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Dualistic roles and management of non-cultivated plants in lowland rice systems of East Africa

D.W. Makokha [a], R. Irakiza [a], I. Malombe [b], T. Le Bourgeois [c], J. Rodenburg [a,*]

[a] Africa Rice Center (AfricaRice), East and Southern Africa, Dar es Salaam, Tanzania
[b] East African Herbarium, National Museums of Kenya, Nairobi, Kenya
[c] Centre de coopération internationale en recherche agronomique pour le développement (CIRAD), Montpellier, France

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ABSTRACT

An ethnobotanical study in lowland rice areas in East Africa was undertaken to assess farmers' knowledge on the usage of non-cultivated plants occurring in paddy fields, and to understand what rice farmers in this region do with useful species once they encounter them in their crop. Inventories of weed species in 19 rice schemes in Tanzania and Kenya were followed by interviews among 380 experienced rice farmers, community elders and traditional healers, grouped into 19 informant groups. Among informant groups, a high degree of consensus about uses of weeds growing in rice paddies was observed. From a total of 222 observed rice weed species, the informant groups identified 67 species with usages described in 1300 use reports. Among these 67 species, 20 are among the most commonly cited weed species in rice paddies in sub-Saharan Africa. Only in 42 cases (3% of the total use reports) did the farmers indicate that they collected (13 species) or spared (four species) these weeds during weeding. In all other cases, such plants were removed or killed during weeding, irrespective of their usefulness. Non-cultivated plants that are spared are those of which the putative agronomic qualities (i.e. for crop protection or soil improvement) are considered more important than their crop competition effects (i.e. *Azolla filiculoides* and *Marsilea crenata*) and those that are found in the field margins, which do not compete with the crop. Non-cultivated plants that are collected during weeding have food, fodder or medicinal purposes or a combination of purposes. The most cited species that are collected or spared during weeding were *Bidens pilosa*, *Ipomoea aquatica*, *Corchorus olitorius* and *Stachytarpheta jamaicensis*. This study revealed that lowland rice farmers in East Africa generally have a high level of understanding and consensus on the usefulness of the non-cultivated plants growing in lowland rice schemes. When they occur in their crop however, the vast majority of these species are primarily seen as weeds and consequently removed or killed.

1. Introduction

Among the numerous production challenges African rice farmers are facing, competition from weeds is considered as one of the most common and serious (Waddington et al., 2010). Weeds are defined as non-cultivated plants that are not desired in crop fields since they compete with crop for nutrients, soil moisture, sunlight and space. Or more philosophically, as plants whose virtues have not yet been discovered (Zimdahl, 2007). Rice (*Oryza sativa* L.) is the fastest growing cereal commodity in sub-Saharan Africa (SSA), with an estimated annual paddy production increase of 9.5% (Seck et al., 2012). Rice is a volatile crop that can be grown under a range of hydrological conditions ranging from free-draining rain-fed uplands to continuous flooded lowlands (Andriesse and Fresco, 1991). Much of the rice is however grown in the temporary or continuous flooded lowlands (either rain-fed or irrigated) of Africa, covering an estimated 64% of the total area under rice and producing about 73% of the total annual paddy production of the region (Diagne et al., 2013). Rice production systems are predominantly small-scale and subsistence oriented in this region. Yield losses due to uncontrolled weeds are estimated to range between 28% and 74% in transplanted lowland fields, and 28% and 89% in direct-seeded lowland rice (Imeokparia, 1994; Diallo and Johnson, 1997; Johnson et al., 2004). Even despite weed control, rice production in lowlands is estimated to lose 15% (irrigated lowlands) to 23% (rain-fed lowlands) due to competition from weeds under current weed management practices (Becker and Johnson, 2001; Becker et al., 2003). Conservative estimates therefore show that weeds account for annual rice yield losses of 2.2 million tons equating to US$1.45 billion in SSA (Rodenburg and Johnson, 2009).

Non-cultivated plants in agricultural fields are however not just harmful; some species have use values too. They may have various purposes as medicines, food and fodder, construction, fuel and even as pest regulators, green manure or cover crops (Hillocks, 1998). Rural people

* Corresponding author.
E-mail address: j.rodenburg@cgiar.org (J. Rodenburg).

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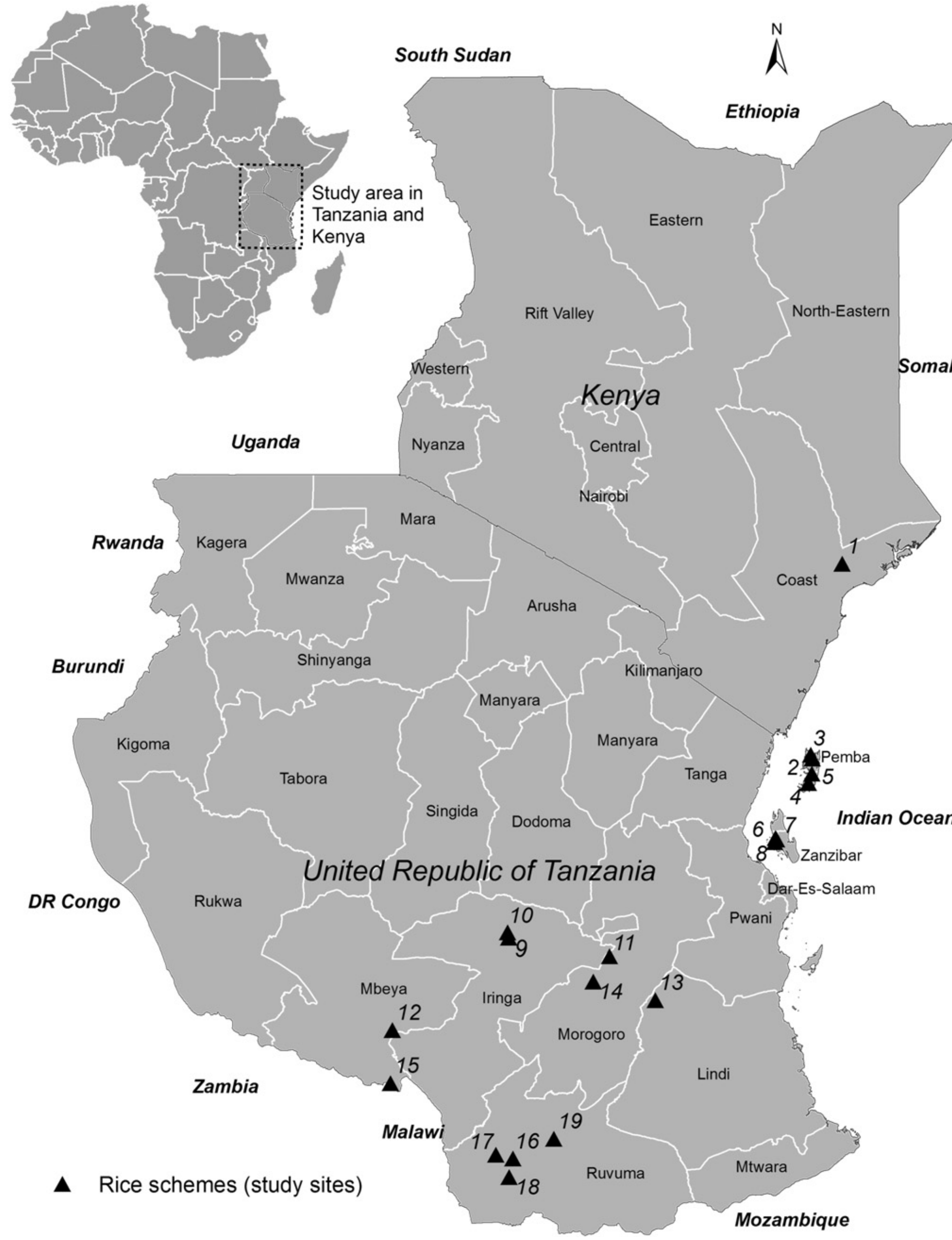

