UC	WV
14		Red crested Pochard	*Netta rufina*	C	WV
15		Tufted Duck	*Aythya fuligula*	C	WV
		Order: Podicipediformes			
16	Podicipedidae	Little Grebe	*Tachybaptus ruficollis*	C	R
		Order: Ciconiiformes			
17	Ciconiidae	Painted Stork	*Mycteria leucocephala*	R	WV
18		Asian Openbill	*Anastomus oscitans*	C	R
		Order: Pelecaniformes			
19	Threskiornithidae	Black headed Ibis	*Threskiornis melanocephalus*	UC	WV
20	Ardeidae	Striated Heron	*Butorides striata*	R	WV
21		Black crowned Night Heron	*Nycticorax nycticorax*	UC	R
22		Cinnamon Bittern	*Ixobrychus cinnamomeus*	UC	WV
23		Indian pond Heron	*Ardeola grayii*	C	R
24		Grey Heron	*Ardea cinerea*	C	WV
25		Purple Heron	*Ardea purpurea*	C	WV
26		Cattle Egret	*Bubulcus ibis*	C	R
27		Great Egret	*Casmerodius albus*	C	R
28		Intermediate Egret	*Mesophoyx intermedia*	C	R
29		Little Egret	*Egretta garzetta*	C	R

		Order: Suliformes			
30	Anhingidae	Darter	*Anhinga melanogaster*	C	WV
31	Phalacrocoracidae	Little cormorant (Order- Pelecaniformes)	*Phalacrocorax niger* (Vieillot, 1817)	C	R
32		Indian Shag	*Phalacrocorax fuscicollis*	UC	WV
33		Great Cormorant	*Phalacrocorax carbo*	UC	R
		Order: Falconiformes			
34	Falconidae	Common Kestrel	*Falco tinnunculus*	O	WV
		Order: Accipitriformes			
35	Accipitridae	Black Winged Kite	*Elanus caeruleus*	O	WV
36		Black kite	*Milvus migrans*	C	R
37		Black eared kite	*Milvus ineatus*	R	R
38		White bellied Sea eagle	*Haliaeetus leucogaster*	R	PV
39		Greater Spotted eagle	*Clanga clanga*	R	PV
40		Brahminy kite	*Haliastur indus*	O	PV
41		Osprey	*Pandion haliaetus*	UC	PV
42		Short toed snake eagle	*Circaetus gallicus*	O	PV
43		Crested Hawk eagle	*Nisaetus cirrhatus*	O	PV
44		Crested Serpent eagle	*Spilornis cheela*	UC	PV
45		Booted eagle	*Hieraaetus pennatus*	O	PV
46		White eyed buzzard	*Butastur teesa*	UC	WV
47		Crested Goshawk	*Accipiter trivirgatus*	R	WV
48		Shikra	*Accipiter badius*	C	R
		Order: Gruiformes			
49	Rallidae	Common Moorhen	*Gallinula chloropus*	C	R
50		White-breasted Waterhen	*Amaurornis phoenicurus*	C	R
51		Grey headed Swamphen	*Porphyrio porphyrio*	C	WV
52		Common Coot	*Fulica atra*	UC	WV
		Order: Charadriiformes			
53	Turnicidae	Yellow legged Buttonquail	*Turnix tanki*	UC	R
54		Barred Buttonquail	*Turnix suscitator*	UC	R
55	Burhinidae	Indian Thick Knee	*Burhinus oedicnemus*	UC	R
56		Great Thick knee	*Esacus recurvirostris*	R	R
57	Jacanidae	Pheasant-tailed Jacana	*Hydrophasianus chirurgus*	UC	WV
58		Bronze-winged Jacana	*Metopidius indicus*	C	R
59	Recurvirostridae	Black winged Stilt	*Himantopus himantopus*	C	WV

