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Utilization of weeds in rice ecosystem by farmers in Odisha, India

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ABSTRACT

The aim of this study was to compile an inventory of the weeds in a rice ecosystem as livelihood support to farmers of Bhadrak district, Odisha, India. Information was collected from 165 local inhabitants during 2017-2019, using standard procedures. In the rice fields, altogether 37 plant species belonging to 30 genera and 24 families were recorded. Amaranthaceae was the dominant family. The systematic documentation of the weed flora in the Bhadrak district showed that the area is rich in plants with edible, fodder and ethnomedicinal value and that the inhabitants of the area had significant knowledge about the use of such plants. Ethnobotanical indices like relative frequencies of citation (RFC) and use value (UV) were calculated for each of the recorded weeds. The commonly used weed/plant species are: *Ipomoea aquatica* Forssk. (UV: 0.588) and *Glinus oppositifolius* (L.) Aug. DC. (UV: 0.576) as vegetables; *Echinochloa crus-galli* (L.) P.Beauv. (UV: 0.552) and *Echinochloa stagnina* (Retz) P. Beauv. (UV: 0.527) as fodder; *Centella asiatica* (L.) Urb. (UV: 0.41) followed by *Bacopa monnieri* (L.) Penn.(UV: 0.37) and *Commelina benghalensis* L. (UV: 0.364) for medicinal purposes. The leaves of the herbaceous plant/weed species are the most used by farmers. The reported ethnomedical wisdom of farmers could contribute to basic primary health care and balanced diets for the benefit of local farming community posterity.

INTRODUCTION

An evolved field knowledge arising from conscious 'hit and trail' methods have resulted in selection of certain plants as edible choices (Sharma *et al.* 2018). The world's agriculture can be regarded as one of the great successes of human civilization. Agricultural biodiversity is the first link in the food chain, developed and safeguarded by indigenous people throughout the world (Nakhauka 2009). Rice fields are rich in biodiversity and playing multifunctional role. It is widely accepted that intensive agriculture plays a decisive role for loss of biodiversity and environmental sustainability in rice agro-ecosytem (Jose-Maria *et al.* 2010). Accordingly, in the ecological and socio-economic context, the protection of diversity of agro-ecosystems is considered to be of immense significance in modern agriculture (Firbank *et al.* 2008). It is well documented that weeds are aggressive, troublesome, compete with crops for water, nutrients and light, reducing detrimentally crop yield and quality, encourage disease problems, reduce the efficiency of agricultural apparatus, decline the germination potential of crops seed, enhance the cost of production and decrease the market value of crops (Rao *et al.* 2014; Gharde *et al.* 2018). However, limited attention has been devoted to understanding their potential use as food, animal fodder, medicine and erosion control (Marcelino *et al.*2005; Bilaliset *al.* 2014, Chandrasena 2014). Moreover, one cannot ignore the importance of weeds in agro-ecosystem food web (Bastiaans *et al.* 2000).

In the context of man-plant interactions (Upadhaya *et al.*2016), the significance of rice ecosystems for food security and the maintenance of biodiversity has been recognized in various Asian countries (Kosaka *et al.*2013, Cruz-Garcia and Price 2014), whereas the role of weeds in rice fields in the provision of foods is underestimated and undervalued (Halwart and Bartley 2007). Furthermore, scientists affianced in agricultural research usually recommend for eradication of weeds, but the same plant referred

as weed is considered as wild food plants by local farmers (Cruz-Garcia and Price 2012), consequently most research on weed diversity in rice field is focused on weed management. But, the fact is that 89% of the 18 most widespread and aggressive weeds in the world are edible (Rapoport *et al.*1995) and many of these species have a high nutritional value and medicinal properties (Duke 1992). As it is known that some arable weeds have declined since the 1950s (Lososova 2003) and some alien weeds have threatened the indigenous flora of ecosystems (Panda *et al.* 2018a), therefore, the continued availability of weeds depend on the maintenance of cooperation between farming and wild biodiversity (Pretty 2007).

The change of cropping system from diversified to simplified (cereal-based systems) has contributed to micronutrient malnutrition in many developing countries (Demment *et al.* 2003). Globally, an estimated 1.02 billion people are undernourished (FAO 2009). In India, about 60% of malnutrition cases are from states which also rank high in poverty. Along with a few other states, Odisha ranks high on both poverty and malnutrition scales (World Bank 2016). There are relatively few studies about weeds based on its usability (Sinha and Larka 2007). Review of literature reveald that no attempts have been made to assess quantitatively the potential value of weeds to farmers of Bhadrak district, Odisha, India. Hence this study was carried out, to evaluate quantitatively the traditional ethnobotanical knowledge of common weeds in rice and to assess its significant role for farmers as supplement to food and primary health care.