Fig. 1. Map of East Africa, indicating the geographic locations of the study sites (numbers 1–19): 1. Garsen (FI), 2. Kimbuni (PI), 3. Mangwena (PI), 4. Kinyakuzi (RF), 5. Tibirinzi (PI), 6. Mwera (PI), 7. Mtwango (PI), 8. Kiyanga (PI), 9. Luganga (FI), 10. Magozi (FI), 11. Wami (FI), 12. Ruandamajenje (FI), 13. Mkula (FI), 14. Lumemo (FI), 15. Kilasilo (RF), 16. Mtopesi (FI), 17. Namatuhi (FI), 18. Mtonya (FI), 19. Makomboni A (RF). FI = fully irrigated lowland, PI = partially controlled lowland, RF = rain-fed lowland.

indeed extensively use non-cultivated plants, including weeds, for their daily needs (Dansi et al., 2008; Rodenburg et al., 2012). Therefore, weeds may play a role in farmers' livelihoods as well as in cropping systems diversification. Useful weed species can be (1) spared during hand weeding operations, (2) nurtured and conserved where they spontaneously emerge or even (3) purposely planted and nurtured (Rodenburg et al., 2012). However, little is known about the useful weed species growing in rice production ecosystems in SSA—East Africa in particular—and the use purposes of these species and the ways subsistence rice farmers deal with the apparent dualism between their usefulness and their weediness. The specific objectives of the study were therefore (1) to assess farmers' ethnobotanic knowledge on rice weeds in East Africa and (2) to understand what rice farmers in this sub-region do with useful species once they encounter them in their crop. We chose rice production systems in East Africa as this area is yet unexplored in this regard.

2. Materials and methods

2.1. Field survey and data collection

An ethnobotanical survey was conducted during the cropping season, from 20 March to 19 July 2012, in 19 rice schemes in Tanzania—in the areas Pemba (4 schemes), Zanzibar (3), Iringa (2), Dakawa (1), Mbarali (1), Kilombero (2), Kyela (1) and Songea (4)—and in Kenya, in the region Garsen (1 scheme) (See Fig. 1). The selected rice schemes are characterized as rain-fed and irrigated lowland rice-growing environments, with a tropical savanna climate characterized by a mono-modal rainfall regime (annual rainfall ranging from 800 to 2200 mm).

A total of 380 informants (96 men and 284 women), 20 from each scheme, were interviewed. Informants were selected prior to the survey with the help of National Agricultural Research Systems (NARS)—Agricultural Research Institute Uyole (ARI-Uyole), Agricultural

Research Institute Cholima (ARI-Cholima), Mikocheni Agricultural Research Institute (MARI), Kilombero Agricultural Training and Research Institute (KATRIN) and Zanzibar Agricultural Research Institute (ZARI) in Tanzania, and Kenya Agricultural & Livestock Research Organization (KALRO) in Kenya—representatives working at the district level and local extension officers at the village level. In each village, selected informants were composed of 14 experienced farmers, two community elders and four traditional healers who were also rice farmers. A Participatory Rural Appraisal was carried out by a facilitator using the Systematic Random Walk method of Cunningham (2001) and Kumar and Bharati (2014). The informants in the rice schemes were gathered before the systematic random walk. They were briefed by the facilitator on the objectives of the survey after which they were accompanied on a walk through the rice scheme. In each rice scheme, a random walk was undertaken from one end of the scheme to the other end with the complete group of 20 informants. At nine random places, three in the beginning, three in the middle and three at the end, a 1 m^2 quadrat was thrown and all weeds encountered in this 1 m^2 were collected and recorded. After the walk, all collected weeds were sorted by species and discussed one by one with all informants during a group discussion. For each weed species, the facilitator asked the same three questions to the group: (1) Do you know this weed and does this weed have a use? (2) If yes, what can it be used for, which parts are used and how? (3) What do you do with this weed when you encounter it during a weeding intervention? In addition, the informants were asked about the main weed management methods in their rice schemes. For each question, the informants were encouraged to share all their knowledge on a specific weed species and the necessary time was reserved to make sure that all knowledge was captured.

Uses, modes of preparation and administration, methods of control and management were recorded. Voucher specimens of weeds were collected at flowering and fruiting stages using standard methods (Jain and Rao, 1977), and preserved at the East African Herbarium (herbarium code: EA), Nairobi, Kenya, and duplicates were kept at the herbarium of the Africa Rice Center and sent to the herbarium of the University of Dar es Salaam (herbarium code: DSM), Tanzania. Most of the specimens were identified according to curated collections in the two herbaria with the help of local flora or guides (i.e. Troupin, 1978-1988; Heines and Lye, 1983; Akobundu and Agyakwa, 1987; Ivens, 1989; Johnson, 1997; Phillips et al., 2003; Caton et al., 2010; Grard et al., 2012).

2.2. Data analyses

The analyses and presentation of the data obtained from the group discussions were limited to weed species with a use purpose, as identified by the informants. The frequency of citation (FC) for each weed species was calculated using the following formula:

$$\mathrm{FC}\,(\%) = (N/T) \times 100 \qquad (1)$$

where, N is the number of informant groups citing the weed species and T is the total number of informant groups (e.g. Collins et al., 2006; Andrade-Cetto, 2009; Heinrich et al., 2009).

To determine the extent of consensus between informant groups on the use category of observed species (e.g. food, fuel, medicines, crop protection), we used the agreement rate (AR):

$$\mathrm{AR} = (N_{ur}/_{Nur\,max}) \times 100 \qquad (2)$$

where N_{ur} is the actual number of use reports by informant groups in a particular use category, $N_{ur\ max}$ is the maximum number of use reports if all the informant groups would agree on the use of all the species associated to a particular use category. The value of $N_{ur\ max}$ is derived as

$$N_{ur\,max} = T \times N_s \qquad (3)$$

where T is the total number of informant groups (19 in this study) and N_s is the total number of weed species mentioned by the informant groups within a specific use category.

Agreement rate values range between 0% and 100%; the higher the AR value, the greater the agreement among informant groups on uses of species within a certain use category. Data were ordinated and analyzed using MS Excel (Microsoft, 2013).

