

Phytosociological Assessment and Biodiversity of Weed Flora in Rice Agroecosystems of Bhatapara tehsil, Chhattisgarh, India



Shankar Lal Negi¹, Devesh Kumar Negi², Deepa Biswas³ and Kavita Sharma*⁴

¹Department of Botany, Govt D K College Balodabazar, Chhattisgarh, India

²Kalinga University, Raipur, Chhattisgarh, India

³Department of Botany, Kalinga University, Raipur, Chhattisgarh, India

⁴SGS Government Arts and Commerce Girls College, Raipur, Chhattisgarh, India

ABSTRACT

Rice agroecosystems support a rich diversity of weed flora that significantly impairs crop productivity and threatens food security. The present study was undertaken during 2018–2020 to systematically assess the phytosociology and biodiversity of weed communities in rice fields of the Semaria and Tarenga of Bhatapara tehsil, Chhattisgarh, India. Three cultivation types transplanted rice fields, direct-seeded rice fields, and fallow land were investigated using randomized quadrat sampling (1 m × 1 m). A total of 51 weed species distributed across 39 genera and 20 families were documented. Cyperaceae emerged as the most species-rich family with 12 species across three genera, followed by Poaceae with seven species. Phytosociological parameters including frequency, density, abundance, relative frequency, relative density, relative abundance, and Importance Value Index (IVI) were computed for each species across all six sites. *Echinochloa colona* recorded the highest IVI (31.69) at the Semaria transplanted site, while *Alternanthera philoxeroides* dominated the Tarenga fallow land (IVI = 41.12). Biodiversity was quantified using Shannon-Wiener (H') and Simpson (D) indices. Tarenga rice fields exhibited consistently higher Shannon diversity than Semaria sites. These findings highlight site-specific and cultivation-type-specific weed community dynamics, offering actionable insights for site-tailored integrated weed management strategies in tropical rice-growing regions.

Keywords: Phytosociology; Importance Value Index; Shannon-Wiener diversity; weed biodiversity; Chhattisgarh.

Citation: Shankar Lal Negi, Devesh Kumar Negi, Deepa Biswas and Kavita Sharma [2026]. Phytosociological Assessment and Biodiversity of Weed Flora in Rice Agroecosystems of Bhatapara tehsil, Chhattisgarh, India. *Journal of Diversity Studies*.

DOI: <https://doi.org/10.51470/JOD.2026.5.1.230>

Corresponding Author: Kavita Sharma

E-mail Address: drktsharma@gmail.com

Article History: Received 15 February 2026 | Revised 17 March 2026 | Accepted 14 April 2026 | Available Online May 18, 2026

Copyright: © 2026 by the author. The license of *Journal of Diversity Studies*. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (<https://creativecommons.org/licenses/by/4.0/>).

1. Introduction

Rice (*Oryza sativa* L.) constitutes the primary caloric staple for over half the global population, with more than 90% of production concentrated in Asia [1]. India, recognised as a centre of origin for rice cultivation, maintains the world's largest rice harvesting area and supports domestic consumption for approximately 65% of its 1.4 billion inhabitants. Chhattisgarh colloquially designated the 'Bowl of Rice' hosts rice as its dominant kharif crop, cultivated primarily through transplanting and direct seeding methods [2]. However, the productivity of these cultivation systems is substantially compromised by weed infestations, which annually account for an estimated 24% of total agricultural losses in India [5, 21-23]. Among all biotic stresses in agriculture, weeds impose the greatest economic burden, primarily because they aggressively compete with cultivated crops for essential resources including light, water, nutrients, and growing space, leading to impaired canopy closure, reduced tillering, and significant grain yield penalties [1]. In direct-seeded rice, the intensity of weed competition is especially pronounced, since the lack of flooding during the early establishment phase eliminates a major natural

weed suppressant, thereby facilitating rapid germination and establishment of a wide range of weed species [15, 22]. Yield losses attributable to uncontrolled weeds in direct-seeded rice range from 62% to 91.7%, representing a major bottleneck to food security [18].

Phytosociological investigations furnish essential quantitative data for documenting weed assemblage composition, ranking species by competitive dominance, and mapping spatial occurrence patterns across diverse crop environments. The Importance Value Index (IVI), derived as the summation of relative frequency, relative density, and relative abundance, constitutes the most comprehensive single metric for evaluating the ecological significance and competitive status of individual species within a plant community [7]. When coupled with biodiversity indices such as the Shannon-Wiener and Simpson measures, phytosociological data enable nuanced comparisons of species richness, evenness, and dominance across sites and management regimes [10].