MATERIALS AND METHODS

Study area

Bhadrak district (20°43′-21°13′N and 86°6′-87° E) is located in north east Odisha and covers an area of 2505 km^2,with a population of 1.507 million (2011 Census). It borders the 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 district is warm and humid. The maximum and minimum temperatures ranged from 37.4°C to 17.7°C, respectively, and the annual average rainfall is approximately 1428 mm (Anonymous 2019) of which about 71% occurs in the monsoon season. The varying intensities of cyclones, drought and flood are the characteristic feature of the district. More than 70% of the people are involved in agriculture. Rice is cultivated in two seasons namely *Kharif* (rainy season, June–Nov) and *Rabi* (winter season, January–April). Both traditional and hybrid rice cultivars are cultivated in the surveyed area. Rice cultivation in Bhadrak district during *Kharif* season depends mostly on monsoon rains. South-West monsoon sets in the district and the state during 2nd fortnight of June and continues up to 1st week of October. Rainfall pattern is highly unpredictable in timing, amount and distribution and therefore, the district suffers either from drought or flood.

Data Collection

The method employed was designed with the purpose of providing base line information on the use of plant species in rice ecosystem by farmers, through literature survey and field visits in seven blocks of the district *i.e*. Basudevpur, Bhadrak, Bhandaripokhari, Bonth, Chandbali, Dhamnagar and Tihidi. The field study was carried out monthly during June 2017 to July 2019 following established and standard procedures (Martin 1995). The information on the use of weed flora was obtained through structured questionnaires, complemented by free interviews and informal conversations (Martin 1995; Huntington 2000). Elderly persons were considered key informants in the study, and the selection process was based on the knowledge base, experience, and current practices in ethnoedible/ ethnomedicine and fodder plant species. The interviews and discussions were carried out individually with members of the inhabitants of the each of the villages visited ,in the local language. During repeated visits to the study site, further group (8-12 people) discussions were held with: i) old-aged key informants, and ii) women key-informants known to be especially skilled in the use of uncultivated plants. The valuable and specific information about the plants obtained during personal interviews and group discussions with local inhabitants was further compared and authenticated by cross-checking (Cunningham 2001). In total 165 (98 women and 67 men) persons of different blocks in the district (Basudevpur: 24 farmers, Bhadrak:18 farmers, Bhandaripokhari: 23 farmers, Bonth: 19 farmers, Chandbali: 29 farmers, Dhamnagar: 27 farmers and Tihidi: 25 farmers) were interviewed. The household surveys were also carried out to get information on farming practices used, use of uncultivated plants and their management and personal demographic features. In addition, field visits were made with the respondents to the areas where the respondents normally collect the

uncultivated species. During the visits, harvesting methods, parts used, harvest quantity, treatment for which they are used and storage of different species for their future use were discussed. The collected specimens were processed, dried, herbarium specimens were prepared and identified by referring to Saxena and Brahmam (1996). Voucher specimens of the collected plant species were deposited in the herbarium of the Department of Botany, Chandbali College, Chandbali.

Quantitative analysis

Relative frequency of citation (RFC): This index determines the local importance of each species and is calculated by the following formula:

$$RFC = \frac{FC}{N} \quad (0 < RFC < 1)$$

Where FC is the number of informants reporting the use of a particular species and N is the total number of informants.RFC value varies from 0 (when nobody refers to a plant as a useful one) to 1 (when all informants mention it as useful) (Tardio and PardodeSantayana 2008).

Use value (UV): The use value demonstrates the relative importance of plants known locally. It is calculated using the following formula (Gazzaneo *et al*.2005).

$$UV = \text{"}\frac{Ui}{N}$$

Where Ui is the number of uses mentioned by each informant for a given species and N is the total number of informants.

