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Research article

Distribution pattern and multifarious use of weeds in rice agro-ecosystems of Bhadrak district, Odisha, India

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Abstract: The weed flora associated with field crop of rice in Bhadrak district of Odisha, India is studied for a period of 2 years (June 2016 to May 2018) based on data obtained from field exploration and literature consultations. Data are collected using standard procedures. The weed association is comprised of 149 species related to 41 angiosperm families and one pteridophytic family. Angiosperms are distributed in 8 superorders and 19 orders. 36.5% of the species are recorded from the superorder Commelinids, 18.9% from Malvids, 14.9% from Lamids, 13.5% from Fabids and 10.1% from Companulids as per APG III classification. Order Poales (48), Gentianales and Asterales (14) each, Caryophyllales (13) and Fabales (11) accounts for about 67.6% of the species in the district. The predominant families are Poaceae and Cyperaceae. The dominant species are *Ammannia baccifera*, *Alternanthera sessilis*, *Argemone mexicana*, *Croton sparsiflorus*, *Cyperus alopecuroides*, *Echinochloa crusgalli*, *Eleocharis dulcis*, *Fimbristylis miliacea*, *Hygrophila auriculata*, *Ludwigia hyssopifolia* and *Oryza rufipogon*. Forty eight of the identified species are perennial and 101 annual species. The therophytes are represented by 45.6% of the life form spectrum. Habitat wise distribution analysis shows forbs share 88 species followed by grasses (29 species) and sedges (18 species) respectively. Of the reported species 37.6% are used for animal fodder, 29.5% for the treatment of various diseases and 7.4% for edible purposes. Considering the importance of weed flora in the rice fields, this research will hopefully improve the monitoring and management of weed flora in the study area and highlight their importance in maintaining ecosystem services which could be a valuable tool for its conservation, preservation and addition of the local biodiversity.

Keywords: Agroecosystem - Artifact - Biodiversity - Rice weed - Fodder - Traditional medicines.

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INTRODUCTION

Rice (*Oryza sativa* L.) is one the world's most important staple food crops and a primary food for more than a third of the world's population and has fed more people longer than any other crop, mainly in the tropics (Kumar & Ladha 2011, Mulungu 2011). In Asia, it is the main diet of 3.5 billion people and most of the countries are highly dependent on their rice yields to meet the increasing demands for food and economical security; thereby the rapidly increasing population in this region is still expected to need 70% additional rice by 2025 (Kim & Krishnan 2002). It is also the major source of income and employment for more than 100 million households in Asia and Africa (FAO 2004). The most frequent crop cultivated in India is rice which covers about 25% of the gross sown area (Singh 1974). The rice supports the local population of 1.25 billion besides other millions of people in Asian and African countries by way of exports (Bumeya & Ramanathan 2014). Odisha is a leading rice-growing state of the country with rich variety of rice cultivars. The state has 0.44 million hectares of land with this crop, producing 10,322,325 tons of paddy per year (Anonymous 2010).

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According to Yaherwandi (2009), the agricultural landscape consists of paddy ecosystem and weeds. Plants are often called weeds when they opportunistically colonize and occupy habitats artificially disrupted and maintained by humans, *e.g.*, agricultural fields, lawns, and gardens (Baker 1974). About 8000 species have been documented as weeds throughout the globe (Holm *et al.* 1977). Of these, about 200 species account for approximately 95% of weed problems in agriculture (Holm *et al.*1977, 1997). There is little doubt that weeds cause severe economic losses (Chandler & Cooke 1992) and pose a major threat to world agriculture by reducing detrimentally crop yield and quality by competing with cultivated crops for nutrients, soil, moisture and sunlight (Nyarko & Datta 1993, Pane *et al.* 2000). Moreover, weeds can significantly influence crop disease incidence by acting as vectors or reservoirs of plant pathogens (Wisler & Norris 2005). However, their positive effects cannot be ignored. Weeds have numerous interactions with other organisms and some of these interactions can have direct impacts on the functioning of the agro-ecosystem (Marshall *et al.* 2003).

Rice fields provide various ecosystem services, such as provisioning of the rice grain, rice straw, and other plant species (*i.e.* weeds) and animals; cultural services of festivals and rituals associated with farming; supporting nutrient cycles and preserving genetic diversity (Zedler & Kercher 2005). Datta & Banerjee (1978), Yamaguchi & Umemoto (1996), Backman & Tiainen (2002) and Gibbons *et al.* (2006) have focused on weeds on paddy crops and pointed out their various functions for food, medicine, prevention of soil erosion, and livestock feed. Flowers of weed can provide alternative feed and as the refuge for insects. Most insect predators and parasitoids get benefit from weeds. Ikeda & Miura (2002) underlined the major contribution of traditional agricultural practices that supports many endangered wetland plants in paddy fields. Bastiaans *et al.* (2000) concluded that weeds form the basis of the agro-ecosystem food web. Moreover, the ecology and conservation of wetlands has received much attention (Gopal & Sah1995). Currently, the number of weeds has been declining drastically in farmed landscapes due to environmental change and anthropogenic activities (Hyvonen 2007, Fried *et al.* 2009). Thus, there is an urgent need to carry out floristic surveys in rice fields, which harbor many wetland plants, especially in regions where the flora is not well documented.

The composition of the weed flora may differ depending on location, water supply, cultural practices, the inherent weed flora in the area, and the crop grown (Janiya & Moody 1983, Bhan 1983, Bernasor & De Datta 1983, Mabbayad *et al.* 1983, Janiya & Moody 1989). There have been several reports on the plant species composition of rice fields in Asia including India (Heckman 1974, Chandrasena 1988, Moody 1989, Hakansson 2003, Singh *et al.* 2008, Chang *et al.* 2009, Khaliq & Matloob 2011, Hakim *et al.* 2013, Mardiyanti *et al.* 2013, Natuhara 2013, Yun-He & Sheng 2014, Parameswaran *et al.* 2014, Fried *et al.* 2017). A perusal of literature reveals that the knowledge of rice weed communities, their diversity, composition, and distribution in Odisha is inadequate (Satapathy *et al.* 2012). This study was performed in the Bhadrak district of Odisha, India, where rice fields were the predominant land use. The purposes of this study are two fold: (1) to create an inventory of and classify rice crop weeds and (2) to describe multifarious use of weeds by the local people.

MATERIALS AND METHODS

Study site

Bhadrak district (20°43′–21°13′ N and 86°6′–87° E) is located in northeast Odisha, India and covers an area of 2505 km^2, with a population of 1.507 million (2011 Census). It is bordered by Balasore district in the north, Jajpur in the south, Bay of Bengal and Kendrapara district in the east and Koenjhar in the west. The district accounts for 1.61% of the state's territory and shares 3.62% of the state's population. The climate of the region is generally hot and humid with May being the hottest month. Three distinct annual seasons are the rainy season (mid-June to mid-October), winter (mid-October to February) and summer (March to mid-June). The maximum and minimum temperatures range from 37.4°C to 17.7°C respectively and the annual average rainfall is approximately 1428 mm (Anonymous 2009, Anonymous 2016). Being located near Bay of Bengal, the district is characterized by periodic earth tremors, rain with thunderstorms and dust storms during April and May (Fig. 1).

The area basically is comprised of deltas formed by two major rivers namely Salandi and Baitarani and half a dozen of rivers and rivulets. Thus the whole district is a fertile monotonous alluvial plain that slopes from west to east following the river gradients. The plain is usually intersected by its own set of rivers and marshland can be seen here and there prominently close to sea line. The soil in Bhadrak district are classified into four categories viz. matured, red & lateritic soil (alfisols), mixed grey soil (inceptisols), unaltered soil with coarse parent materials (entisols) and unclassified soil (with mudflats). Among all these, inceptisols are found to be the most dominant group of soil in most of the blocks of district (Dhamnagar, Tihidi, Chandbali, Bonth, Bhadrak

and Basudevpur) except Bhandaripokhari block where alfisols are the dominant soil group. The rice production of the district is 514113.8 tons (Anonymous 2009, Anonymous 2016).

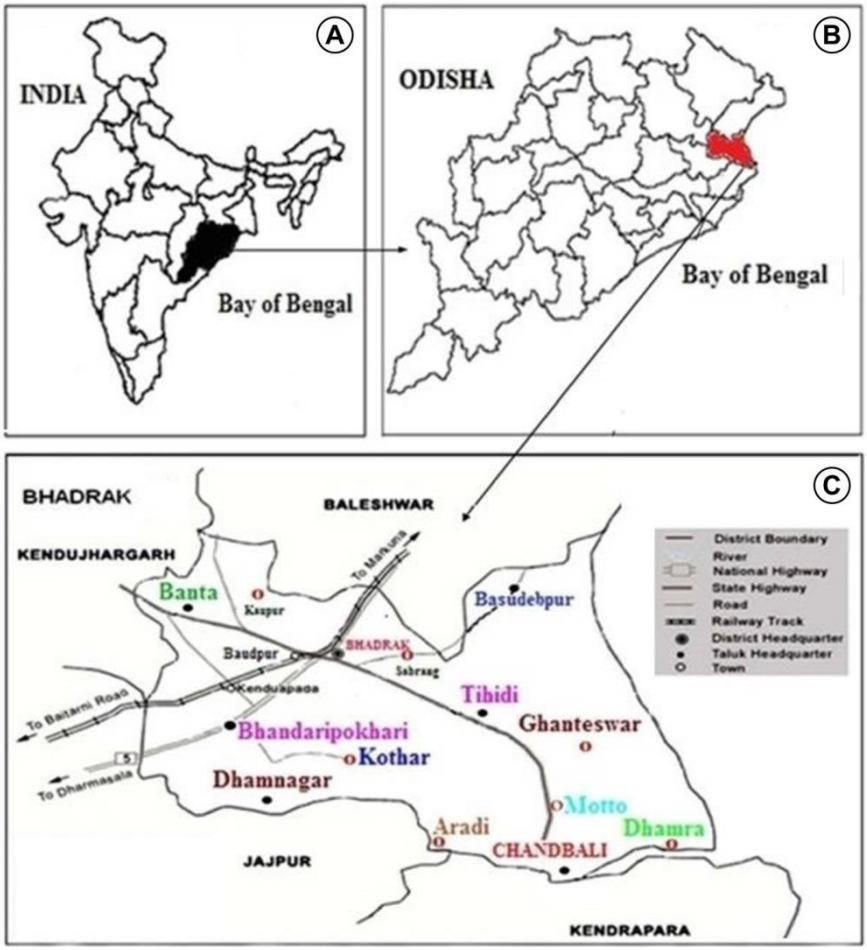

Figure 1. A, Location of Odisha state in the eastern region of India; **B**, Map of Odisha state showing Bhadrak district; **C**, Study area showing different blocks of the Bhadrak district.

