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ORIGINAL ARTICLE

Floristic Compositions and Diversity of Weed Taxa in Lentil (*Lens culinnaris* Medik.) Fields

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ABSTRACT
Floristic composition and diversity of different weed taxa was studied in monocropping and four different mixed cropping of lentil during flowering stage of the crop. Altogether, 42 taxa distributed in 39 genera under 15 different families were identified. With 11 taxa, Asteraceae dominated over other 14 families. Mean Importance Value Index (%) calculated on relative frequency, density and dominance was the highest (25.46) in monocropping, followed by lentil-chickpea (19.63), lentil-grasspea (18.42), lentil-mustard (13.18) and lentil-coriander (8.78) cropping. Eleven taxa including Ageratum conyzoides, Chromolaena odorata, Parthenium hysterophorus, Lantana camara, Amaranthus spinosus and Amaranthus viridis exhibited very high IVI % in both mono- and mixed cropping systems, while 22 species acquired high IVI% either in monocropping or in mixed cropping. Nine taxa manifested low to moderate IVI levels. The diversity indices such as Shannon's index, species richness and dominance were significantly higher in monocropping as well as in lentil-grasspea/chickpea cropping than lentil-mustard/coriander. Results indicated that lentil fields are highly rich in weed taxa in both mono-and mixed cropping. Among four mixed cropping, lentil-chickpea and lentil-grasspea cropping systems exhibited highest diversity and species richness, and dominance of certain aggressive weeds like Parthenium, Ageratum and Lantana.
Keywords: *Lentil; Importance Value Index; Weed composition; Diversity indices*

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INTRODUCTION

Lentil (*Lens culinaris* Medik.) is one of the oldest known protein-rich cool-season food legumes and is highly rich in seed protein, important amino acids, vitamins, minerals and fibers [1]. More than 85% of the annual global production occurs in four specific regions in which eastern half of the Indo-Gangetic plain of South Asia including India, Bangladesh and Nepal occupies the major (32%) share [2]. In this region, lentil is consumed extensively as thick boiled soup ('dhal') made from whole grain or split pulse [3, 4]. Lentil is now incorporated in many traditional recipes and gorgeous cuisines as a substitute of meats due to its high nutritional quality, antioxidant potential, and easy cooking procedures [5, 6].

In India, lentil is predominantly grown as winter pulse crop in Northern and Eastern Indo-Gangetic plain as a sole crop or in mixed cropping pattern [7]. Due to the declining/unstable trend of its production with steadily increasing consumption, lentil has been incorporated as one of the target legume crops in both notational and international coordinated research to ensure pulse food security in developing countries [4, 8]. Besides its sensitivity to diverse types of biotic and abiotic stresses and nutritional deficiency [5, 9, 10, 11], its slow growth in early stages of growth make the crop poorly competitive to weeds [5, 12, 13]. In West Bengal, India, lentil is generally grown after the harvest of *kharif* crops, mixed with grass pea, chickpea, and mustard or as the sole crop of the year. The period from 30 to 60 days (flowering) after sowing was reported most critical for competition with weeds [7]. Integrated weed management in fields of edible crop is extremely important to understand effect of different weed taxa on soil nutrient availability, drought and water –stress conditions, phytotoxicity, sunlight, and other phenological changes [14, 15], for which detail knowledge on distribution and diversity of weed taxa during growth of a particular crop is necessary [16]. Lentil often faces intermediate and terminal drought [4], and its early growth during humid winter in Gangetic plain coincides dense weeds, including some worst invasive taxa [17].

Accumulating evidences also indicate that high weed diversity in crop growing areas may be related to increasing drought and heavy metal contamination and greater fitness of alien weeds than the cultivated crops in these adverse agro-climatic conditions [18-20]. Despite immense threat of the weeds on crop yield and its inclusion in national guidelines of 'rabi crop' in India, no scientific study was carried out to document and analysis of weed diversity in major pulse like lentil growing areas of India.

MATERIALS AND METHODS

Study areas and methodology

The West Bengal province (21°45'–27°16' N and 85°55'–89°56' E) covers a geographical area of 88,752 km^2 in India. Among the 18 districts of the state, lentil cultivation is concentrated in Gangetic south Bengal, and Nadia district in this region occupies a major share, where the present study was carried out (Fig 1). This district is densely populated, but highly rich in floral diversity [20]. The climate is typical summer monsoon, followed by humid winter, and soil texture is clay-loamy with pH 7.2.