RESULTS AND DISCUSSION

Many weeds are edible, serving as traditional food every day for people all over the world (Duke 1992, Lee *et al.* 2007, Maneechote 2007). In India, more than 3000 wild plant species are used as subsidiary food and vegetable by indigenous people, and at least 250 plants can be developed as a new source of food in the near future (Anonymous 1994). At the end of our two year study, 37 rice field weeds belonging to 24 botanical families were considered as edible plants, (**Table 1**) as reported earlier from other states of India (Sinha and Lakra 2007; Parameswaran and Kumar 2017) and different countries of the world (Díaz-Betancourt *et al.* 1999, Cruz-Garcia and Price 2012, Kosaka *et al.* 2013). All these species appear in the Global Compendium of Weeds (HEAR 2007] and were reported as weed in rice (Moody 1989). Halwart (2006) also emphasized the importance of wild foods from rice-based aquatic ecosystems for food and nutritional security. In the Asian-Pacific region, more than 150 weed species are considered edible (Kim *et al.*2007). The importance of wild food plant diversity from agricultural ecosystems has been highlighted by Cruz-Garcia and Price (2012). In this study, Amaranthaceae was the most common family represented by six species, followed by Asteraceae and Poaceae with three species each. Both reproductive (flowers and fruits) and vegetative parts (shoots, leaves, tuber *etc*.) were used for vegetables. Leaves (42.1%) and shoots (33.3%) were eaten most frequently (**Table 1**). However, in most cases the fruit was not eaten as a vegetable.

The most important species according to their use value with highest RFC and used for vegetable purposes were: *Ipomoea aquatica* (UV 0.588;UR 160), *Glinus oppositifolius* (UV 0.576; UR 155) and *Marsilea minuta* (UV 0.558; UR 149) (**Table 2**). The importance of edible weeds was emphasized in India (Datta and Banerjee 1978, Sinha and Lakra 2007 and Mishra *et al.* 2012), Philippines (Marcelino *et al.* 2005), Korea and China (Pemberton and Lee 1996), Thailand (Maneechote 2007) and in Laos (Kosaka *et al.*2013) of Asia; and also in Africa, America and Europe (Grivetti *et al.* 1987, Duke 1992, Pemberton and Lee 1996, Díaz-Betancourt *et al.* 1999, Turner *et al.* 2011). The three top edible weeds in Asian culinary delights are: *Alternanthera sessilis*, *Centella asiatica* and *Ipomoea aquatica* (Chandrasena 2007). These edible weeds of Bhadrak district are also consumed in other Asian countries, for example: *Centella asiatica* in China (Hu 2005), *Glinus oppositifolius* in Thailand (Cruz-Garcia and Price 2012), *Alternanthera sessilis* and *Ipomoea aquatica* in the Philippines and China (Marcelino *et al.* 2005; Hu 2005) and *Coccinia grandis* in Vietnam (van Chin 1999). The reported weeds such as *Glinus oppositifolius, Ipomoea aquatica* and *Marsilea minuta* were found, during the survey period, to be sold in the local markets particularly by poor and economically marginalised families, thereby generating a supplementary income to their household economy. Village farmers stated that these food plants are being sold in market for 50 or 60 years, and that demand for these foods has increased with time. The selling of *Glinus oppositifolius*, *Ipomoea aquatica* and *Marsilea minuta* in the local markets was also reported by Srivastava *et al.* (2018).

In addition to food, vegetables usage, the weeds were also used for fodder purpose (**Table 1**). The study considered as important sources for animal well being because, many weed species are utilized as fodder for buffaloes and cattle as reported elsewhere

Table 1. List of weeds consumed as vegetables and used for various purposes in Bhadrak district, Odisha, India