3. Results and discussion

3.1. Species and use categories

A total of 222 weed species, belonging to 46 families, were observed in the 19 rice schemes visited in this study (Appendix A). Of these 222 species, 67 species, belonging to 26 families, were found to be of ethnobotanical importance (Table 1) according to a total of 1300 use reports (Table 2). Of the 67 species, 20 are among the most commonly cited weed species of rice farming systems in SSA (Rodenburg and Johnson, 2009). Seven of these 20 species (i.e. *Amaranthus viridis*, *Calopogonium mucunoides*, *Tridax procumbens, Euphorbia heterophylla*, *Euphorbia hirta, Cynodon dactylon* and *Eleusine indica*) are considered weeds of rain-fed uplands rather than lowland rice-growing environments (Rodenburg and Johnson, 2009). It is, however, not uncommon to find such species in less favorable environments as many rice weeds are adapted to a rather broad environmental range (Toure et al., 2014) and rice is often grown along the upland–lowland continuum, whereby limits between upland and lowland become ambiguous (Rodenburg et al., 2014).

The highest number of weed species, identified as useful, was used for food (28) followed by fodder (20) and medicines (17) (Table 1). This corroborates earlier ethnobotanic studies on weeds and non-cultivated plants in Africa (e.g. Hillocks, 1998; Rodenburg et al., 2012). Of the remaining uses, nine species were mentioned to have crop management purposes, six are useful in construction, four are used for traditions and ceremonies and three are used for fuel. For each of the remaining use categories—i.e. crop protection, insect repellence and household and ornamental—only two weed species were mentioned.

The informant agreement rate (AR) among the use categories ranged from 58% to 97%, with a mean of 75% (Table 2). The AR compares the actual number of citations to the maximum possible citations that could be made across the informant groups. The highest AR was found for the category insect repellent (IR). Although it was mentioned for only two species ($N_s = 2$) (*Basilicum polystachyon* and *Cyanthillium cinereum*), there was a high level of agreement among informants as these two species were mentioned in 37 use reports ($N_{ur} = 37$; $_{Nur\ max} = 38$). The other two use categories with a high AR (>90%) were construction (CO) and traditions and ceremonies (TC). The lowest AR (58%) was in the crop protection (CP) and household and ornamental (HO) categories.

From useful species, the leaves were the most preferred parts of the plant; leaves were mentioned by respondents in 35% of the usage reports, mainly for food, fodder and medicines (Table 1; Table 3). The dominance as well as the importance of the leaves as the most useful plant part confirms previous reports (e.g. Uddin et al., 2012). In 30% of the cases, the whole plant, including the roots, are used mainly as fodder, medicines or for crop protection. The whole plants without the roots were mentioned in 15% of the cases, mainly as fodder. The roots, grains and fruits were mentioned in 7% of the uses cases. The inflorescence and stems were mentioned in only 3% of the use cases.

3.2. Usages of weeds

While our surveys resulted in 67 useful weed species, we will here only discuss those that were cited by at least one-third of the informant groups (FC > 33%; comprising 6 species), as well as the 20 species listed as the most common weed species of rice in SSA according to Rodenburg

Table 1
Family, species names, uses, useful plant parts and frequency of citations (FC in %) of weeds identified as useful by rice farmers in 19 rice schemes in East Africa.

Family	Species	Use category	Plant parts	FC
Acanthaceae	*Asystasia gangetica* (L.) T. Anderson	FO; FD	Lf; Ag	5.3
	Hygrophila auriculata (Schumach.) Heine	ME	Wh; Rt	10.5
Amaranthaceae	*Alternanthera sessilis* (L.) R.Br. ex DC.	FO	Lf	5.3
	Amaranthus spinosus L.	FO	Lf	26.3
	Amaranthus viridis L.*	FO	Lf	21.1
	Celosia trigyna L.	FO	Lf	5.3
	Achyranthes aspera L.	FO	Lf	5.3
Asteraceae	*Acmella oleracea* (L.) R.K. Jansen	FO	Lf	5.3
	Ageratum conyzoides (L.) L.*	ME; CM	St; Wh	15.8
	Bidens pilosa L.	FO	Lf	36.8
	Crassocephalum crepidioides (Benth.) S. Moore	FO	Lf	5.3
	Cyanthillium cinereum (L.) H. Rob.	ME; IR	Wh	5.3
	Eclipta prostrata (L.) L.*	ME	Lf	5.3
	Launaea cornuta (Hochst. ex Oliv. & Hiern) C. Jeffrey	FO; ME; FD	Lf	15.8
	Sonchus sp.	FO	Lf	5.3
	Tridax procumbens (L.) L.*	FD	Wh	5.3
	Vernoniastrum ambiguum (Kotschy & Peyr.) H. Rob.	ME	Lf	10.5
Azollaceae	*Azolla filiculoides* Lam.	CP	Wh	26.3
Cleomaceae	*Cleome gynandra* L.	FO	Lf	5.3
Commelinaceae	*Aneilema aequinoctiale* (P. Beauv.) Loudon	FO; FD	Lf; Wh	5.3
	Commelina africana L.	FD; FU	Wh	10.5
	Commelina benghalensis L.*	ME; CM; FD; FO	In; Wh	10.5
	Commelina erecta L.	FU; CM	Wh	10.5
	Murdannia simplex (Vahl) Brenan	CM	Wh	5.3
Convolvulaceae	*Ipomoea aquatica* Forssk.*	FO; FD; CO	Lf; Vn	47.4
	Ipomoea vagans Baker	FD	Ag	10.5
Curcurbitaceae	*Cucurbita pepo* L.	FO	Lf; Fr	10.5
Cyperaceae				
	Cyperus distans L.f.	CM; FD	Wh	5.3
	Cyperus esculentus L.*	FO; ME; TC	Rt	31.6
Euphorbiaceae	*Euphorbia heterophylla* L.*	CM; FD	Wh	36.8
	Euphorbia hirta L.*	ME	Lf; Rt	21.1
Fabaceae	*Calopogonium mucunoides* Desv.*	FO;FD	Lf	15.8
	Crotalaria retusa L.	ME	Lf	5.3
	Mimosa diplotricha Sauvalle	CO	Wh	26.3
	Mimosa pigra L.	ME	Lf; Rt	21.1
	Vigna vexillata (L.) A. Rich.	FD	Ag	5.3
Lamiaceae	*Basilicum polystachyon* (L.) Moench	TC; ME; IR	Lf; Wh	57.9
	Platostoma rotundifolium (Briq.) A.J. Paton	ME	Lf	10.5
Lythraceae	*Ammannia auriculata* Willd.	FO	Lf	10.5
Malvaceae	*Corchorus olitorius* L.	FO	Lf	52.6
	Melochia corchorifolia L.	FD	Ag	10.5
	Sida acuta Burm.f.	HO	Wh	15.8
Marsileaceae	*Marsilea crenata* C. Presl.	CP	Wh	15.8
Menispermaceae	*Stephania abyssinica* (Quart.-Dill. & A. Rich.) Walp.	ME	Rt	10.5
Onagraceae	*Ludwigia abyssinica* A. Rich.*	CM; CO	Wh	10.5
Phyllanthacae	*Phyllanthus amarus* Schumach. & Thonn.	ME	Wh	47.4
Poaceae	*Cynodon dactylon* (L.) Pers.*	CM; FD	Wh	15.8
	Coix lacryma-jobi L.	TC	Fr	5.3
	Echinochloa colona (L.) Link*	FO; FD	Gr; Ag	21.1
	Echinochloa crus-galli (L.) P. Beauv.	FO; FD	Gr; Ag	10.5
	Echinochloa crus-pavonis (Kunth) Schult.*	FO	Gr; Ag	15.8
	Echinochloa haploclada (Stapf) Stapf	FO	Gr; Ag	10.5
	Echinochloa pyramidalis (Lam.) Hitchc. & Chase*	FO	Gr; Ag	5.3
	Eleusine indica (L.) Gaertn.*	CO	Lf	5.3
	Ischaemum rugosum Salisb.*	FD; CM	Ag; Wh	5.3
	Leersia hexandra Sw.*	FD	Ag	5.3
	Panicum maximum Jacq.*	CO	Ag	5.3
	Pennisetum polystachion (L.) Schult.	FD	Ag	5.3
	Phragmites australis (Cav.) Trin. ex Steud.	CO, FD	Ag	15.8
Polygonaceae	*Persicaria pulchra* (Blume) Soják	FO; FU	Lf; St	5.3
Portulacaceae	*Portulaca oleracea* L.	FO	Lf	5.3
Rubiaceae	*Agathisanthemum bojeri* Klotzsch	ME	In; Rt	10.5
	Pentodon pentandrus (Schumach. & Thonn.) Vatke	FO; FD	Lf	15.8
Sphenocleaceae	*Sphenoclea zeylanica* Gaertn.*	HO	Lf	5.3
Thelypteridaceae	*Thelypteris totta* (Thunb.) Schelpe	TC	Wh	10.5
Thyphaceae	*Typha domingensis* Pers.	HO	St;In	5.3
Verbenaceae	*Stachytarpheta jamaicensis* (L.) Vahl	FO; ME	Lf	26.3

