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, Echinolochia crassgalli, 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.

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).
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 & Ttainen (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 & Sah 1995). 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, Bernasar & 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, Mardiyantri 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 km², 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 Baiturani 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 (alfsols), 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, Caryophyllales (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 Rothb., Cyperus diffusis L., Cyperus iria L., Cyperus rotundus L., Desmodium triflorum (L.) DC., Echinocloa crusgalli (P.) Beauv., Echinocloa colona (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 articularus 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                 | Kain        | Forb  | P         | Hyd       | Medicinal, Edible |
|                          | Nymphaea nouchali Burn. f.   |             |       |           |           |              |
|                          | Nymphaea pubescens Willd.    | Rangakain   | Forb  | P         | Hyd       | Edible      |
| MONOCOTS                 | Aponogetonaceae              | Jhechu      | Forb  | P         | Hyd       | Edible      |
| Alismatales              | Aponogeton natans (L.) Engl. & Krause |     |       |           |           |              |
|                          | Aponogeton undulatus Roxb.   | Forb        | Forb  | P         | Hyd       | Edible      |
| Araceae                  | Pistia stratiotes L.         | Borajhanji  | Forb  | A         | Hyd       | Medicinal   |
| Hydrocharitaceae         | Hydrilla verticillata (L.f.) Royle. |   |       |           |           |              |
|                          | Ottelia alismoides (L.) Pers. | Panikundri  | Forb  | P         | Hyd       | Medicinal   |
| Asparagales              | Amaryllidaceae               | Arsa        | Forb  | P         | Cr        | Medicinal   |
|                          | Crinum asiaticum L.          |             |       |           |           |              |
| COMMELINIDS              | Commelinaceae                | Kansiri     | Forb  | A         | Ch        | Medicinal   |
| Commelinales             | Commelina benghalensis L.    |             |       |           |           |              |
|                          | Commelina difusa Burm.f.     | Forb        | Forb  | A         | Ch        | Medicinal   |
|                          | Cyanotis axillaris (L) Schult. & Schult. f. |     |       |           |           |              |
|                          | Murdannia nudiflora (L.) Brenan | Kanduli     | Forb  | A         | Ch        | Fodder      |
| Pontederiaceae           | Eichhornia crassipes Solms   | Bilatidala  | Forb  | P         | Hyd       | Not Known   |
|                          | Monochoria hastata Solm-Laub. | Forb       | Forb  | P         | Hyd       | Edible      |
| Poales                   | Poaceae                      | Grassy      | A     | Ch        | Fodder    |              |
|                          | Brachiaria reptans (L.) Garde. & Hubb. |   |       |           |           |              |
|                          | Chloris barbata Sw.          | Grass       | P     | Hem       | Fodder    |              |
|                          | Chrysopogon aciculatus (Retz.) Trin. | Guguchia   | Grass | P         | Cr        | Medicinal   |
| Scientific Name               | Common Name     | Plant Type | Use               | Cultural Use     |
|------------------------------|-----------------|------------|-------------------|------------------|
| 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 ciliaris Retz. Koeler | Swanghas        | Grass      | A                 | Th               | Edible          |
| Echinochloa colona (L.) Link  | Dhera           | Grass      | A                 | Th               | Edible          |
| Echinochloa crusgalli (L.) P. Beauv. | Anamandia     | Grass      | A                 | Hem              | Fodder          |
| Eleusine indica (L.) Gaertn.  | Chhana ghas     | Grass      | P                 | Cr               | Fodder          |
| Ergrostris ciliata (Roxb) Nees. | Kankra chare    | Grass      | A                 | Cr               | Fodder          |
| Ergrostris gangetica (Roxb.) Steud. | Dauria         | Grass      | P                 | Cr               | Fodder          |
| Heteropogon contortus (L.) P. Beauv. | Chhana ghas    | Grass      | P                 | Hem              | Fodder          |
| Imperata cylindrica (L.) Rauesch. | Tuli           | Grass      | A                 | Th               | Fodder          |
| Isachne globosa (Thunb.) Kuntze | Balunga         | Grass      | P                 | Th               | Fodder          |
| Ischaemum rugosum Salisb.    | Noto            | Grass      | A                 | Th               | Fodder          |
| Leptochloa chinensis (L.) Nees. | Bhuru           | Grass      | A                 | Hem              | Fodder          |
| Oplismenus burmanii (Retz.) P. Beauv. | Sial legunda   | Grass      | A                 | Th               | Fodder          |
| Oryza rafipogon Griff.       | Sial legunda    | Grass      | A                 | Th               | Fodder          |
| Panicum psilopodium Trin.    | Reda            | Grass      | P                 | Th               | Fodder          |
| Panicum repens L.            | Paspalum distichum L. | Grass      | P                 | Th               | Fodder          |
| Phragmites karka (Retz.) Trin. ex Steud. | Sial legunda  | Grass      | A                 | Th               | Fodder          |
| Saccharum spontaneum L.      | Kashatundi      | Grass      | P                 | Hem              | Fodder          |
| Setaria intermedia Roem. & Schult. | Sial legunda  | Grass      | A                 | Th               | Fodder          |
| Setaria pumila (Poir.) Roem. & Schult. | Chhana ghas    | Grass      | A                 | Th               | Fodder          |
| Setaria verticillata (L.) P. Beauv. | Sial legunda  | Grass      | A                 | Th               | Fodder          |
| Sporobolus indicus (L.) R. Br. | Kankra chara    | Grass      | P                 | Th               | Fodder          |
| Vetiveria zizanioides (L.) Nash. | Bena            | Grass      | P                 | Th               | Artifact        |

