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Surveillance and distribution of different weeds in transplanted rice as influenced by integrated plant nutrition system (IPNS) in rice-wheat cropping system in Hilly area

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Abstract
The present investigation was undertaken in a long-term experiment on IPNS in rice-wheat cropping system. Twelve treatments *viz*., control (no fertilizer/manure), 50, 75 and 100% NPK each to rice and wheat through fertilizers, 50% NPK to rice and 100% NPK to wheat through fertilizers, 50% substitution of N through FYM, wheat straw and green manure in rice and 100% NPK through fertilizers in wheat; 25% substitution of N through FYM, wheat straw and green manure in rice and 75% NPK through fertilizers in wheat; and farmers' practice (40% NPK through fertilizers to each crop plus 5 t FYM/ha on dry weight basis to rice) were evaluated for a period of two years (2014 and 2015) with four replications. *Ammannia baccifera* was the most dominant weed constituting 40 and 35% of the total weed flora during *kharif* 2014 and 2015, respectively. This was followed by *Monochoria vaginalis, Eleocharis* sp., *Scirpus* sp., *Echinochloa* sp. and *Cyperus difformis* during 2014 and *Monochoria vaginalis, Brassica* sp., *Eleocharis* sp., *Scirpus* sp., *Cyperus difformis* and *Cynodon dactylon* during 2015. On an average *Ammannia baccifera* was the most dominant and problematic weed found in rice.

Keywords: rice, weed, importance weed index, integrated plant nutrition system

Introduction
Of the 30 major cropping systems identified in India (Yadav and Prasad 1998) [28], rice-based cropping system is the most predominant in India occupying around 10.5 mha area (Sharma 2009) [20]. Farmers realize much of their food security from this cropping system. Besides food security, the low production levels jeopardize farmers' economic security to a considerable extent. To strengthen the economic conditions of the farmers, it is imperative to sustain the productivity of this system. In India, total area under rice is 43.9 mha with production of 104.3 mt (Anonymous 2016) [3]. However, fertilizers are the kingpin in increasing crop productivity. But in case of intensive cultivation, growing of exhaustive crops like rice, use of unbalanced and inadequate fertilizers accompanied by restricted use of organic manures and biofertilizers have made the soils not only deficient in the nutrients, but also deterioration in its health resulting in decline in crop response to the recommended dose of N-fertilizer. Under such a situation, integrated nutrient management (INM) has assumed a great importance and has vital significance for the maintenance of soil productivity. The integrated use of organic manures and inorganic fertilizers can help to maintain optimum crop yields and long-term soil productivity (Puli *et al*. 2016) [17].
Weeds are the serious constraints in rice-wheat cropping system. Weed infestation is one of the factors responsible for low productivity (Singh *et al*. 2015) [23]. They reduce the crop yield and deteriorate the quality of produce (Arif *et al*. 2006) [6]. If left uncontrolled, the weeds in many fields are capable of reducing yields by more than 80% (Karlen *et al*. 2002) [16]. In rice-wheat system, yield reduction in rice due to weeds has been reported to the extent of 45% depending upon the soil type and rainfall pattern of a particular area (De Datta 1981) [13]. Researchers believe that application of organic manures is more superior for boosting crop yield and soil fertility over the synthetic fertilizers (Arif *et al.* 2012) [5]. This concept was further strengthened by Jones *et al.* (2009) [15] who found that plants are able to utilize nitrogen in organic form as well. However, it was found that application of organic manure can increase weeds population (Arif *et al.* 2013) [4] as most of the time incorporation of organic manure such as FYM served as weed seeds store bank (Baig *et al.* 2001; Ali *et al*. 2015) [8, 1].