Abbreviations: CM = crop management; CO = construction; CP = crop protection; FD = fodder; FO = food; FU = fuel; HO = household and ornamental; ME = medicines; IR = insect repellent; TC = traditions and ceremonies; Ag = above-ground; Lf = leaves; In = inflorescence; Rt = roots; St = stems; Wh = whole plant; Fr = fruits; Gr = grain; Vn = vines.
* Most common weed species in rice in SSA according to Rodenburg and Johnson (2009).

and Johnson (2009). The six most cited species were: *B. polystachyon* (FC = 58%), *Corchorus olitorius* (FC = 53%), *Ipomoea aquatica* (FC = 47%), *Phyllanthus amarus* (FC = 47%), *E. heterophylla* (FC = 37%) and *Bidens pilosa* (FC = 37%). Two species, *I. aquatica* and *E. heterophylla* were both highly cited in this survey and listed among the most commonly cited rice weeds of SSA.

Table 2
The number of weed species associated with a certain use category (N_s), the actual number of use reports (N_{ur}) in that category as mentioned by the informant groups ($n = 19$) and the agreement rate (AR) indicating the extent of consensus between informant groups on the use category of observed species; AR is derived from N_{ur} and the maximum possible number of use reports ($N_{ur\ max}$)—the number of informant groups (19) times N_s—as ($N_{ur}/N_{ur\ max}$) × 100.

Use category	Total number of species in a use category (N_s)	Actual number of use reports (N_{ur})	Max possible number of citations ($N_{ur\ max}$)	Agreement rate (AR)
FO	28	391	532	73.4
FD	20	235	380	61.8
ME	17	257	323	79.6
CM	9	117	171	68.4
CO	6	109	114	95.6
TC	4	73	76	96.0
CP	2	22	38	57.9
IR	2	37	38	97.4
FU	3	37	57	64.9
HO	2	22	38	57.9
Total	93	1300	1786	Mean: 75.3

CM = crop management, CO = construction, CP = crop protection, FD = fodder, FO = food, FU = fuel, HO = household and ornamental, ME = medicines, IR = insect repellent, TC = traditions and ceremonies.

We observed several uses for *B. polystachyon*. Informants indicated that (1) the leaves of *B. polystachyon* are burnt to repel mosquitoes, chicken fleas and nightmares (customary belief); (2) the sap is applied on infant bodies to protect from evil (customary belief) and also as eye drops and (3) a leaf decoction is used for a range of medical treatments, i.e. fever, fatigue, menstrual problems, flu, chronic malaria, stomach disorders and infertility. Wardani (2001) previously provided an overview of partly overlapping traditional uses for *B. polystachyon* by rural communities in Africa: (1) in Tanzania and Ghana, fresh roots and leaf sap of this species are chewed for medicinal purposes; (2) nomads in Kenya burn the plant inside milking pots to give a pleasant aroma; (3) in Kenya, Uganda and Tanzania, the plant is burnt indoors as a mosquito and snake repellent and (4) in Nigeria and Tanzania, the leaves are used to flavor food and as a sedative.

C. olitorius leaves have been reported as vegetables all over Africa (e.g. Dansi et al., 2008; Rensburg et al., 2004) and our survey showed a similar use of this species throughout the study sites.

According to informants of this survey, *I. aquatica*, a common weed in lowland rice schemes in Kenya and Tanzania, is used as a vegetable and fodder for cattle and pigs, while mature vines are used for construction. The species' use as a traditional leafy vegetable in SSA has been reported before; in Benin, for instance, *I. aquatica* is a frequently grown vegetable in rural home gardens (Salako et al., 2014).

Another widely cited species, *P. amarus*, is used to treat fever and fits (according to the informant group in Kenya) and for a range of other medical treatments, i.e. stomachaches, eye infections, skin fungal infections, asthma, chronic malaria, placental delivery and orchitis (according to informant groups in Tanzania). This resembles the traditional uses reported from Cote d'Ivoire, Mali, Benin, Kenya, Congo, DRC and Uganda, where *P. amarus* is taken to facilitate childbirth, to treat oedema, pain caused by fever, sore throats and poisoning by snakebites (Neuwinger, 2000; Burkill, 2004).

E. heterophylla is used for compost and as fodder according to informants in Tanzania and Kenya. This confirms the report by Burkill (2004) concerning the fodder value of this species.

Table 3
The use frequency of plant parts as a percentage of the total use reports with examples of their uses.

Plant part	% of uses	Examples of use
Leaves	34.9	*Alternanthera sessilis*, as vegetable
Whole plant with roots	29.8	*Azolla filiculoides*, for weed control
Whole plant without roots	14.9	*Asystasia gangentica*, for fodder
Roots	6.8	*Stephania abyssinica*, as stomach medicine
Grains or fruits	6.8	*Cucurbita pepo*, as vegetable/fruit
Inflorescence	3.4	*Agathisanthemum bojeri*, to treat ringworms
Stems and vines	3.4	*Ipomoea aquatica*, as ropes in construction

B. pilosa was reported to be used as a leafy vegetable and its ground leaves are mixed with detergent to contol white flies in rice farms in Tanzania, especially in Kilombero District. Its use as a leafy vegetable corroborates previous studies from SSA (Uusiku et al., 2010), while the traditional pesticidal use of the species was reported previously from Uganda (Mwine et al., 2011). The plant species is also traditionally used to treat malaria in Uganda (Adia et al., 2014) as well as a range of other diseases in other parts of the world (Connelly, 2009).