**Cyperaceae**

| Scientific Name | Common Name | Plant Type | Use     |
|-----------------|-------------|------------|---------|
| Balbostylis barbata (Roxb.) C.B.Cl. | Noto        | Sedge      | A       |
| Cyperus alopecuroides Rottb. | Sedge       | P          | Th      |
| Cyperus brevifolius (Rottb.) Hassk. | Sedge       | P          | Cr      |
| Cyperus castaneus Wild. | Sedge       | A          | Th      |
| Cyperus compressus L. | Sedge       | A          | Hel     |
| Cyperus difformis L. | Sedge       | A          | Ch      |
| Cyperus iria L. | Sedge       | A          | Ch      |
| Cyperus rotundus L. | Sedge       | P          | Hem     |
| Eleocharis acutangula (Roxb.) Schultz. & Schult. | Sedge     | P          | Cr      |
| Eleocharis dulcis (Burm.f.) Henschef | Sedge       | A          | Cr      |
| Fimbristylis dichotoma (L.) Vahl | Sedge       | A          | Ch      |
| Fimbristylis ferruginea (L.) Vahl | Sedge       | P          | Hem     |
| Fimbristylis miliaeae(L.) Vahl | Sedge       | A          | Hem     |
| Fimbristylis ovata (Burm.f.) J.Kern. | Sedge       | A          | Hem     |
| Fuirena ciliaris (L.) Roxb. | Sedge       | A          | Th      |
| Kylinga nemoralis (J.R. & G. Forst) | Sedge     | P          | Th      |
| Dandy ex Hutch. & Dalz. | Scirpus articulatus L. | Kanri | Sedge | A | Hem |
| Scirpus grossus L. | Santara     | Sedge      | P        | Cr      | Not known       |

**Typhaceae**

| Scientific Name | Common Name | Plant Type | Use     |
|-----------------|-------------|------------|---------|
| Typha angustata Bory. & Chaub | Hangla    | Forb       | P        | Ph      | Medicinal     |

**CORE EUDICOTS**

**Ranunculales**

| Scientific Name | Common Name | Plant Type | Use     |
|-----------------|-------------|------------|---------|
| Papaveraceae    | Argemone mexicana L. | Kantakusuma | Forb | A | Th | Medicinal |

**Zygophyllales**

| Scientific Name | Common Name | Plant Type | Use     |
|-----------------|-------------|------------|---------|
| Zygophyllaceae  | Tribulus terrestris L. | Gokhara | Forb | P | Ch | Medicinal |

**Oxalidales**

| Scientific Name | Common Name | Plant Type | Use     |
|-----------------|-------------|------------|---------|
| Oxalidaceae     | Oxalis corniculata L. | Ambiliti | Forb | A | Cr | Medicinal, edible |

