Archives of Agriculture and Environmental Science 7(3): 450-462 (2022)
https://doi.org/10.26832/24566632.2022.0703020

e-ISSN: 2456-6632

This content is available online at AESA

Archives of Agriculture and Environmental Science

Journal homepage: journals.aesacademy.org/index.php/aaes

ORIGINAL RESEARCH ARTICLE

Floristic divergence of weeds in rice fields under subtropical condition

Sirajam Monira[1*], Md. Imran Ali[2], Uttam Kumer Sarker[1], Mahfuza Begum[1] and Md. Romij Uddin[1]

[1]Department of Agronomy, Bangladesh Agricultural University, Mymensingh - 2202, BANGLADESH
[2]Bangladesh Jute Research Institute, Dhaka, BANGLADESH
[*]Corresponding author's E-mail: sirajam37297@bau.edu.bd

ARTICLE HISTORY

Received: 14 July 2022
Revised received: 31 August 2022
Accepted: 21 September 2022

Keywords

Relative abundance
Similarity co-efficient
Weed diversity

ABSTRACT

Weed infestation pattern changes over time for continuous adaptation of similar weed control methods. So, a survey was conducted at Agronomy Field Laboratory, Bangladesh Agricultural University from July 2019 to June 2020 to identify the most dominant and abundant weed species as well as to indicate the probable problematic weed in *boro* and *T. aman* rice. Seven fields were randomly selected for each of the *boro* and *T. aman* rice. The surveys were performed according to quantitative survey technique by using 0.25m^2 quadrate with 16 samples from each of the field following the zig-zag method. Sampling was done twice, while the rice plants were at the vegetative stage and at reproductive stage. Fifty one weed species under 23 families were recorded at experimental area of which 42 species (under 18 families) and 38 species (under 20 families) were observed in *boro* and *T. aman*, respectively. Poaceae topped the list with 10 species, while Cyperaceae ranked second with six species. The highest number of weed species (no. 42) was observed in *boro* rice compared to *T. aman* rice (no. 38). Besides, divergence in the weed composition was also high between both rice fields. Among the 11 abundant weed species, *Eleocharis atropurpurea*, *Echinochloa crusgalli* and *Monochoria vaginalis* were the most frequent and abundant weed species found in both *boro* rice and *T. aman* rice. Broadleaves had higher abundance value (246.26% in *boro* and 332.39% in *T. aman*) than grasses (188.76% in *boro* and 146.68% in *T. aman*) and sedges (164.98% in *boro* and 120.93% in *T. aman*). Moreover, the annuals were dominant over the perennials. Therefore, the present results having diversified weed species with different ranks and orders indicated that the weed management strategies should be taken regarding the infestation of dominant weed species of the respective crop.

Citation of this article: Monira, S., Ali, M. I., Sarker, U. K., Begum, M., & Uddin, M. R. (2022). Floristic divergence of weeds in rice fields under subtropical condition. *Archives of Agriculture and Environmental Science*, 7(3), 450-462, https://dx.doi.org/10.26832/24566632.2022.070320

INTRODUCTION

Weeds are possibly the most ever-present class of crop pests from time immemorial and are responsible for significant economic losses in today's input-intensive farming systems. In comparison to pathogens (18%) and animal pests (16%), weeds produced the highest potential loss (about 34%) (Oerke, 2005). Generally, 45% of yield loss occurred by weeds (Katiyar and Singh, 2015) but it can go up to 34% in wheat, 50% in pulses, 72% in sugarcane, and around 90% in almost all vegetables with the increase in weed infestation. In rice, weed competition was projected to result in yield loss of about 40-60% on average and this loss may reach 94-96% under season-long weedy conditions (Ramana *et al*., 2007; Chauhan and Johnson, 2011; Islam *et al*., 2017). The losses brought on by weeds may vary from one area to another depending on the prevailing weed flora, duration of weed infestation, and the farming practices employed to control them. In Australia, weeds amounted to 2.7 million tons of grain yield losses per year at a national level (Llewellyn *et al*., 2016). But the estimated rice yield reduction in Sri Lanka and Malaysia due to weeds was close to 30-40% (Abeysekera, 2001) and 10-35% (Karim *et al*., 2004), respectively. Whereas, weeds reduce grain yield in Bangladesh by 70-80% in *aus* rice, 30-40% in transplanted *aman* rice, and 22-36% in *boro* rice (BRRI, 2008) because weeds compete with the crop for different natural resources such as light, air, water, space and nutrients throughout the growing season (Ashiq and Aslam, 2014). Besides, weeds indirectly affect crop production by sheltering crop pests, interfering with water management, reducing yield and quality, and subsequently by increasing the cost of processing (Zimdahl, 2013).

Weed diversity means differences in weed composition under different agro-ecological conditions or different crops. Rice fields exhibit dynamic weed succession and dispersion pattern due to combined effects of ecological and human factors. The composition of weed flora may differ depending on location (Janiya and Moody, 1983; Begum *et al*., 2008; Uddin *et al*., 2010), water supply (Bhan, 1983), cultural practices such as irrigation, fertilizer management, cultivar, herbicide and crop rotation (Bernasor and De Datta, 1983; Mabbayad *et al*., 1983), the inherent weed flora in the area, and the crop grown therein. Edaphic factors such as soil structure, pH, nutrients, and moisture status also strongly affect weed diversity (Kim *et al*., 1983). Nowadays, herbicidal weed control is gaining popularity in Bangladesh because of the unavailability and rising wages of labor (Anwar *et al*., 2012). Repeated application of herbicides with a similar mode of action for a long time is very congenial for the evolution of herbicide-resistant weed species and causes shifting of weed flora (Chauhan and Opeña, 2013), and also alters the soil health. The researchers stated that the plots repeatedly applied with 2-4 D amine resulted in a drastic increase of *Echinochloa crus-galli* (Azmi, 2002) and *Fimbristylis miliacea* (Watanabe *et al*., 1997), but suppressed *Scirpus grossus* and *Monochoria vaginalis* effectively (Azmi, 2002). Therefore, Moody (1990) stated that herbicide use moves the agro-ecosystem towards low species diversity with new problem weeds, stressing the need for an ecological approach to weed control. In addition, annual weeds generally react very quickly to the alteration of their environment. Thus, the weed flora changes during the year, and from year to year to adapt the changing conditions (Holzner, 1982). Therefore, current information on the presence, composition, abundance, importance, and ranking of weed species is required for developing effective weed management strategies to produce optimum rice yield (Begum *et al*., 2005). Weed population in agricultural systems is frequently characterized by surveys (Uddin *et al*., 2010). In a weed management program, a thorough survey is necessary to address the current weed problems in the rice field and survey information is important in building target-oriented research programs (Boldt *et al*., 1998). Specific sound knowledge of the nature and extent of infestation of weed flora in the rice field through weed surveys is essential and more effective for planning and execution of effective weed control measures rather than a countrywide blanket recommendation using standard herbicides in appropriate doses or other control measures. Besides, without the ability to predict weed composition, management decisions are less efficient, less reliable, and often more prone to agronomic and financial risk. But, very few studies regarding the floristic composition of weed species in rice were found in Bangladesh. The present study could help to identify and learn about the most dominant as well as abundant weed species in our rice fields. And, the more we know about the dominant weed species, the closer we get to controlling them effectively. Besides, knowledge of the residual weed species and their distribution in this area would provide valuable indications of future weed problems and could help formulate relevant weed control strategies to boost the rice production. Therefore, a field survey was conducted to investigate the distribution and severity of prevailing weed flora in a rice field at the Agronomy Field Laboratory.

MATERIALS AND METHODS

The weed survey was conducted at Agronomy Field Laboratory at Bangladesh Agricultural University, Mymensingh, Bangladesh (latitude: 24°75´N and longitude: 90°50´E) from July 2019 to June 2020. The study area was belonging to non- calcareous dark grey floodplain soil under the sonatala series of Old Brahmaputra Floodplain that falls under Agro- Ecological Zone-9 (AEZ- 9) (UNDP and FAO, 1988). The soil of the study area was close to neutral in reaction with pH value 6.8 with low organic matter and fertility level. The land type was medium high with silty loam in texture. The week survey was conducted in boro and *T. aman* rice fields during the period of February-May and August-November, respectively. Sampling was done twice, while the rice plants were at the vegetative stage (after sowing) and reproductive stage (before harvesting). Seven fields were randomly selected for each of the *boro* and T. *aman* rice and each field was divided into four parts which were considered as replication. The surveys were performed according to quantitative survey technique by using 0.25m^2 quadrate with 16 samples from each of the field following the zig-zag method. The headlands, field edges, foot slopes, potholes, and ditches were avoided during data collection. The weeds within the quadrate were properly identified, counted, and recorded species-wise. For annual grasses and other broadleaf species, a rooted individual was considered as a single plant, whereas, for perennial grasses the number of shoots was counted rather than the number of plants. Species that could not be identified in the field were tagged, pressed and transported for later identification (Chancellor and Froud-Williams, 1984). The data were summarized using five quantitative measures as frequency, field uniformity over all fields, density over all fields, density occurrence fields and relative abundance (Thomas, 1985).