According to the survey respondents, tubers of the common weed *Cyperus esculentus* (FC = 32%) are used as a food source, and to treat stomach ailments and coughs. In Zanzibar, tubers are either eaten raw or cooked and a bracelet made of tubers from *C. esculentus* is used to protect infants from evil spirits (customary belief). The informants from Zanzibar also indicated that the juice of the *C. esculentus* roots is used in the treatment of fever, the leaves and culms are used for weaving and basketry, while the presence of the species in their fields is used as an indicator for fertile soils. The use of *C. esculentus* as source for food and medicines was reported before by Hillocks (1998) and Neuwinger (2000).

Informants in Tanzania mentioned that *E. hirta* (FC = 21%), is used for a range of medicinal purposes. The latex is used for the treatment of eye infections and bleeding, while the roots and leaves are used to treat stomach ailments. This seems to corroborate earlier usages reports from Nigeria, where *E. hirta* is known to treat diarrhea (Etuk et al., 2009). All over Africa, the latex of *E. hirta* is known to be used for wound healing (Berhaut, 1975).

Respondents of the survey mentioned *Echinochloa colona* (FC = 21%) to be used as a cereal during famine, confirming earlier reports (e.g. Salih et al., 1992). According to informants of the current study, it is also used as fodder. Related species *E. pyramidalis* (FC = 5%) was observed to be used as cereal and fodder source, while *E. crus-pavonis* (FC = 16%) was used for food. The genus *Echinochloa* contains some of the worst weed species to rice (Holm et al., 1991; Rao et al., 2007; Rodenburg and Johnson, 2009). However, reports on the use of these species, in particular from Africa, are scarce.

Informant groups in both Kenya and Tanzania indicated that *A. viridis* (FC = 21%) is used as a leafy vegetable, confirming previous use reports from Niger (Sena et al., 1998) and Mali (Nordeide et al., 1996).

According to informants in Tanzania, *C. mucunoides* (FC = 16%) is used as food and fodder especially in the dry season. Apart from its use as forage for animals during the dry season, it was reported as a (potential) cover crop for plantations and as green manure for soil improvement in West Africa (Akanvou et al., 2001; Burkill, 2004).

The stem sap of the common weed *Ageratum conyzoides* (FC = 16%) is used for blood clotting and treatment of ear infections by informants in Tanzania, while the whole plant is useful as fodder and for compost in Kenya and Tanzania. In Kenya, the traditional dermatological and anti-bacterial use of *A. conyzoides* by rural communities has been reported before by Johns et al. (1990). In other parts of Africa (i.e. Madagascar, Nigeria, Congo, Benin, Togo and Sierra Leone), it is used to treat stomach ailments, while in Gabon, Cote d'Ivoire and Congo, it is used for traditions and ceremonies (Neuwinger, 2000).

The common weed *C. dactylon* (FC = 16%) is used as manure and fodder, and strengthens bunds in rice irrigation systems according to the informants of this study. In Zanzibar, the species is known under the vernacular name 'Ukokabonde', a Swahili word meaning 'grass to make bunds strong'. No traditional use reports on *C. dactylon* in Africa are found in the literature, but its anti-erosion and stabilizing characteristics have been previously reported (e.g. Tenten et al., 2010).

Informants in Tanzania indicated the use of *Ludwigia abyssinica* (FC = 11%) for compost and for the production of black dye (the latter only mentioned in Zanzibar). The leaves are cooked to provide black dye that is used in basketry and textiles. The traditional use of *L. abyssinica* as a dye has been reported previously by Van der Burg (2004).

Commelina benghalensis (FC = 11%) is associated with the highest number of use categories (4) among all cited species. Informants use it as a vegetable, confirming a previous study from Kenya by Johns and Kokwaro (1991), and further mentioned the use of *C. benghalensis* in the treatments of eye infections and wounds (as a disinfectant) as well as in compost making and fodder.

Leersia hexandra (FC = 11%) is one of the most widespread grass weeds in rice systems in Africa (Rodenburg and Johnson, 2009). It is difficult to weed as the sharp edges of the leaf blades of full grown plants can injure the skin while young plants may be difficult to distinguish from the crop as they are morphologically similar to rice. Informants reported its use as a source of fodder, confirming observations from Venezuela by Sarmiento et al. (2004). In Senegal, the plant is used in folk medicine (Burkill, 2004).

For six common weeds, *Eclipta prostata*, *E. indica*, *T. procumbens*, *Ischaemum rugosum* and *Sphenoclea zeylenica*, unique use reports have been collected (FC = 5%). The leaves of *E. prostata* are used for facilitating blood clotting and a variety of other medicinal uses, such as treatments of skin diseases, leprosy, herpes, elephantiasis, hemorrhoids, ringworms, scorpion stings and snakebites. Traditional medicinal use of the leaves of this species in Africa has earlier been reported by Neuwinger (2000). Culms of *E. indica* are used for basketry and weaving ropes for construction according to survey respondents in Tanzania. This species has previously been reported for its use as fodder (Neuwinger, 2000), a famine food and for household purposes (Hillocks, 1998). To our knowledge, its use in construction and basketry has not been reported before in the literature. *T. procumbens* was reported as fodder, specifically for goats, in Zanzibar. *I. rugosum* is used in making compost in Zanzibar. The fruit of *S. zeylenica* is used as a hand soap in Tanzania. While all three species are mentioned as useful plants by Burkill (2004), the specific use purposes observed in the current study have not been reported before. *Panicum maximum* (FC = 5%) was indicated by an informant group in Tanzania for its use in roofing and broom making. This confirms Burkill (2004) reporting the use of *P. maximum* for making brushes and brooms in Kenya and Tanzania. In Uganda, the species is used as fodder (Nampanzira et al., 2015).

3.3. Weed management

In the surveyed rice schemes, hand weeding and the use of post-emergence herbicides were the main weed management practices. The most frequently used herbicide was 2,4-D. Other herbicides were based on propanil, thiobencarb or glyphosate. All these herbicides are common in lowland rice production systems in Africa (Rodenburg and Johnson, 2009).

During weeding, the far majority of non-cultivated plants encountered in the crop are removed and killed as indicated by the informant groups. Exceptions to this rule were found in 15 of the 19 rice schemes (Table 4). Only in 42 use reports, 3.2% of the total of 1300 reports, did informants indicate that a species was purposely not removed or killed during weeding. This challenges the old definition of weeds by Emerson from 1912, cited in Zimdahl (2007) that a weed is a plant whose virtues have not yet been discovered. In small-scale rice farming, at least in East Africa, a weed is rather a plant whose virtues have either not yet been discovered or whose virtues the farmer considers less important than its detriments to the crop. The 42 reports where weeds were not removed or killed at weeding, covered only 17 different species, 25% of the total number of 67 useful species. Farmers indicated in these reports that the plants were either collected for use after weeding (13 species) or spared (4 species) during weeding interventions.