Weed	Family	Vernacular name	Edible part(s) as mentioned by respondents	Uses*
Alternanthera philoxeroides (Mart.) Griseb.	Amaranthaceae	Ghodamadaranga	Leaf, shoot	F, FD
Alternanthera sessilis (L.) R. Br. Ex DC.	Amaranthaceae	Madaranga	Shoot, leaf	F, FD M
Amaranthus viridis L.	Amaranthaceae	Leutia	Leaf, shoot	F, FD
Amaranthus spinosus L.	Amaranthaceae	Kantaneutia	Leaf	F, FD, M
Amaranthus tricolor L.	Amaranthaceae	Nautia	Leaf	F
Aponogeton natans (L.) Engl. & Krause	Aponogetonaceae	Ghechu	Bulbil	F, FD
Argemone mexicana L.	Papaveraceae	Kantakusuma	Leaf	F, FD, M
Bacopa monnieri (L.) Penn.	Scrophulariaceae	Brahmi	Shoot	F, FD, M
Boerhavia diffusa L.	Nyctaginaceae	Puruni	Leaf, shoot	F, FD, M
Centella asiatica (L.) Urb.	Apiaceae	Thalkudi	Leaf, petiole	F, FD, M
Chenopodium album L.	Amaranthaceae	Bathuasaga	Leaf, shoot	F, FD, M
Coccinia grandis (L.) Voigt.	Cucurbitaceae	Kundri	Fruit	F
Colocasia esculenta (L.) Schott.	Araceae	Saru	Leaf, tuber	F, FD, M
Commelina benghalensis L.	Commelinaceae	Kansiri	Leaf, shoot	F, M
Crinum asiaticum L.	Amaryllidaceae	Panikenduli	Rhizome	F, M
Echinochloa crus-galli (L.) P. Beauv.	Poaceae	Dhera	Grain	F, FD
Echinochloa stagnina (Retz) P. Beauv.	Poaceae	Jhipa	Grain	F, FD
Eclipta alba (L.) Hassk.	Asteraceae	Bhrungaraj	Shoot	F, FD, M
Emilia sonchifolia (L.) DC.	Asteraceae	Sarkara	Shoot	F
Enydra fluctuans Lour.	Asteraceae	Hidimicha	Leaf, shoot	F, FD, M
Glinus oppositifolius (L.) Aug. DC.	Molluginaceae	Pitasaga	Leaf, shoot	F, FD, M
Hydrolea zeylanica (L.) Vahl	Hydrophyllaceae	Langulia	Whole plant	F, FD, M
Hygrophila auriculata (Schumach)Heine	Acanthaceae	Koelikhia	Leaf	F, M
Ipomoea aquatica Forssk.	Convolvulaceae	Kalamasaga	Leaf, shoot	F, FD, M
Limnophila indica (L.) Druce.	Scrophulariaceae	Keralata	Leaf	F
Ludwigia adscendens (L.) H. Hara	Onagraceae	Jagal	Shoot, leaf	F, FD, M
Ludwigia prostrata Roxb.	Onagraceae		Shoot, leaf	F
Marsilea minuta L.	Marsileaceae	Sunsunia	Leaf, petiole	F, FD, M
Monochoria hastata (L.) Solms	Pontederiaceae		Leaf, shoot, flower	F, FD
Nymphaea nouchali Burm. f.	Nymphaeaceae	Nilakain	Fruit	F, M
Nymphaea pubescens Willd.	Nympaeaceae	Rangakain	Fruit	F
Ottelia alismoides (L.) Pers.	Hydrocharitaceae	Panikundri	Shoot, flower	F, FD, M
Oryza rufipogon Griff.	Poaceae	Balunga	Grain	F, FD
Oxalis corniculata L.	Oxalidaceae	Ambiliti saga	Leaf	F, FD, M
Polygonum plebeium R.Br.	Polygonaceae	Muthisaga	Leaf, shoot	F
Portulaca oleracea L.	Portulacaceae	Badabalbaula	Leaf, shoot	F, FD, M
Portulaca quadrifida L.	Portulacaceae	Balbaula	Leaf, shoot	F, FD

*F= Food; FD= Fodder; M= Medicinal use

by Marcelino *et al.* (2005). The most significant species according to their use value for fodder were *Echinochloa crus-galli* (0.552), *Echinochloa stagnina* (0.527) and *Alternanthera. philoxeroides* (0.436). The rice fields are abundant sources of forage production for dairy cattle (Zahra *et al.*2014) and weeds such as *E. crus-galli* and *E. stagnina* are considered as a source of protein as well as additives to the fodder for animals (Sherag *et al.*2014). The use of *Alternanthera philoxeroides* as forage for animals was also reported (Banerjee and Matai 1990, Sushilkumar and Vishwakarma) in addition to its reported use as medicine (Panda and Misra 2011) and food (as leafy vegetables) for human consumption (Sarma and Saikia 2010).

The plant species with use value (UV) for medicinal purposes were *Centella asiatica* (L.)Urb. (UV: 0.41) followed *by Bacopa monnieri* (L.) Penn. (UV: 0.37) and *Commelina benghalensis* L. (UV: 0.364) (**Table 2**). *Centella asiatica* use, for the treatment of various ailments such as stomach disorders, irregular menstruation, maternal health care, has been reported (Prakash *et al.* 2017, Panda *et al.* 2018b). In Ayurveda, *Bacopa monnieri* is recommended for improvement of memory, variety of diseases like anti-inflammatory, analgesic, antipyretic and sedative (Russo and Borrelli 2005). Aguiar and Borowski (2013) and Kongkeaw *et al.* (2014) stated that *Bacopa monnieri* targets the CNS and manage conditions such as memory, lack of concentration, and anxiety. Similarly, *Glinus oppositifolius* has been used in the treatment of skin disease, increase appetite, cures kapha, piles, leukoderma, tonic to intestine, urinary infections, fever, cough, liver problem and also used as antioxidant due to its excellent properties and potent phytoconstituents (Sheu *et al.* 2014). Likewise, *Ipomoea aquatica* is effectively used against