60	Charadriidae	River Lapwing	*Vanellus duvaucelli*	C	R
61		Grey headed Lapwing	*Vanellus cinereus*	UC	WV
62		Yellow wattled Lapwing	*Vanellus malabaricus*	C	R
63		Red wattled Lapwing	*Vanellus indicus*	C	R
64		Little ringed Plover	*Charadrius dubius*	C	R
65		Kentish Plover	*Charadrius alexandrines*	C	WV
66		Lesser sand Plover	*Charadrius mongolus*	C	WV
67	Scolopacidae	Common Snipe	*Gallinago gallinago*	C	WV
68		Common Redshank	*Tringa totanus*	UC	WV
69		Common Greenshank	*Tringa nebularia*	C	WV
70		Green Sandpiper	*Tringa ochropus*	C	R
71		Wood Sandpiper	*Tringa glareola*	C	R
72		Marsh Sandpiper	*Tringa stagnatilis*	UC	WV
73		Common Sandpiper	*Actitis hypoleucos*	C	R
74		Little Stint	*Calidris minuta*	UC	WV
75		Temminck's Stint	*Calidris temminckii*	C	WV
76	Glareolidae	Small Pratincole	*Glareola lactea*	C	WV
77	Laridae	River Tern	*Sterna aurantica*	C	R
78		Little Tern	*Sternula albifrons*	R	WV
79		Black bellied Tern	*Sterna acuticauda*	R	WV
80		Indian Skimmer	*Rynchops albicollis*	R	WV
81		Whiskered Tern	*Chlidonias hybrida*	UC	WV
	Order: Columbiformes				
82	Columbidae	Eurasian Collared Dove	*Streptopelia decaocto*	C	WV
83		Spotted Dove	*Streptopelia chinensis*	C	R
84		Laughing Dove	*Streptopelia senegalensis*	C	R
85		Common Pigeon	*Columba livia*	C	R
86		Oriental Turtle Dove	*Streptopelia orientalis*	O	WV
	Order: Psittaciformes				
87	Psittacidae	Alexandrine Parakeet	*Psittacula eupatria*	C	R
88		Rose-ringed Parakeet	*Psittacula krameri*	C	R
89		Plum-headed Parakeet	*Psittacula cyanocephala*	R	WV
	Order: Cuculiformes				
90	Cuculidae	Jacobin Cuckoo	*Clamator jacobinus*	O	WV
91		Common Hawk Cuckoo	*Hierococcyx varius*	C	R
92		Grey bellied Cuckoo	*Cacomantis passerinus*	UC	WV
93		Asian Koel	*Eudynamys scolopacea*	C	R
94		Southern Coucal	*Centropus sinensis*	C	R

		Order: Strigiformes			
95	Tytonidae	Barn Owl	*Tyto alba*	R	R
96	Strigidae	Indian Scops Owl	*Otus bakkamoena* (Pennant, 1769)	R	R
97		Spotted Owlet	*Athene brama*	C	R
98		Indian Eagle Owl	*Bubo bubo*	R	R
99		Jungle Owlet	*Glaucidium radiatum*	R	R
		Order: Bucerotiformes			
100	Upupidae	Common Hoopoe	*Upupa epops*	O	WV
		Order: Caprimulgiformes			
101	Caprimulgidae	Jungle Nightjar	*Caprimulgus indicus*	R	R
102		Indian Nightjar	*Caprimulgus asiaticus*	UC	R
		Order: Apodiformes			
103	Apodidae	Asian palm swift	*Cypsiurus balasiensis*	UC	R
		Order: Coraciiformes			
104	Coraciidae	Indian roller	*Coracias benghalensis*	C	R
105	Halcyonidae	Stork billed kingfisher	*Halcyon capensis*	R	R
106		White throated kingfisher	*Halcyon smyrnensis*	C	R
107	Alcedinidae	Common kingfisher	*Alcedo atthis*	UC	R
108	Cerylidae	Pied Kingfisher	*Ceryle rudis*	C	R
109	Meropidae	Blue-tailed Bee-eater	*Merops philippinus* (Linnaeus, 1766)	C	R
110		Small Bee-eater	*Merops orientalis* (Latham, 1801)	C	R
		Order: Piciformes			
111	Megalaimidae	Brown headed Barbet	*Megalaima zeylonica*	C	R
112		Coppersmith Barbet	*Megalaima haemacephala*	C	R
113	Picidae	Rufous woodpecker	*Celeus brachyurus*	UC	R
114		Black rumped Flameback	*Dinopium benghalense*	C	R
		Order: Passeriformes			
115	Aegithinidae	Common Iora	*Aegithina tiphia*	C	R
116	Artamidae	Ashy woodshallow	*Artamus fuscus*	UC	WV
117	Campephagidae	Large cuckooshrike	*Coracina macei*	UC	WV
118		Black winged cuckooshrike	*Coracina melaschistos*	R	WV
119		Black headed cuckooshrike	*Coracina melanoptera*	R	WV