Materials and Methods
Experimental site
Geographically, the experimental site is situated at $32^{o}\ 6^{'}$ N latitude, $76^{o}\ 3^{'}$ E longitude and 1223.7 m altitude. in North Western Himalaya in the Palam Valley of Kangra district of Himachal Pradesh. The present study was undertaken during 2014 and 2015 in an ongoing long - term experiment which was initiated during kharif 1991 with rice - wheat cropping system at the Bhadiarkhar farm of CSK HPKV Palampur university. Palampur represents the sub-temperate humid zone of Himachal Pradesh which is characterized by mild summers and cool winters. The area receives a very high rainfall during monsoon and medium to high rainfall with an occasional snowfall during winters. Agro-climatically, the experimental site falls in the sub-temperate zone in the mid-hills of Shivalik ranges of Himalayas which is endowed with mild summers and cool winters along with high rainfall during south-west monsoons. Average rainfall at the experimental site is 2600 mm/annum, major portion of which (80%) is received during monsoon season (June to September).

The soil of the experimental site was silty clay loam in texture, acidic in reaction (pH 5.5), high in available nitrogen (675 kg/ha), medium in available P (22 kg/ha) and K (221 kg/ha) with CEC of 11.5 c mol (p±). Taxonomically the soils of the region are classified as 'Typic Hapludalf'. The field experiment was established with rice and wheat as test crops. In this field investigation, 12 treatments were evaluated in a randomized block design with four replications which are as follows (Table 1):

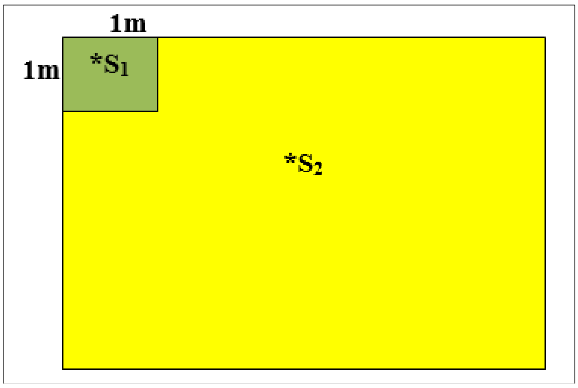
Table 1: Details of treatments in rice-wheat cropping system

Treatment	*Kharif*	*Rabi*
T_1	Control (No fertilizer, no manures)	Control (No fertilizer, no manures)
T_2	50% NPK* through fertilizer	50% NPK through fertilizer
T_3	50% NPK through fertilizer	100% NPK through fertilizer
T_4	75% NPK through fertilizer	75% NPK through fertilizer
T_5	100% NPK through fertilizer	100% NPK through fertilizer
T_6	50% NPK+50% N through farmyard manure (FYM)	100% NPK through fertilizer
T_7	75% NPK+25% N through farmyard manure	75% NPK through fertilizer
T_8	50% NPK+50% N through wheat cut straw (WCS)	100% NPK through fertilizer
T_9	75% NPK+25% N through wheat cut straw	75% NPK through fertilizer
T_{10}	50% NPK+50% N through green manure (GM)	100% NPK through fertilizer
T_{11}	75% NPK+25% N through green Manure	75% NPK through fertilizer
T_{12}	Farmers' practice (40% NPK+ 5t FYM/ha)	Farmers' practice (40% NPK through fertilizer)
*NPK - Through chemical fertilizer		

In farmers' practice, FYM 5 t/ha was applied along with 40% NPK to rice followed by 40% NPK to wheat. The recommended (100%) dose of nutrients in rice and wheat was 90:40:40 and 120:60:30 kg N, P_2O_5 and K_2O/ha, respectively. Samples of organic sources were analyzed for N, P and K contents as per the methods outlined before application in rice season and data have been reported in Table 2. Quantity of farmyard manure (FYM), wheat cut straw (WCS) and *ex-situ* green manure (GM) used in the experiment were worked out on field weight basis and incorporated before transplanting of rice.