Despite a substantial body of phytosociological work on rice weeds at the pan-Indian level [19,13,16],

Bhatapara Tehsil is widely recognised as an important rice-producing region. The fertile soil and favourable climatic conditions of the area make it highly suitable for paddy cultivation. Nearly all the 113 villages under the tehsil are primarily engaged in rice farming. During the Kharif season, large-scale paddy production takes place across these villages. In addition, the region has several rice mills and poha mills that process the locally produced crop, thereby strengthening the agriculture-based economy of the area. Semaria is a village/gram panchayat which is a part of Bhatapara tehsil and development block (CD Block). Tarenga is a village panchayat in the Bhatapara development block, yet no systematic weed survey had previously been conducted in these blocks. The present study addresses this gap by providing the first quantitative assessment of weed floristics, phytosociology, and biodiversity across multiple cultivation types in this ecologically and agriculturally significant zone.

2. Materials and Methods

2.1 Study Area

The study was conducted in Semaria and Tarenga, situated within Bhatapara tehsil (21.73334° N, 81.94651° E), Chhattisgarh State, central India, experiences a tropical monsoon climate with mean annual rainfall of approximately 1135.15 mm, concentrated during the southwest monsoon (June–October). Summer temperatures may exceed 45°C, while winters (November–January) are mild with low humidity. Soils in the area belong primarily to Entisol and Inceptisol orders categorized locally as bhata (lateritic), matasi (sandy loam), dorsa (clay loam), and kanhar (deep black cotton soil). The survey was carried out from 2018–2020 during peak weed growth periods.

2.2 Experimental Design and Sampling

Six sites were established for systematic weed surveys: three in Semaria (transplanted, direct-seeded, and fallow fields) and three corresponding sites in Tarenga. At each site, quadrat sampling was conducted using iron-frame quadrats of 1 m × 1 m. Fields were divided into 10 × 10 m grid units, and quadrat locations were selected using a random number table; four quadrats were sampled per field. Weed species were identified in situ using standard taxonomic references, and voucher specimens were collected for herbarium preparation. All weed individuals within each quadrat were counted at the species level.

2.3 Phytosociological Parameters

Frequency, density (ha⁻¹), and abundance were calculated for all recorded weed species following standard ecological formulae [6]. Relative frequency, relative density, and relative abundance were derived as percentages of the respective totals across all species per site. The Importance Value Index (IVI) was computed as the sum of relative frequency, relative density, and relative abundance for each species, yielding values on a scale of 0–300.

2.4 Diversity Indices

The Shannon-Wiener index (H') was calculated as $H' = -\sum P_i \ln P_i$, where P_i represents the proportional IVI of each species relative to the total IVI. Margalef's richness index ($M = (S - 1)/\ln N$), Simpson's dominance index ($D = \sum P_i^2$), Simpson's diversity index ($1 - D$), and Simpson's evenness index were additionally computed to characterize community structure comprehensively [7, 10, 12, 17].

3. Results

3.1 Floristic Composition

A total of 51 weed species, belonging to 39 genera and 20 families, were recorded across all six study sites (Table 1). Of these, 29 species were dicotyledonous (distributed across 27 genera and 16 families), 21 species were monocotyledonous (11 genera; 3 families), and one aquatic pteridophyte (*Marsilea minuta* L.) was also documented. Cyperaceae was the most species-rich family, contributing 12 species across 3 genera (*Cyperus*, *Fimbristylis*, *Eleocharis*), followed by Poaceae with 6 genera and 7 species. Amaranthaceae (6 species; 5 genera) and Fabaceae (5 species; 5 genera) were the most diverse dicotyledonous families.

Morphologically, the weed flora was categorized into three functional groups: (i) sedges dominated by *Cyperus* and *Fimbristylis* species; (ii) grasses represented by *Echinochloa*, *Cynodon*, *Panicum*, and allied genera; and (iii) broad-leaved weeds comprising dicotyledonous species from 16 families. This tripartite categorisation, consistent with standard weed science practice, is ecologically informative because each functional group exhibits distinct competitive traits and responds differentially to management interventions.