120	Lanidae	Long tailed Shrike	*Lanius schach*	C	WV
121		Brown Shrike	*Lanius cristatus*	C	R
122		Bay backed Shrike	*Lanius vittatus*	R	WV
123	Dicruridae	Black Drongo	*Dicrurus macrocerus*	C	R
124	Oriolidae	Indian golden Oriole	*Oriolus oriolus*	C	WV
125		Black hooded Oriole	*Oriolus xanthornus*	C	R
126	Corvidae	Rufous Treepie	*Dendrocitta vagabunda*	C	R
127		House Crow	*Corvus splendens*	C	R
128		Jungle Crow	*Corvus macrorhynchos*	C	R
129	Hirundinidae	Streak throated Swallow	*Hirundo fluvicola*	O	WV
130		Barn Swallow	*Hirundo rustica*	C	R
131		Red rumped Swallow	*Hirundo daurica*	UC	WV
132	Alaudidae	Jerdon's bushlark	*Mirafra affinis*	C	R
133		Indian bushlark	*Mirafra erythroptera*	UC	R
134		Bengal bushlark	*Mirafra assamica*	O	WV
135		Ashy crowned sparrow Lark	*Eremopterix grisea*	O	WV
136		Oriental Skylark	*Alauda gulgula*	C	R
137	Pycnonotidae	Red-vented Bulbul	*Pycnonotus cafer*	C	R
138		Red-whiskered Bulbul	*Pycnonotus jocosus*	C	R
139		White browed Bulbul	*Pycnonotus luteolus*	UC	WV
140	Cisticolidae	Ashy prinia	*Prinia socialis*	UC	SV
141		Plain Prinia	*Prinia inornata*	C	R
142		Zitting Cisticola	*Cisticola zuncidis*	UC	WV
143	Sylvidae	Greenish Leaf warbler	*Phylloscopus trochiloides*	C	WV
144		Yellow eyed Babbler	*Chrysomma sinense*	C	R
145		Common Tailor Bird	*Orthotomus sutorius*	C	R
146		Clamorous Reed Warbler	*Acrocephalus stentoreus*	UC	WV
147		Blyth's Reed Warbler	*Acrocephalus dumetorum*	UC	WV
148		Booted Warbler	*Iduna caligata*	UC	R
149		Common Chiffchaff	*Phylloscopus collybita*	C	R
150	Pellorneidae	Puff throated Babbler	*Pellorneum ruficeps*	O	WV
151	Leiothrichidae	Jungle Babbler	*Turdoides striatus*	C	R
152	Sturnidae	Jungle myna	*Acridotheres fuscus*	C	R
153		Common myna	*Acridotheres tristis*	C	R
154		Asian pied starling	*Gracupica contra*	C	R
155		Chestnut tailed starling	*Sturnus malabaricus*	C	WV
156		Brahminy starling	*Sturnus pagodarum*	C	WV
157		Rosy starling	*Sturnus roseus*	C	WV

158	Monarchidae	Indian paradise flycatcher	*Terpsiphone paradisi*	O	WV
159		Black naped monarch	*Hypothymis azurea*	R	WV
160	Muscicapidae	Orange headed Thrush	*Zoothera citrina*	O	WV
161		Oriental Magpie Robin	*Copsychus saularis*	C	R
162		Indian Robin	*Saxicoloides fulicata*	C	R
163		Pied bushchat	*Saxicola caprata*	C	R
164		Blue rock Thrush	*Montocola solitarius*	R	WV
165		Asian brown flycatcher	*Muscicapa dauurica*	UC	WV
166		Taiga flycatcher	*Ficedula albicila*	UC	WV
167	Irenidae	Jerdon's Leafbird	*Chloropsis cochinchinensis*	C	R
168	Dicacidae	Pale bellied Flowerpecker	*Dicacum erythrohynchos*	UC	WV
169	Nectariniidae	Purple rumped sunbird	*Nectarinia zeylonica*	C	R
170		Purple sunbird	*Nectarinia asiatica*	C	WV
171	Passeridae	House sparrow	*Passer domesticus*	UC	R
172		Baya Weaver	*Ploceus philippinus*	R	WV
173	Estrildidae	Red Munia	*Amandava amandava*	R	WV
174		White-throated Munia	*Lonchura malabarica*	O	WV
175		White-rumped Munia	*Lonchura striata*	O	WV
176		Scaly breasted Munia	*Lonchura punctulata*	C	WV
177		Black-headed Munia	*Lonchura malacca*	UC	WV
178	Motacillidae	Yellow wagtail	*Motacilla flava*	C	WV
179		Citrine wagtail	*Motacilla citreola*	C	WV
180		Forest Wagtail	*Dendronanthus indicus*	R	SV
181		Grey wagtail	*Motacilla cinerea*	UC	WV
182		White wagtail	*Motacilla alba*	C	WV
183		White browed wagtail	*Motacilla maderaspatensia*	UC	WV
184		Paddy field pipit	*Anthus rufulus*	C	R
185		Olive backed pipit	*Anthus hodgsonii*	O	WV

M-Migrant, Ra-Rare, Re-Resident, UC-Uncommon, C-Common, WV-Winter visitor, PV-Passage visitor

There are no such major threats in Mundali area. Threats are mainly due to human settlements near the water bodies and River side for which the maximum habitat disturbance occur. People use the water of Mahanandi River in daily basis and put all their garbage in the river, which is the main concern of study area and also intensive fishing for which the habitat gets disturbed. These activities mainly create disturbance for migratory species which entirely depend on river vegetation. Due to lots of fishing activities these under water vegetations are vanishing causing scarcity of food in the long run.