Frequency

The frequency (F) value was the percentage of fields infested by a species k, at least in one quadrate per field. It is expressed as follows:

$$F_k = \frac{\sum_{i=0}^{n} Y_i}{n} \times 100$$

Where,

F_k = Frequency value for species K

Y_i = Presence (1) or absence (0) of K in the field i

n = Number of field survey

Field uniformity (FU)

It is the sampling locations (4 quadrats per field) in which a species occurred, expressed as a percentage of the total number of samples. This measure was used to estimate the area infested with a species. It is expressed as follows:

$$U_k = \frac{\sum^{n}\sum^{4} X_{ij}}{4n} \times 100$$

Where,

U_k = field uniformity values for species K

X_{ij}= Presence (1) or absence (0) of the species K in quadrat J of the field I

n = Number of fields surveyed.

Density (D)

It is the number of individual of a species per square meter for each weed species.

$$D_{ki} = \frac{\sum^{4} Z_j}{n} \times 4$$

Where,

D_{ki} = Density (individuals per square meter) of species k in field i and

Z_j = Number of plants of each species in quadrate j (each quadrate is 0.25 m^2)

Mean field density (MFD)

The mean field density (MFD) value indicates the number of plants per square meter for each species averaged over all fields sampled. It is the value is obtained by totaling each field density (D) and dividing by the total number of fields.

$$MFD_k = \frac{\sum^{n} D_{ki}}{n}$$

Where,

MFD_k = Mean field value of species K

D_{ki} = density (numbers per square meter) of species k in field i,

n = Number of all fields surveyed.

Relative frequency for species K (RF_k)=

$$\frac{\text{Frequency value of species 'K'}}{\text{Sum of frequency value for all species}} \times 100$$

Relative field uniformity for species K (RFU_k)=

$$\frac{\text{Field uniformity value of species 'K'}}{\text{Sum of field uniformity value for all species}} \times 100$$

Relative mean field density for species K ($RMFD_k$)=

$$\frac{\text{Mean field density value of species 'K'}}{\text{Sum of mean field density value for all species}} \times 100$$

Relative abundance

It can be calculated by following formula

Relative abundance for species K, $RA_k = RF_k + RFU_k + RMFD_k$.

The relative abundance value is 300.

Co-efficient of similarity (C): The mean field density of weed community at different time was used and is calculated by the following formula:

$$C = \frac{2w}{a+b} 100$$

Where,

C = Co-efficient of similarity (%) of two communities

w = The sum of lower values of two mean field densities for species shared by two communities

a = The sum of mean field density values for the first community

b = The sum of mean field density values for the second community

RESULTS AND DISCUSSION

Weed diversity in *boro* rice at 35 DAT

Thirty weed species belonging to 15 families infested the *boro* rice fields (Table 1). Poaceae family topped the list with eight weed species and Cyperaceae family ranked second with five species. Each of the following families such as Amaranthaceae, Compositae, Pontederiaceae, and Umbelliferae represented two weed species, while other families i.e., Araceae, Commelinaceae, Marsileaceae, Nymphaeaceae, Onagraceae, Oxalidaceae, Polygonaceae, Scrophulariaceae, and Sphenocleaceae represented only one species each. Based on their relative abundance value, the most dominant weed species in descending order were *Eleocharis atropurpurea* (33.85%)>*Fimbristylis miliacea* (28.43%)>*Monochoria vaginalis* (20.56%)>*Echinochloa crus-galli* (18.31%)>*Digitaria sanguinalis* (16.96%), and rest of the 25 species represented 181.89% of total relative abundance value (Figure 1). Other studies showed that 20 weed species belonging to 10 families (Huda *et al.*, 2017), and 12

Table 1. Distribution of infested weed species with their morphology, common name, English name, scientific name, family name, life cycle and relative abundance value in *boro* rice at 35 DAT.

Morphological Type	Common name	English name	Scientific name	Family name	Life cycle	Relative Abundance value %
Grass	Durba	Bermuda grass	*Cynodon dactylon* L.	Poaceae	Perennial	8.85
	Shama	Burnyard grass	*Echinochloa crus-galli* L.	Poaceae	Perennial	18.31
	Khudeshama	Jungle grass	*Echinochloa colonum* L.	Poaceae	Annual	4.33
	Chela ghash	Sheand grass	*Parapholis incurua* L.	Poaceae	Annual	7.48
	Angta	Joint grass	*Panicum distichum* Lam.	Poaceae	Annual	10.52
	Arail	Swamp rice grass	*Leersia hexandra* Sw.	Poaceae	Perennial	11.33
	Angulighash	Crab grass	*Digitaria sanguinalis* L.	Poaceae	Perennial	16.96
	Goicha	Knot grass	*Paspalum commersonii* Lam.	Poaceae	Annual	6.12
Sedge	Joina	Grass like fimbry	*Fimbristylis miliacea* L.	Cyperaceae	Perennial	28.43
	Borochucha	Rice flat sedge	*Cyperus iria* L.	Cyperaceae	Perennial	8.83
	Mutha	Slendar flat grass	*Cyperus nemporalis* Cherm.	Cyperaceae	Perennial	5.47
	Chechra	Purple spike rush	*Eleocharis atropurpurea*(Retz)	Cyperaceae	Perennial	33.85
	Sobujnakful	Small flower umbrella grass	*Cyperus difformis* L.	Cyperaceae	Perennial	12.35
Broadleaf	Chanchi	Joyweed	*Alternanthera sessilis* R.Br.	Amaranthaceae	Annual	5.54
	Maloncho	Alligator weed	*Alternanthera philoxeroides* Moq.	Amaranthaceae	Annual	6.23
	Kochu	Taro	*Calocasia esculenta* Schoot.	Araceae	Perennial	5.79
	Keshuti	False daisy	*Eclipta alba* Hassk.	Compositae	Annual	10.67
	Holud nakful	Toothache plant	*Spilanthes acmella* L.	Compositae	Perennial	1.89
	Monayna	Spreading day flower	*Commelina diffusa* Burn.f.	Commelinaceae	Annual	9.46
	Shushnishak	Pepperwort	*Marsilea crenata* Pressl.	Marsileaceae	Annual	3.87
	Panishapla	Waterlily	*Nymphaea nouchali* L.	Nymphaeaceae	Perennial	3.68
	Panilong	Winged water primerose	*Ludwigia hyssopifolia* L.	Onagraceae	Annual	10.46
	Amrul	Indian sorrel	*Oxalis europaea* Jord	Oxalidaceae	Annual	5.93
	Gang palong	Seashore dock	*Rumex maritimus* L.	Polygonaceae	Annual	4.78
	Panikochu	Pickerel weed	*Monochoria vaginalis* (Burm.f.)	Pontederiaceae	Perennial	20.56
	Kochuripana	Water hyacinth	*Eichhornia Crassipes* (Mart.)	Pontederiaceae	Perennial	5.47
	Bacopa	Sparrow false pimperne	*Lindernia antipoda* L.	Scrophulariaceae	Annual	3.69
	Jhilmorich	Goose weed	*Sphenoclea zeylancia* L.	Sphenocleaceae	Annual	5.68
	Khudmanik	Marsh pennywort	*Hydrocotyle sibthorpioides L.*	Umbelliferae	Annual	12.37
	Thankuni	Asiatic penny wort	*Hydrocotyle asiatica* L.	Umbelliferae	Annual	11.1

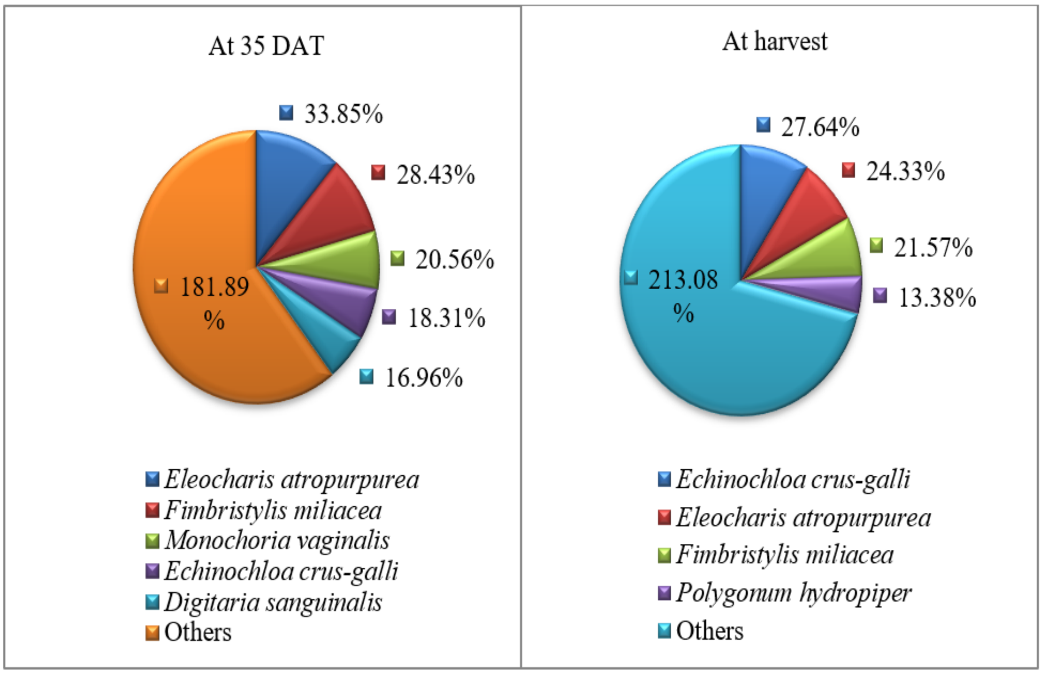

Figure 1. *The five most dominant weed species based on relative abundance value in boro rice.*

Table 2. Distribution of infested weed species with their morphology, common name, scientific name, family name and life cycle and relative abundance value of *boro* rice at harvest.