Table 1: Taxonomic summary of weed flora recorded in rice agroecosystems of Bhatapara tehsil

Category	Families	Genera	Species
Dicotyledonae	16	27	29
Monocotyledonae	3	11	21
Pteridophyta	1	1	1
Total	20	39	51

Table 2: Dominant weed families with number of genera and species

Family	Genera (n)	Species (n)	Dominant Species
Cyperaceae	3	12	<i>Cyperus iria</i> , <i>C. difformis</i> , <i>C. rotundus</i>
Poaceae	6	7	<i>Echinochloa colona</i> , <i>Cynodon dactylon</i>
Amaranthaceae	5	6	<i>Alternanthera philoxeroides</i> , <i>A. paronychioides</i>
Fabaceae	5	5	<i>Aeschynomene indica</i> , <i>Cassia tora</i>
Asteraceae	4	4	<i>Ageratum conyzoides</i> , <i>Eclipta alba</i>
Malvaceae	3	4	<i>Sida acuta</i> , <i>Melochia corchorifolia</i>

3.2 Phytosociology

3.2.1 Semaria Transplanted Field

Cyperus iria and *Cyperus difformis* exhibited maximum frequency (100%) at the Semaria transplanted site, indicating ubiquitous presence across all sampled quadrats. *Cynodon dactylon* followed with 90% frequency. Maximum density was recorded for *Echinochloa colona* (13.90 individuals quadrat⁻¹), succeeded by *Cynodon dactylon* (10.20) and *Cyperus difformis* (3.40). The IVI rankings indicated ecological dominance by *Echinochloa colona* (IVI = 31.69), *Cynodon dactylon* (IVI = 30.21), and *Cyperus difformis* (IVI = 15.07), underscoring the competitive supremacy of grasses and sedges in flooded transplanted conditions (Table 3).

3.2.2 Semaria Direct-Seeded Field

Under direct-seeded conditions in Semaria, *Cyperus iria* and *Cyperus difformis* retained 100% frequency, while *Cynodon dactylon* occurred in 80% of quadrats. The highest density was recorded for *Cynodon dactylon* (8.40), followed by *Merremia emarginata* (7.30). The IVI was dominated by *Merremia emarginata* (25.58), with *Cyperus difformis* (15.65) and *Marsilea minuta* (14.68) ranking second and third. The prominent IVI of *M. emarginata* in this habitat is ecologically notable, as direct-seeded fields lack the pre-germination flooding that suppresses broad-leaved trailing vines.

3.2.3 Semaria Fallow Land

Alternanthera paronychioides, *Cyperus iria*, and *Merremia emarginata* each recorded 100% frequency in the Semaria fallow fields, with *Commelina benghalensis* at 80%. Despite having the second-highest density overall (*Cynodon dactylon* = 10.20), the IVI leadership shifted to *Merremia emarginata* (22.32), followed by *Melochia corchorifolia* (21.86) and *Alternanthera paronychioides* (21.19). These shifts in IVI leadership relative to density reflect differences in abundance patterns and suggest that fallow conditions favoured sprawling, multi-stemmed dicotyledonous species over monocots.

3.2.4 Tarenga Transplanted Field

At the Tarenga transplanted site, *Alternanthera philoxeroides*, *Cynodon dactylon*, *Cyperus iria*, and *Cyperus difformis* all exhibited 100% frequency. Maximum density was recorded for *Cynodon dactylon* (19.00), followed by *Alternanthera philoxeroides* (18.00), *Ludwigia octovalvis* (14.80), and *Cyperus iria* (12.20). The IVI hierarchy placed *Cynodon dactylon* first (30.09), *Alternanthera philoxeroides* second (28.79), and *Ludwigia octovalvis* third (24.83). The dominance of *Ludwigia octovalvis* an aquatic/semi-aquatic onagraceous weed, is consistent with the waterlogged conditions characteristic of transplanted rice in Tarenga's heavier Inceptisol soils.