Combining Tables 1 and 4, shows that the thirteen species that were collected during weeding most often have food purposes (5); medicinal purposes (2) or combined purposes like food, medicinal, fodder, construction or crop management (6). Five of these weeds—i.e. *P. amarus*, *C. olitorius*, *E. heterophylla*, *I. aquatica* and *B. pilosa*—had a citation frequency higher than 33%. Among the three species that were most cited to be collected during weeding, two—i.e. *C. olitorius* (mentioned 4 times) and *B. pilosa* (mentioned 6 times)—are common rice weeds adapted to upland growing environments. Only two of the 13 weed species that are collected during weeding (i.e. *I. aquatica*, mentioned 5 times and *Pentodon pentandrus*, mentioned twice) are truly lowland weed species. Moreover, only two of the collected species (i.e. *E. heterophylla* and *I. aquatica*), are among the most common or noxiuous weeds in rice in SSA as listed by Rodenburg and Johnson (2009). A number of weeds with relatively high citation frequencies and important use purposes—i.e. food, fodder or medicines—like *A. viridis*, *C. esculentus*, *E. hirta*, *E. colona, Mimosa pigra* and *B. polystachyon* were not collected or spared during weeding. The latter two species, *M. pigra* and *B. polystachyon*, are most remarkable in this respect as they are not among the most cited weed species of rice in SSA (Rodenburg and Johnson, 2009). *B. polystachyon* is the species that was most frequently mentioned by informant groups of this study, with many usages, showing that a high citation frequency and multiple use does not necessarily mean a non-cultivated plant is not considered a weed when encountered in the crop.

The collection of useful weeds during weeding also depends on their maturity level. *Amaranthus spinosus*, *B. pilosa* and *Stachytarpheta jamaicensis*, for instance, were sometimes reported to be collected while young but disposed when old. These species are used as leafy vegetables and only young leaves are suitable for that purpose.

Among the four species that were spared during weed interventions *Azolla filiculoides* was the most frequently mentioned (3 times). This species was cited for its use as green manure and weed control characteristic. It is a floating fern species that has little interference with crop growth. The combination of these two characteristics may explain why farmers encountering it in their rice field have an incentive to spare it during weed interventions or a lack of incentive to remove it. The same applies to *Marsilea crenata*, another fern species which was cited for its crop protection purposes and which was also left behind during weeding. The other two species that are being left during weeding are *Cucurbita pepo* (pumpkin) and *Crotalaria retusa*. Informant reports indicate that in the cases where these plants were spared, they were growing in places where they do not severely interfere with the rice crop, according to the farmer's perception.

In subsistence rice farming in SSA, weeding is most often done by hand or hoe (Gianessi, 2013; Ogwuike et al., 2014). This weed control intervention seems perfectly adapted to the traditional uses of weeds as uprooted plants with a use purpose can then be selected and kept apart or maintained as has been observed elsewhere in Africa (Rodenburg et al., 2012). This practice may however not be feasible in more intensified and larger-scale lowland rice systems. Such systems will mostly rely on mechanical or chemical weed control, as these are known to save considerable labour (Rodenburg et al., 2015). It is therefore likely that the practice of using rice weeds for supplementary food, fodder, traditional medicines or crop or household purposes, as well as the local

Table 4
Names and management of useful weed species that are not removed or killed during weed control interventions, locations of informant groups where this practice was observed and the dominant weed control interventions at those locations.

Location	Dominant weed control	Useful weed species	Management during weed control
Tibirinzi	Hand weeding and use of herbicides	*Alternanthera sessilis*	C
		Stachytarpheta jamaicensis	C*
		Phyllanthus amarus	C
Luganga	Hand weeding (twice); post-emergence herbicides (2,4-D)	*Amaranthus spinosus*	C*
		Corchorus olitorius	C
		Azolla filiculoides	L
		Cucurbita pepo	L
		Euphorbia heterophylla	C
		Marsilea crenata	L
		Phragmites australis	C
		Ipomoea aquatica	C
Magozi	Hand weeding (twice); post-emergence herbicides (2,4-D)	*Amaranthus spinosus*	C
		Azolla filiculoides	L
		Corchorus olitorius	C
Kimbuni	Hand weeding and use of herbicides	*Amaranthus spinosus*	C
		Stachytarpheta jamaicensis	C
Mwera	Push weeder	*Stachytarpheta jamaicensis*	C
		Azolla filiculoides	L
		Ipomoea aquatica	C
Mtopesi	Hand weeding and use of herbicides	*Crotalaria retusa*	L
		Bidens pilosa	C
		Crassocephalum crepidioides	C
Mtonya	Hand weeding and use of herbicides	*Corchorus olitorius*	C
		Crassocephalum crepidioides	C
		Bidens pilosa	C
Mtwango	Hand weeding and use of herbicides	*Bidens pilosa*	C
		Pentodon pentandrus	C
		Ipomoea aquatica	C
Mangwena	Hand weeding and use of herbicides	*Hygrophila auriculata*	C
		Ipomoea aquatica	C
		Stachytarpheta jamaicensis	C
Kinyakuzi	Hand weeding and use of herbicides	*Phyllanthus amarus*	C
Namatuhi	Hand weeding	*Bidens pilosa*	C
Garsen	Early post-emergence herbicides (thiobencarb + propanil); flooding	*Crassocephalum crepidioides*	C
Namtumbo	Post-emergence herbicides (2,4-D); early post-emergence herbicides (propanil); transplanting	*Bidens pilosa*	C
Ifakara	Pre-emergence herbicides (glyphosate); post-emergence herbicides (2,4-D)	*Hygrophila auriculata*	C
		Ipomoea aquatica	C
		Launaea cornuta	C
		Pentodon pentandrus	C
		Phyllanthus amarus	C
		Corchorus olitorius	C
Wami	Post-emergence herbicides (2,4-D)	*Bidens pilosa*	C*

Management of useful species during weed control interventions: L = left untouched in the field during weeding, C = collected during weeding, C* = young plants collected/old plants disposed during weeding.

knowledge on these usages, will become more rare with an increasing intensification of rice production systems in SSA.

4. Conclusions

We identified a total of 67 non-culivated plant species, collected from rice schemes in East Africa, with various uses for local rural communities. This represents 30% of the total number of non-cultivated plant species observed in these schemes. The six most cited species were *B. polystachyon*, *C. olitorius*, *I. aquatica*, *P. amarus*, *E. heterophylla* and *B. pilosa*. While many of the cited species and use purposes have been reported before, this study is the first to relate them directly to their status as weeds in rice systems. Of the useful species identified here, 30% are among the most commonly cited rice weeds in sub-Saharan Africa. Only 27% of the useful species are sometimes spared or collected during weeding. Hence, the majority, 73% of the useful species and 92% of all the non-cultivated plant species found in this study, are principally perceived as weeds.