Grazing of livestock on the dry river land also damage the breeding ground of some migratory species like lapwings, terns, pratincoles, Indian skimmer etc. So, people should be made aware not to use the breeding ground for their purpose during the migration period. Also sand mining from the river for construction purpose is damaging the river habitat and making it too deep, causing flooding of

water and reduction of the feeding habitat. Mega structures in and around Mahanadi and Kathajodi river basin are the major concern, where lots of terrestrial birds previously perch will be vanished slowly from these places. Though no poaching activities have been recorded in the past, now-a-days fishing nets sometimes become a threat for the migratory birds

a. *Pavo cristatus*

b. *Lonchura striata*

c. *Dendronanthus indicus*

d. *Esacus recurvirostris*

e. *Sterna acuticauda*

f. Athene brama

Fig. 3. Birds (a-f) of Mahanadi river (Mundali area), Cuttack Forest Division

a. *Anser indicus*

b. *Tadorna ferruginea*

c. *Haliaeetus leucogaster*

d. *Netta rufina*

Fig. 4. Migratory birds (a-d) of Mahanadi river (Mundali area), Cuttack Forest Division

Fig. 5. Migratory birds habitat of Mahanadi river (Mundali area), Cuttack Forest Division

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REFERENCES

Acharya, S. and Kar, S.K. 1996. Checklist of waders (Charadriiformes) in Chilika Lake, Orissa. *Newsletter for Birdwatchers* **36**: 89-90.

Acharya, S., Kar, S.K., and Bohidar, K. 1999. Habitat utilisation by shorebirds. (Charaadriiformes) wintering in Chilika lake, Orissa. *Pranikee*. **12-14**: 39-46.

Ball, V. 1877. Notes on birds observed in the region between the Mahanadi and Godavari rivers. *Stray Feathers* **5**: 410-420.

Ball, V. 1878. From the Ganges to the Godaveri. On the distribution of Birds, so far as it is at present know, throughout the hill region which extends from the Rajmehal Hills to the Godaveri valley. *Stray Feathers* **7**: 191-235.

Gopi, G.V. and Pandava, B. 2007a. Observation on breeding biology of three stork species in Bhitarkanika mangroves, India. *Indian Birds* **3** (2): 45-50.

Gopi, G.V. and Pandava, B. 2007b. Avifauna of Bhitarkanika Mangroves, India. *Zoo's Print J.* **22** (10): 2839-2847.

Inskipp, T. 2014. Checklist and bibliography of birds of Odisha, Birds of Odisha Facebook Group.

Kar, S.K. and Sahu, H.K. 1999. Study on feeding pattern of Anatids in Nalaban sanctuary of Chilika lake, Orissa. In: *Proc. 42 Annual Conf. Zool. Soc. Orissa,* Khurda, p. 5.

Kar, S.K., Sahu, H.K. and Acharya, S. 1999. Ringing or banding of birds during 1993 migration season at Nalaban (Chilika) wildlife sanctuary, Orissa. *Bihang J.* **1**(4): 13.

Kar, S.K. and Sahu, H.K. 1993. Preliminary study on ecology of aquatic birds in Chilika lake, Orissa. In: *Proc. First National Seminar on Changing Scenario of Bird Ecology and Conservation,* Bangalore, pp. 62-64.

Mukherjee, A.K. 1952. On a collection of birds from the Similipal hills, Mayurbhanj district. *Orissa. Rec. Indian Mus*. **50**: 157-171.

Palei, H.S., Mohapatra, P.P. and Sahu, H.K. 2012a. Birds of Hadagarh Wildlife Sanctuary, Odisha, Eastern India. *World J. Zool.* **7** (3): 221-225.

Palei, N.C., Mishra, S.R., Sahu, H.K., and Rout, S.D. 2011. Birds of Sunabeda Wildlife Sanctuary, Odisha. *Newsletter for Birdwatcher* **51** (4): 2011.

Palei, N.C., Rath, B.P. and Sahu, H.K. 2012b. Birds of Lakhari Valley Wildlife Sanctuary, Odisha. *Newsletter for Birdwatcher* **52** (4): 201.

Palei, H.S., Debata, S., Mohapatra, P.P. and Mishra, A.K. 2017. Diversity and status of birds in Bonai Forest Division, Odisha, India. *e-planet* **15** (2): 166-177.

Palei, N.C., Rath, B.P., Sajan, S.K. and Mishra, A.K. 2014a. Avifauna of Athgarh Forest Division, Odisha, India. *J. Entomol. Zool. Stud.* **2** (5): 329-334.