**Malpighiales**

| Scientific Name | Common Name | Plant Type | Use     |
|-----------------|-------------|------------|---------|
| Euphorbiaceae   | Chamaesyce hirta (L.) Millsp. | Forb | A | Th | Medicinal |
| Croton sparsiflorus Morong. | Nandababuli | Forb | P | Th | Medicinal |
| Family         | Genus                              | Species                          | Type    | Use        | Notes                      |
|---------------|------------------------------------|----------------------------------|---------|------------|----------------------------|
| Euphorbiaceae | Euphorbia hirta L.                 | Harharika                        | Forb    | A          | Th                        |
|               | Euphorbia heterophylla L.          | Harharika                        | Forb    | A          | Th                        |
|               | Phyllanthus amarus Schum. & Thonn. | Bhuianla                         | Forb    | A          | Th                        |
|               | Phyllanthus urinaria L.            | Bhuiamla                         | Forb    | A          | Th                        |
| Violaceae     | Hybanthus enneaspermus (L.) F.v.Muell. | Madan mastak                     | Forb    | A          | Ch                        |
| Fabaceae      | Aeschynomone indica L.             | Sola                             | Legume  | A          | Cr                        |
|               | Aeschynomone aspera L.             | Sola                             | Legume  | A          | Cr                        |
|               | Alysicarpus monilifer (L.) DC.     | Jhumka                           | Legume  | A          | Th                        |
|               | Crotalaria prostrata Rottl. ex Willd. | Th                  | Legume  | P          | Th                        |
|               | Desmodium triflorum (L.) DC.       | Kaansisna                        | Legume  | A          | Th                        |
|               | Indigofera limnaei Ali             | Lajakuli                         | Legume  | P          | Th                        |
|               | Melilotus indica (L.) All          | Bana methi                       | Legume  | A          | Th                        |
|               | Mimosa pudica L.                   | Lajakuli                         | Legume  | P          | Th                        |
|               | Smithia conferta J.E. Sm.          | Sanomungo                        | Legume  | A          | Th                        |
|               | Tephrosia purpurea (L.) Pers.      | Banakolathi                      | Legume  | P          | Th                        |
|               | Vigna trilobata (L.) Verdc.        |                                  | Legume  | A          | Cr                        |
| MALVIDS       | Onagraceae                         |                                  |         |            |                            |
| Myrtales      | Ludwigia adscendens (L.) Hara      | Jagal                            | Forb    | A          | Hyd                       |
|               | Ludwigia hyssopifolia (G.Don) Exell|                                  | Forb    | A          | Hyd                       |
|               | Ludwigia octovalvis (Jacq.) Raven  | Latkera                          | Forb    | A          | Hyd                       |
|               | Ludwigia perennis L.               |                                  | Forb    | A          | Hyd                       |
| Lythraceae    | Ammannia baccifera L.              |                                  | Forb    | A          | Th                        |
|               | Ammannia multiflora Roxb.          |                                  | Forb    | A          | Th                        |
|               | Rotala indica (Willd.) Koehne      |                                  | Forb    | A          | Th                        |
| Brassicales   | Cleome gynandra L.                 |                                  | Forb    | A          | Th                        |
|               | Cleome monophylla L.               |                                  | Forb    | A          | Th                        |
|               | Cleome rutidosperma DC.            |                                  | Forb    | A          | Th                        |
|               | Cleome viscosa L.                  |                                  | Forb    | A          | Th                        |
| Malvaes       | Corchorus aestuans L.              |                                  | Forb    | A          | Th                        |
|               | Corchorus olitorius L.             |                                  | Forb    | A          | Th                        |
|               | Melochia corchorifolia L.          |                                  | Forb    | A          | Th                        |
|               | Sida acuta Burm.f.                 |                                  | Forb    | A          | Th                        |
| Caryophyllae  | Aizoaceae                          |                                  |         |            |                            |
|               | Trianthema portulacastrum L.       |                                  | Forb    | A          | Th                        |
| Polygonaceae  | Polygonum plebeium R.Br.           |                                  | Forb    | A          | Th                        |
| Molluginaceae | Glinus oppositifolius (L.) A. DC.  |                                  | Forb    | A          | Th                        |
| Amaranthaceae | Achyranthes aspera L.              |                                  | Forb    | A          | Th                        |
|               | Aerva lanata (L.) Juss ex Sch.     |                                  | Forb    | A          | Th                        |
|               | Alternanthera philoxerooides (Mart)Griseb. | Th                        | Forb    | P          | Hyd                       |
|               | Alternanthera sessilis (L.) R.Br. ex DC. | Th                        | Forb    | P          | Hyd                       |
|               | Amaranthus spinosus L.              |                                  | Forb    | P          | Ch                        |
|               | Celosia argentea L.                |                                  | Forb    | A          | Ch                        |
|               | Gomphrena serrata L.               |                                  | Forb    | A          | Th                        |
| Portulacaceae | Portulaca oleracea L.              |                                  | Forb    | A          | Ch                        |
|               | Portulaca quadrifida L.            |                                  | Forb    | A          | Ch                        |