Table 2: Nitrogen, phosphorus and potassium contents (%) of organics (dry wt. basis)

Organics	N	P	K
FYM (Cow dung manure)	1.20	0.225	1.013
Wheat cut straw	0.46	0.048	1.300
Green manure (Dhaincha)	2.40	0.163	1.556



Two situations as shown above were established in each plot
*(i) S_1 - No weed control/weedy without herbicide spray or hand weeding during both seasons and,
*(ii) S_2 - Usual weed control both in *kharif* and *rabi*. Two samples from S_2 were taken randomly during each observation. From S_1, only one sample was drawn each time.

The important quantitative analysis such as density, frequency and abundance of weed species, was done as per Curtis and McIntosh (1950) [10].

Weed studies
Analysis of weed diversity: Weeds are dynamic in nature. The crop(s), cropping systems and management practices mainly influence the weed shifts. Of the total losses caused by pests, weeds have a major share (30%). Studying the weed dynamics is helpful to understand the dominance or absence of a particular species in a crop/cropping system, devise means and ways to reduce their population, find out ways to delay or avoid the development of resistance by them against a herbicide, identify suitable crops for crop rotation / diversification and modify agronomic practices in favour of healthy crop growth. Manure is mainly used as a nutrient source and also in order to improve soil fertility (Baitilwake *et al.* 2011; Ali *et al.* 2012) [9, 2].

Density
Density is an expression of the numerical strength of a species where the total number of individuals of each species in all the quadrates is divided by the total number of quadrates studied. It is calculated by the equation as below:

$$\text{Density} = \frac{\text{Total number of individuals of a species in all quadrates}}{\text{Total number of quadrates studied}}$$

Importance value index

This index is used to determine the overall importance of each species in the community structure. In calculating this index, the percentage values of the relative frequency, relative density and relative abundance are summed up together and this value is designated as the Importance Value Index or IVI of the species. This index is used to determine the overall importance of each species in the community structure (Curtis, 1959) [11].

Summed dominance ratio (SDR)

It indicates the degree of dominance of a species over other species in a given sample plot. SDR of the weed species was computed using the following equation:

$$SDR = \frac{\text{Important Value Index}}{3}$$

Similarity index

Similarity index is a measure of the relative abundance of the different species making up the richness of an area (Azizi 2016) [7].

$$SI = \frac{\text{Relative frequency of particular sp.}}{\text{Relative frequency of total of sp.}}$$

Simpson's diversity index

The idea behind this index is that the diversity of a community is similar to the amount of information in a code or message. Simpson Diversity index is often used to quantify the biodiversity of a habitat (Simpson 1949) [21]. It takes into account the number of species present, as well as the large quantity of each species. It measures the probability that two individuals randomly selected from a sample will belong to same species. It can be measured with the following formula:

$$D = \frac{n\,(n-1)}{N\,(N-1)}$$

Where, n= total number of organisms of a particular species, N=total number of organisms of all species, Simpson's Diversity index = 1-D

As D increases, diversity decreases and Simpson's index was therefore usually expressed as 1 – D or 1/ D. Simpson's Diversity Index is a measure of diversity which takes into account the number of species present, as well as the relative abundance of each species. As species richness and evenness increase, so diversity increases. With this index, 1 represents infinite diversity and 0, no diversity.

Results and Discussion

Rice (*Kharif*)

Surveillance of weed flora

Weeds are dynamic over times and places and their competition depends on soil, climate and management practices. The weed flora in rice is very much diverse and consists of different species. In India, rice is grown under a wide variety of cultural practices in different agro-ecological conditions that is why weed diversity varied (Duary *et al.* 2015) [14]. The experimental field was monitored at different crop growth phases to look for the association of different weed species at a particular time. The occurrence of weed species noticed at a particular time of the crop growth. During a period of two years, 8 weed species were found growing in association with rice. This clearly indicated the greater diversity of weed flora that invaded the rice crop (Punia *et al*. 2007; Singh *et al*. 2012; Tiwari *et al*. 2013) [18, 22, 26]. *Monochoria vaginalis* and *Ammannia baccifera* have shown their presence at most of the stages of observation during both the years (Table 3). *Eleocharis* sp. and *Scirpus* sp. were also recorded during both the years. *Echinochloa* sp. was recorded at few observations during the first year only. *Brassica* sp. and *Cynodon dactylon* were recorded during 2015 only. It was indicated that weeds like *Brassica* sp. and *Cynodon dactylon* may likely be the menace of future in rice-wheat system (Singh *et al*. 2012) [22].