Palei, N.C., Rath, B.P., Pradhan, S.R., Swain, K.K. and Pati, M. 2014b. The water birds of Paradeep Phosphate Limited (PPL) campus of Jagatsinghpur district in Odisha, India. *World J. Zool.* **9** (3): 208-213.

Palei, N.C., Mishra, S.R. and Sahu, H.K. 2014c. White-bellied sea eagle (*Haliaeetus leucogaster*) in Bhitarkanika National Park, Odisha, India. *J. Cheetal* **51**: 28-37.

Palei, N.C., Palei, H.S., Rath, B.P. and Sahoo, P.K. 2015. Avifauna of Kapilash Wildlife Sanctuary, Odisha, India, *J. Newsletter for Birdwatcher.* **55** (3): 27-31.

Pradhan, S.R., Palei, N.C., Rath, B.P. and Swain, K.K. 2014. Assessment of floristic diversity of mangrove vegetation in Bagagahan Heronry of the Bhitarkanika National Park, Odisha, India. *Am. Euras. J. Agric. Environ. Sci*. **15** (2): 237-242.

Rajguru, S.K. 2017. Breeding biology of Indian Skimmer Rynchops albicollis at Mahanadi River, Odisha, India. *Indian Birds* **13** (1): 1–7.

Sahu, H.K., Das, K. Sunit, and Palei, N.C. 2012. Some observations on white-bellied sea eagle (*Haliaeetus leucogaster*) in Bhitarkanika National Park, Eastern India. *J. Tiger Paper* **39** (1): 6-9.

Sahu, H.K. and Kar, S.K. 2000. Habitat utilisation of Anatids (Family: Anatidae) in Nalaban sanctuary of Chilika lake, Orissa, India. In: *Proc. Ninth All India Cong. Zool.,* pp. 127-128.

Sahu, H.K. and Rout, S.D. 2005. Checklist of water birds in Mayurbhanja district, Orissa. *Zoo's Print J.* **20** (9): 1992-1993.

Singh, L.A.K. 1993. Survey of raptors seen in Similipal Tiger Reserve, Orissa. *Bihang Newsletter*. **1** (2): 5-6.

e-planet **16** (2): 177-181 (December 2018)

Call of conservation: Restoring the population of *Hyaena hyaena* (Linnaeus, 1758) in upper Gangetic plains, India

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ABSTRACT

Hyaena hyaena is one of the protected species in India and is listed in Schedule III of the Indian Wildlife (Protection) Act, 1972. However, only few studies have been studied on the aspect of its distribution, ecology and status in India. In the State of Uttarakhand, *Hyaena hyaena* has a patchy distribution, especially across the upper Gangetic plains. Two small populations, consisting of about 15 and five individuals have been recorded from Chilla and Gohri range of Rajaji National Park and Shyampur and Chiriapur range of the Haridwar Forest Division. Besides, 14 dens of striped hyaena have also been documented from the same forests. The movement of hyaena along the long stretch of river Ganges, from Gohri forest of the Rajaji National Park to Chiriapur forest of the Haridwar Forest Division (about 35 kilometers long) indicates that the forests in upper Gangetic plains serve as a potential breeding ground for the species. There is an urgent need to conduct a base-line survey on the distribution and ecology of the species, which includes their past and present distribution, habitat type, movement and range utilization, diet composition, breeding behaviour and success, human interactions in response to environmental pressures. Considering the species on priority in wildlife management planning is also needed for long-term conservation of the species in Uttarakhand.

Key words: Conservation, habitat, *Hyaena hyaena*, Rajaji National Park, upper Gangetic plains

INTRODUCTION

Striped hyaena is listed under Schedule III of the Indian Wildlife (Protection) Act of 1972 (Anonymous, 2017), CITES Appendix III (UNEP-WCMC, 2014), and as Near Threatened in the IUCN Red List of Threatened Species (AbiSaid and Dloniak, 2015). Striped hyaena, *Hyaena hyaena*, encompasses Africa north of and including the Sahel zone, eastern Africa south into Tanzania, the Arabian Peninsula and the Middle East up to the Mediterranean shores, Turkey, Iraq, the Caucasus, Iran, Turkmenistan, Uzbekistan, Tadzhikistan, Afghanistan and the Indian subcontinent, though not reaching Assam (in India), Bhutan or Myanmar (Hofer and Mills, 1998). It has also been presumed that they may have expanded into Nepal, where they were sighted during 1970s and 1980s (Hofer and Mills, 1998). AbiSaid and Dloniak (2015) have indicated that the global population of *H. hyaena* is below 10,000 mature individuals.