Table 3: Top five weed species by IVI across all six study sites

Site	Rank 1 (IVI)	Rank 2 (IVI)	Rank 3 (IVI)	Rank 4 (IVI)	Rank 5 (IVI)
Semaria Transplanted	<i>E. colona</i> (31.69)	<i>C. dactylon</i> (30.21)	<i>C. difformis</i> (15.07)	<i>C. iria</i> (12.40)	<i>H. contortus</i> (12.72)
Semaria Direct Seeded	<i>M. emarginata</i> (25.58)	<i>C. difformis</i> (15.65)	<i>M. minuta</i> (14.68)	<i>C. exaltatus</i> (13.33)	<i>H. contortus</i> (13.26)
Semaria Fallow	<i>M. emarginata</i> (22.32)	<i>M. corchorifolia</i> (21.86)	<i>A. paronychioides</i> (21.19)	<i>C. iria</i> (12.67)	<i>C. exaltatus</i> (13.07)
Tarenga Transplanted	<i>C. dactylon</i> (30.09)	<i>A. philoxeroides</i> (28.79)	<i>L. octovalvis</i> (24.83)	<i>C. iria</i> (high)	<i>A. paronychioides</i> (high)
Tarenga Direct Seeded	<i>S. indicus</i> (27.17)	<i>C. dactylon</i> (26.32)	<i>E. alba</i> (18.01)	<i>Phyla modiflora</i> (18.01)	<i>A. philoxeroides</i> (high)
Tarenga Fallow	<i>A. philoxeroides</i> (41.12)	<i>M. corchorifolia</i> (28.38)	<i>S. indicus</i> (21.56)	<i>C. dactylon</i> (high)	<i>C. iria</i> (high)

3.3 Biodiversity Indices

Shannon-Wiener diversity indices (H') were consistently higher at Tarenga sites than at corresponding Semaria sites, indicating greater evenness in species distribution at Tarenga. This pattern may reflect the greater soil heterogeneity and hydrological variability of Tarenga's Inceptisol-dominated landscape. The Simpson dominance index (D) was lowest at Tarenga Transplanted ($D = 0.0447$), confirming maximum species diversity at that site, while highest D values were recorded at Semaria Direct Seeded, indicating strong dominance by a few species. Simpson's evenness was highest at Semaria Fallow (0.56) and lowest at Semaria Direct Seeded (0.09). The Simpson Dominance index confirmed that Tarenga Transplanted exhibited the highest dominance value (22.37) among all sites (Table 4), reflecting the overwhelming competitive superiority of *Cynodon dactylon* and *Alternanthera philoxeroides* in that habitat.

Table 4: Biodiversity indices across six study sites in Bhatapara tehsil rice agroecosystems

Site	Shannon H'	Simpson D	1-D (Diversity)	Evenness	Dominance
Semaria Transplanted	Higher	Moderate	Moderate	Moderate	Moderate
Semaria Direct Seeded	Moderate	Highest	Lowest	0.09 (lowest)	High
Semaria Fallow	Moderate	Moderate	Moderate	0.56 (highest)	Moderate
Tarenga Transplanted	Highest	0.0447 (lowest)	Highest	Moderate	22.37 (highest)
Tarenga Direct Seeded	High	Low	High	Moderate	Moderate
Tarenga Fallow	High	Low	High	High	Moderate

3.2.5 Tarenga Direct-Seeded Field

Cyperus iria maintained 100% frequency, while *Alternanthera philoxeroides* registered 90%. Maximum density was conferred by *Alternanthera philoxeroides* (14.90), with *Sphaeranthus indicus* (12.40) and *Cynodon dactylon* (11.90) following. Notably, the IVI was highest for *Sphaeranthus indicus* (27.17), followed by *Cynodon dactylon* (26.32) and *Eclipta alba* (18.01). *Sphaeranthus indicus*, an asteraceous annual, is frequently associated with direct-seeded and moisture-variable conditions, and its dominance here signals its highly competitive ability under less-flooded regimes.

3.2.6 Tarenga Fallow Land

The Tarenga fallow site exhibited the broadest array of high-frequency species; six species *Alternanthera philoxeroides*, *Cynodon dactylon*, *Cyperus iria*, *Melochia corchorifolia*, *Sida acuta*, and *Cyperus difformis* each attained 100% frequency. Maximum density was recorded for *Melochia corchorifolia* (18.00). The IVI was decisively led by *Alternanthera philoxeroides* (41.12), followed by *Melochia corchorifolia* (28.38) and *Sphaeranthus indicus* (21.56). The exceptionally high IVI of *A. philoxeroides* in fallow land reflects its perennial, stoloniferous growth form that enables rapid colonization of disturbed, unshaded habitats.

3.4 Phenological Patterns

All 51 weed species exhibited strong phenological coupling with the rice crop cycle, displaying vegetative growth from July through September, coincident with the monsoon-driven crop establishment phase. Flowering and fruiting progressed from September through October, with seed maturation and dispersal occurring by late November precisely coinciding with rice harvest. This tight phenological synchrony, characteristic of what may be termed 'obligate monsoon annuals, represents an evolutionary adaptation that maximizes weed seed production concurrent with crop canopy senescence, replenishing the soil seed bank before post-harvest tillage. Perennial species such as *Cynodon dactylon* and *Cyperus rotundus* additionally propagate vegetatively through stolons and tubers, enabling year-round persistence independent of seed set.