Data Collection

The methods employed in this study were designed with the purpose of providing a base line information on the distribution and use of weed plant species through literature survey and field visits to various areas (seven blocks of the district *i.e.* Basudevpur, Bhadrak, Bhandaripokhari, Bonth, Chandbali, Dhamnagar and Tihidi) from June 2016 to May 2018 in Bhadrak district, Odisha, India. A total of 42 sample plots (29 plots in autumn-ripening fields, and 13 plots in summer-ripening fields) covering all the blocks were selected. The field study was carried out monthly following established and standard procedures (Jain 1987, Martin 1995). In this investigation, weed species were collected in rice field proper and the bund (levee). The information on the use of weed plants if any was obtained through questionnaires, complemented by free interviews and informal conversations (Martin 1995, Huntington 2000). Elderly farmers in each village were considered the key informants, and the selection process was based on the knowledge base, experience, and current agricultural practices. The interviews and discussions were carried out individually as well as in groups with members of the local population in the local language for each of the villages visited. Personal interviews and group discussions with local inhabitants revealed some valuable and specific information about the plants, which were further compared and authenticated by crosschecking (Cunningham 2001). Eighty-nine (77 men and 12 women) persons were interviewed. Interviews with people were conducted to know local names and uses of sampled plants if any as well as the rice cropping system (cropping seasons, fertilizer application, water management, weed control, yield, grazing after harvest). The collected specimens were processed, dried and herbarium specimens were prepared. All the voucher specimens were maintained in the herbarium of Chandbali College, Chandbali. The plant species are enumerated and arranged as per Angiosperm Phylogeny Group III Classification (APG III 2009). The consulted literatures during field time for identification of species were Haines (1925) and Saxena & Brahmam (1996). All the plant species were classified on the basis of life forms as defined by Raunkiaer (1934).

RESULTS

In the present study, altogether 149 weed species belonging to 41 families and 112 genera from angiosperm and one pteridophyte family were recorded from different rice fields of Bhadrak district (Table 1; Figs. 2–7). The angiosperm taxa were distributed in 112 genera.These taxa were grouped under 9 superorders and 19 orders. 36.5% of the species were reported from the superorder Commelinids, 18.9% from Malvids, 14.9% from Lamids, 13.5% from Fabids, and 10.1% from Commelinids as per APG III classification (Fig. 8). Order Poales (48), Gentianales and Asterales (14) each, Carylophyllales (13) and Fabales (11) shared for about 67.6% of the species in the district. The families Poaceae, Cyperaceae, Asteraceae, Fabaceae and Amaranthaceae were well represented. Commelinaceae, Euphorbiaceae, Onagraceae, Cleomaceae, Malvaceae, Convolvulaceae, Lythraceae, Rubiaceae, Acanthaceae and Scrophulariaceae were moderately represented, while other families between one and two species. The foremost species recorded were *Aeschynomene aspera* L., *Alternanthera sessilis* (L.) R.Br. ex DC., *Ammannia baccifera* L., *Argemone mexicana* L., *Centella asiatica* (L.) Urb., *Corchorus olitorius* L., *Croton sparsiflorus* Morong., *Cyperus alopecuroides* Rottb., *Cyperus difformis* L., *Cyperus iria* L., *Cyperus rotundus* L., *Desmodium triflorum* (L.) DC., *Echinochloa crusgalli* (L.) P. Beauv., *Echinochloa colona* (L.) Link., *Eleusine indica* (L.) Gaertn., *Eclipta prostrata* (L.) L., *Fimbristylis dichotoma* (L.) Vahl, *Fimbristylis miliacea* (L.) Vahl, *Hygrophila auriculata* (Schum.) Heine., *Hydrolea zeylanica* (L.) Vahl, *Ipomoea aquatica* Forssk., *Ischaemum rugosum* Salisb., *Lindernia antipoda* (L) Alston., *Ludwigia hyssopifolia* (G.Don) Exell, *Ludwigia perennis* L. *Murdannia nudiflora* (L.) Brenan, *Oryza rufipogon* Griff., *Oxalis corniculata* L., *Scirpus articulatus* L. and *Scoparia dulcis* L. With respect to life span, annual weeds with 101 species were the most diverse and the remaining were perennials. The therophytes were the most dominant class with 68 plant species (45.6%) followed by chamaephytes with 27 species (18.1%), hydrophytes with 20 species(13.4%), cryptophytes and hemicryptophytes with 15 species each (10.1%), helophytes with 3 species (2%) and phanerophytes having one species (0.7%) respectively.

Table 1. List of weed flora recorded from Bhadrak district, arranged according to the Angiosperm Phylogeny Group Classification III.

Superorder/Order	Family / Species	Common Name	Habit	Life Span	Life Form	Uses
EARLY ANGIOSPERMS						
Nymphaeales	**Nymphaeaceae**					
	Nymphaea nouchali Burm. f.	Kain	Forb	P	Hyd	Medicinal, edible
	Nymphaea pubescens Willd.	Rangakain	Forb	P	Hyd	Edible
MONOCOTS						
Alismatales	**Aponogetonaceae**					
	Aponogeton natans (L.) Engl. & Krause	Jhechu	Forb	P	Hyd	Edible
	Aponogeton undulatus Roxb.		Forb	P	Hyd	Edible
	Araceae					
	Pistia stratiotes L.	Borajhanji	Forb	A	Hyd	Medicinal
	Hydrocharitaceae					
	Hydrilla verticillata (L.f.) Royle.	Chingudiadala	Forb	P	Hyd	Medicinal
	Ottelia alismoides (L.) Pers.	Panikundri	Forb	P	Hyd	Medicinal
Asparagales	**Amaryllidacea**e					
	Crinum asiaticum L.	Arsa	Forb	P	Cr	Medicinal
COMMELINIDS						
Commelinales	**Commelinaceae**					
	Commelina benghalensis L.	Kansiri	Forb	A	Ch	Medicinal
	Commelina difusa Burm.f		Forb	A	Ch	Medicinal
	Cyanotis axillaris (L) Schult. & Schult. f.		Forb	A	Ch	Fodder
	Murdannia nudiflora (L.) Brenan	Kanduli	Forb	A	Ch	Fodder
	Pontederiaceae					
	Eichhornia crassipes Solms	Bilatidala	Forb	P	Hyd	Not Known
	Monocharia hastata Solm-Laub.		Forb	P	Hyd	Edible
Poales	**Poaceae**					
	Brachiaria reptans (L.) Garde. & Hubb.		Grass	A	Ch	Fodder
	Chloris barbata Sw.		Grass	P	Hem	Fodder
	Chrysopogon aciculatus (Retz.) Trin.	Guguchia	Grass	P	Cr	Medicinal

	Coix lacryma-jobi L.	Gargara	Grass	A	Th	Fodder
	Cynodon dactylon (L.) Pers.	Duba	Grass	P	Hem	Medicinal/ Rituals
	Dactyloctenium aegyptium (L.) P. Beauv.	Kakhuriya	Grass	A	Hem	Fodder
	Digitaria cilliaris Retz. Koeler		Grass	A	Ch	Fodder
	Echinochloa colona (L.) Link	Swanghas	Grass	A	Th	Edible
	Echinochloa crusgalli (L.) P. Beauv.	Dhera	Grass	A	Th	Edible
	Eleusine indica (L.) Gaertn.	Anamandia	Grass	A	Hem	Fodder
	Eragrostis ciliata (Roxb) Nees.		Grass	P	Cr	Fodder
	Eragrostis gangetica (Roxb.) Steud.	Kankra chare	Grass	A	Cr	Fodder
	Heteropogon contortus (L.) P. Beauv.	Dauria	Grass	P	Cr	Fodder
	Imperata cylindrica (L.) Raeusch.	Chhana ghas	Grass	P	Hem	Fodder
	Isachne globosa (Thunb.) Kuntze		Grass	A	Th	Fodder
	Ischaemum rugosum Salisb.	Tuli	Grass	A	Hem	Fodder
	Leptochloa chinensis (L.) Nees.	Bhuru	Grass	A	Hem	Fodder
	Oplismenus burmanii (Retz.) P. Beauv.	Kanguria	Grass	A	Th	Fodder
	Oryza rufipogon Griff.	Balunga	Grass	P	Th	Fodder
	Panicum psilopodium Trin.		Grass	A	Th	Fodder
	Panicum repens L.	Reda	Grass	P	Th	Fodder
	Paspalum distichum L.		Grass	P	Th	Fodder
	Phragmites karka (Retz.) Trin. ex Steud.	Noto	Grass	A	Th	Fodder
	Saccharum spontaneum L.	Kashatundi	Grass	P	Hel	Fodder
	Setaria intermedia Roem. & Schult.		Grass	A	Th	Fodder
	Setaria pumila (Poir.) Roem. & Schult.	Sial legunda	Grass	A	Th	Fodder
	Setaria verticillata (L.) P. Beauv.		Grass	A	Th	Fodder
	Sporobolus indicus (L.) R. Br.	Kankra chara	Grass	P	Th	
	Vetiveria zizanioides (L.) Nash.	Bena	Grass	P	Th	Artifact
	Cyperaceae					
	Bulbostylis barbata (Roxb.) C.B.Cl.		Sedge	A	Th	Fodder
	Cyperus alopecuroides Rottb.	Hensuati	Sedge	P	Th	Artifact
	Cyperus brevifolius (Rottb.) Hassk.		Sedge	P	Cr	Fodder
	Cyperus castaneus Willd.		Sedge	A	Th	Fodder
	Cyperus compressus L.		Sedge	A	Hel	Fodder
	Cyperus difformis L.	Swonli	Sedge	A	Ch	Fodder
	Cyperus iria L.		Sedge	A	Ch	Fodder
	Cyperus rotundus L.	Mthaghas	Sedge	P	Hem	Medicinal
	Eleocharis acutangula (Roxb.) Schult. & Schult.		Sedge	P	Cr	Not known
	Eleocharis dulcis (Burm.f.) Henschef		Sedge	A	Cr	Not known
	Fimbristylis dichotoma (L.) Vahl		Sedge	A	Ch	Fodder
	Fimbristylis ferruginea (L.) Vahl		Sedge	P	Hem	Fodder
	Fimbristylis miliacea(L.) Vahl		Sedge	A	Hem	Fodder
	Fimbristylis ovata (Burm.f.) JKern.		Sedge	A	Hem	Fodder
	Fuirena ciliaris (L.) Roxb.		Sedge	A	Th	Fodder
	Kylinga nemoralis (J.R. & G. Forst) Dandy ex Hutch. & Dalz.		Sedge	P	Th	Not Known
	Scirpus articulatus L.	Kanri	Sedge	A	Hem	Not Known
	Scirpus grossus L.	Santara	Sedge	P	Cr	Not Known
	Typhaceae					
	Typha angustata Bory. & Chaub	Hangla	Forb	P	Ph	Medicinal
CORE EUDICOTS						
Ranunculales	**Papaveraceae**					
	Argemone mexicana L.	Kantakusuma	Forb	A	Th	Medicinal
FABIDS						
Zygophyllales	**Zygophyllaceae**					
	Tribulus terrestris L.	Gokhara	Forb	P	Ch	Medicinal
Oxalidales	**Oxalidaceae**					
	Oxalis corniculata L.	Ambiliti	Forb	A	Cr	Medicinal, edible
Malpighiales	**Euphorbiaceae**					
	Chamaesyce hirta (L.) Millsp.		Forb	A	Th	Medicinal
	Croton sparsiflorus Morong.	Nandababuli	Forb	P	Th	Medicinal