Table 3: Surveillance of weed flora in rice during 2014 and 2015

Weed species	2014				2015			
	30 DAT	60 DAT	90 DAT	Harvest	30 DAT	60 DAT	90 DAT	Harvest
Monochoria vaginalis	√	√	√	√	√	√	√	√
Ammannia baccifera	√	√	√	√	√	√	√	√
Cyperus difformis	√	√	-	-	-	-	√	-
Echinochloa sp.	√	-	-	√	-	-	-	-
Eleocharis sp.	-	√	√	-	√	√	√	-
Scirpus sp.	-	√	√	√	√	√	√	√
Brassica sp.	-	-	-	-	√	√	-	√
Cynodon dactylon	-	-	-	-	-	-	√	√
Others	-	-	√	√	√	√	√	√

√ - indicating presence

Distribution of weed species

The year-wise overall distribution of different weeds associated in rice crop showed the *Ammannia baccifera* as most dominant weed constituting 40 and 35% of the total weed flora during *kharif* 2014 and 2015, respectively (Fig. 1a and 1b). This was followed by *Monochoria vaginalis* (33 and 25%), *Eleocharis* sp. (5 and 8%) and *Scirpus* sp. (5 and 15%). *Cyperus difformis* (4%) and *Echinochloa* sp. (1%) had shown their invasion in a negligible proportion during 2014. Similarly, *Brassica* sp. (8%) and *Cynodon dactylon* (1%) had invaded rice during *kharif* 2015 only. Weed shift may be the reason of occurrence of new weed species. Weed shifts have occurred in response to changes in tillage (Tuesca *et al*. 2001) [27], irrigation, fertility (Davis *et al*. 2005) [12], crop rotation (Takim *et al*. 2014) [25] and herbicide use practices (Davis *et al*. 2005; Rana *et al*. 2016) [12]. Weed shifts occur when weed management practices do not control an entire weed community or population. The other unidentified weed species as a whole constituted 12 and 8% of the total weed flora during 2014 and 2015, respectively.