Morphological Type	Common name	English name	Scientific name	Family name	Life cycle	Relative abundance value %
Grass	Durba	Bermuda grass	*Cynodon dactylon* L.	Poaceae	Perennial	7.42
	Shama	Burnyard grass	*Echinochloa crus-galli* L.	Poaceae	Perennial	27.64
	Khudeshama	Jungle grass	*Echinochloa colonum* L.	Poaceae	Annual	9.58
	Chela ghash	Sheand grass	*Parapholis incurua* L.	Poaceae	Annual	11.54
	Angta	Joint grass	*Panicum distichum* Lam.	Poaceae	Annual	10.52
	Arail	Swamp rice grass	*Leersia hexandra* Sw.	Poaceae	Perennial	18.43
	Angulighash	Crab grass	*Digitaria sanguinalis* L.	Poaceae	Perennial	11.37
	Moyurleja	Moyurleja	*Leptochloa panacea* L.	Poaceae	Annual	3.26
	Chapra	Yard grass	*Eluesine indica* L.	Poaceae	Annual	5.1
Sedge	Joina	Grass like fimbry	*Fimbristylis miliacea* L.	Cyperaceae	Perennial	21.57
	Borochucha	Rice flat sedge	*Cyperus iria* L.	Cyperaceae	Perennial	8.43
	Mutha	Slendar flat grass	*Cyperus nemporalis* Cherm.	Cyperaceae	Perennial	7.58
	Chechra	Purple spike rush	*Eleocharis atropurpurea*(Retz)	Cyperaceae	Perennial	24.33
	Sobujnakful	Small flower umbrella grass	*Cyperus difformis* L.	Cyperaceae	Perennial	10.47
	Holde mutha	Yellow nutsedge	*Cyperus esculentus* L.	Cyperaceae	Annual	3.67
Broadleaf	Chanchi	Joyweed	*Alternanthera sessilis* R.Br.	Amaranthaceae	Annual	10.33
	Maloncho	Alligator weed	*Alternanthera philoxeroides* Moq.	Amaranthaceae	Annual	12.4
	Shaknotey	Slender amaranth	*Amaranthus viridis* L.	Amaranthaceae	Annual	4.5
	Katanotey	Spiny amaranth	*Amaranthus spinosus* L.	Amaranthaceae	Annual	3.76
	Holud nakful	Toothache plant	*Spilanthes acmella* L.	Compositae	Perennial	2.36
	Monayna	Spreading day flower	*Commelina diffusa* Burn.f.	Commelinaceae	Annual	8.52
	Kanaibashi	Tropical spiderwort	*Commelina benghalensis* L.	Commelinaceae	Annual	5.1
	Kanainala	Spreading day flower	*Cyanotis axillaris* L.	Commelinaceae	Annual	4.25
	Kalmilata	Bind weed	*Ipomoea indica* L.	Convolvu laceae	Annual	2.43
	Lozzaboti	Sensitive plant	*Mimosa pudica* L.	Leguminosae	perennial	1.73
	Shushnishak	Pepperwort	*Marsilea crenata* Pressl.	Marsileaceae	Annual	9.26
	Panilong	Winged water primerose	*Ludwigia hyssopifolia* L.	Onagraceae	Annual	8.5
	Amrul	Indian sorrel	*Oxalis europaea* Jord	Oxalidaceae	Annual	6.53
	Bishkataly	Smart weed	*Polygonum hydropiper* L.	Polygonaceae	Annual	13.38
	Panikochu	Pickerel weed	*Monochoria vaginalis* (Burm.f.)	Pontederiaceae	Perennial	6.45
	Panimorich	False pimpernel	*Lindernia hysopioides* L.	Scrophulariaceae	Annual	5.08
	Foska begun	Clamy ground cherry	*Physalis minima* L.	Solanaceae	Annual	6.43
	Khudmanik	Marsh pennywort	*Hydrocotyle sibthorpioides L.*	Umbelliferae	Perennial	4.52
	Thankuni	Asiatic penny wort	*Hydrocotyle asiatica* L.	Umbelliferae	Perennial	3.56

weed species belonging to five families (Nahid *et al*., 2014) were found in *boro* rice at early growth stage. Besides, Huda *et al*. (2017) reported that *Eleocharis atropurpurea* (46.2%) >*Cyperus difformis* (36.4%)>*Monochoria vaginalis* (29.0%) >*Echinochloa crus-galli* (28.0%)>*Leersia hexandra* (27.3%) were the most dominant weed species in *boro* rice fields at the early growth stage in the same area. The three dominant weed species such as *Eleocharis atropurpurea*, *Echinochloa crusgalli* and *Monochoria vaginalis* are similar with my findings. On the other hand, *Scirpus juncoides* (Sultana, 2012) and *Cyperus iria* (Begum *et al*., 1999) were found as the most dominant weed species in the *boro* rice in the same location. The recent study also revealed that annual weeds were dominant over perennial weeds but the perennials had higher relative abundance value (205.24%) than annuals (94.76%). In my study, the relative abundance value of broadleaves, sedges, and grasses were 127.17%, 88.93%, and 83.9%, respectively (Figure 2), which is dissimilar with the findings of Huda *et al.* (2017). In their study, it was observed that sedges had higher relative abundance value (103.4%) than the broadleaves (101.9%) and grasses (94.8%).

Weed diversity in *boro* rice at harvest

In *boro* rice, 34 weed species belonging to 15 families were identified at harvest (Table 2). The Poaceae was found to be the most dominant family as it contributed nine weed species followed by Cyperaceae family which contributed six weed species. The families like Amaranthaceae, Commelinaceae and Umbelliferae contributed four, three and two weed species, respectively. Whereas, each of the following families such as Compositae, Convolvulaceae, Leguminosae, Marsileaceae, Onagraceae, Oxalidaceae, Polygonaceae, Pontederiaceae, Scrophulariaceae, and Solanaceae represented only one weed species. The five most dominant weed species based on abundance value in descending order were *Echinochloa crusgalli* (27.64%) >*Eleocharis atropurpurea* (24.33%)>*Fimbristylis miliaceae* (21.57%)>*Leersia hexandra* (18.43%)>*Polygonum hydropiper* (13.38%), and rest of the 29 species represented 213.08% of total relative abundance value (Figure 1). Monira *et al*. (2020) stated that 19 weed species belonging to nine families were

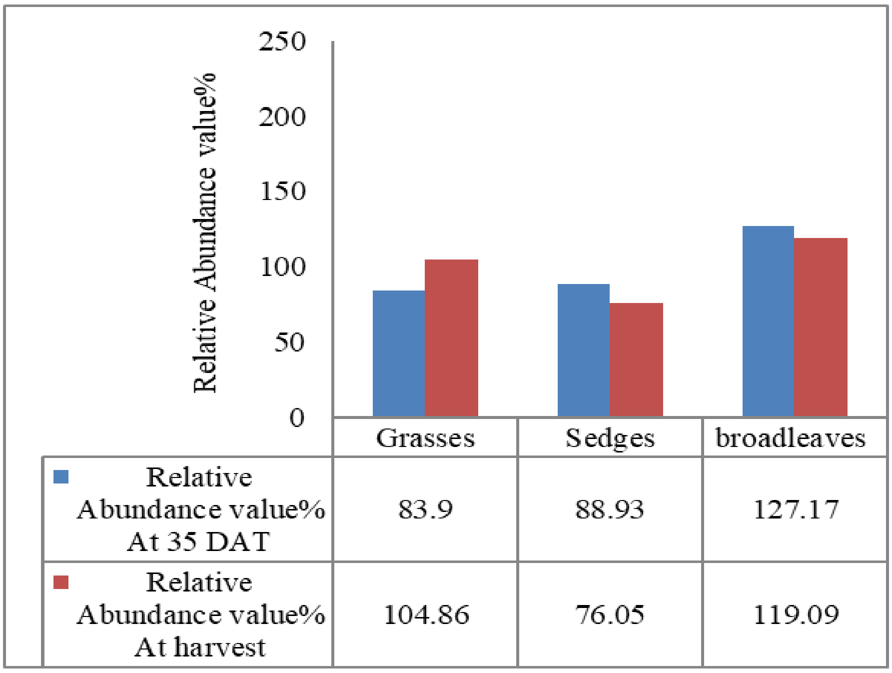

Figure 2. *Relative abundance value of broad leaf, grass and sedge weeds in boro rice.*

observed in *boro* rice at harvest. *Echinochloa crusgalli* was also reported as the most dominant weed species in *boro* rice by others (Popy *et al*., 2017; Islam *et al*., 2018; Afroz *et al*., 2019; Monira *et al*., 2020) at the same location. The probable cause of the present finding was mimic nature of *Echinochloa crusgalli*, which helps them to escape at the early crop growth stage as well as to compete with crop throughout the growing season and sheds their seeds to contribute in the soil weed seed bank. Rao and Moody (1988) supported the findings and stated that identical growth of *Echinochloa crusgalli* and rice seedlings increases the difficulty in control measures and thus becomes dominant at harvest. The present findings also stated that annual weeds (relative abundance value- 155.51%) were dominant over perennial weeds (relative abundance value -144.49%). The relative abundance value of broadleaves, grasses and sedges were 119.09%, 104.86%, and 76.05%, respectively (Figure 2). This result is in corroborated with the findings of Afreen (2019) and she stated that broadleaves were more abundant than grasses and sedges at harvest in *boro* rice.