	Euphorbia hirta L.	Harharika	Forb	A	Th	Medicinal
	Euphorbia heterophyla L.		Forb	A	Th	Not known
	Phyllanthaceae					
	Phyllanthus amarus Schum. & Thonn.	Bhuianla	Forb	A	Th	Medicinal
	Phyllanthus urinaria L.	Bhuiamla	Forb	A	Th	Medicinal
	Violaceae					
	Hybanthus enneaspermus (L.) F.v.Muell.	Madan mastak	Forb	A	Ch	Medicinal
Fabales	**Fabaceae**					
	Aeschynomene indica L.	Sola	Legume	A	Cr	Not Known
	Aeschynomene aspera L.	Sola	Legume	A	Cr	Artifact
	Alysicarpus monilifer (L.) DC.		Legume	A	Th	Fodder
	Crotalaria prostrata Rottl. ex Willd.	Jhumka	Legume	P	Th	Fodder
	Desmodium triflorum (L.) DC.	Kaansisna	Legume	A	Th	Fodder
	Indigofera linnaei Ali		Legume	P	Th	Fodder
	Melilotus indica (L.) All	Bana methi	Legume	A	Th	Fodder
	Mimosa pudica L.	Lajakuli	Legume	P	Th	Medicinal
	Smithia conferta J.E. Sm.	Sanomungo	Legume	A	Th	Fodder
	Tephrosia purpurea (L.) Pers.	Banakolathi	Legume	P	Th	Medicinal
	Vigna trilobata (L.) Verdc.		Legume	A	Cr	Fodder
MALVIDS						
Myrtales	**Onagraceae**					
	Ludwigia adscendens (L.) Hara	Jagal	Forb	A	Hyd	Edible
	Ludwigia hyssopifolia (G.Don) Exell		Forb	A	Hyd	Medicinal, edible
	Ludwigia octovalvis (Jacq.) Raven		Forb	A	Hyd	Medicinal
	Ludwigia perennis L.	Latkera	Forb	A	Hyd	Not Known
	Lythraceae					
	Ammannia baccifera L.	Ramdauni	Forb	A	Th	Fodder
	Ammannia multiflora Roxb.		Forb	A	Th	Fodder
	Rotala indica (Willd.) Koehne		Forb	A	Th	Fodder
Brassicales	**Cleomaceae**					
	Cleome gynandra L.	Arakasago	Forb	A	Th	Medicinal
	Cleome monophylla L.	Rangasorish	Forb	A	Th	Not Known
	Cleome rutidosperma DC.		Forb	A	Th	Medicinal
	Cleome viscosa L.	Anasorisho	Forb	A	Th	Medicinal
Malvales	**Malvaceae**					
	Corchorus aestuans L.	Bananalita	Forb	A	Th	Medicinal
	Corchorus olitorius L.		Forb	A	Th	Not Known
	Melochia corchorifolia L.	Telpuri	Forb	**A**	Th	Not Known
	Sida acuta Burm.f.	Sunakhadika	Forb	A	Th	Medicinal
Caryophyllales	**Aizoaceae**					
	Trianthema portulacastrum L.	Purinisaga	Forb	A	Th	Medicinal
	Polygonaceae					
	Polygonum plebeium R.Br.	Muthisaga	Forb	A	Th	Medicinal
	Molluginaceae					
	Glinus oppositifolius (L.) A. DC.	Pitasaga	Forb	A	Th	Medicinal, edible
	Amaranthaceae					
	Achyranthes aspera L.	Apamaranga	Forb	A	Th	Medicinal
	Aerva lanata (L.) Juss ex Sch.	Paunsia	Forb	A	Th	Fodder
	Alternanthera philoxeroides (Mart) Griseb.		Forb	P	Hyd	Fodder
	Alternanthera sessilis (L.) R.Br. ex DC.	Madranga	Forb	P	Hyd	Medicinal, edible
	Amaranthus spinosus L.	Kantaneutia	Forb	P	Ch	Medicinal, edible
	Celosia argentea L.	Chulia	Forb	A	Ch	Medicinal
	Gomphrena serrata L.		Forb	A	Th	Medicinal
	Portulacaceae					
	Portulaca oleracea L.	Badabalbaula	Forb	A	Ch	Medicinal, edible
	Portulaca quadrifida L.	Balbaula	Forb	A	Ch	Edible

	Nyctaginaceae					
	Boerhavia diffusa L.	Puruni	Forb	P	Th	Medicinal, edible
LAMIDS						
Gentianales	**Rubiaceae**					
	Dentella repens (L.) J.R. & Forst.		Forb	A	Th	Fodder
	Hedyotis corymbosa (L.) Lam.	Jarjati	Forb	A	Ch	Medicinal
	Spermacoce articularis L.f.	Solaganthi	Forb	A	Ch	Fodder
Lamiales	**Acanthaceae**					
	Acanthus ilicifolius L.	Harkanch	Shrub	P	Hel	Medicinal
	Hygrophila auriculata (Schum.) Heine.	Koelekha	Forb	P	Ch	Medicinal
	Rungia pectinata (L.) Nees.		Forb	A	Th	Not Known
	Lamiaceae					
	Leucas aspera (Willd.) Link.	Gaiso	Forb	P	Ch	Medicinal
	Scrophulariaceae					
	Bacopa monnieri (L.) Pennell.	Brahmi	Forb	A	Ch	Medicinal
	Lindernia antipoda (L) Alston.		Forb	A	Th	Fodder
	Lindernia crustacea (L.) F.v.Muell.		Forb	A	Th	Not Known
	Plantaginaceae					
	Mecardonia procumbens (Mills.) Small		Forb	A	Ch	Not Known
	Scoparia dulcis L.	Chirarita	Forb	P	Ch	Not Known
	Verbenaceae					
	Phyla nudiflora (L.) Greene		Forb	A	Th	Fodder
	Lippia javanica (Burn.f) Spreng	Naguari	Forb	P	Ch	Medicinal
Solanales	**Convolvulaceae**					
	Evolvulus alsinoides (L.) L.	Bichhamalia	Forb	A	Hem	Medicinal
	Evolvulus nummularius (L.) L.		Forb	A	Hem	Not Known
	Ipomoea aquatica Forssk.	Kalamasaga	Climber	A	Hyd	Medicinal, edible
	Merremia tridentate (L.) Hall. f.		Climber	A	Th	Fodder
	Hydroleaceae					
	Hydrolea zeylanica (L.) Vahl	Languliya	Forb	P	Hyd	Fodder
	Sphenocleaceae					
	Sphenoclea zeylanica Gaerntn.	Panimircho	Forb	A	Hyd	Fodder
	Solanaceae					
	Solanum surattense Burm. f.	Beji-begun	Forb	P	Th	Medicinal
Boraginales	**Boraginaceae**					
	Heliotropium indicum L.	Hatisundha	Forb	A	Th	Medicine
CAMPANULIDS						
Asterales	**Asteraceae**					
	Ageratum conyzoides L.	Poksunga	Forb	A	Th	Medicinal
	Blumea membranacea Wall. ex. DC.	Poksunga	Forb	A	Th	Not Known
	Eclipta prostrata (L.) L.	Bhrungaraj	Forb	A	Th	Medicinal
	Emila sonchifolia (L.) DC. ex Wight.	Sarkara	Forb	A	Ch	Not Known
	Enydra fluctuans Lour.	Hidmichi	Forb	A	Cr	Medicinal
	Gnaphalium polycaulon Pers.		Forb	A	Th	Not Known
	Grangea *maderaspatana* (L.) Poir.	Painjari	Forb	A	Ch	Not Known
	Sphaeranthus indicus L.	Bhuikadamba	Forb	A	Th	Not Known
	Spilanthes paniculata Wall. ex. DC.		Forb	A	Ch	Fodder
	Tridax procumbens L.	Bisalyakarani	Forb	P	Th	Medicinal
	Vernonia cinerea (L.) Less.	Poksunga	Forb	A	Th	Medicinal
	Xanthium indicum Koenig.		Forb	A	Ch	Not Known
	Menyanthaceae					
	Nymphoides hydrophylla (Lour.) Kuntze		Forb	P	Hyd	Edible
	Nymphoides indicum (L.) Kuntze		Forb	P	Hyd	Edible
Apiales	**Apiaceae**					
	Centella asiatica (L.) Urb.	Thalkudi	Forb	A	Hem	Medicinal, edible
Pteridophyte	**Marsileaceae**					
	Marsilea minuta L.		Forb	A	Cr	Edible

Note: A, Annual; P, Perennial; Ch, Chamaephyte; Cr, Cryptophyte; Hem, Hemicryptophyte; Ph, Phanerophyte; Hel, Helophytes; Hyd, Hydrophyte; Th, Therophyte.