4. Discussion

The dominance of Cyperaceae (12 species) and Poaceae (7 species) across all six study sites is consistent with broader patterns documented in rice agroecosystems across South and Southeast Asia [19-21]. The ecological explanation for sedge and grass supremacy lies in their crop-mimicry traits narrow leaves, rapid tillering, and aerenchymatous roots that provide competitive advantages under flooded transplanted conditions where broad-leaved dicots are physiologically suppressed. These findings align with reports from Kashmir Valley, where Gramineae constituted the most dominant family with 11 weed species [19], and from Korla District, Chhattisgarh, where *Echinochloa colona* and *Cyperus iria* consistently dominated the IVI hierarchy [16].

The shift in IVI dominance from *Echinochloa colona* in transplanted fields to *Merremia emarginata* in direct-seeded and *Alternanthera philoxeroides* in fallow land underscores the sensitivity of weed community composition to cultivation type and hydrological regime. *Echinochloa colona*'s dominance in transplanted conditions (IVI = 31.69) is well documented globally as the most competitive grass weed of paddy [2, 11]; its reduced IVI under direct-seeded conditions is attributable to the lower initial soil moisture that disadvantages early submergence-tolerant germination. By contrast, *M. emarginata*'s prominence in direct-seeded plots suggests that trailing convolvulaceous species flourish when the competitive suppression of standing water is absent.

The higher Shannon diversity indices at Tarenga versus Semaria mirror edaphic differences between the two blocks. Tarenga's soils predominantly are Inceptisols with higher available iron and manganese support more heterogeneous micro-habitats, enabling coexistence of a broader array of weed functional types. Semaria's soils, with generally lower organic carbon and higher acidity in direct-seeded plots, tend to favor fewer, more stress-tolerant, and ecologically generalist species, resulting in lower evenness and higher dominance (D) at the Direct-Seeded site. These edaphic-diversity relationships are consistent with the resource heterogeneity hypothesis, which predicts that higher resource variability supports greater species coexistence [10].

From a weed management perspective, the high frequency (100%) and elevated IVI of *Cynodon dactylon* and *Cyperus iria* across both transplanted sites signals that these perennial species represent priority targets for long-term suppression strategies. The phenological synchrony of annual weed species with the rice crop cycle with seed maturation coinciding with harvest underlines the critical importance of pre-flowering intervention. Early post-emergence herbicide application (within 15–20 days after transplanting or sowing), combined with manual weeding at the tillering stage, would interrupt seed set in annual weeds before they replenish the soil seed bank [8,14]. Integrated weed management incorporating competitive rice cultivars, closer plant spacing, and site-specific herbicide selection remains the most sustainable approach [3].

5. Conclusion

This study provides the first systematic phytosociological baseline for weed communities of Semaria and Tarenga in Bhatapara tehsil, Chhattisgarh. The documentation of 51 weed species across six sites, with site-specific IVI hierarchies demonstrating clear cultivation-type effects, constitutes ecologically meaningful data for designing targeted weed management.

Cyperaceae and Poaceae dominated all sites, while the prominence of specific species such as *Echinochloa colona* in transplanted rice, *Merremia emarginata* in direct-seeded fields, and *Alternanthera philoxeroides* in fallow land points to habitat-specific competitive advantages. Higher Shannon diversity at Tarenga sites reflects greater edaphic heterogeneity. Phenological synchrony between weed and crop life cycles reinforces the necessity of pre-anthesis weed control. Future research should incorporate seed bank analyses, allelopathic screening of dominant weed species, and multi-season trials to evaluate integrated weed management efficacy under changing climatic regimes in central India.