Comparison of infested weed species in *boro* rice between 35 DAT and at harvest

Forty two weed species belonging to 18 families were observed in *boro* rice fields of which 10 were grasses, six were sedges and 26 were broad leaves (Table 3). Whereas, Afreen (2019) identified a total of 38 weed species belonging to 18 families in *boro* rice fields comprising 11 grasses, six sedges and 21 broad leaves. Twenty two weed species were common at both periods (Table 3). But eight weed species such as *Paspalum commersonii*, *Calocasia esculenta*, *Eclipta alba*, *Nymphaea nouchali*, *Rumex maritimus*, *Eichhornia crassipes*, *Lindernia antipoda*, and *Sphenoclea zeylancia* were present at 35 DAT but completely eliminated at harvest. Whereas, 12 new weed species such as *Leptochloa panacea*, *Eleusine indica*, *Cyperus esculentus*, *Amaranthus viridis*, *Amaranthus spinosus*, *Commelina benghalensis*, *Cyanotis axillaris*, *Ipomoea indica*, *Mimosa pudica*, *Polygonum hydropiper*, *Lindernia hysopioides*, and *Physalis minima* appeared at harvest. The annual weeds were dominant over the perennial weeds at both data collecting periods. The shift of weed species from perennials to annuals and vice-versa might be due to frequent change in soil and water management and it is supported by De Datta (1988). The relative abundance value of broadleaf was also higher than grasses and sedges. In case of the five most dominant weed species, *Eleocharis atropurpurea* was the most dominant weed at 35 DAT, whereas, *Echinochloa crusgalli* was the most dominant weed at harvest as the rice-mimic nature of *Echinochloa crusgalli* helps to escape weed control measures at early growth stage. Three weed species i.e., *Eleocharis atropurpurea*, *Echinochloa crusgalli*, and *Fimbristylish miliaceae* were common and dominant with different ranks and orders in both periods, whereas, *Leersia hexendra* and *Polygonum hydropiper* were found at harvest instead of *Monochoria vaginalis* and *Digitaria sangunalis* found at 35 DAT. Broadleaves showed higher abundance value (127.17% at 35 DAT and 119.09% at harvest) than grasses (83.9% at 35 DAT and 104.86% at harvest) and sedges (88.93% at 35 DAT and 76.05% at harvest) in both periods. Results also showed that sedges were more abundant than grasses at 35 DAT, whereas, at harvest grasses were more abundant than sedges. The co-efficient of similarity in *boro* rice between two data collecting periods was 53.92% (Figure 3) which indicated a moderate to high association of weed species between the two data collecting periods. This is due to season-long competitive ability of weeds with same crops on the same land with same growth factor requirements.

Weed diversity of *T. aman* rice at 35 DAT

Twenty six weed species belonging to 15 families were found in *T. aman* rice fields (Table 4). Poaceae and Cyperaceae families contributed seven and four weeds, respectively. In the

Table 3. Occurrence of weed species in *boro* rice and T.*aman* rice at the agronomy field laboratory.

Common name	Scientific Name	*Boro* rice		*T. aman* rice	
		35 DAT	At harvest	35 DAT	At harvest
Grasses					
Durba	*Cynodon dactylon* L.	+	+	+	+
Shama	*Echinochloa crus-galli* L.	+	+	+	+
Khudeshama	*Echinochloa colonum* L.	+	+	+	-
Chela ghash	*Parapholis incurua* L.	+	+	+	-
Angta	*Panicum distichum* Lam.	+	+	+	+
Arail	*Leersia hexandra* Sw.	+	+	+	+
Angulighash	*Digitaria sanguinalis* L.	+	+	-	-
Goicha	*Paspalum commersonii* Lam.	+	-	+	+
Moyurleja	*Leptochloa panacea* L.	-	+	-	+
Chapra	*Eleusine indica* L.	-	+	-	-
Sedges					
Joina	*Fimbristylis miliacea* L.	+	+	+	+
Borochucha	*Cyperus iria* L.	+	+	-	+
Mutha	*Cyperus nemporalis* Cherm.	+	+	+	-
Chechra	*Eleocharis atropurpurea*(Retz)	+	+	+	+
Sobujnakful	*Cyperus difformis* L.	+	+	+	+
Holde mutha	*Cyperus esculentus* L.	-	+	-	-
Broadleaves					
Chanchi	*Alternanthera sessilis* R.Br.	+	+	+	+
Maloncho	*Alternanthera philoxeroides* Moq.	+	+	-	-
Shaknotey	*Amaranthus viridis* L.	-	+	-	-
Katanotey	*Amaranthus spinosus* L.	-	+	-	-
Kochu	*Calocasia esculenta* Schoot.	+	-	+	-
Topapana	*Pistia stratiotes* L.	-	-	-	+
Azolla	*Azolla pinnata* R.Br.	-	-	-	+
Kesuti	*Eclipta alba* Hassk.	+	-	+	-
Holud nakful	*Spilanthes acmella* L.	+	+	-	-
Monayna	*Commelina diffusa* Burn.f.	+	+	+	+
Kanaibashi	*Commelina benghalensis* L.	-	+	-	+
Kanainala	*Cyanotis axillaris* L.	-	+	-	+
Kanduli	*Murdania nudiflora* L.	-	-	+	-
Kalmilata	*Ipomoea indica* L.	-	+	+	-
Lozzaboti	*Mimosa pudica* L.	-	+	-	-
Bonmotor	*Vicia sativa* L.	-	-	-	+
Tripotrishak	*Desmodium triflorum* DC.	-	-	-	+
Acid pata	*Rotala ramosior* L.	-	-	+	-
Shushnishak	*Marsilea crenata* Pressl.	+	+	+	-
Fern	*Nephrolepis cordifolia*	-	-	-	+
Panishapla	*Nymphaea nouchali* L.	+	-	+	-
Panilong	*Ludwigia hyssopifolia* L.	+	+	+	+
Amrul	*Oxalis europaea* Jord	+	+	-	-
Hazardana	*Phyllanthus niruri* L.	-	-	+	+
Bishkataly	*Polygonum hydropiper* L.	-	+	-	+
Gangpalong	*Rumex maritimus* L.	+	-	-	-
Panikochu	*Monochoria vaginalis* (Burm.f.)	+	+	+	+
Kochuripana	*Eichhornia Crassipes* (Mart.)	+	-	+	+
Khetpapri	*Hedyotis corymbosa* L.	-	-	+	-
Panimorich	*Lindernia hysopioides* L.	-	+	-	-
Bacopa	*Lindernia antipoda* L.	+	-	-	+
Foska begun	*Physalis minima* L.	-	+	-	-
Jhilmorich	*Sphenoclea zeylancia* L.	+	-	-	-
Khudmanik	*Hydrocotyle sibthorpioides* L.	+	+	+	+
Thankuni	*Hydrocotyle asiatica* L.	+	+	-	+
	Total	30	34	26	27