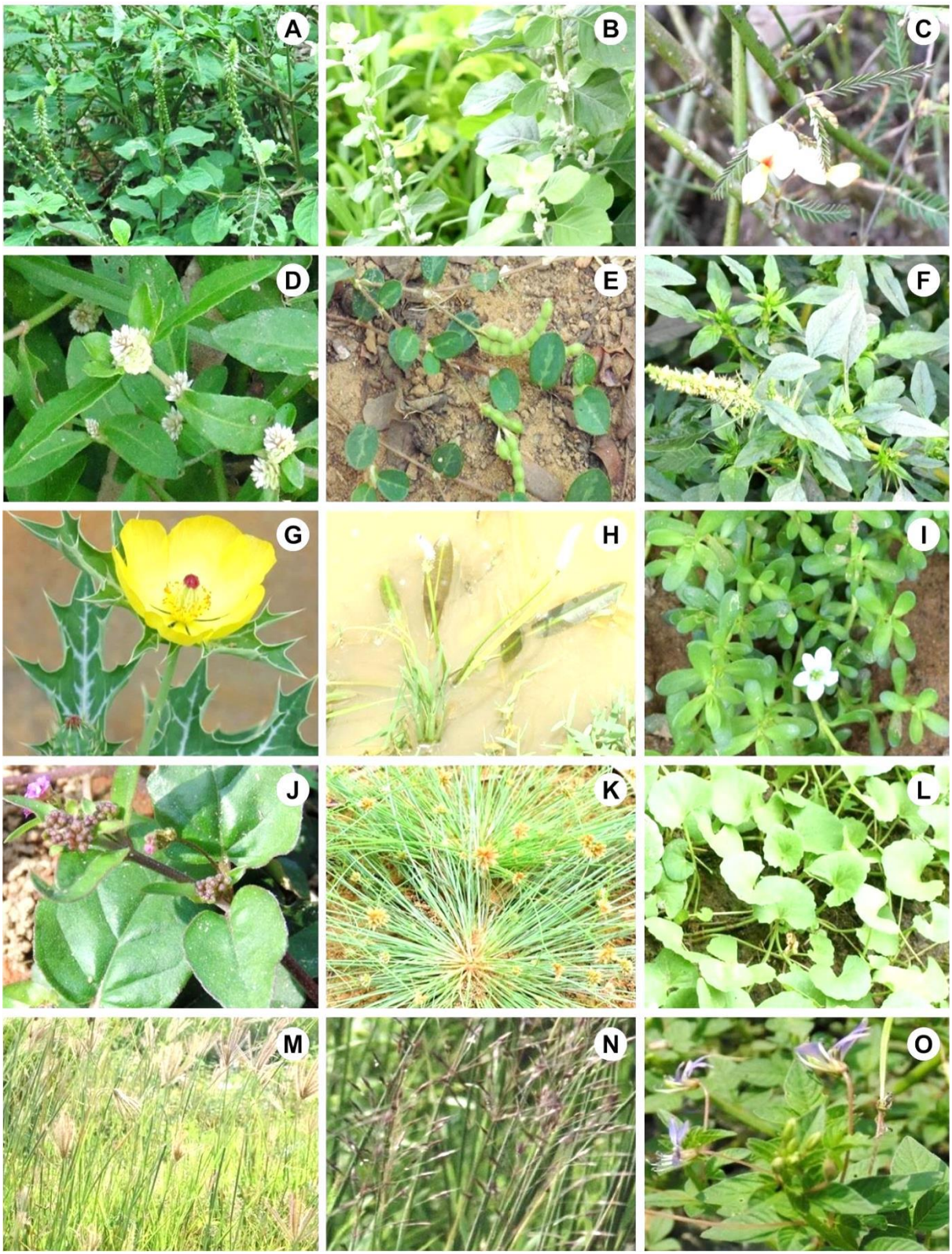

Figure 2. Some plant species observed during the study: **A**, *Achyranthes aspera* L.; **B**, *Aerva lanata* (L.) Juss ex Sch.; **C**, *Aeschynomene aspera* L.; **D**, *Alternanthera sessilis* (L.) R.Br. ex DC.; **E**, *Alysicarpus monilifer* (L.) DC.; **F**, *Amaranthus spinosus* L.; **G**, *Argemone mexicana* L.; **H**, *Aponogeton natans* (L.) Engl. & Krause; **I**, *Bacopa monnieri* (L.) Pennell.; **J**, *Boerhavia diffusa* L.; **K**, *Bulbostylis barbata* (Rottb.) C.B.Cl.; **L**, *Centella asiatica* (L.) Urban; **M**, *Chloris barbata* Sw.; **N**, *Chrysopogon aciculatus* (Retz.) Trin.; **O**, *Cleome rutidosperma* DC. [Photographs by Taranisen Panda]

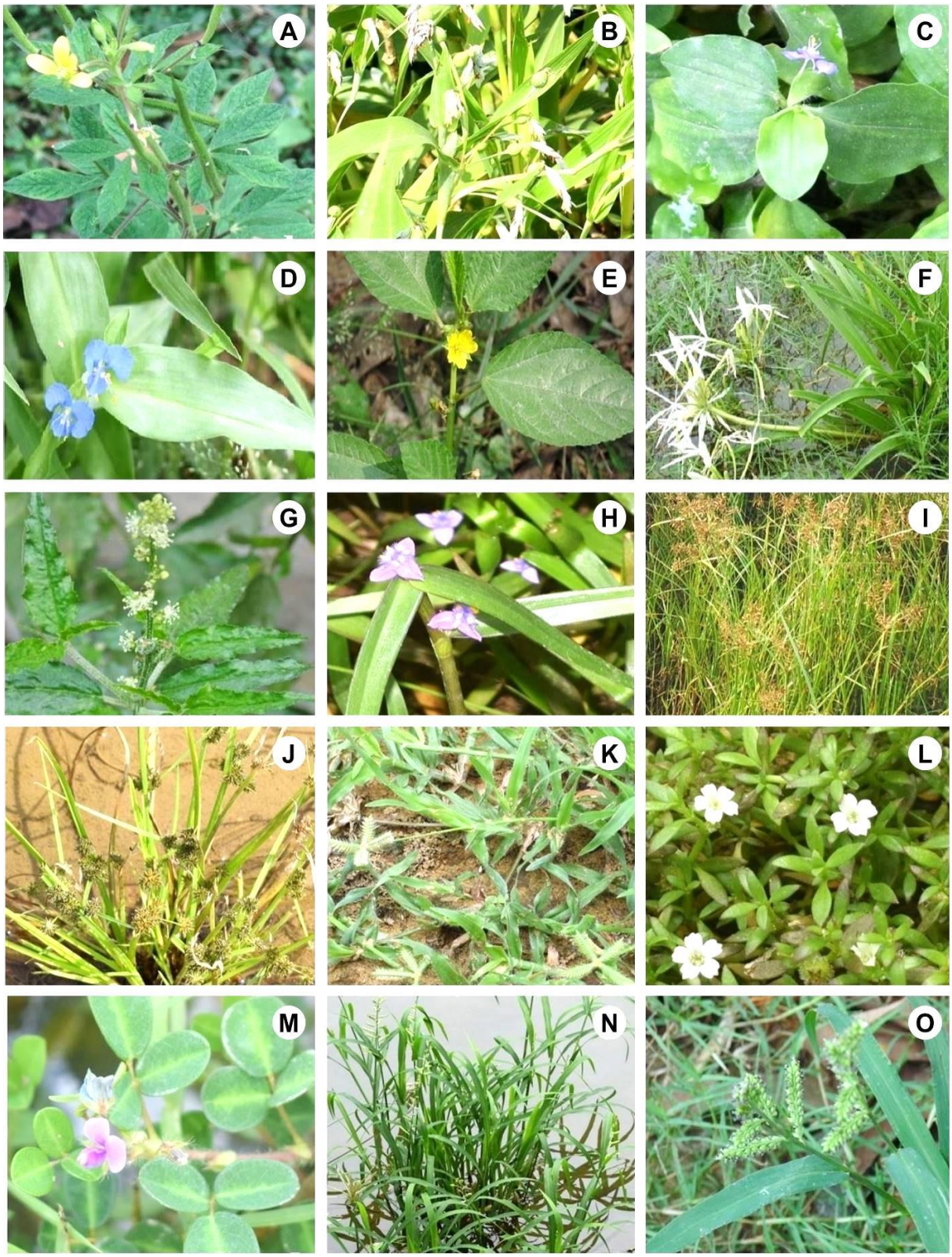

Figure 3. Some plant species observed during the study: **A**, *Cleome viscosa* L.; **B**, *Coix lacryma-jobi* L.; **C**, *Commelina benghalensis* L.; **D**, *Commelina difusa* Burm.f.; **E**, *Corchorus olitorius* L.; **F**, *Crinum asiaticum* L.; **G**, *Croton sparsiflorus* Morong.; **H**, *Cyanotis axillaris* (L) Schult. & Schult. f.; **I**, *Cyperus alopecuroides* Rottb.; **J**, *Cyperus difformis* L.; **K**, *Dactyloctenium aegyptium* (L.) P. Beauv.; **L**, *Dentella repens* (L.) Forst. et Forst.; **M**, *Desmodium triflorum* (L.) DC.; **N**, *Echinochloa colona* (L.) Link; **O**, *Echinochloa crusgalli* (L.) P. Beauv.;. [Photographs by Taranisen Panda]

Figure 4. Some plant species observed during the study: **A**, *Eclipta alba* (L.) Hassk.; **B**, *Eichhornia crassipes* Solms; **C**, *Eleocharis dulcis* (Burm. f) Henschef; **D**, *Eleusine indica* (L.) Gaertn.; **E**, *Evolvulus alsinoides* (L.) L.; **F**, *Evolvulus nummularius* (L.) L.; **G**, *Fimbristylis miliacea* (L.) Vahl; **H**, *Hybanthus enneaspermus* (L.) F.v. Muell.; **I**, *Glinus oppositifolius* (L.) A. DC.; **J**, *Gnaphalium polycaulon* Pers.; **K**, *Gomphrena serrata* L.; **L**, Grangea *maderaspatana* (L.) Poir.; **M**, *Heliotropium indicum* L.; **N**, *Hydrilla verticillata* (L. f.) Royle.; **O**, *Hydrolea zeylanica* (L.) Vahl. [Photographs by Taranisen Panda]

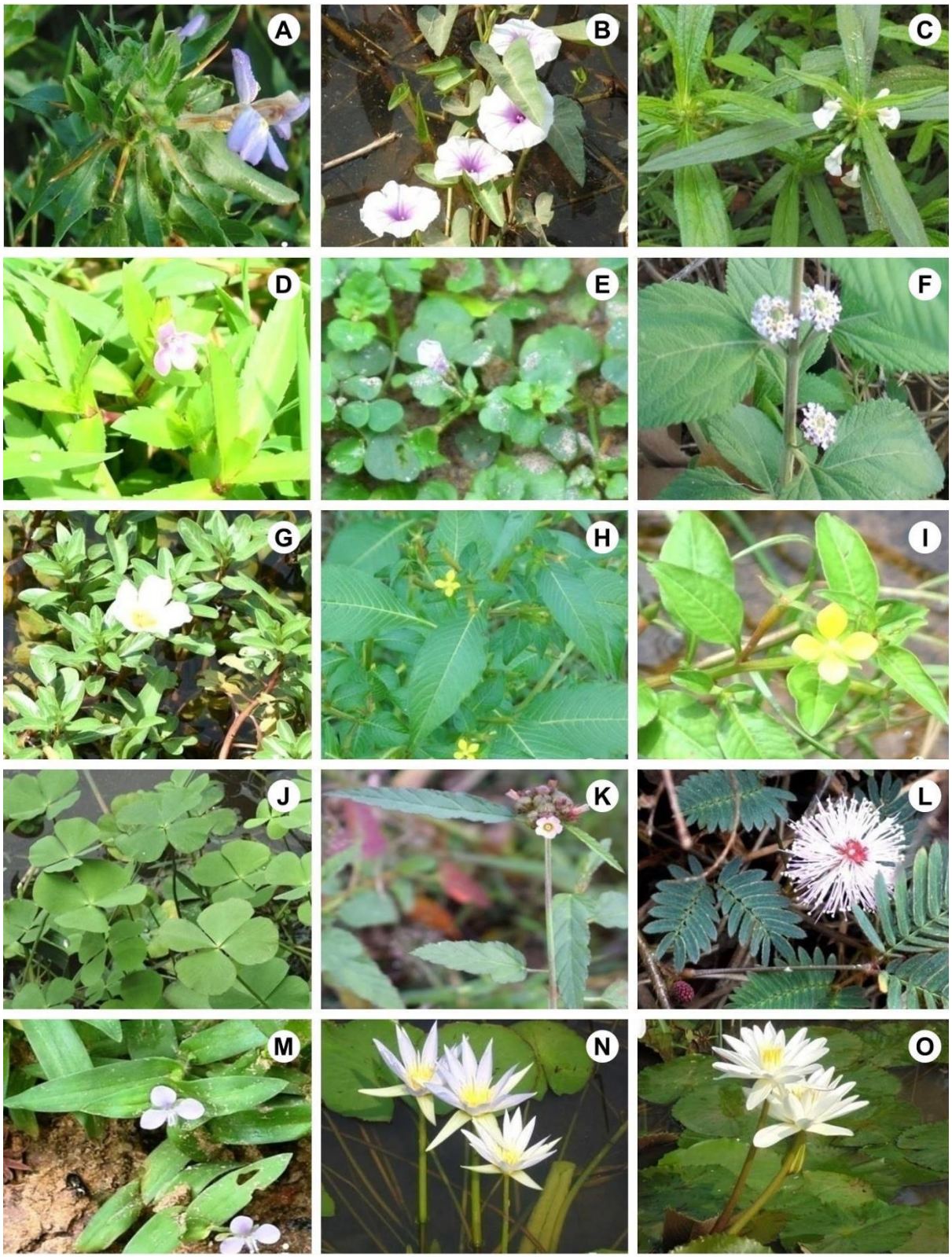

Figure 5. Some plant species observed during the study: **A**, *Hygrophila auriculata* (Schum.) Heine.; **B**, *Ipomoea aquatica* Forssk.; **C**, *Leucas aspera* (Willd.) Link.; **D**, *Lindernia antipoda* (L) Alston.; **E**, *Lindernia crustacea* (L.) F.v.Muell.; **F**, *Lippia javanica* (Burn.f) Spreng; **G**, *Ludwigia adscendens* (L.) Hara; **H**, *Ludwigia hyssopifolia* (G.Don) Exell; **I**, *Ludwigia perennis* L.; **J**, *Marsilea minuta* L.; **K**, *Melochia corchorifolia* L.; **L**, *Mimosa pudica* L.; **M**, *Murdannia nudiflora* (L.) Brenan; **N**, *Nymphaea nouchali* Burm.f.; **O**, *Nymphaea pubescens* Willd. [Photographs by Taranisen Panda]