Table 2. Quantitative analysis of weeds use in Bhadrak district, Odisha, India

Weed	Number of respondents* using the weed as			Relative frequency of citation	Use value		
	Food	Fodder	Medicine		Food	Fodder	Medicinal use
Alternanthera sessilis	52	51	22	0.824	0.315	0.309	0.133
Alternanthera philoxeroides	11	72	02	0.552	0.067	0.436	0.012
Amaranthus viridis	87	11	NR	0.612	0.527	0.067	-
Amaranthus spinosus	18	11	33	0.418	0.109	0.067	0.2
Amaranthus tricolor	57	NR	NR	0.412	0.345	-	-
Aponogeton natans	17	12	NR	0.188	0.103	0.072	-
Argemone mexicana	06	13	36	0.455	0.036	0.079	0.218
Bacopa monnieri	37	05	61	0.661	0.224	0.03	0.37
Boerhavia diffusa	51	34	44	0.83	0.309	0.206	0.27
Centella asiatica	33	14	67	0.709	0.2	0.085	0.41
Chenopodium album	53	9	15	0.497	0.321	0.054	0.09
Coccinia grandis	47	NR	NR	0.333	0.284	-	-
Colocasia esculenta	85	03	32	0.733	0.515	0.018	0.193
Commelina benghalensis	19	NR	60	0.491	0.115	-	0.364
Crinum asiaticum	22	NR	30	0.352	0.133	-	0.182
Echinochloa crus-galli	14	91	NR	0.666	0.084	0.552	-
Echinochloa stagnina	09	87	NR	0.624	0.054	0.527	-
Eclipta alba	24	33	51	0.672	0.145	0.2	0.309
Emilia sonchifolia	19	NR	NR	0.158	0.115	-	-
Enydra fluctuans	41	16	34	0.618	0.248	0.097	0.206
Glinus oppositifolius	95	13	47	0.976	0.576	0.079	0.284
Hydrolea zeylanica	03	56	03	0.388	0.018	0.34	0.018
Hygrophila auriculata	31	NR	29	0.484	0.188	-	0.176
Ipomoea aquatica	97	14	49	0.982	0.588	0.084	0.297
Limnophila indica	35	18	11	0.461	0.212	0.109	0.067
Ludwigia adscendens	48	34	24	0.715	0.291	0.206	0.145
Ludwigia prostrata	24	15	08	0.309	0.145	0.091	0.048
Marsilea minuta	92	16	41	0.945	0.558	0.097	0.248
Monochoriahastata	17	06	11	0.212	0.103	0.036	0.067
Nymphaea nouchali	28	05	29	0.412	0.17	0.03	0.176
Nymphaea pubescens	39	NR	22	0.43	0.236		0.133
Ottelia alismoides	28	17	23	0.473	0.17	0.103	0.139
Oryza rufipogon	09	33	NR	0.345	0.055	0.2	
Oxalis corniculata	72	20	15	0.661	0.436	0.121	0.091
Polygonum plebeium	83	NR	NR	0.558	0.503		
Portulaca oleracea	26	27	17	0.436	0.158	0.164	0.103
Portulaca quadrifida	19	13	NR	0.206	0.115	0.079	

***Total number of respondents =165);** RFC = Relative frequency of citation *i.e.* use range - 0: when nobody refers to a plant as a useful one, to 1: when all informants mention it as useful Medicinal use; NR= Not reported

nosebleed, high blood pressure, leukoderma, leprosy, jaundice, liver complaints and as anthelmintic (Malakar and Choudhury 2015). Thus, the weeds in rice are an important resource for farmers of Bhadrak district, not only as food (vegetables) but also because of the multiple additional uses they have.

Our results indicated that the distribution of weed species varies seasonally within rice ecosystems. Abundance and distribution of weed flora in rice field is inclined to interaction multiple factors of local environmental conditions (Travlos *et al.* 2018, Kurniadie *et al.* 2019). In this study, a higher number of weeds were observed during *Kharif* (Rainy-wet) (June–Nov) than the *Rabi* (Post-rainy -dry) (January–April) season. Rainfall and flooding were the 'major drivers' of this variability. Species diversity increases in the monsoon with bund (levee) being the most diverse; whereas in the dry season the greatest diversity was in the rice field as observed by Halwart (2006), Kosaka *et al.* (2013) and Subudhi *et al.* (2015).

It may be concluded that traditional knowledge and usage of weeds as supplementary food and primary health care is intimately linked to the livelihood needs of the local communities. However, most of this traditional use of weed is now in danger of vanishing. Therefore, it is important to preserve as much of this traditional knowledge as possible in written form. Hopefully, such knowledge may some day constitute the special heritage of the people of Bhadrak to the world. The reported edible weeds could contribute to basic primary health care and balanced diets for the benefit of posterity.

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