+ = Present, - = Absent

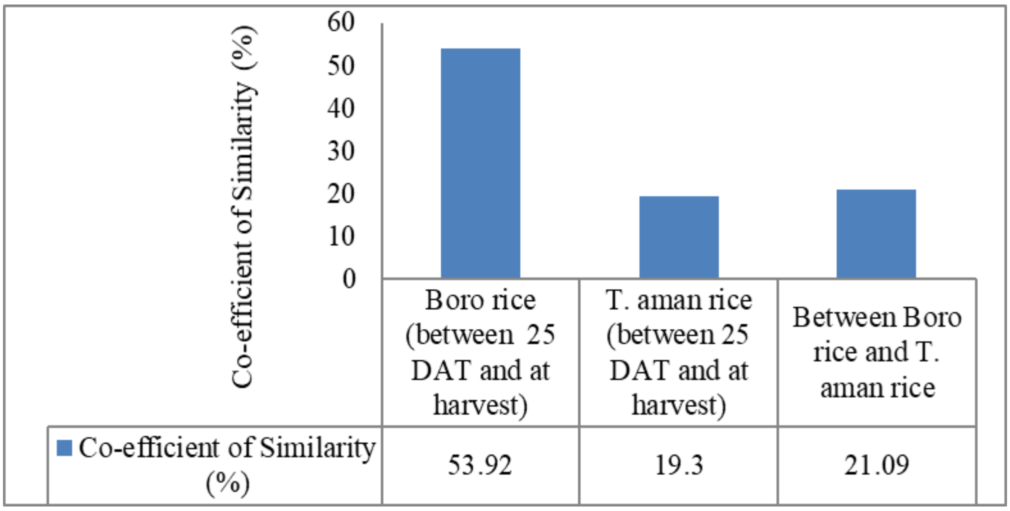

Figure 3. *Co-efficient of similarity in boro and T. aman rice.*

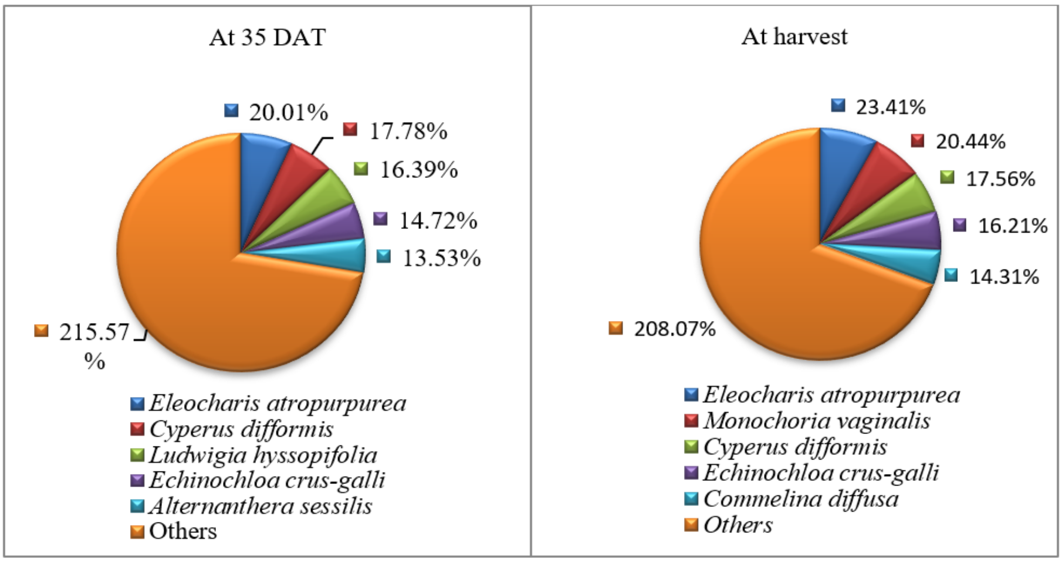

Figure 4. *The five most dominant weed species based on relative abundance value in T. aman rice.*

case of broadleaves, Commelinaceae and Pontederiaceae families had two weed species each, whereas, each of the following families such as Amaranthaceae, Araceae, Compositae, Convolvolaceae, Lythraceae, Marsileaceae, Nymphaeaceae, Onagraceae, Phyllanthaceae, Rubiaceae and Umbelliferae contributed one weed species. The weeds of major importance were *Eleocharis atropurpurea* (20.01%)>*Cyperus difformis* (17.78%) >*Ludwigia hyssopifolia* (16.39%)>*Echinochloa crusgalli* (14.72%) >*Alternanthera sessilis* (13.53%) and the rest of the 21 species represented 215.57% of total relative abundance value (Figure 4). Parvez *et al*. (2013) reported a partially different result that *Paspalum scrobiculatum*, *Echinochloa crusgalli*, *Leersia hexandra*, *Oxalis europaea* and *Monochoria vaginalis* were the most dominant weed species in *T. aman* rice. The reason of the present findings might be due to the degree of flooding occurred during the growing season. Because, the flooded condition during and after transplanting suppress grasses, but encourage sedges to dominate (Mabbayad *et al*., 1983). The annual weeds were dominant over perennials, and the relative abundance value of annual and perennial weeds were 154.01% and 145.99%, respectively. Broadleaved weeds were dominant over grass and sedge weeds. The total relative abundance value of broadleaves was also higher (165.45%) than grasses (75.16%) and sedges (59.39%) (Figure 5) which is dissimilar with the findings of Afreen (2019). She reported that the grasses had higher relative abundance value (126.61%) than broadleaves (124.82%) and sedges (48.48%).

Weed diversity in *T. aman* rice at harvest

In *T. aman* rice field, the number of infesting weed species was 27 belonging to 14 families (Table 5). Six weeds were under Poaceae family, whereas, Cyperaceae family contributed four weed species. In case of broadleaves, three weeds were identified from Commelinaceae family and two from each of the following families Leguminosae, Pontederiaceae and Umbelliferae. And, rest of the following families Amaranthaceae, Araceae, Azollaceae, Nephrolepidaceae, Onagraceae, Phyllanthaceae, Polygonaceae, Pontederiaceae, and Scrofulariaceae represented one weed species each. The weeds of major importance in descending order were *Eleocharis atropurpurea* (23.41%)>*Monochoria vaginalis* (20.44%)>*Cyperus difformis* (19.39%)>*Echinochloa crusgalli* (16.21%)>*Commelina diffusa* (14.31%), and rest of the 22 weed species represented 208.07% of total relative abundance value (Figure 4). Khan

Table 4. Distribution of infested weed species with their morphology, common name, scientific name, family name, life cycle and relative abundance value of *T. aman* rice at 35 DAT.

Morphological Type	Common name	English name	Scientific name	Family Name	Life cycle	Relative abundance value %
Grass	Durba	Bermuda grass	*Cynodon dactylon* L.	Poaceae	Perennial	6.54
	Shama	Burnyard grass	*Echinochloa crus-galli* L.	Poaceae	Perennial	14.72
	Khudeshama	Jungle grass	*Echinochloa colonum* L.	Poaceae	Annual	7.99
	Chela ghash	Sheand grass	*Parapholis incurua* L.	Poaceae	Annual	10.57
	Angta	Joint grass	*Panicum distichum* Lam.	Poaceae	Annual	12.46
	Arail	Swamp rice grass	*Leersia hexandra* Sw.	Poaceae	Perennial	12.67
	Goicha	Knot grass	*Paspalum commersonii* Lam.	Poaceae	Annual	10.21
Sedge	Joina	Grass like fimbry	*Fimbristylis miliacea* L.	Cyperaceae	Perennial	10.38
	Mutha	Slendar flat grass	*Cyperus nemporalis* Cherm.	Cyperaceae	Perennial	11.22
	Chechra	Purple spike rush	*Eleocharis atropurpurea*(Retz)	Cyperaceae	Perennial	20.01
	Sobujnakful	Small flower umbrella grass	*Cyperus difformis* L.	Cyperaceae	Perennial	17.78
Broadleaf	Chanchi	Joyweed	*Alternanthera sessilis* R.Br.	Amaranthaceae	Annual	13.53
	Kochu	Taro	*Calocasia esculenta* Schoot.	Araceae	Perennial	11.42
	Keshuti	False daisy	*Eclipta alba* Hassk.	Compositae	Annual	12.85
	Monayna	Spreading day flower	*Commelina diffusa* Burn.f.	Commelinaceae	Annual	10.93
	Kanduli	Kanduli	*Murdania nudiflora* L.	Commelinaceae	Annual	9.71
	Kalmilata	Bind weed	*Ipomoea indica* L.	Convolvolaceae	Annual	10.65
	Acid pata	Lowland rotala	*Rotala ramosior* L.	Lythraceae	Annual	8.79
	Susni shak	Pepper wort	*Hedyotis corymbosa* L.	Marsileaceae	Annual	8.95
	Panishapla	Waterlily	*Nymphaea nouchali* L.	Nymphaeaceae	Perennial	5.5
	Panilong	Winged water pri-merose	*Ludwigia hyssopifolia* L.	Onagraceae	Annual	16.39
	Hazardana	Gale of the wind	*Phyllanthus niruri* L.	Phyllanthaceae	Annual	9.48
	Panikochu	Pickerel weed	*Monochoria vaginalis* (Burm.f.)	Pontederiaceae	Perennial	12.53
	Kochuripana	Water hyacinth	*Eichhornia Crassipes* (Mart.)	Pontederiaceae	Perennial	10.33
	Khetpapri	Old world diamond flower	*Hedyotis corymbosa* L.	Rubiaceae	Annual	11.5
	Khudmanik	Marsh pennywort	*Hydrocotyle sibthorpioides L.*	Umbelliferae	Perennial	12.89

(2018) found 26 weed species under 12 families in T. *aman* rice at the same study area. He also reported that *Fimbristylis miliacea* (57.76%), *Lindernia hyssopifolia* (35.41%), *Monochoria hastate* (20.12%), *Echinochloa crus-galli* (17.63%) and *Digitaria sanguinalis* (15.89%) were the five most dominant weed species in T. *aman* rice. The findings were partially dissimilar with my findings. Annual weeds were dominant over perennials. The relative abundance value of broadleaves, grasses and sedges were 166.94%, 71.52%, and 61.54%, respectively (Figure 5) and this result is in accordance with the findings of Afreen (2019).