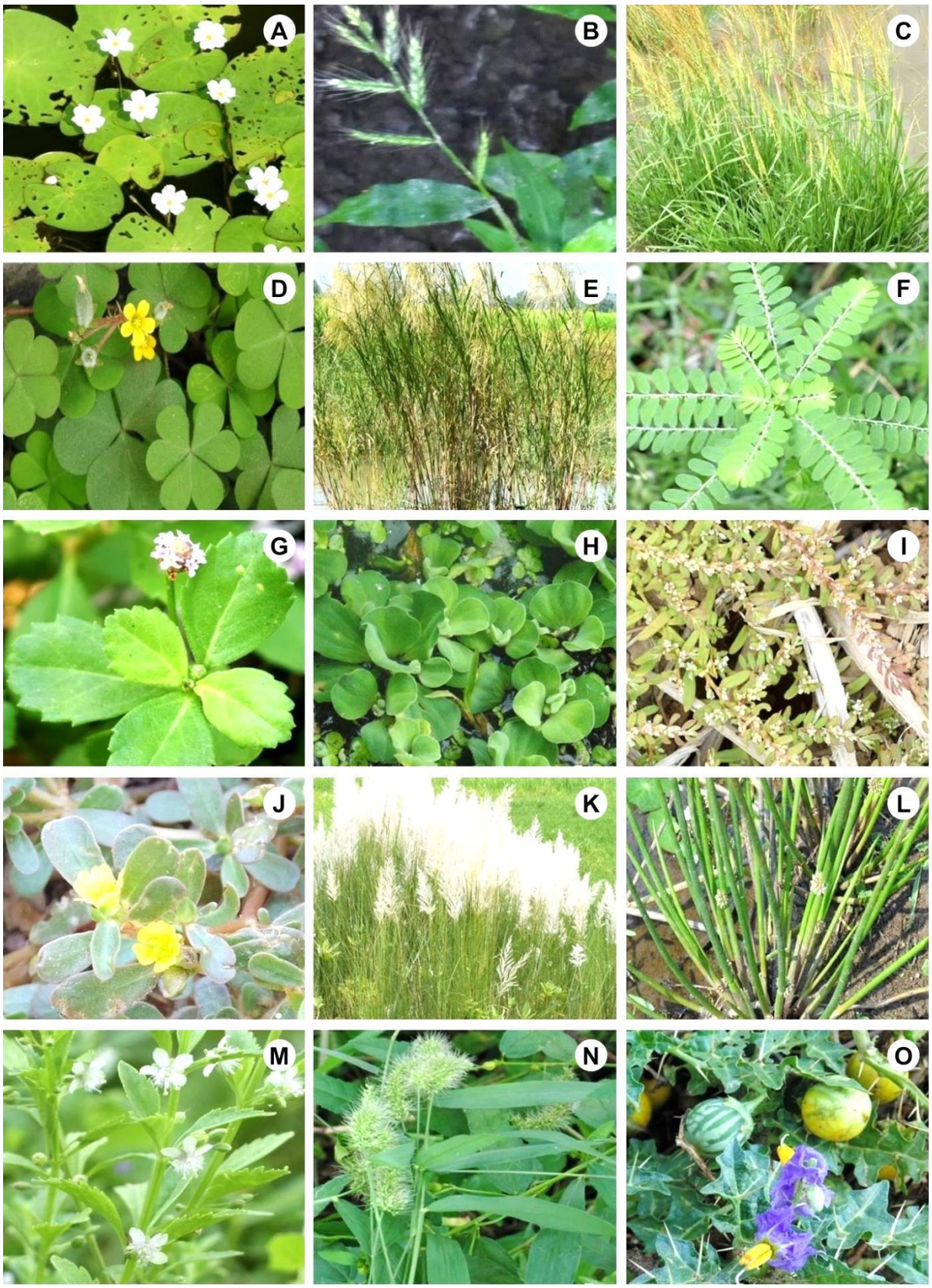

Figure 6. Some plant species observed during the study: **A**, *Nymphoides hydrophylla* (Lour.) Kuntze; **B**, *Oplismensus burmanii* (Retz.) P. Beauv.; **C**, *Oryza rufipogon* Griff.; **D**, *Oxalis corniculata* L.; **E**, *Phragmites karka* (Retz.) Trin. ex Steud.; **F**, *Phyllanthus amarus* Schum. & Thonn.; **G**, *Phyla nudiflora* (L.) Greene; **H**, *Pistia stratiotes* L.; **I**, *Polygonum plebeium* R.Br.; **J**, *Portulaca oleracea* L.; **K**, *Saccharum spontaneum* L.; **L**, *Scirpus articulatus* L.; **M**, *Scoparia dulcis* L.; **N**, *Setaria verticillata* (L.) P. Beauv.; **O**, *Solanum surattense* Burm. f. [Photographs by Taranisen Panda]

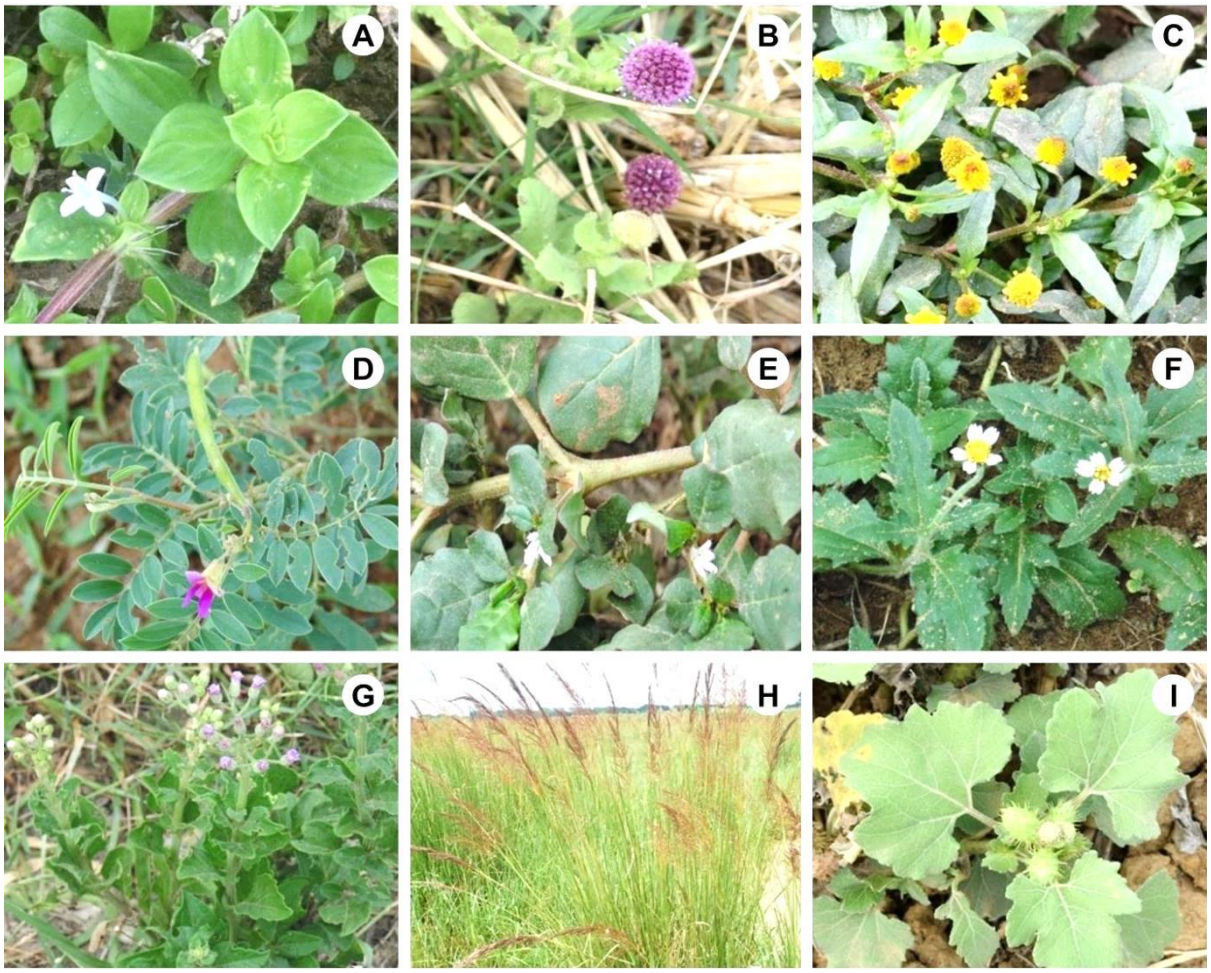

Figure 7. Some plant species observed during the study: **A**, *Spermacoce articularis* L.f.; **B**, *Sphaeranthus indicus* L.; **C**, *Spilanthes paniculata* Wall ex DC.; **D**, *Tephrosia purpurea* (L.) Pers.; **E**, *Trianthema portulacastrum* L.; **F**, *Tridax procumbens* L.; **G**, *Vernonia cinerea* (L.) Less.; **H**, *Vetiveria zizanioides* (L.) Nash.; **I**. *Xanthium indicum* Koenig. [Photographs by Taranisen Panda]

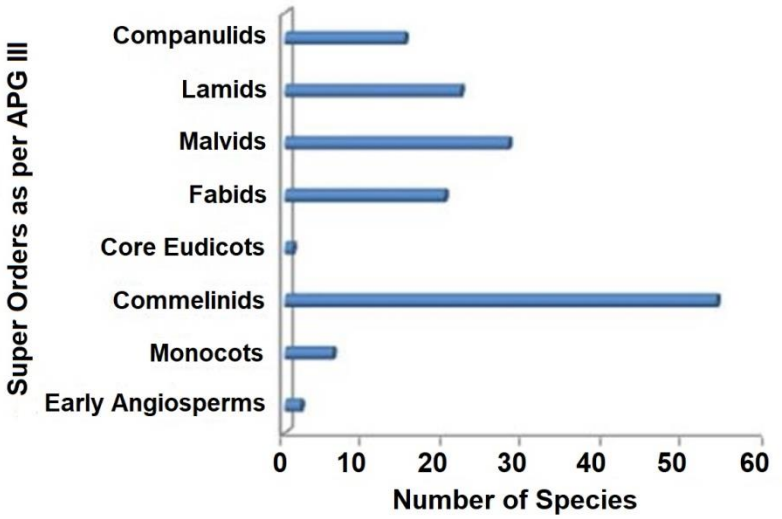

Figure 8. Distribution of species in super order as per APG III.