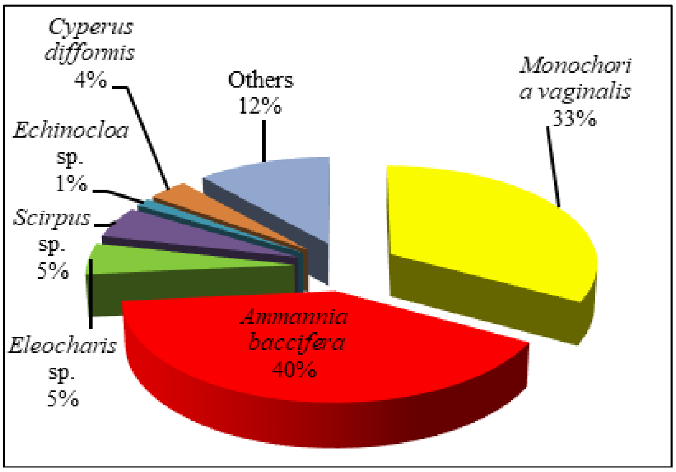


Fig 1(a): Distribution (%) of weed flora during *kharif* 2014 (rice) season

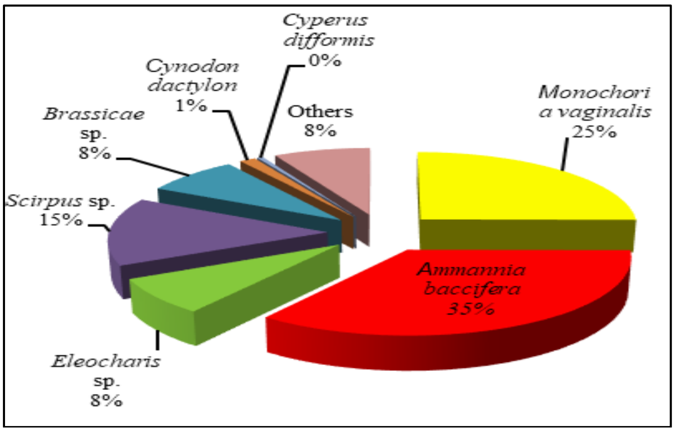


Fig 1(b): Distribution (%) of weed flora during *kharif* 2015(rice) season

Phytosociology of rice weeds and their interpretation

Phytosociological study of weeds, which provides knowledge of the dynamics and relative importance of species in a particular phytosociety or across phytosocieties assume enough relevance in crop-weed ecosystem. It gives an appraisal of species through quantitative characters which allow effective weed management decisions (Sinha and Banerjee 2016) [24]. The treatment-wise phytosociological analysis has been presented in Table 4 (Important Value Index), 5 (Summed Dominance Ratio), 6 (Similarity Index) and 7 (Shimpson Diversity Index). The critical perusal of the data in indicated that *Ammannia baccifera* was the most important weed having highest IVI (Important Value Index), SDR (Summed Dominance Ratio), SI (Similarity Index) and lowest SDI (Shimpson Diversity Index) in all the treatments except T_2 (50% NPK through fertilizer to both rice and wheat), T_6 (50% NPK through fertilizers and 50% N through FYM to rice and 100% NPK through chemical fertilizers to wheat) and T_{10} (50% NPK through fertilizers and 50% N through WCS (wheat cut straw) to rice and 100% NPK through fertilizers to wheat during 2015.

Under the treatments T_2 (50% NPK through fertilizer to both rice and wheat), T_5 (100% NPK through fertilizer to both rice and wheat), T_6 (50% NPK through fertilizers and 50% N through FYM to rice and 100% NPK through chemical fertilizers to wheat) and T_9 (75% NPK through fertilizers and 25% N through WCS to rice and 75% NPK through fertilizers to wheat) and T_{12} (Farmers' practice). *Monochoria vaginalis* had higher value of IVI, SDR, SI and lowest value of SDI followed by *Ammannia baccifera* during 2014. While, *Brassica* sp. had highest value of IVI, SDR, SI and lowest SDI in T_2 (50% NPK through chemical fertilizer to both crops) during 2015 than other weeds. These indices shows the diversity and prevalence of weed species in rice –wheat cropping system.

Table 4: Effect of fertility treatments on IVI (Important Value Index) of weeds in rice