Comparison of infested weed species in T. *aman* rice between 35 DAT and at harvest

Thirty eight weed species belonging to 20 families were recorded in T. *aman* rice fields (Table 3). Among them, eight were grasses, five were sedges and 25 were broadleaves. But literature showed that nine weed species under five families (Bely *et al*., 2016), 22 weed species with 19 annuals and 3 perennials belonging to 16 families (Iqbal *et al*., 2001) were observed in T. *aman* rice. Among the five most dominant weed species, *Eleocharis atropurpurea*, *Cyperus difformis*, and *Echinochloa crus-galli* were found common in both periods but their rank and order were different. Besides, *Monochoria vaginalis* and *Commelina diffusa* were found at harvest instead of *Alternanthera sessilis and Ludwigia hyssopifolia* observed at 35 DAT (Figure 4). Akter *et al.* (2018) also reported *Eleocharis atroperpurea* as the dominant one, whereas, *Marselia crenata* (Bely *et al*., 2016), *Paspalum scrobiculatum* (Rahman *et al*., 2007; Rashid, 2011; Parvez *et al*., 2013) and *Fimbristylis miliacea* (Mamun *et al*., 1995) were found to be the dominant weed in T. *aman* rice at the same study area. This is due to the variation in management practices taken by the farmers during that time and the contribution of weed seed bank in the soil as well.

Fifteen weed species were common in both periods such as at 35 DAT and at harvest (Table 3). Eleven weed species namely *Echinochloa colonum*, *Parapholis incurua*, *Cyperus nemporalis*, *Calocasia esculenta*, *Eclipta alba*, *Murdania nudiflora*, *Ipomea indica*, *Rotala ramosior*, *Marsilea crenata*, *Nymphaea nouchali*, and *Hedyotis corymbosa* were present at 35 DAT but absent at harvest and 12 new species such as *Leptochloa panacea*, *Cyperus iria*, *Pistia stratiotes*, *Azolla pinnata*, *Commelina benghalensis*, *Cyanotis axillaris*, *Vicia sativa*, *Desmodium triflorum*, *Nephrolepis cordifolia*, *Polygonum hydropiper*, *Lindernia antipoda* and *Hydrocotyle asiatica* appeared at harvest. The emergence of weed species found at 35 DAT might be favored by the high water table due to heavy rainfall during that time, while the weed species identified at harvest emerged best because of having the low water table in the study area. Annual weeds were dominant over perennials in both periods. Broad leaves had more abundance value (165.45% at 35 DAT and 166.94% at harvest) than grasses (59.39% at 35 DAT and 71.52% at harvest) and sedges (75.16% at 35 DAT and 61.54% at harvest). The co-efficient of similarity between two different periods of *T. aman* rice was 19.30% which reflected a wide divergence in

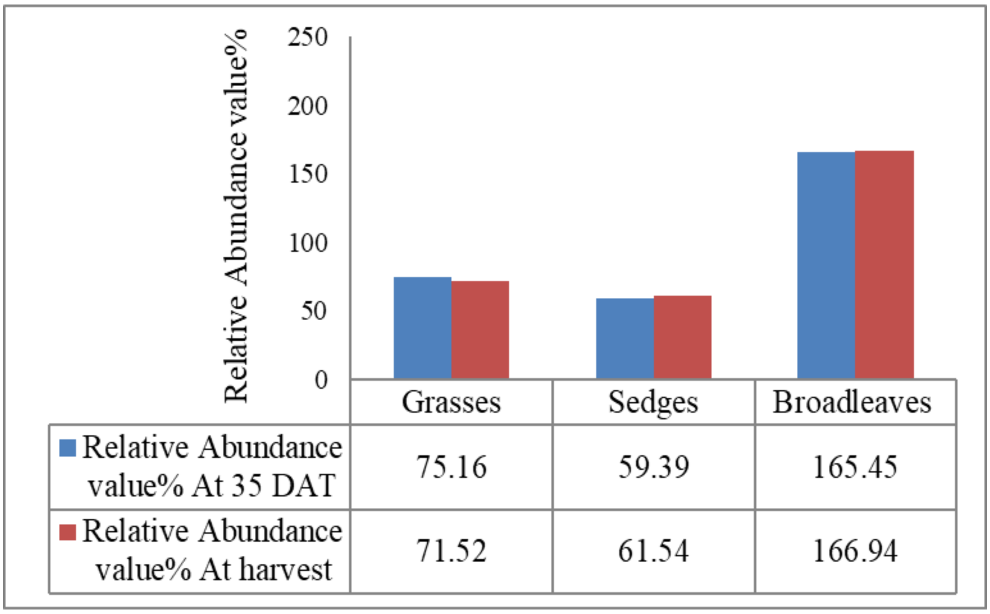

Figure 5. *Relative abundance value of broad leaf, grass and sedge weeds in T. aman rice.*

species composition in two growing periods (Figure 3). This is due to the presence of deeper water depth during the onset of the season compared to the harvesting period. Begum *et al.* (2006) stated that deeper water depth for a long duration exerted a stronger inhibition on germination as well as on the growth of weed species.

Comparison of infesting weed species between *boro* rice and *T. aman* rice

Fifty one weeds (Table 3) belonging to 23 different families were recorded in the study area irrespective of rice growing season. Among them, 10 were grasses, six were sedges and 35 were broad leaves. On the contrary, Afreen (2019) observed that rice fields were infested with 45 weed species belonging to 18 families comprising 12 grasses, seven sedges and 26 broadleaves. The highest number of weed species (no. 42) was observed in *boro* rice compared to *T. aman* rice (no. 38). Poaceae was the most dominant family followed by Cyperaceae in both *boro* and *T. aman* rice. *Eleocharis atropurpurea* was the most dominant weed species in *boro* rice at 35 DAT and *T. aman* rice (at 35 DAT and at harvest) but in *boro* rice (at harvest) *Echinochloa crusgalli* appeared as the most dominant weed. The grasses viz., *Cynodon dactylon*, *Echinochloa crusgalli*, *Panicum distichum* and *Leersia hexandra*; the sedges viz., *Fimbristylish miliaceae*, *Eleocharis atropurpurea* and *Cyperus difformis*; and the broadleaves viz., *Alternanthera sessilis*, *Commelina diffusa*, *Ludwigia hyssopifolia*, *Monochoria vaginalis*, and *Hydrocotyle sibthorpioides* were the most frequent and abundant weed species in both rice growing season (Table 3). Some weeds i.e., *Digitaria sangunalis*, *Eleusine indica*, *Cyperus esculentus*, *Alternanthera philoxeroides*, *Amaranthus spinosus*, *Spilanthes acmella*, *Mimosa pidica*, *Oxalis europaea*, *Rumex maritimus*, *Lindernia hysopioides*, *Physalis minima* and *Sphenoclea zylencia* were present only in *boro* rice, whereas, *Pistia stratiotes*, *Azolla pinnata*, *Murdania nudiflora*, *Vicia sativa*, *Desmodium triflorum*, *Rotala ramosior*, *Nephrolepis cordifolia*, *Phyllanthus niruri*, and *Hedyotis corymbose* were observed only in *T. aman* rice (Table 3). From the above results, it was revealed that the presence, composition, abundance, importance and ranking of weed species change over time and it is a continuous process. The variation of weed composition mostly depends on the agro-climatic conditions, crop management and weed seed bank composition of the area (Anwar *et al.*, 2013). Therefore, the agro-climatic condition of the study area is very congenial for the exuberant growth of numerous weeds (Bely *et al.*, 2016). On the other hand, weed seedbank in the soil acts as the prime source of weed infestations (Cavers, 1983). This phenomenon favors the continuous emergence of weeds throughout the crop growing season and speed-up crop-weed competition. Besides, dormancy in weed seeds could be another important cause of diversity in weed composition in different periods. In addition, time and type of tillage, crop establishment methods, irrigation and fertilizer used, and type, rate and efficiency of herbicides used especially application of herbicides with a similar mode of action with the same dose, improper crop management, etc. enhance the chance of emerging less dominant weed species to the most dominant one (Begum *et al.*, 2008). Besides, the perennial weeds were dominant over the annual weeds. Broad leaves had higher abundance (246.26% in *boro* and 332.39% in *T. aman*) value than grasses (188.76% in *boro* and 146.68% in *T. aman*) and sedges (164.98% in *boro* and 120.93% in *T. aman*). The cause of the present findings might be due to practicing continuous puddling method in the rice fields which is also supported by Moody (1982). But, Huda *et al.* (2017) found a totally different result that sedges (103.4%) had higher abundance value compared to broadleaf (101.9%) and grasses (94.8%) in *boro* rice. Therefore, this ecological shift of weed species from broadleaves and sedges to competitive grassy weeds was also found to be related to the continuous use of herbicides in weed control operations (Azmi and Baki, 1995; Ho, 1998).

In this experiment, co-efficient of similarity of weed diversity

Table 5. Distribution of infested weed species with their morphology, common name, scientific name, family name, life cycle and relative abundance value of *T. aman* rice at harvest.