Of the four species of hyaenas found in the world (striped hyaena, *Hyaena hyaena*; brown hyaena, *Parahyaena brunnea*; spotted hyaena, *Crocuta crocuta* and aard wolf, *Proteles cristata*), *H. hyaena* is found in India and remaining three in the African continent. Striped hyaena is widely distributed in India through peninsular India, south of the Himalayas, in arid and semi-arid tracts with the exception of dense forests, true deserts and coasts; however, it is not present in the Western Ghats, or most of Tamil Nadu and Kerala, the North-East and

most of West Bengal (Menon, 2014). Even though, the striped hyaena has an important functional role in maintaining the ecosystem, only few studies have been carried out on its ecology and status, especially on species' population estimation, habitat utilization and food habits (Ilayaraja et al., 2018). As the consequences, there is a lack of reliable estimates on its distribution across most of the Indian ranges. Hofer and Mills (1998) have indicated that the distribution of striped hyaena has been patchy in most of the places, which suggested that it occurs in many small isolated populations. Mills and Hofer (1998) have estimated the population of *H. hyaena* to be over 1000 within India.

Striped hyaena is known for their powerful jaws and teeth, which help them, carry their carrion to their dens. As scavengers, hyenas are known to consume a huge variety of food, including leaves, fruits, insects, fishes, reptiles, birds and mammals (Leakey et al., 1999; Alam and Khan, 2015). The principal food of the striped hyaena consists of the carcasses of animals that have died of disease or been killed by the predators and very often it carries off portions of the body to its den (Blanford, 1888).

In the State of Uttarakhand, striped hyaena is distributed primarily in the Rajaji National Park (RNP) and Haridwar and Lansdowne forest divisions, respectively. Recently, it has also been recorded from parts of Corbett Tiger Reserve (Kalagarh forest) and three territorial forest divisions in Nandhaur valley, e.g. Haldwani, Terai East and Champawat (Gusain, 2014; Belal and Ansari, 2017). Earlier it was assumed that only a small population of this spp. is restricted to the Chilla forest of RNP.

MATERIALS AND METHODS

Rajaji National Park (RNP; 29°51′-30°15′ N, 77°52′-78°22′ E, 302 to 1000 m amsl) is a crucial wildlife habitat in the Shivalik landscape, forming the north-western limit of the range of Asian elephants, tigers, great pied hornbills and king cobras in the Indian subcontinent. It falls within the Gangetic Plains biogeographic zone and upper Gangetic Plains province (Rodgers et al., 2002), and a major portion of this area is dominated by tropical moist deciduous forest. The dominant vegetation is *Shorea robusta* (sal), *Mallotus phillipinensis* (rohini), *Senegalia catechu* (khair), *Haldina cordifolia* (haldu), *Terminalia bellirica* (bahera), *Ficus benghalensis* (Indian banayan) and *Dalbergia sissoo* Roxb. ex DC (Indian rosewood). The dominant fauna of the park consists of *Panthera tigris* (tigers), *Panthera pardus* (leopards), *Ursus thibetanus* (Himalayan black bears), *Melursus ursinus* (sloth bears), *Muntiacus muntjak* (barking deer), *Nemorhaedus goral* (goral), *Axis axis* (spotted deer), *Rusa unicolor* (sambar) and *Sus scrofa* (wild boars), and among reptiles, *Crocodylus palustris* (mugger crocodile) and *Ophiophagus hannah* (king cobra) were also reported from the park.

While studying the ecology and behaviour of Asian elephants in RNP, some observations were made on the presence of striped hyaenas in eastern part of the RNP during June 2009 to May 2010. Direct sighting and indirect evidences like presence of tracks, fresh feeding signs near dens and remains of body parts such hairs were considered for recording the presence of species. Field binoculars (Nikon Action Series, 10 × 50 CF) were used to observe the animals and a Nikon Coolpix 8700 camera was used to produce photographic evidence. Geographical coordinates were recorded using a handheld GPS receiver (Garmin GPS 72).

RESULTS AND DISCUSSION

During the field surveys, direct sightings of the species were made from Chilla and Gohri forest ranges of Rajaji National Park. Within the Chilla forest range, species was recorded from Chilla (29°58′05.2"N, 78°12′42.8"E), Khara (29°54′12.6"N, 78°16′03.5"E) and Rawasan (29°51′35.5"N, 78°19′01.3"E) forests, respectively (Table 1). Within Gohri forest range, the species was recorded from the Dugadda (30°01′16.71"N, 78°24′75.69"E) forest. Besides, observations were also made from the Shyampur (29°89'86.9"N, 78°17'41.4"E) and Chiriapur forests (29°79′81.36"N, 78°20′62.52"E) of the Haridwar Forest Division (HFD), which are contiguous to the eastern part of RNP. A total of (n=14) dens were recorded during the survey periods. The highest number of den (n=9) were collected from Chilla followed by Khara (n=4) and Rawasan (n=1).Most of the dens were found in small hillocks in rocky

terrains. Of the 14 dens, two were left over by the animals. However, dens were not documented from Gohri forest of RNP and Shyampur and Chiriapur forests of HFD.