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| Family                  | Genus                                | Common Name | Type       | Use              |
|------------------------|--------------------------------------|-------------|------------|------------------|
| Nyctaginaceae          | Boerhavia diffusa L.                 | Puruni      | Forb P Th  | Medicinal, edible|
| LAMIDS Gentianales     | Rubiaceae                            |             |            |                  |
|                        | Dentella repens (L.) J.R. & Forst.   |             | Forb A Th  | Fodder           |
|                        | Hedysorhis corymbosa (L.) Lam.       | Jarjati     | Forb A Ch  | Medicinal        |
| Lamiales               | Spermacoce articularis L.f.          | Solaganthi  | Forb A Ch  | Fodder           |
| Acanthaceae            | Acanthus ilicifolius L.              |             |            |                  |
|                        | Hygrophila auriculata (Schum.) Heine. | Koelkha     | Forb P Ch  | Medicinal        |
|                        | Rangia 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            | Phyllostegia globosa (L.) Greene     |             |            |                  |
| Convolvulaceae         | Lippia javanica (Burn.f) Spreng      | Nuguari     | Forb P Ch  | Medicinal        |
|                        | Ipomoea aquatica Forssk.             | Kalamasaga   | Climer A Hyd| Medicinal, edible|
| Solanaceae             | Merremia tridentata (L.) Hall. f.    | Climer A Th  | Fodder     |                  |
|                        | Hydrolea zeylanica (L.) Vahl         | Languliya   | Forb P Hyd | Fodder           |
|                        | Sphenocloa zeylanica Gaertn.         | Panimircho  | Forb A Hyd | Fodder           |
|                        | Solanum surattense Burm. f.          | Beji-begun  | Forb P Th  | Medicinal        |
| Boraginaceae           | Heliotropium indicum L.              | Hatisundha  | Forb A Th  | Medicine         |
| CAMPANULIDS Asterales  | 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 polycodon 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.                 | Bisyalakarani| P Th Hyd  | 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                         |             | 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.CI.; 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* (Burn. f) Henschef; D, *Eleusine indica* (L.) Gaertn.; E, *Evolvulus alsinoides* (L.) L.; F, *Evolvulus nummularius* (L.) L.; G, *Fimbristyliis miliaea* (L.) Vahl; H, *Hybanthus enneaspermus* (L.) F.v. Muell.; I, *Glinus oppositifolius* (L.) A. DC.; J, *Guaphallium polycaudon* Pers.; K, *Gomphrena serrata* L.; L, *Grangea maderaspatana* (L.) Poir.; M, *Heliotropium indicum* L.; N, *Hydrida 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. Oplismenus 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]
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 unexpected 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).

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 Eichhornia 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 (Ciliers 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 the world (Noda 1977). Echinochloa crusgalli is 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. milieae 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, Cydonon dactylon (L.) Pers., Echinochloa colona, Fimbristylis milieae, Cyperus iria and Marsilea minuta 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 phytoclimatic of that region. Higher percentage of therophytes in the studied area reflects a therophytic phytoclimatic 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 Cydonon 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

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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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