Morphological type	Common name	English name	Scientific name	Family name	Life cycle	Relative abundance value %
Grass	Durba	Bermuda grass	*Cynodon dactylon* L.	Poaceae	Perennial	9.94
	Shama	Burnyard grass	*Echinochloa crus-galli* L.	Poaceae	Perennial	16.21
	Angta	Joint grass	*Panicum distichum* Lam.	Poaceae	Annual	13.79
	Arail	Swamp rice grass	*Leersia hexandra* Sw.	Poaceae	Perennial	10.58
	Goicha	Knot grass	*Paspalum commersonii* Lam.	Poaceae	Annual	11.03
	Moyurleja	Moyurleja	*Leptochloa panacea* L.	Poaceae	Annual	10.97
Sedges	Joina	Grass like fimbry	*Fimbristylis miliacea* L.	Cyperaceae	Perennial	8.34
	Borochucha	Rice flat sedge	*Cyperus iria* L.	Cyperaceae	Perennial	9.23
	Chechra	Purple spike rush	*Eleocharis atropurpurea* (Retz)	Cyperaceae	Perennial	23.41
	Sobujnakful	Small flower umbrella grass	*Cyperus difformis* L.	Cyperaceae	Perennial	17.56
Broadleaf	Chanchi	Joyweed	*Alternanthera sessilis* R.Br.	Amaranthaceae	Annual	10.55
	Topapana	Water lettuce	*Pistia stratiotes* L.	Araceae	Perennial	6.73
	Azolla	Azolla	*Azolla pinnata* R.Br.	Azollaceae	Perennial	8.71
	Monayna	Spreading day flower	*Commelina diffusa* Burn.f.	Commelinaceae	Annual	14.31
	Kanaibashi	kanaibashi	*Commelina benghalensis* L.	Commelinaceae	Annual	13.99
	Kanainala	kanainala	*Cyanotis axillaris* L.	Commelinaceae	Annual	10.64
	Tripotrishak	Creeping trefoil	*Desmodium triflorum* DC.	Leguminosae	Annual	9.57
	Bonmotor	Vetch	*Vicia sativa* L.	Leguminosae	Annual	12.6
	Fern	Fern	*Nephrolepis cordifolia*	Nephrolepidaceae	Annual	7.61
	Panilong	Winged water primerose	*Ludwigia hyssopifolia* L.	Onagraceae	Annual	8.09
	Hazardana	Gale of the wind	*Phyllanthus niruri* L.	Phyllanthaceae	Annual	9.32
	Bishkataly	Smart weed	*Polygonum hydropiper* L.	Polygonaceae	Annual	8.69
	Panikochu	Pickerel weed	*Monochoria vaginalis* (Burm.f.)	Pontederiaceae	Perennial	20.44
	Kochuripana	Water hyacinth	*Eichhornia crassipes* Mart.	Pontederiaceae	Perennial	6.16
	Bacopa	Sparrow false pim-perne	*Lindernia antipoda* L.	Scrophulariaceae	Annual	11.2
	Thankuni	Asiatic penny wort	*Hydrocotyle asiatica* L.	Umbelliferae	Perennial	5.63
	Khudmanik	Marsh pennywort	*Hydrocotyle sibthorpioides L.*	Umbelliferae	Perennial	4.7

between *boro* and *T. aman* rice was 21.09% (Figure 3) which indicated high divergence in weed composition between *boro* and T. *aman* rice. The cause might be due to growing crops in different seasons with different climatic requirements and cultural practices. Uddin *et al.* (2018) observed that the co-efficient of similarity between T. *aman* and *boro* was 48.87%, between *T. aman* and vegetable was 28.12% and between *boro* and vegetable was 52.03% which indicated low to moderate similarity in the composition of infesting weed species. Sima (2018) observed that the similarity index of weed vegetation between *boro* and T. *aman* rice was 56.80% which indicates low divergence in weed composition.

Conclusion

The present study revealed that there was a high range of divergence in the weed composition as well as in ranking of the most dominant weed species in *boro* and T. *aman* rice fields. Variation in weed diversity was also observed in same crop at different data collecting periods. As per results, annuals were dominant over perennials. Moreover, broadleaf weeds were more abundant compared to grass and sedge weeds. Among the 11 abundant weed species, *Eleocharis atropurpurea*, *Echinochloa crusgalli* and *Monochoria vaginalis* were the most abundant weed species found in both *boro* and T. *aman* rice. But the other weed species such as F*imbristylis miliacea*, *Leersia hexendra*, *Polygonum hydropiper*, and *Digitaria sangunalis* (in *boro* rice) and *Cyperus difformis*, *Ludwigia hyssopifolia*, *Alternanthera sessilis*, and *Commelina diffusa* (in *T. aman* rice) may emerge as the most problematic weed in their respective rice fields due to any alteration in the crop management strategies. So, weed management strategies such as, use of standard herbicides, application rates, time and type of tillage, crop establishment methods, etc. should be adopted based on the present findings rather than any countrywide recommended control measures. Moreover, more survey work is required on a regular basis to identify possible problematic weed and weed population shifts and to direct research toward new or improved control measures.

Conflict of interests

The authors have declared that there is no conflict of interests regarding the publication of this paper.

RREFERENCES

Abeysekera, S. K. (2001). Management of *Echinochloa* spp. in rice in Sri Lanka. Paper presented at the FAO workshop on *Echinochloa* spp. control, Beijing, China.

Afroz, R., Salam, M. A., & Begum, M. (2019). Effect of weeding regime on the performance of *boro* rice cultivars. *Journal of the Bangladesh Agricultural University*, *17*, 265–273, https://doi.org/10.3329/jbau.v17i3.43192

Akter, F., Begum, M., & Salam, M. A. (2018). Floristic diversity of the soil weed seedbank in *boro* rice fields: in situ and ex situ evaluation. *Journal of the Bangladesh Agricultural University*, *16*(3), 396–402.

Anwar, M. P., Juraimi, A. S., Mohamed, M. T. M., Uddin, M. K., Samedani, B., Puteh, A., & Man, A. (2013). Integration of agronomic practices with herbicides for sustainable weed management in aerobic rice. *The Scientific World Journal*, 2013, 1-12.

Anwar, M. P., Juraimi, A. S., Puteh, A., Man, A. & Rahman, M. M. (2012). Efficacy, phytotoxicity and economics of different herbicides in aerobic rice. *Acta Agriculturae Scandinavica*, Section B - *Soil & Plant Science*, *62*, 604–615, https://doi.org/10.1080/09064710.2012.681060

Ashiq, M. & Aslam, Z. (2014). Chemical control of weeds. In: weeds and weedicides. Dept. Agronomy, Ayub Agricultural Research Institute, Faisalabad and University of Agriculture, Faisalabad, Pakistan. pp. 235-256.

Azmi, M. (2002). Weed succession as affected by repeated application of the same herbicide in direct-seeded rice. *Journal of Tropical Agriculture and Food Science*, *30*(2), 151-161.

Azmi, M.& Baki, B. B.(1995). The succession of noxious weeds in tropical Asian rice fields with emphasis on Malaysia rice ecosystem. Proceedings of the 15thAsian Pacific weed science society conference, Tsukuba, Japan, 51-67.

Begum, M., Juraimi, A. S., Man, A., Rastan, S. O. S., & Amartalingam, R. (2008). Weed flora of different farm blocks in Block-1 of Muda rice granary in Peninsular Malaysia, *Journal of Bioscience*, *19*(1), 33-43.

Begum, M., Juraimi, A. S., Rajan, A., Azmi, M., & Syed Omar, S. R. (2006). The effects of sowing depth and flooding on the emergence, survival, and growth of *Fimbristylis miliaceae* (L.) Vahl. *Weed Biology and Management*, 6, 157-164.

Begum, M., Juraimi, A.S., Azmi, M., Rajan, A., & Syed-Omar, S. R. (2005). Weed vegetation of direct seeded rice fields in Muda rice granary areas of Paninsular Malaysia. *Pakistan Journal of Biological Science*, *8*(4), 537-541.

Begum, M., Mamun, A. A., Karim, M. M. & Hossain, S. M. A. (1999). A study on weed vegetation of *boro* rice in two agro-ecological zones of Bangladesh. *Bangladesh Journal of Agricultural Science*, 26(2), 205-211.

Bely, F. A., Uddin, M. R., Sarker, U. K., Harun-Or-Rashid, A. K. M., Sarker, M.Y., & Begum, M. (2016). Soil applied herbicide influence on weed growth and performance of transplant aman rice varieties. *Fundamental and Applied Agriculture*, *1*(2), 59-65.

Bernasor, P. C., & De Datta, S. K. (1983). Integration of cultural management and chemical control on weeds in broadcastseeded flooded rice. In: Proceedings of 9th Asian Pacific Weed Science Society Conference, 137-155.

Bhan, V.M. (1983). Effect of hydrology, soil moisture regimes, and fertility management on weed populations and their control in rice. In: Weed Control in Rice. International Rice Research Institute, Los Banos, Laguna, Philippines, pp. 47-56.