The most cited weed species that are collected or spared during weeding were *B. pilosa*, *I. aquatica*, *C. olitorius* and *S. jamaicensis*. Non-cultivated plant species in rice schemes are primarily collected for food—with a high number of leafy vegetable types—fodder and medicinal purposes and consequently the most prefered plant parts were the leaves. Of the 13 non-cultivated plants that were collected during weeding, only two species were among the most cited weeds species in rice, and only two were uniquely adapted to wetland environments. Among the four useful non-cultivated plant species that were spared during weed interventions, none is known as a noxious weed to rice. Spared species are those that are useful for crop protection or crop management purposes with little crop interference (i.e. *A. filiculoides* and *M. crenata*), or species that do not directly interfere with crop production as they are found in field margins or on bunds.

Lowland rice farmers in East Africa have a broad understanding and high degree of consensus on the usefulness of non-cultivated plants growing in agricultural fields. When such useful non-cultivated plant species occur in crops of smallholder rice farmers, some of them are collected or spared during weeding, but the vast majority of such plant species are primarily seen as weeds and therefore removed or killed. The practice of collecting useful weeds during weeding is possible because the most frequent type of weed control by rice farmers in East Africa, characterized by small-scale farms and low levels of inputs, is hand weeding. It is however expected that a future increase in scale and intensity of lowland rice production systems in sub-Sahraran Africa will imply a shift from manual to mechanical or chemical weed control. Under such a scenario, the practice of using rice weeds for supplementary food, fodder, traditional medicines, crop protection or household purposes, as well as the local knowledge on these use purposes, will become more rare.

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Appendix A. Complete list of 222 weed species, from 46 families, encountered at the 19 rice schemes visited across Tanzania and Kenya

1[*]	*Asystasia gangetica* (L.) T. Anderson
	Hygrophila auriculata (Schumach.) Heine
	Justicia anselliana (Nees) T. Anderson
	Justicia cordata (Nees) T. Anderson
2	*Trianthema portulacastrum* L.
3	*Alisma plantago-aquatica* L.
	Burnatia enneandra Micheli
	Sagittaria guayanensis Kunth
4	*Achyranthes aspera* L.
	Alternanthera nodiflora R. Br.
	Alternanthera sessilis (L.) R.Br. ex DC
	Amaranthus graecizans L.
	Amaranthus spinosus L.
	Amaranthus viridis L.
	Celosia trigyna L.
	Gomphrena celosioides Mart.
	Pupalia atropurpurea (Lam.) Moq.
5	*Centella asiatica* (L.) Urb.
6	*Pistia stratiotes* L.
7	*Acanthospermum hispidum* DC.
	Acmella caulirhiza Delile
	Acmella uliginosa (Sw.) Cass.
	Acmella oleracea (L.) R.K. Jansen
	Acmella radicans (Jacq.) R.K. Jansen
	Ageratum conyzoides L.
	Bidens pilosa L.
	Chromolaena odorata (L.) R. M. King & Robinson
	Crassocephalum crepidioides (Benth.) S. Moore
	Cyanthillium cinereum (L.) H. Rob.
	Eclipta prostrata (L.) L.
	Emilia coccinea (Sims.) G. Don
	Erigeron bonariensis L
	Ethulia conyzoides L.f.
	Galinsoga parvifolia Cav.
	Guizotia scabra (Vis.) Chiov.
	Helichrysum cymosum (L.) D. Don
	Launaea cornuta (Hochst. ex Oliv. & Hiern) C. Jeffrey
	Sonchus sp.
	Sphaeranthus senegalensis D.C.
	Sphaeranthus suaveolens (Forssk.) DC.
	Spilanthes costata Benth.
	Synedrella nodiflora (L.) Gaertn.
	Tridax procumbens L.
	Vernoniastrum ambiguum (Kotschy & Peyr.) H. Rob.
8	*Azolla filiculoides* Lam.
9	*Heliotropium ovalifolium* Forssk.
10	*Ceratophyllum dermesum* L.
11	*Cleome gynandra* L.
12	*Combretum constrictum* (Benth) M.A.L.
13	*Aneleima acquinoctiale* (P. Beauv.) Kunth
	Commelina africana L.
	Commelina benghalensis L.
	Commelina diffusa Burm.f.
	Commelina erecta L.
	Cyanotis axillaris (L.) D. Don ex Sweet
	Murdania simplex (Vahl.) Brenan
14	*Hewittia malabarica* (L.) Suresh
	Ipomoea aquatica Forssk.
	Ipomoea cairica (L.) Sweet
	Ipomoea vagans L.
	pomoea obscura (L.) Ker Gawl.
15	*Crassula granvikii* Mildbr.
16	*Cucurbita pepo* L.
17	*Courtoisina cyperoides* (Roxb.) Soják
17	*Cyperus iria* L.
	Cyperus longus L.
	Cyperus maderaspatanus Willd.
	Cyperus prolifer Lam.
	Cyperus rotundus L. subsp. rotundus
	Cyperus reduncus Hochst. ex Boeckeler
	Cyperus rigidifolius Steud.
	Cyperus rotundus subsp. Merkeri (C.B. Clarke) Kük.
	Eleocharis atropurpurea (Retz.) J. Presl & C. Presl
	Fimbristylis ferruginea (L.) Vahl
	Fimbristylis ferruginea (L.) Vahl subsp. Sieberiana (Kunth). K. Lye
	Fimbristylis littoralis Gaudich.
	Fuirena ciliaris (L.) Roxb.
	Fuirena umbellata Rottb.
	Fuirena angolensis (C.B. Clarke) Lye ex J. Raynal & Roessler
	Fuirena stricta subsp. chlorocarpa (Ridl.) Lye
	Kyllinga erecta Schum.
	Kyllinga pumila Michaux
	Kyllinga polyphylla Willd. ex Kunth
	Lipocarpha chinensis (Osbeck) J. Kern
	Pycreus flavescens (L.) P. Beauv. ex Rchb.
	Pycreus lanceolatus (Poiret) C.B. Clarke
	Pycreus macrostachyos (Lam.) J. Raynal
	Pycreus polystachyos (Rottb.) P. Beauv.
	Pycreus sp.
	Queenslandiella hyalina (Vahl) Ballard
	Schoenoplectiella senegalensis (Steud.) Lye
18	*Acalypha cilliata* forssk.
	Acalypha ornata Hochst. Ex A. Rich.
	Euphorbia heterophylla L.
	Euphorbia hirta L.
	Euphorbia hypericifolia L.
19	*Aeschynomene indica* L.
	Aeschynomene sensitiva Sw.
	Alysicarpus glumaceus (Vahl) D.C. var. glumaceus
	Calopogonium mucunoides Desv.
	Chamaecrista mimosoides (L.) Greene
	Crotalaria glauca Willd.
	Crotalaria laburnifolia L.
	Crotalaria retusa L.
	Desmodium scorpiurus (Sw.) Desv.
	Desmodium tortuosum (Sw.) DC.
	Indigofera hirsuta L.
	Indigofera microcarpa Desv.
	Mimosa diplotricha Sauvalle
	Mimosa pigra L.
	Mimosa pudica L.
	Senna hirsuta (L.) H.S. Irwin & Barneby
	Vigna vexillata (L.) R. Rich.
20	*Hypoxis angustifolia* Lam.
21	*Basilicum polystachyon* (L.) Moench.
	Hyptis suaveolens (L) Poit.
	Hyptis spicigera Lam.
	Platostoma rotundifolium (Briq.) A.J.Paton
22	*Crepidorhopalon hepperi* Eb. Fisch.
23	*Ammania auriculata* Wild
	Ammania baccifera L.
	Ammania prieureana Guill. & Perr.
24	*Abutilon grandiflorum* G. Don
	Abutilon indicum var. *guineense* (Schumach.) K.M. Feng
	Corchorus olitorius L.
	Hibiscus surattensis L.
	Melochia corchorifolia L.
	Sida acuta Burm.f.
30	*Nymphaea lotus* L.
	Nymphaea nouchali Burm.f.
31	*Ludwigia abyssinica* (A. Rich.) Dandy & Brenan
	Ludwigia adcendens (L.) Hara
	Ludwigia hyssopifolia (G. Don) Exell
	Ludwigia octovalvis(Jacq.) Raven
32	*Rhamphicarpa fistulosa* (Hochst.) Benth.
	Striga asiatica (L.) Kuntze
33	*Biophytum umbraculum* Welw.
34	*Phyllanthus amarus* Schumach. & Thonn.
	Phyllanthus pseudoniruri Muell. Arg.
	Phyllanthus rotundifolius Klein ex Willd.
	Phyllanthus niruroides Müll. Arg.
35	*Brachiara lata* (Schumach) C.E. Hubbard
	Cenchrus ciliaris L.
	Chloris pycnothrix Trin.
	Coix lacryma-jobi L.
	Cynodon dactylon (L.) Pers.
	Dactyloctenium aegyptium(L.) P. Beauv.
	Digitaria horizontalis Willd.
	Digitaria milanjiana (Rendle) Stapf.
	Digitaria pseudodiagonalis Chiov.
	Echinochloa colona L. (Link)
	Echinochloa crus-galli (L.) P. Beauv.
	Echinochloa crus-pavonis (Kunth) Schultes
	Echinochloa haploclada (Staft) Staft
	Echinochloa pyramidalis (Lam.) Hitchc. & Chase
	Eleusine indica (L.) Gaertn
	Eragrostis ciliaris (L.) R. Br.
	Eragrostis tenuifolia (A. Rich.) Hochst. ex Steud.
	Hackelochloa granularis (L.) Kuntze
	Heteropogon contortus (L.) P. Beauv. ex Roem. & Schult.
	Hyparrhenia figariana (Chiov.) Clayton
	Imperata cylindrica (L.) Raeusch.
	Ischaemum rugosum Salisb.
	Leersia hexandra Swartz
	Leptochloa squarrosa Pilg.
	Oryza barthii A. Chev.
	Oryza longistaminata A. Chev.
	Panicum maximum Jacq.
	Panicum parvifolium Lam.
	Paspalum scrobiculatum L.
	Paspalum conjugatum P.J. Bergius
	Pennissetum polystachyion (L.) Schultz.
	Pennissetum purpureum Schumach.
	Phragmites australis (Cav.) Trin. ex Steud.
	Rottboellia cochinchinensis (Lour.) Clayton
	Sacciolepis africana C.E Hubb. et Snowden
	Setaria verticilata (L.) P. Beauv.
	Sorghum arundinaceum (Desv.) Stapf
	Sporobolus pyramidalis P. Beauv.
	Vossia cuspidata (Roxb.) Griff.
36	*Persicaria decipiens* (R.Br.) K.L.Wilson
	Persicaria pulchra (Blume) Soják
	Persicaria senegalensis (Meisn.) Soják
37	*Heteranthera callifolia* Rchb. Ex Kunth
38	*Portulaca oleracea* L.
39	*Ceratopteris cornuta* (P. Beauv.) Lepr.
40	*Agathisanthemum bojeri* Klotzsch
	Mitracarpus hirtus (L.) DC.
	Oldenlandia corymbosa L.
	Oldenlandia herbacea (L.) Roxb.
	Pentodon pentandrus (Schumach. & Thonn.) Vatke
	Spermacoce laevis Lam.