In terms of multifarious use of weeds (Fig. 9), 37.6% of the recorded species were used for animal fodder, 29.5% for the treatment of various diseases and 7.4% for edible purposes. Habitat wise distribution analysis (Fig. 10) showed forbs share 88 species followed by grasses (29 species) and sedges (18 species) respectively.

DISCUSSION

The abundance and distribution of weed species within the landscape of the rice field play pivotal role for maintenance of biodiversity. The years of agricultural practices have coevolved with the environment, and the resulting interactions brought forth local wisdom in rice farming practices that has also influenced and shaped

the cultural heritage of the society (Norgaard 1984). Farmers experiment and innovate new methods in an uxexpectrd way on trial and error method to improve their livelihood without any policy of the government (Dey 2012). However, through modern agricultural methods, higher yields and greater food security have come by degrading environment, reducing interspecific competition and enhancing biodiversity loss. Therefore by adopting alternative sustainable agriculture practices the diversity of paddy ecosystem can be protected (Chappell & Lavalle 2011). The number of weed species recorded from Bhadrak district is comparable with other regions of Asia [191 species in Japan (Kasahara 1959),136 species in Sri Lanka (Chandrasena 1988), 96 species in Thailand (Tomita *et al.* 2003a,b), 145 species in Tamil Nadu, India (Dhanam & Elayaraj 2014), 82 species in Nepal (Nowak *et al.* 2016), 113 species in Vietnam and the Philippines (Fried *et al.* 2017), 272 species in China (Yun-he & Sheng 2014)]. The highest contribution of family Poaceae is in accordance with Turki & Sheded (2002) and Hakim *et al.* (2013).

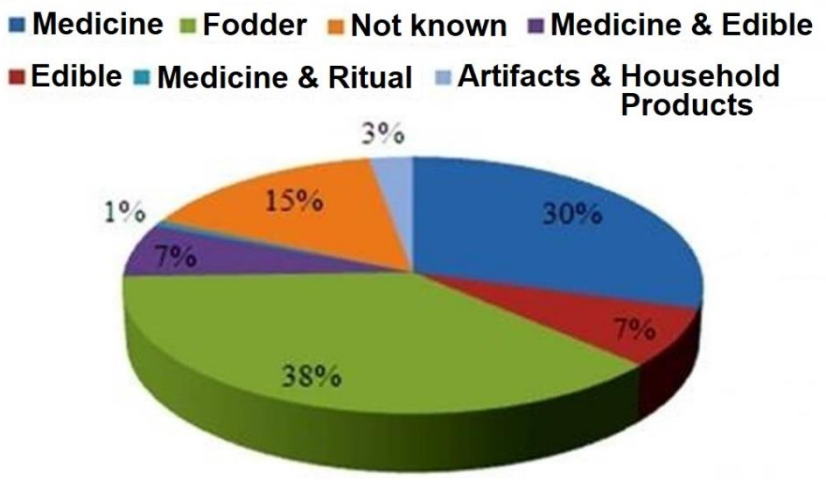

Figure 9. Multifarios use of weed species collected at the study site.

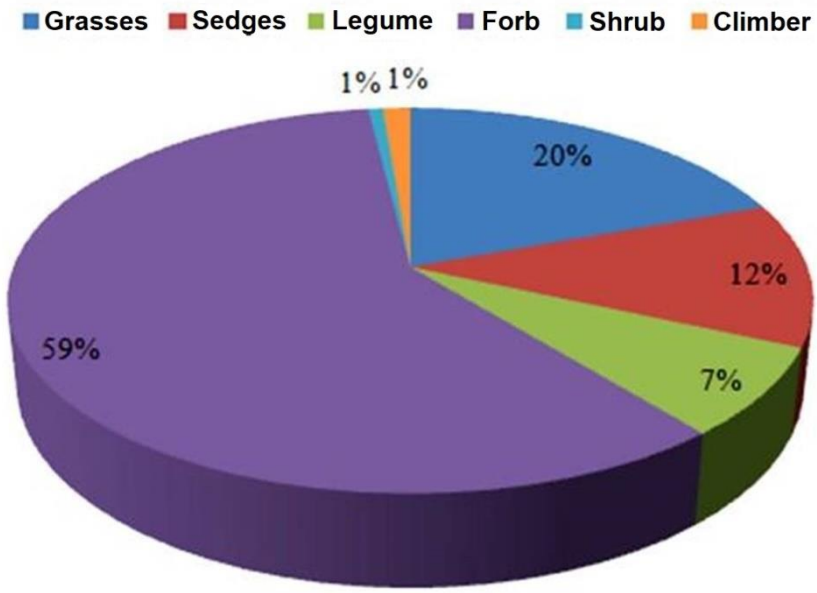

Figure 10. Habitat wise distribution of weed species at the study site.

The species listed in this study are also reported as weeds in other countries (Dekker 1997, Qiang 2002, Bhatt *et al.* 2009, Hakim *et al.* 2010, Jaya Suria *et al.* 2011, Khaliq *et al.* 2011). In fact, from the recorded 12 species of Asia's worst weed (IRRI 2010), Bhadrak district harbors seven weed species (*Cyperus iria*, *Cyperus difformis* L., *Echinochloa colona*, *Ischaemum rugosum*, *Leptochloa chinensis* Nees, *Ludwigia hyssopifolia*, *Sphenochlea zeylanica* Gaertn.). Out of the ten major weeds reported from transplanted rice of India (Rao *et al.* 2017), Bhadrak district represents eight species (*Echinochloa colona*, *Echinochloa crusgalli*, *Cyperus difformis*, *Cyperus iria*, *Fimbristylis miliacea*, *Eclipta prostrata*, *Cyperus rotundus*, *Ammannia baccifera*). Individually, the incursion by *Cyperus rotundus*, *Eichhornia crassipes* (C. Martius) Solms., *Fimbristylis dichotoma* and *F. miliacea*, *Cyperus iria* and *Cyperus difformis* are causing great concern in many rice fields of this district. Freshwater species like *Eichornia crassipes* is of the most nuisance as it causes hindrance by choking all

possible water bodies and reducing their utility. Because of its rapid growth rate, water hyacinth is able to outcompete native aquatic plants by utilising the available nutrients in the water, and successfully competing for space and sunlight (Cilliers 1991). *Echinochloa crusgalli* is one of the widespread weeds of rice globally (Michael 1978). It finds a place on the list of 10 worst weeds of the world (Noda 1977). *Echinochloa crusgalli* is reported as a dominant weed in rice fields of Malaysia (Hakim *et al.* 2010), Nepal (Bhatt *et al.* 2009), Pakistan (Khaliq *et al.* 2011) and India (Parameswaran *et al.* 2014). While studying the weed community of Zhejiang Province, southeastern China Yu *et al.* (1993) stated that *Echinochloa crusgalli* is the dominant weed species of the early and late rice stages respectively. Famers confuse this weed because it mimics rice plants during the early stage. *Cyperus rotundus* is considered the world's worst weed because of its ability to survive, spread, and compete, especially in agricultural areas (Holm *et al.* 1977, Terry 2001). It is reported in 52 crops and 92 countries (Holm *et al.* 1979, 1997). Their rhizomes form tubers that give rise to new aerial plants or produce other rhizomes or they may remain dormant during periods of adverse environmental conditions including heat, cold, drought, flooding, or inadequate aeration (Wills 1987, Miles *et al.* 1996). *Cyperus difformis* and *C. iria* are ranked 32nd and 33rd among the world's worst weeds, respectively (Holm *et al.* 1977). They often produce clumps of many culms and have become established in tropical and temperate areas of the world. *Fimbristylis dichotoma* and *F. miliacea* are co-ranked as the world's 40th worst complex of weeds (Holm *et al.* 1977). *Fimbristylis dichotoma* is a rapidly growing and thrives in poorly aerated soils with high moisture content (Holm *et al.* 1977). It has been reported as a weed of paddy crops, in 21 countries throughout the tropical and semitropical regions of the world including Africa, Asia, the Pacific Islands, and North and South America (Holm *et al.* 1977). Nowak *et al.* (2016) observed the higher occurrence of *Alternanthera sessilis, Cyperus difformis, Centella asiatica, Cynodon dactylon* (L.) Pers., *Echinochloa colona, Fimbristyllis miliacea, Cyperus iria* and *Marsilea minuta* L. in rice field of central Nepal.

Studies of Sharma *et al.* (2014) and Thakur (2015) have shown that biological spectrum of a region indicates the phytoclimate of that region. Higher percentage of therophytes in the studied area reflects a therophytic phytoclimate of the district. The rich therophytic flora may be due to the grazing, weeding or other anthropogenic interference in the area during the process of cultivation which reduces the number of other life forms. The predominance of annual weed species over the perennial ones is similar to the findings of Shivakumar *et al.*(2014).

Even though agricultural scientists and extension officers recommend eradication of weeds, 89% of the most widespread and aggressive weeds in the world are edible (Rapoport *et al.* 1995). Moreover, many of these species have a high nutritional value and medicinal properties (Duke 1992). Most of the plant species of the study area have important economic uses. Weeds like *Amaranthus spinosus* L., *Echinochloa crusgalli, Glinus oppositifolius* (L.) A.DC., *Marsilea minuta*, *Monochoria hastata* (L.) Solms, *Nymphaea nouchali* Burm. f., *Nymphaea pubescens* Willd., *Oxalis corniculata, Portulaca oleracea* L. and *Portulaca quadrifida* L. are used for edible purposes by the local inhabitants. The consumption of weeds is a world-wide phenomenon that is noted as having an important role for human nutrition (Duke 1992, Pemberton *et al.* 1996, Marcelino *et al.* 2005, Maneechote 2007, Turner *et al.* 2011). Some of the edible weed plants like *Ipomoea aquatica* and *Marsilea minuta* are collected by local people and sold in the local markets particularly by poor and economically marginalised families, thereby generating a supplementary income.