Boldt, P. E., Rosenthal, S. S., & Srinivasan, R. (1998). Distribution of field bind weed and hedge bind weed in the USA. *Journal of Production Agriculture*, 11, 377–381.

BRRI, Bangladesh Rice research Institute. (2008). Annual report for 2007.Bangladesh Rice Research Institute, Joydebpur, Gazipur, Bangladesh.

Cavers, P. B. (1983). Seed demography. *Canadian Journal of Botany*, 61, 3578–3590, https://doi.org/10.1139/b83-407

Chancellor, R.J. & Froud-Williams, R. J. (1984). A second survey of cereal weeds in Central Southern England.*Weed Research*, 24, 29-36.

Chauhan, B. S., & Johnson, D. E. (2011). Competitive interactions between weedy rice and cultivated rice as a function of added nitrogen and the level of competition. *Weed Biology and Management*, *11*, 202-209, https://doi.org/10.1111/j.1445-6664.2011.00421.x

Chauhan, B. S., & Opeña, J. (2013). Weed management and grain yield of rice sown at low seeding rates in mechanized dry-seeded systems. *Field Crops Research*, *141*, 9–15, http://dx.doi.org/10.1016/j.fcr.2012.11.002

De Datta, S. K. (1988). Progress in weed science and control technology in tropical rice. Proceedings 1988 Tropical Weed Science Society Conference, Thailand, 14-35.

Ho, (1998). The rice agro-ecosystem of the Muda irrigation scheme: An overview, in Nashriah *et al.* (Eds). Rice agro-ecosystem of the Muda irrigation scheme, Malaysia. Bangi Malaysia: Malaysian Institute of nuclear technology research (MINT) and MADA, pp. 1-24.

Holzner, W. (1982). Weeds as indicators, in Biology and Ecology of weeds (Eds.), Junk Publication. pp. 187-190.

Huda, M., Begum, M., Rahman, M. & Akter, F. (2017). Weed composition study on wheat and *boro* rice in research and farmers' fields. *Journal of the Bangladesh Agricultural University*, *15*(2), 148–157.

Iqbal, M. Z., Mamun, A. A., Hossain, S. M. A., Bhuiya, M. S. U., & Begum, M. (2001). Weed vegetation and productivity of transplant aman rice in two agro-ecological Zones of Bangladesh. *Journal of crop science*, 12(1&2), 79-86.

Islam, A. K. M. M., Hia, M. A. U. H., Sarkar, S. K., & Anwar, M. P. (2018). Herbicide based weed management in aromatic rice of Bangladesh. *Journal of the Bangladesh Agricultural University*, 16, 31–40, https://doi.org/10.3329/jbau.v16i1.36478

Islam, A. K. M. M., Popy, F. S., Hasan, A. K., & Anwar M. P. (2017). Efficacy and economics of herbicidal weed management in monsoon rice of Bangladesh. *Journal of Scientific Agriculture*, 1, 275, https://doi.org/10.25081/jsa.2017.v1.834

Janiya, J. D., & Moody, K.(1983). Weed growth and yield of two rice crops grown in sequence in three rainfed locations in the Philippines. *Philippine Agriculturist*, 66, 90-101.

Karim, S. M. R., Azmi, B. M., & Ismail, B. S. (2004). Weed problems and their management in rice fields of Malaysia: An overview. *Weed Biology and Management*, *4*, 177–186.

Katiyar, A., & Singh, S. K. (2015). Ecological approaches of weed management in pulses: the need of new commands for sustainable farming. *Popular Kheti*, 3 (3), 27-32.

Khan, I. S. M. (2018).Diversity of weeds in T. *aman* rice at research and farmers' fields in Mymensingh district.MS thesis, Dept. Agronomy, Bangladesh Agricultural University, Mymensingh, Bangladesh.

Kim, S. C., Park, R. K. & Moody, K. (1983). Changes in the weed flora in transplanted rice as affected by introduction of improved rice cultivars and the relationship between weed communities and soil chemical properties. *Research Report ORD*, *25*(1), 90-97.

Llewellyn, R. S., Ronning, D., Ouzman, J., Walker, S., Mayfield, A.& Clarke, M. (2016). Impact of Weeds on Australian Grain Production: The Cost of Weeds to Australian Grain Growers and the Adoption of Weed Management and Tillage Practices. Report for GRDC. CSIRO, pp. 112.

Mabbayad, M.O., Pablico, P. P. & Moody, K. (1983).The effect of time and method of land preparation on weed populations in rice. In: Proceedings of 9th Asian-Pacific Weed Science Society Conference, 357-368.

Mamun, A. A., Karim, S. M. R. & Barman, P. C.(1995). Weed survey in rice, wheat and lentil at different agro-ecological zones of Bangladesh. *Bangladesh Agricultural University Research progressive*, 7, 17-22.

Monira, S., Begum, M., & Uddin, M. R. (2020). Impact of weed control practices on weed suppression and crop performance in boro rice. *Fundamental and Applied Agriculture*, *5*(3), 372–382, https://doi.org/10.5455/faa.125478

Moody, K. (1982). The status of weed control in rice in Asia. *FAO Plant Protection Bulletin*, 30, 119-123.

Moody, K. (1990). Pest interaction in rice in the Philippines, in: Grayson, B. T., Green, M.B., Copping, L.G. (Eds.), Pest Management in Rice. Society of Chemical Industry and Elsevier Applied Science, New York, pp. 269-299.

Nahid, A., Bhuiya, M. S. U., Uddin, M. R., Haque, M. S., & Park, K. W. (2015).Combined effect of herbicides on the weed management of rice. *Research on Crops*, *16*(3), 416-421.

Oerke, E. C. (2005). Crop losses to pests. *The Journal of Agricultural Science*, *144*, 31–43, https://doi.org/10.1017/S0021859605005708

Parvez, M. S., Salam, M. A., Kato-Noguchi, H., & Begum, M.(2013). Effect of cultivar and weeding regime on the performance of transplant *aman* rice. *International Journal of Agriculture and Crop Sciences*, *6*(11), 654-666.

Popy, F. S., Islam, A. K. M. M., Hasan, A. K. & Anwar, M. P. (2017). Integration of chemical and manual control methods for sustainable weed management in inbred and hybrid rice. *Journal of the Bangladesh Agricultural University*, *15*, 158–166.

Rahman, A. B. M. Z., Islam, M. A., Haque, M. A. & Karim, S. M. R. (2007). Economic study of different level of herbicide and hand weeding methods in controlling weeds in transplant *aman* rice (*Oryza sativa* L.). *Journal of socioeconomic research development*, *3*(1), 66-73.

Ramana, A. V., Reddy, D. S. & Reddy, K. R. (2007). Influence of sowing time and nitrogen levels on growth, yield and N uptake of rainfed upland rice (*Oryza sativa* L.) varieties. *The Andhra Agricultural Journal*, 54, 114–120.

Rao, A. N. & Moody, K. (1988). Weed control in rice seedling nurseries. *Crop Protection*, *7*, 202–206.

Rashid, M. M. (2011). Effect of different weed control measures on the yield of transplanted *aman* rice. MS Thesis, Dept. Agronomy, Bangladesh Agricultural University, Mymensingh..

Sima, R. S. M. (2018). Weed vegetation in different field crops at Bangladesh Agricultural University farm, Mymensingh. MS thesis, Dept. Agronomy, Bangladesh Agricultural University, Mymensingh.

Afreen, S. (2019). Weed diversity in field crops of agronomy field laboratory at Bangladesh Agricultural University, Mymensingh.MS Thesis, Dept. Agronomy, Bangladesh Agricultural University, Mymensingh, Bangladesh.

Sultana, Y. (2012). Study on weed vegetation in different field crops of *rabi* season in Mymensingh District. MS Thesis, Dept. Agronomy, Bangladesh Agricultural University, Mymensingh, Bangladesh.

Thomas, A. G. (1985). Weed survey system used in Saskatchewan for cereal and oilseed crops. *Weed Science*, *33*, 34-43.

Uddin, A., Begum, M., Uddin, R., Akter, F., Razibul &Islam K. M. (2018). Floristic composition of weeds in *T. aman*-potato-*boro* rice cropping pattern in Bangladesh. *Journal of Research in Weed Science*, *1*, 48-62.

Uddin, M. K., Juraimi,A. S., Ismail, M. R., & Brosnan, J. T. (2010). Characterizing weed populations in different turfgrass sites throughout the klang valley of western peninsular Malaysia. *Weed Technology*, *24*, 173– 181.

UNDP& FAO, (1988). Land resources appraisal of Bangladesh for Agricultural Development, Report 2. Agro-ecological regions of Bangladesh. BARC.UNDP. New Airport Road, Farmgate, Dhaka 1215.

Watanabe, H., Zuki, Md., & Ho, N. K. (1997). Response of 2,4-D resistant biotype of *Fimbristylis miliacea* (L.) Vahl.to 2,4-D dimethylamine and its distribution in Muda plain, Peninsular Malaysia. *Journal of Weed Science and Technology*, *42*(3), 240-249.

Zimdahl, R. L. (2013). Fundamentals of Weed Science, fourth ed. Academic Press.