Weed species	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	T_9	T_{10}	T_{11}	T_{12}
2014												
Monochoria vaginalis	28.4	99.7	68.2	67.4	91.6	138.6	79.5	69.4	84.4	96.4	92.3	84.6
Ammannia baccifera	134.0	88.2	130.2	88.4	59.9	80.4	82.7	112.0	82.1	110.2	121.0	82.9
Eleocharis sp.	23.6	75.4	23.2	19.6	22.4	15.0	11.2	17.0	25.6	19.9	14.5	22.5
Scirpus sp.	36.1	15.4	18.4	33.8	16.5	18.8	26.5	26.2	36.2	34.3	20.4	24.3
Echinocloa sp.	5.7	11.9	13.9	9.9	12.9	9.9	12.0	11.3	12.2	17.1	10.0	4.1
Cyperus difformis	36.8	9.5	16.6	15.8	21.1	11.6	18.3	26.5	23.8	8.9	12.8	25.8
Others	35.3	0.0	29.5	65.1	75.6	25.7	69.8	37.6	35.7	13.3	29.1	55.9
2015												
Monochoria vaginalis	55.9	54.1	66.1	54.2	57.0	78.5	72.6	75.7	60.1	100.9	77.0	66.1
Ammannia baccifera	105.7	52.7	86.5	110.9	80.9	58.3	86.7	77.2	90.5	52.9	91.3	104.2
Eleocharis sp.	24.4	18.4	35.8	43.7	33.4	38.1	21.7	29.7	21.8	42.9	39.9	26.4
Scirpus sp.	66.6	42.0	41.4	49.6	34.8	33.2	46.7	54.7	48.9	41.5	45.3	52.6
Brassica sp.	0.0	82.2	28.9	0.0	42.9	25.2	43.6	28.6	45.1	22.0	29.6	17.9
Cynodon dactylon	16.1	11.7	0.0	8.7	6.2	23.3	3.2	14.2	3.0	8.5	5.8	10.3
Cyperus difformis	8.1	8.4	5.9	15.8	0.0	6.1	0.0	4.6	7.3	8.5	4.1	9.9
Others	23.2	30.5	35.3	17.2	44.9	37.3	25.4	15.4	23.3	22.6	7.0	12.7

Table 5: Effect of fertility treatments on SDR (Summed Dominance Ratio) of weeds in rice

Weed species	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	T_9	T_{10}	T_{11}	T_{12}
2014												
Monochoria vaginalis	9.5	33.2	22.7	22.5	30.5	46.2	26.5	23.1	28.1	32.1	30.8	28.2
Ammannia baccifera	44.7	29.4	43.4	29.5	20.0	26.8	27.6	37.3	27.4	36.7	40.3	27.6
Eleocharis sp.	7.9	25.1	7.7	6.5	7.5	5.0	3.7	5.7	8.5	6.6	4.8	7.5
Scirpus sp.	12.0	5.1	6.1	11.3	5.5	6.3	8.8	8.7	12.1	11.4	6.8	8.1
Echinocloa sp.	1.9	4.0	4.6	3.3	4.3	3.3	4.0	3.8	4.1	5.7	3.3	1.4
Cyperus difformis	12.3	3.2	5.5	5.3	7.0	3.9	6.1	8.8	7.9	3.0	4.3	8.6
Others	11.8	0.0	9.8	21.7	25.2	8.6	23.3	12.5	11.9	4.4	9.7	18.6

2015												
Monochoria vaginalis	18.6	18.0	22.0	18.1	19.0	26.2	24.2	25.2	20.0	33.6	25.7	22.0
Ammannia baccifera	35.2	17.6	28.8	37.0	27.0	19.4	28.9	25.7	30.2	17.6	30.4	34.7
Eleocharis sp.	8.1	6.1	11.9	14.6	11.1	12.7	7.2	9.9	7.3	14.3	13.3	8.8
Scirpus sp.	22.2	14.0	13.8	16.5	11.6	11.1	15.6	18.2	16.3	13.8	15.1	17.5
Brassica sp.	0.0	27.4	9.6	0.0	14.3	8.4	14.5	9.5	15.0	7.3	9.9	6.0
Cynodon dactylon	5.4	3.9	0.0	2.9	2.1	7.8	1.1	4.7	1.0	2.8	1.9	3.4
Cyperus difformis	2.7	2.8	2.0	5.3	0.0	2.0	0.0	1.5	2.4	2.8	1.4	3.3
Others	7.7	10.2	11.8	5.7	15.0	12.4	8.5	5.1	7.8	7.5	2.3	4.2

Table 6: Effect of fertility treatments on SI (Similarity Index) of weeds in rice