A number of weeds reported from the study area are used by local people in traditional medicines for their primary health care. For instance, burned root ashes of *Achyranthes aspera* L. are applied topically to reduce the pain of the skin infected with worms as well as to expel the dead worms out. Warmed leaves of *Amaranthus spinosus* are applied locally to cure boils and burns. Fresh leaf paste of *Argemone mexicana* is applied topically to treat eczema. Decoction of whole plant of *Boerhavia diffusa* L. is used to treat leucorrhoea. Juice of *Cynodon dactylon* is used to stop nose bleeding. Latex of *Euphorbia hirta* L. is effective for healing of wounds. *Glinus oppositifolius* is used either in raw or cooked form to cure various types of skin disease like scabies, itches etc. *Mimosa pudica* L. roots are chewed for toothache. Rhizome paste of *Nymphaea nouchali* is administered to regulate menstruation. Tender twig of *Phyllanthus amarus* Schum. & Thonn. is used to cure dysentery. Leaf decoction of *Tephrosia purpurea* L. *is* prescribed to women against post natal complications. Decoction of *Tridax procumbens* L. leaf is applied topically on the boils, cuts, sores, wounds and eczema to promote healing. Crushed tuber powder of *Cyperus rotundus* is taken orally for jaundice. Root bark of *Scoparia dulcis* is chewed for toothache and dental caries. The present finding draws support from the studies of Mishra (2016) and Parameswaran & Kumar (2017). A number of weeds such as *Alternanthera sessilis, Bacopa monnieri* (L.) Pennell., *Centella asiatica*, *Boerhavia diffusa, Commelina benghalensis* L., *Eclipta prostrata, Enydra fluctuans*

Lour., *Hygrophila auriculata* are reported to have both therapeutic and dietary functions and hence are used as medicinal food remedy. This overlap indicates the close relationship between health and food. Overlapping between food and medicines is quite well known in traditional societies (Panda & Misra 2011, Swapna *et al.* 2011, Mishra *et al.* 2012). The study area is also considered as important source for animal wellbeing where many weed species are utilized as fodder for buffaloes and cattle (Marcelino *et al.* 2005).

A good number of artifact items and household articles are prepared from *Aeschynomene aspera*, *Cyperus alopecuroides* and *Vetiveria zizanioides* (L.) Nash. by the artisans of the district. Similar observations have also been made in earlier studies (Mohanty *et al.* 2012, Tripathy *et al.* 2014).

The increased frequency of burning crop residues after harvesting caused a dramatic loss of weed biodiversity in January-February. Burning could be an attractive residual management option for farmers to prepare for the subsequent rice cropping. However, burning have the negative aspects such as greenhouse gas emission, nutrient loss, diminished soil biota, and reduced total N and C in the topsoil (Gupta & Sahai 2005, Wassmann *et al.* 2009), as many governments in developing Asian countries made it illegal to burn crop residues (Singh *et al.* 2005). Farmers might lack an understanding of these negative aspects of burning for environment, as well as knowledge of available technology for in situ incorporation of the residues (Samra *et al.* 2003).

CONCLUSIONS

Rice fields are an important component of Odishan culture and play a pivotal role in the agricultural ecological system. The results highlight the significant contribution of rice field in conserving biodiversity of this region, since rice fields form the largest freshwater ecosystem of the district. It can be concluded that the vegetation of the agro-climatic zone of Bhadrak district is mostly seasonal and annual weeds predominate, majority of which continue to survive in subsequent periods by their seeds or vegetative propagules. Agricultural chemicals (including pesticides, synthetic fertilizers and growth regulators) have contributed substantially to the development of modern agriculture, but the overuse has also damaged agricultural areas and the surrounding natural vegetation, aquatic environment and wildlife, thus decreasing rice paddy biodiversity whichleads to the unsustainable development of the rice field ecosystem. The conservation of the rice field ecosystem and biodiversity needs to be further strengthened through protecting the ecological environment surrounding the rice fields, improving rice cropping patterns, growing rice with less agricultural chemicals and synthetic fertilizers and promoting ecological education and public awareness and, thus, achieves ecological sustainability.

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REFERENCES

Anonymous (2009) *District statistical hand book*. Bhadrak. Directorate of economics & statistics, Bhubaneswar, Odisha.

Anonymous (2010) *Districts at a Glance*. Bhubaneswar, Odisha.

Anonymous (2016) *Proceedings of the 2nd district level implementation committee of the Pradhan Mantri Krushu Sinchayee Jojana of Bhadrak district.*

APG III (2009) An update of the angiosperm phylogeny group classification for the orders and families of flowering plants. *Botanical Journal of the Linnaean Society* 161 (2): 105–121.

Baker HG (1974) The evolution of weeds. *Annual Review of Ecology Evolution System* 5: 1–24.

Backman JPC & Tiainen J (2002) Habitat quality of field margins in a Finnish farmland area for bumblebees (Hymenoptera: *Bombus* and *Psithyrus*). *Agriculture, Ecosystems & Environment* 88: 53–68.

Bastiaans L, Kropff MJ, Goudriaanb J & Van Laar HH (2000) Design of weed management systems with a reduced reliance on herbicides poses new challenges and prerequisites for modeling crop-weed interactions. *Field Crop Research* 67: 161–179.

Bernasor PC & De Datta SK (1983) Integration of cultural management and chemical control on weeds in broadcast seeded flooded rice. In: *Proceedings of 9thAsian Pacific Weed Science Society Conference*, pp. 137–155.

Bhan VM (1983) Effect of hydrology, soil moisture regimes, and fertility management on weed populations and their control in rice. In: *Weed Control in Rice*. Laguna, pp. 47–56.

Bhatt MD, Tewari A & Singh SP (2009) Floristic Composition of weeds in paddy fields In Mahendranagar, Nepal. *Ecoprint* 16: 15–19.

Bumeya J & Ramanatha V(2014) Recent climate and air pollution impacts on Indian agriculture. *PNAS* 111: 16319–16324.

Chandler JM & Cooke FT (1992) Economics of cotton losses caused by weeds. In: Mcwhorter CG & Abernathy JR (eds) *Weeds of Cotton: Characterization and Control*. Memphis, pp. 85–116.

Chandrasena JPNR (1988) Floristic composition and abundance of rice-field weeds in four low country wet zone districts of Sri Lanka. *Tropical Pest Management* 34 (3): 278–287.

Chang X, Li R, Zhu W & Chen Q (2009) Weed communities and distribution characteristics in the paddy fields of main rice growing regions of Hubei Province. *Chinese Journal of Eco-Agriculture* 17: 533–536.

Chappell MJ & Lavalle LA (2011) Food security and biodiversity: can we have both? An agroecological analysis. *Agriculture Human Values* 28: 3–26.

Cilliers CJ (1991) Biological control of water hyacinth, *Eichhornia crassipes* (Pontederiaceae), in South Africa. *Agriculture Ecosystems & Environment* 37: 207–218.

Cunningham AB (2001) *Applied ethnobotany: People, wild plant use and conservation.* Earthscan Publishing Ltd., London, UK.

Datta SC & Banerjee AK (1978) Useful weeds of west Bengal rice fields. *Economic Botany* 32: 297–310.

Dekker J (1997) Weed diversity and weed management [J]. *Weed Science* 45(3): 357–363.

Dey MM, Spielman DJ, Mahfuzul Haque ABM, Rahman MS & Valmonte-Santos RA (2012) *Change and diversity in smallholder rice–fish systems: recent evidence from Bangladesh*. IFPRI Discussion Paper 01220, Washington.

Dhanam S & Elayaraj B (2014) Ethnomedicinal aspects of some weeds from paddy fields of Villupuram district in Tamil Nadu, India. *International Letters of Natural Sciences* 14: 1–10.

Duke JA (1992) *Handbook of edible weeds*. Boca Raton.

FAO (2004) *Rice and us*. Food and Agriculture Organization of the United Nations.

Fried G, Petit S, Dessaint F & Reboud X (2009) Arable weed decline in Northern France: Crop edges as refugia for weed conservation? *Biological Conservation* 142: 238–243.

Fried O, Kühn I, Schrader J, Van Sinh N & Bergmeier E (2017) Plant diversity and community composition of rice agroecosystems in Vietnam and the Philippines. *Phytocoenologia* 47(1): 49–66.

Gibbons DW, Bohan DA & Rothery P (2006) Weed seed resources for birds in fields with contrasting conventional and genetically modified herbicide-tolerant crops. *Philosophical Transactions of Royal Society of London* B273: 1921–1928.

Gopal B & Sah M (1995) Inventory and classification of wetlands in India. *Vegetatio* 118: 39–48.

Gupta PK & Sahai S (2005) Residue open burning in rice wheat cropping systemsin India: an agenda for conservation of environment and agricultural resources. In: Abrol IP, Gupta, RK & Malik RK (eds) *Conservation Agriculture Status and Prospects*. New Delhi, pp. 50–54.

Haines HH (1925) *The Botany of Bihar and Orissa*. Adland and Son, West Newman Ltd., London.

Hakim MA, Juraimi AS, Ismail MR, Hanafi MM & Selamat A (2010) Distribution of weed population in coastal; rice growing area of Kedha in Peninsular Malaysia. *Journal of Agronomy* 9(1): 9–16.

Hakim MA, Juraimi AS, Ismail MR, Hanafi MM & Selamat A (2013) A comparison of weed communities of coastal rice fields in Peninsular Malaysia. *Journal of Environmental Biology* 34: 847–856.

Heckman CW (1974) The seasonal succession of species in a rice paddy in Vientiane, Laos. *Internationale Revue Der Gesamten Hydrobiologie* 59: 489–507.

Hakansson S (2003) *Weeds and weed management on arable land. An ecological approach.* Wallingford, p. 288.

Holm LG, Plucknett DL, Pancho JV & Herberger JP (1977) *The World's worst weeds: Distribution and biology.* University of Hawaii Press, Honolulu.

Holm LG, Pancho JV, Herberger JP & Plucknett DL (1979) *A Geographical atlas of world weeds.* New York.

Holm LG, Doll J, Holm E, Pancho J & Herberger J (1997) *World Weeds: Natural Histories and Distribution.* John Wiley & Sons, Inc., New York.

Hyvonen T (2007) Can conversion to organic farming restore the species composition of arable weed communities. *Biological Conservation* 137: 382–390.

Huntington HP (2000) Using traditional ecological knowledge in science: Methods and applications. *Ecological Applications* 10(5): 1270–1274.

Ikeda R & Miura R (2002) Tsurugashi nakaikemi no shitsudennoukou to zetsumetsukigu syokubutsu. *Noukou no Gijutsu to Bunka* 23: 43–72. [in Japanese]

IRRI (2010) *Rice knowledge bank*. International Rice Research Institute, Makati.

Jain SK (1987) *Glimpses of Indian ethnobotany*.Oxford & IBH Publishing Co., New Delhi.

Janiya JD & Moody K (1983) Weed growth and yield of two rice crops grown in sequence in three rainfed locations in the Philippines. *Philipine Agriculture* 66: 90–101.

Janiya JD & Moody K (1989) Weed populations in transplanted and wet-seeded rice as affected by weed control method. *Tropical Weed Management* 35(1): 8–11.