References

1. Chauhan, B. S., Mahajan, G., & Singh, R. G. (2012). Ecology and management of weeds under conservation agriculture: A review. *Crop Protection*, 38, 57–65. <https://doi.org/10.1016/j.cropro.2012.03.010>
2. Chauhan, B. S., Ahmed, S., & Awan, T. H. (2015). Performance of sequential herbicides in dry-seeded rice in the Philippines. *Crop Protection*, 74, 124–130. <https://doi.org/10.1016/j.cropro.2015.04.015>
3. Chauhan, B. S., Kumar, V., Mahajan, G., & Gill, G. (2017). Integrated weed management strategies in direct-seeded rice and weed management challenges for the 21st century. *Weed Science*, 65(Special Issue), 4–12. <https://doi.org/10.1017/wsc.2016.41>
4. Ghosh, D., Singh, U. P., Ray, K., & Das, A. (2016). Weed management through herbicide application in direct-seeded rice and yield modeling by artificial neural network. *Spanish Journal of Agricultural Research*, 14(2), e1003. <https://doi.org/10.5424/sjar/2016142-8062>
5. Gupta, O. P. (2000). Modern weed management. Agrobios India.
6. Jha, A. K., & Sinha, S. (1989). Phytosociological studies on the rice field weeds of Darbhanga. *Environment and Ecology*, 7(4), 911–914.
7. Kent, M., & Coker, P. (1992). Vegetation description and analysis: A practical approach. Belhaven Press.
8. Kumari, B. K., Kumar, S., & Singh, R. K. (2018). Effect of moisture regimes and weed management on weeds, yield and economics of direct-seeded rice. *Journal of Crop and Weed*, 14(1), 101–108.
9. Kumar, V., Singh, S., Chhokar, R. S., Malik, R. K., Brainard, D. C., & Ladha, J. K. (2013). Weed management strategies to reduce herbicide use in zero-till rice-wheat cropping systems of the Indo-Gangetic Plains. *Weed Technology*, 27, 241–254. <https://doi.org/10.1614/WT-D-12-00062.1>
10. Magurran, A. E. (2004). Measuring biological diversity (2nd ed.). Blackwell Science.
11. Mncube, T. L., Mloza-Banda, H. R., Kibirige, D., Khumalo, M. M., Mukabwe, W. O., & Dlamini, B. P. (2017). Composition and management of weed flora in smallholder farmers' fields in Swaziland. *African Journal of Rural Development*, 2(3), 441–453.
12. Shannon, C. E. (1948). The mathematical theory of communication. University of Illinois Press.
13. Sharma, R. P., & Dubey, V. (2009). Floristic diversity of weeds of dry-seeded and transplanted rice fields in Bilaspur, Chhattisgarh. In *Proceedings of National Seminar on Agri-Food and Plant Science*, pp. 103–104.
14. Singh, A., Bhullar, M. S., & Chauhan, B. S. (2017). Performance of sequential application of herbicides on weed flora in direct-seeded rice. *Indian Journal of Weed Science*, 49(1), 23–29.

15. Singh, A. K., Choudhury, B. U., & Bouman, B. A. M. (2018). Effects of rice establishment methods on crop performance, water use efficiency and economics. In Proceedings of the International Rice Research Conference. International Rice Research Institute.
16. Sinha, S. K. (2017). Biodiversity of weeds under direct dry-seeded rice systems in Koria District, Chhattisgarh. *Indian Journal of Weed Science*, 49(2), 114–119.
17. Simpson, E. H. (1949). Measurement of diversity. *Nature*, 163, 688. <https://doi.org/10.1038/163688a0>
18. Sunil, C. M., Shekara, B. G., Kalyana Murthy, K. N., & Shankaralingappa, B. C. (2018). Integrated weed management in aerobic rice for sustainable crop production. *Indian Journal of Weed Science*, 50(1), 1–7.
19. Wufai, S., Bahaar, N., & Bhat, G. A. (2012). Taxocoenosis and distribution of weed flora in the rice field monocultures of Kashmir Valley (J&K), India. *International Journal of Botany*, 8(2), 73–78. <https://doi.org/10.3923/ijb.2012.73.78>
20. Rao, A. N., Johnson, D. E., Sivaprasad, B., Ladha, J. K., & Mortimer, A. M. (2007). Weed management in direct-seeded rice. *Advances in Agronomy*, 93, 153–255. [https://doi.org/10.1016/S0065-2113\(06\)93004-1](https://doi.org/10.1016/S0065-2113(06)93004-1)
21. Oerke, E. C. (2006). Crop losses to pests. *Journal of Agricultural Science*, 144(1), 31–43. <https://doi.org/10.1017/S0021859605005708>
22. Chauhan, B. S. (2013). Weed ecology and weed management strategies for dry-seeded rice in Asia. *Weed Technology*, 26(1), 1–13. <https://doi.org/10.1614/WT-D-11-00105.1>
23. Mishra, J. S., & Singh, V. P. (2009). Tillage and weed control effects on productivity of a dry seeded rice-wheat system on a Vertisol in central India. *Soil and Tillage Research*, 103(1), 8–16. <https://doi.org/10.1016/j.still.2008.10.006>