Table 1. Sites in Rajaji National Park from where individuals of striped hyaenas were recorded from June 2009 to May 2010.

Sl.	Locality with Coordinates and date	Remarks
1.	Rajaji National Park Chilla forest (29°58′05.2”N, 78°12′42.8”E; 7 November 2009) Khara forest (29°54′12.6”N, 78°16′03.5”E; 14 May 2009) Rawasan forest (29°51′35.5”N, 78°19′01.3”E; 28 March 2010)	Individual from Chilla forest was recorded in the riparian corridor of the river Ganges. However, individuals from Khara and Rawasan forests were recorded near annual/ torrential rivers adjacent to the Shyampur and Laldhang forests of Haridwar and Lansdowne Forest Divisions, respectively.
2.	Rajaji National Park Gohri/Dugadda forest (30°01′16.71”N, 78°24′75.69”E; 14 June 2009)	An individual was recorded near boundary of Chilla and Gohri forests, adjoining to the river Ganges.
3.	Haridwar Forest Division Shyampur forest (29°89'86.9"N, 78°17'41.4"E; 18 July 2009) Chiriapur forest (29°79′81.36”N, 78°20′62.52”E; 23 May 2010)	Individuals were recorded from annual/ torrential rivers near the river Ganges

Fig. 1. Striped hyaena in Chilla forest of the Rajaji National Park.

Fig. 2. An lone striped hyaena recorded from Shyampur forest of Haridwar Forest Division.

Fig. 3. A den of striped hyaena in Khara forest of Rajaji National Park.

Fig. 4. Footprints of striped hyaena recorded from Rawasan forest of the Rajaji National Park.

Considering the direct sightings of the animals and fresh tracks in different forests, it was estimated that two small populations exist in RNP; (i) which move along the river Ganges, in Chilla and Gohri forests of the RNP and Shyampur and Chiriapur forests of HFD, respectively. This population consisted of about 15 individuals; (ii) the population which moves across the Khara, Luni and Rawasan forests of RNP, respectively, and Laldhang forest of the Lansdowne Forest Division. This population consisted of about five individuals. During the years 1999-2000, the movements of striped hyaenas were recorded across the Chilla-Motichur wildlife corridor. Besides, during the year 2006, tracks of the species were also observed from Dudhia and Ganga Majhara forest beats (small islands in the river Ganges) of the Haridwar and Motichur forest ranges. These observations indicated that nearly two decade back, striped hyaena also used to move across the Haridwar, Motichur, Dholkhand and Kansrao forest ranges of the RNP. However, their movements were rare in the southwestern part of RNP. Since the beginning of year 2000, the movement of striped hyaenas has been found restricted to the eastern part of RNP and adjoining habitats.

Harihar et al. (2010) have indicated about the presence of six to eight individuals of striped hyaena in the Chilla forest of the RNP. Another study carried out on the mammalian fauna of RNP has indicated about the presence of a small population of hyaena (~10 individuals) in the Chilla forest range of RNP (Joshi, 2016). Striped hyaenas are known to occur near human habitations, which facilitate them to feed upon domestic sources of carrion and garbage (Sharma et al., 2011; Tourani et al., 2012; Alam et al., 2014). In all study areas, most of the populations were found residing inside the protected areas. Movement of leopards (*Panthera pardus*) were frequently recorded from all the forest ranges from where striped hyaenas were recorded. Presence of animal and its dens in the eastern part of the RNP and its adjoining habitats is indicating that the population of striped hyaenas is increasing in upper Gangetic plains. Though, the rate of population rise is slow. Considering this study and the recent documentation of species from some other forest ranges in Uttarakhand State, it can be presumed that the forests in upper Gangetic plains and Terai landscape serve as a potential habitat for the species.

In order to implement the provisions contained in the Indian Wildlife (Protection) Act, 1972, the maximum families of the Gujjars (a nomadic pastoral community), which were residing within the park area were rehabilitated outside the park area has strengthened the frequent movement of wildlife within the park. Since the beginning of the year 2002 onwards substantial increases in the encounter rates of several species were apparent (Joshi, 2017; Ilayaraja et al., 2018). In the year 2015, RNP has been notified as Rajaji Tiger Reserve, which has also strengthened the management and conservation approaches within the landscape.

Increasing development and anthropogenic activities across the riparian corridors of the Ganges, shrinkage of natural water sources inside protected areas, expansion of the road network across a long chain of protected habitats, and lack of awareness among the local people regarding the ecological role of species include some of the threats observed in the study area. Since the region falls within the upper Gangetic plains, which constitutes an important repository for the mammalian fauna, it is proposed that a base-line study be initiated to evaluate the habitats and status of the species. Moreover, ensuring the active participation of local communities in wildlife management planning would be of paramount importance which can be reiterated from a recent study of human-hyaena conflict in Uttarpradesh (Ilayaraja et al., 2018).