Jaya Suria ASM, Juraimi AS, Rahman MM, Man AB & Selama TA (2011) Efficacy and economics of different herbicides in aerobic rice system. *African Journal of Biotechnology* 10: 8007–8022.

Kasahara Y (1959) Studies on the species of the weeds in Japan and their geographical distribution. *Nogaku Kenkyu* 47: 123–140. [in Japanese]

Khaliq A, Matloob A, Shafique HM, Cheema ZA & Wahid A (2011) Evaluating sequential application of pre and post emergence herbicides in dry seeded fine rice. *Pakistan Journal of Weed Science Research* 17(2): 111–123.

Khaliq A & Matloob A (2011) Weed-crop competition period in three fine rice cultivars under direct-seeded rice. *Pakistan Journal of Weed Science Research* 17(3): 229–243.

Kim JK & Krishnan HB (2002) Making rice a perfect food: Turning dreams into reality. *Journal of Crop Production* 5: 93–130.

Kumar V& Ladha JK (2011) Direct seeding of rice: recent developments and future needs. *Advances in Agronomy* 111: 297–413.

Mabbayad MO, Pablico PP & Moody K (1983) The effect of time and method of land preparation on weed populations in rice. In: *Proceedings of 9th Asian-Pacific Weed Science Society Conferenc*e, pp. 357–368.

Maneechote C (2007) Utilization of weeds and their relatives as resources in Thailand. In: Kim KU, Shin DH & Lee IJ (eds) *Utility of weeds and their relatives as resources*. Daegu, pp. 107–121.

Mardiyanti ED, Karuniawan PW & Medha B (2013) Dynamics of plant species diversity post-planting rice. *Produksi Tanaman* 1(1): 24–35. [in Indonesian]

Marshall EJP, Brown VK, Boatman ND, Lutman PJW, Squire GR & Ward LK (2003) The role of weeds in supporting biological diversity within crop fields. *Weed Research* 43: 77–89.

Martin GJ (1995) *Ethnobotany - A methods manual*. Chapman and Hall, London.

Marcelino LR, Inocencio AI, Zaballa CC & Paller EC (2005) Bicol's weed recipes. *Philippine Journal of Weed Science* 23: 40–43.

Michael P (1978) Notes on *Echinochloa* in the Philippines. *Philippine Journal of Weed Science* 5: 16–18.

Miles JE, Nishimoto KK & Kawabata O (1996) Dirurnally altering temperatures stimulate sprouting of purple nut sedge (*Cyperus rotundus*) tubers. *Weed Science* 44: 122–125.

Misra MK, Panda A & Sahu D (2012) Survey of useful wetland plants of south Odisha,India. *Indian Journal of Traditional Knowledge* 11(4): 658–666.

Mishra N (2016) Ethnomedicinal uses of some bioresources for healing of different ailments in Odisha, India, (Ph. D Thesis). V.K.S. University, Ara.

Mohanty RB, Tripathy BK & Panda T (2012) Utilization of pith plant (*Aeschynomene aspera* L., Leguminosae: Papilionoideae) by traditional florists cum craftsmen in Jajpur district, Odisha, India. *Nelumbo* 54: 168–171.

Moody K (1989) *Weeds reported in rice in South and Southeast Asia*. Los Baños, 442 p.

Mulungu LS, Jilala MR, Mwatawala MW & Mwalilino JK (2011) Assesment of damage due to larger grain borer (*Prostephanus truncates* Horn) on stored paddy rice (*Oryza sativa* L. Poaceae). *Journal of Entomology* 8: 295–300.

NatuharaY (2013) Ecosystem services by paddy fields as substitutes of natural wetlands in Japan. *Ecological Engineering* 56: 97–106.

Noda K (1977) Integrated weed control in rice. In: Freyer JD & Mastu S (eds) *Integrated control of weeds*. University of Tokyo Press, Tokyo.

Norgaard RB (1984) Coevolutionary agricultural development. *Economic Development & Cultural Change* 32: 525–546.

Nowak A, Sylwia NS & Marcin NM (2016) Spring weed communities of rice agrocoenoses in central Nepal. *Acta Botanica Croatica* 75(1): 99–108.

Nyarko KA & Datta SKD (1993) Effects of light and nitrogen and their interaction on the dynamics of rice-weed competition. *Weed Research* 33: 1–8.

Panda A & Misra MK (2011) Ethnomedicinal survey of some wetland plants of South Orissa and their conservation. *Indian Journal of Traditional Knowledge* 10(2): 296–303.

Pane H, Noor ES, Dizon M & Mortimer AM (2000) Weed communities of gogorancah rice and reflections on management. In: *Proceedings of the International Workshop on Characterizing and Understanding Rain fed Environments*. Los Banos.

Parameswaran P, Ratheesh NMK & Kumar AN (2014) Diversity of vascular plants associated with wetland paddy fields (Vayals) of Wayanad District in Western Ghats, India. *Annals of Plant Sciences* 3(5): 704–714.

Parameswaran P & Kumar AN (2017) An account of the 'useful weeds' associated with wetland paddy fields (Vayals) of wayanad, Kerala, India. *Annals of Plant Sciences* 6(1): 1516–1526.

Pemberton RW & Lee NS (1996) Wild food plants in South Korea; market presence, new crops, and exports to the United States. *Economic Botany* 50(1): 57–70.

Qiang S (2002) Weed diversity of arable land in China [J]. *Journal of Korean Weed Science* 22(3): 187–198.

Rao AN, Wani SP, Ahmed SH, Haider Ali H & Marambe B (2017) An overview of weeds and weed management in rice of South Asia. In: Rao AN & Matsumoto H (eds) *Weed management in rice in the Asian-Pacific region. Asian-Pacific Weed Science Society (APWSS)*. The Weed Science Society of Japan, Japan and Indian Society of Weed Science, India, pp. 248–281.

Raunkiaer C (1934) *The life forms of plants and statistical plant geography*. Clarendon Press, Oxford.

Rapoport EH, Raffaele E & Ghermandi L (1995) Edible weeds: a scarcely used resource. *Bulletin of Ecological Society of America* 76(3): 163–166.

Samra JS, Singh B & Kumar K (2003) Managing crop residues in the rice–wheat system of the Indo-Gangetic plain. In: Ladha JK, Hill JE, Duxbury JM, Gupta RK & Buresh RJ (eds) *Improving the productivity and sustainability of rice–wheat systems: Issues and impacts*. Madison, pp. 173–195.

Satapathy KB, Sahu BB & Jena GS (2012) Crop weeds diversity and their ethno- medicinal uses in the treatment of common ailments in Jajpur district of Odisha (India). *International Journal of Medicinal and Aromatic Plants* 2(l): 80–89.

Saxena HO & Brahmam M (1996) *The Flora of Orissa*. Vol. I-IV. Orissa Forest Development Corporation, Bhubaneswar.

Sharma J, Raina AK & Sharma S (2014) Life form classification and biological spectrum of Lamberi Forest Range, Rajouri, J&K, India. *International Journal of Current Microbiology and Applied Sciences* 3(11): 234–23.

Shivakumar KV, Devendra R, Muniswamappa MV, Halesh GK & Mahadevamurthy M (2014) Weed seed production potentials in *Bidens pilosa* L. in plantation crops in hill zone of Karnataka. *International Journal of Research in Applied, Natural & Social Sciences* 2(2): 11–18.

Singh A, Sharma GP & Raghubanshi AS (2008) Dynamics of the functional groups in the weed flora of dry land and irrigated agroecosystems in the Gangetic plains of India. *Weed Biology and Managemen*t 8: 250–259.

Singh J (1974) *An Agricultural Atlas of India: Geographical Analysis.*Vishal Publications, New Delhi. pp. 156.

Singh Y, Singh B & Timsina J (2005) Crop residue management for nutrient cyclingand improving soil productivity in rice-based cropping systems in the tropics. *Advances in Agronomy* 85: 269–407.

Swapna MM, Prakashkumar R, Anoop KP, Manju CN & Rajith, NP (2011) A review on the medicinal and edible aspects of aquatic and wetland plants of India. *Journal of Medicinal Plant Research* 5: 7163–7176.

Terry PJ (1976) The Cyperaceae–Still the world's worst weeds? In: Riches CR (eds) *The World's Worst Weeds*. Farnham, pp. 3–18.

Thakur AS (2015) Floristic composition, life-forms and biological spectrum of tropical dry deciduous forest in Sagar District, Madhya Pradesh, India. *Tropical Plant Research* 2(2): 112–119.

Tomita S, Nawata E, Kono Y, Inamura T, Nagata Y, Noichana C & Sributta A (2003a) Impact of direct dry seeding on rain fed paddy vegetation in north-east Thailand. *Weed Biology and Management* 3: 68–76.

Tomita S, Nawata E, Kono Y, Nagata Y, Noichana C, Sributta A & InamuraT (2003b) Differences in weed vegetation in response to cultivating methods and water conditions in rainfed paddy fields in north-east Thailand. *Weed Biology and Management* 3: 117–127.

Tripathy BK, Panda T & Mohanty RB (2014) Traditional artifacts from 'Bena' grass (*Vetiveria zizanioides* (L.) Nash., Poaceae) in Jajpur district of Odisha, India. *Indian Journal of Traditional Knowledge* 12(4): 771–777.

Turki Z & Sheded M (2002) Some observations on the weed flora of rice fields in the Nile Delta, Egypt. *Feddes Repert* 113: 394–403.

Turner NJ, Łuczaj ŁJ, Migliorini P, Pieroni A, Dreon AL & Sacchetti LE (2011) Edible and tended wild plants,

traditional ecological knowledge and agroecology.*Critical Review of Plant Science* 30(1&2): 198–225.

Wassmann R, Jagadish SVK, Sumfleth K, Pathak H, Howell G, Ismail A, Serraj R, Redona E, Singh RK & Heuer S (2009) Regional vulnerability of climate change impacts on Asian rice production and scope for adaptation. *Advances in Agronomy* 102: 91–133.

Wills GD (1987) Description of purple and yellow nut sedge (*Cyperus rotundus* and *C. esculentus*).*Weed Technology* 1: 2–9.

Wisler GC & Norris RE (2005) Interactions between weeds and cultivated plants as related to management of plant pathogens. *Weed Science* 53: 914–917.

YaherwandiY (2009). Structure of community parasitoids Hymenoptera in various agriculture landscape, West Sumatra. *Jurnal Entomologi Indonesia* 6 (1):1–14. [in Indonesian]

Yamaguchi H & Umemoto S (1996) Classification of paddy levees in terms of plant resource complex. *Weed Research Japan* 41: 286–294. [in Japanese with English summary]

Yu L, Jiang R, Gao Z, Hu S, Li M, Wu M, Yu T & Chen L (1993) The community and itssuccession of paddy weeds in Zhejiang Province. *Weed Science* 4: 10–12. [In Chinese]

Yun-He H & ShengQ (2014) Analysis of farmland weeds species diversity and its changes in the different cropping systems. *Bulgarian Journal of Agricultural Science* 20(4): 786–794.

Zedler JB & Kercher S (2005) Wetland resources: status, ecosystem services, degradation, and restorability. *Annual Review of Environmental Resources* 30: 39–74.