Appendix A. (*continued*)

	Cyperus alopecuroides Rottb.		*Sida alba* L.		*Spermacoce octodon* (Hepper) Hakki
	Cyperus articulatus L.		*Sida cordifolia* Linn.	41	*Physalis angulata* L.
	Cyperus compressus L.		*Sida ovata* Forssk.		*Physalis micrantha* L.
	Cyperus denudatus L.f.		*Sida rhombifolia* L.		*Solanum nigrum* L.
	Cyperus difformis L.	25	*Marsilea crenata* C. Presl	42	*Sphenoclea zeylanica* Gaertn.
	Cyperus distans L. f.		*Marsilea diffusa* Lepr.	43	*Thelypteris totta* (Thunb.) Schelpe
	Cyperus dives Delile.	26	*Dissotis pachytricha* R. E. Fr.	44	*Triumfetta pilosa* Roth
	Cyperus esculentus L.	27	*Stephania abyssinica* (Quart.-Dill. & A. Rich.) Walp.		*Triumffetta cordifolia* A. Rich.
	Cyperus haspan L.	28	*Mollugo nudicaulis* Lam.	45	*Typha domingensis* Pers.
	Cyperus imbricatus Retz.	29	*Boerhavia diffusa* L.	46	*Stachytarpheta jamaicensis* (L.) Vahl

* Numbers 1–46 represent family names: 1 = Acanthaceae, 2 = Aizoaceae, 3 = Alismataceae, 4 = Amaranthaceae, 5 = Apiaceae2, 6 = Araceae, 7 = Asteraceae, 8 = Azollaceae, 9 = Boraginaceae, 10 = Cerathophyllaceae, 11 = Cleomaceae, 12 = Combretaceae, 13 = Commelinaceae, 14 = Convolvulaceae, 15 = Crassulaceae, 16 = Curcurbitaceae, 17 = Cyperaceae, 18 = Euphorbiaceae, 19 = Fabaceae, 20 = Hypoxidaceae, 21 = Lamiaceae, 22 = Linderniaceae, 23 = Lytraceae, 24 = Malvaceae, 25 = Marsileaceae, 26 = Melastomataceae, 27 = Menispermaceae, 28 = Mulluginaceae, 29 = Nyctaginaceae, 30 = Nympheaceae, 31 = Onagraceae, 32 = Orobanchaceae, 33 = Oxalidaceae, 34 = Phyllanthacae, 35 = Poaceae, 36 = Polygonaceae, 37 = Pontederiaceae, 38 = Portulacaceae, 39 = Pteridaceae, 40 = Rubiaceae, 41 = Solanaceae, 42 = Sphenocleaceae, 43 = Thelypteridaceae, 44 = Tiliaceae, 45 = Typhaceae, 46 = Verbenaceae.

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