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REFERENCES

AbiSaid, M. and Dloniak, S.M.D. 2015. *Hyaena hyaena*. The IUCN Red List of Threatened Species 2015: e.T10274A45195080. http://dx.doi.org/10.2305/IUCN.UK.2015-2.RLTS.T10274A45195080.en.

Alam, Md. S., Khan, J.A., Kushwaha S.P.S., Agrawal, R., Pathak, B.J. and Kumar S. 2014. Assessment of suitable habitat of near threatened striped hyaena (*Hyaena hyaena* L., 1758) using remote sensing and geographic information system. *Asian J. Geoinformatics* **14**(2): 1-10.

Alam, M.S. and Khan, J.A. 2015. Food habits of Striped Hyena (*Hyaena hyaena*) in a semi-arid conservation area of India. *J. Arid Land* **7**(6): 860-866.

Anonymous. 2017. *The Wildlife (Protection) Act, 1972*. Universal Law Publishing, New Delhi, India, pp. 1-204.

Belal, S.M. and Ansari, N.A. 2017. Striped hyaena *Hyaena hyaena* (Linnaeus, 1758) (Carnivora: Hyaenidae) new reports in Nandhaur valley, Terai arc landscape, Uttarakhand, India. *Int. J. Adv. Engg. Manage. Sci*. **3**(6): 651-655.

Blanford, W.T. 1888. *The Fauna of British India, Including Ceylon and Burma, Part I – Mammalia*. Taylor and Francis, Red Lion Court Fleet Street, London, pp. 1-617.

Gusain, R. 2014. First striped hyaena comes to Corbett. *India Today*. https://www.indiatoday.in/india/story/first-striped-hyena-comes-to-corbett-229928-2014-12-05. Accessed 23 October 2018.

Harihar, A., Ghosh, M., Fernandes, M., Pandav, B. and Goyal, S.P. 2010. Use of photographic capture-recapture sampling to estimate density of Striped Hyaena (*Hyaena hyaena*): implications for conservation. *Mammalia* **74**(1): 83-87.

Hofer, H. and Mills, M.G.L. 1998. Worldwide distribution of Hyaenas. In: M.G.L. Mills and H. Hofer (eds), *Hyaenas. Status Survey and Conservation Action Plan*, IUCN/SSC Hyaena Specialist Group. IUCN, Gland, Switzerland and Cambridge, UK, pp. 39-63.

Ilayaraja, S., Arun, A.S. and Baiju Raj, M.V. 2018. Prevailing human - hyena conflict in Agra district, Uttar Pradesh, India and its conservation strategies. *e-planet* **16**(1): 79-84.

Joshi, R. 2016. Mammalian fauna of Rajaji National Park, India: a review on ecological observations and checklist. *Check List* **12**(3): 1-11.

Joshi, R. 2017. Status and conservation of Asian elephant in Rajaji National Park, north India: a review on a decade of research on elephant's behavior and ecology. *NeBio*. **8**(2): 111-120.

Leakey, L.N., Milledge, S.A.H., Leakey, S.M., Edung, J., Haynes, P., Kiptoo, D.K. and McGeorge, A. 1999. Diet of striped hyaena in northern Kenya. *Afr. J. Ecol*. **37**(3): 314-326.

Menon, V. 2014. *Indian Mammals, A Field Guide*. Hachette India, Gurgaon, India, pp. 1-528.

Mills, M.G.L. and Hofer, H. 1998. *Hyaenas: Status Survey and Conservation Action Plan*. IUCN/SSC Hyaena Specialist Group. IUCN, Gland, Switzerland, pp. 1-154.

Rodgers, W.A., Panwar, H.S. and Mathur, V.B. 2002. *Wildlife Protected Areas in India: A Review (Executive Summary)*. Wildlife Institute of India, Dehradun, India, pp. 1-44.

Sharma, G., Vijay, P., Rajpurohit, L.S. and Ram, C. 2011. Ecobehaviour study and status of striped hyaena (*Hyaena hyaena* Linnaeus, 1758) in south western Rajasthan, India. *J. Evol. Biol. Res.* **3**(4): 44-46.

Tourani, M. Moqanaki, E.M. and Kiabii, B.H. 2012. Vulnerability of striped hyaena, *Hyaena hyaena*, in a human-dominated landscape of Central Iran. *Zool. Middle East*. **56**(1): 133-136.

UNEP-WCMC (Comps.) 2014. *Checklist of CITES species*. CITES Secretariat, Geneva, Switzerland and UNEP-WCMC, Cambridge, United Kingdom. Accessed on 23 October 2018.

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