Weed species	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	T_9	T_{10}	T_{11}	T_{12}
2014												
Monochoria vaginalis	16.7	33.8	14.8	23.9	25.2	38.2	25.6	26.2	25.7	36.8	28.9	27.7
Ammannia baccifera	30.0	27.5	13.2	28.9	23.3	21.1	26.7	28.2	25.7	32.9	30.9	24.8
Eleocharis sp.	5.6	12.5	14.3	9.0	9.7	6.6	7.8	9.7	9.9	3.9	9.3	7.9
Scirpus sp.	20.0	10.0	15.9	13.9	10.7	13.2	13.3	14.6	13.9	7.9	12.4	13.9
Echinocloa sp.	4.4	8.8	12.6	6.5	7.8	6.6	5.6	6.8	6.9	7.9	4.1	2.0
Cyperus difformis	10.0	7.5	14.8	6.0	10.7	6.6	7.8	6.8	5.9	5.3	6.2	8.9
Others	13.3	0.0	14.3	11.9	12.6	7.9	13.3	7.8	11.9	5.3	8.2	14.9
2015												
Monochoria vaginalis	17.2	21.8	23.1	18.3	24.3	28.4	23.2	26.4	22.5	31.7	26.1	20.0
Ammannia baccifera	26.7	21.8	25.6	29.8	25.2	20.6	25.9	26.4	24.2	17.8	26.1	27.3
Eleocharis sp.	12.1	6.7	12.4	13.5	13.1	8.8	8.0	10.9	8.3	9.9	11.8	10.9
Scirpus sp.	23.3	17.6	21.5	22.1	13.1	12.7	18.8	19.1	22.5	13.9	21.8	20.9
Brassica sp.	0.0	9.2	7.4	0.0	7.5	2.9	10.7	1.8	8.3	7.9	4.2	5.5
Cynodon dactylon	7.8	6.7	0.0	4.8	3.7	6.9	2.7	4.5	0.8	4.0	3.4	6.4
Cyperus difformis	4.3	2.5	3.3	1.0	0.0	2.9	0.0	2.7	2.5	4.0	1.7	0.9
Others	8.6	13.4	6.6	10.6	13.1	16.7	10.7	8.2	10.8	10.9	5.0	8.2

Table 7: Effect of fertility treatments on SDI (Shimpson Diversity Index) of weeds in rice

Weed species	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	T_9	T_{10}	T_{11}	T_{12}
2014												
Monochoria vaginalis	1.0	0.6	0.8	0.8	0.4	0.2	0.6	0.8	0.5	0.6	0.7	0.6
Ammannia baccifera	0.1	0.7	0.2	0.5	0.8	0.8	0.6	0.2	0.6	0.4	0.3	0.6
Eleocharis sp.	1.0	0.9	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Scirpus sp.	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Echinocloa sp.	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Cyperus difformis	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Others	1.0	0.7	1.0	0.8	0.7	1.0	0.8	1.0	1.0	1.0	1.0	0.9
2015												
Monochoria vaginalis	0.9	0.8	0.7	0.9	0.8	0.4	0.7	0.6	0.8	0.3	0.7	0.8
Ammannia baccifera	0.3	0.8	0.4	0.2	0.4	0.8	0.5	0.6	0.4	0.9	0.5	0.3
Eleocharis sp.	1.0	1.0	1.0	1.0	1.0	0.9	1.0	1.0	1.0	1.0	1.0	1.0
Scirpus sp.	0.8	0.9	0.9	0.9	1.0	1.0	0.9	0.8	0.9	0.9	0.9	0.9
Brassica sp.	1.0	0.5	1.0	1.0	0.9	1.0	0.9	1.0	0.9	1.0	1.0	1.0
Cynodon dactylon	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Cyperus difformis	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Others	1.0	1.0	1.0	1.0	0.9	0.9	0.9	1.0	1.0	0.9	1.0	1.0

Conclusion

The overview of this experiment throws light on the impact of IPNS (Integrated plant nutrition system) on composition and abundance of weed species in rice field is helpful in understanding the dynamics of particular weed species, in terms of numbers and diversity. IPNS can contribute to the suppression of weeds. Although weeds create problems in economic gains but simultaneously conserving weeds biodiversity as an integral part of maintaining balanced agro ecosystems.

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