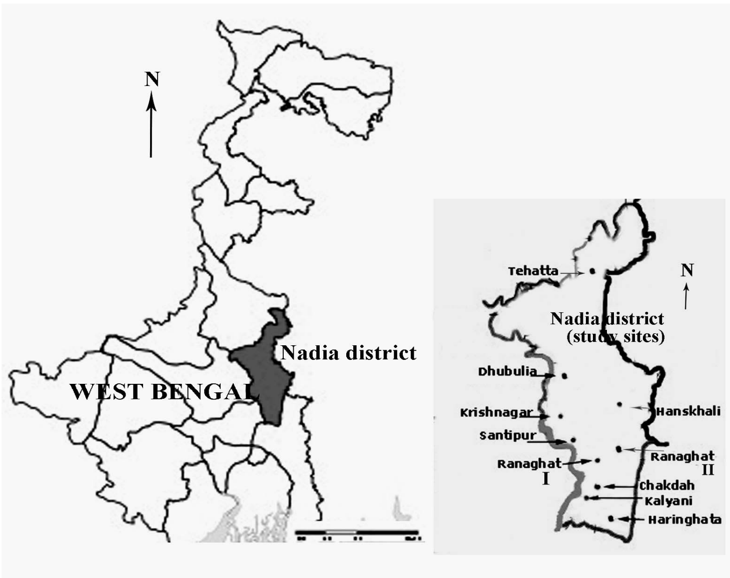

Figure 1. Selected study sites in Nadia district of West Bengal, India.

Ten blocks [Haringhata (88.34 ºE/22.57 ºN), Kalyani (88.26 ºE/22.58 ºN), Chakdaha (88.31 ºE/23.05 ºN), Ranaghat I (88.35 ºE/23.11 ºN) and II (88.33 ºE/23.14 ºN), Shantipur (88.28 ºE/23.15 ºN), Krishnagar (88.30 ºE/23.24 ºN), Hanskhali (88.60 ºE/23.36 ºN), Dhubulia (88.27 ºE/ 23.29 ºN), Tehatta (88.53 ºE/23.72 ºN)] of Nadia district, West Bengal (Figure 1) and five villages of each block with a total of 50 sites were selected to study weed taxa of lentil fields (2010-2012) during flowering stage of the crop. At each site, a total of eight unweeded plots were selected and divided into two groups; lentil as monocrop in first group (four plots) and lentil in mixed crop (with mustard, grass pea, chickpea, coriander, designated as mixed crop plot 1, plot 2, plot 3 and plot 4, respectively, one plot each). Quadrat size and number were determined by species area curve method [21]. Quadrats of 1 m x 1 m were found appropriate. At the flowering stage of the crop (January), 5 square quadrats were laid down randomly at each plot. Individuals of each weed species were counted from each quadrat. Authenticity of plant specimen was identified by available literature, botanical monographs, web-based index such as International Plant Names Index [22], and through Central National Herbarium of Botanical Survey of India, Kolkata, India. Vaucher specimens of weed taxa were deposited in departmental herbarium of R.P.M. College, Uttarpara, West Bengal for future reference.

Diversity indices and statistical analysis

Frequency (%), dominance and density were carried out following earlier method [23], their relative values were calculated and used to calculate importance value index (IVI %) for each taxa [21, 24]. Shannon–Weaver index was calculated using the formula $H' = -\sum pi \log_2 pi$, where pi is the relative abundance of the species (pi = ni/N; ni is the number of individual species, *N* is the total number of individuals). Species dominance index $C = \sum(pi)^2$, Species richness index ($d = S-1/ \log N$; where S is the number of species) and evenness index E = H' / log_2S were also calculated. Data for each taxa were pooled when homogeneous to calculate diversity indices. Multiple comparisons of means were carried out by ANOVA using SPSS v. 10 software (SPS Inc.,USA) and separated by Duncan's Multiple Range Test with significance level at $P < 0.05$.

RESULTS AND DISCUSSION

Taxonomic diversity and ecological indices

Table 1. Importance value index (%)* of weed taxa in lentil (flowering stage) growing areas of West Bengal, India under lentil monocrop and four predominant mixed crop conditions.

Sl.	Botanical names	IVI (mc1)	IVI (mc2)	IVI (mc3)	IVI (mc4)	IVI (lentil monocrop)
1	*Achyranthes aspera* L.	0.56^b	0.67^b	0.89^a	0.34^c	0.54^b
2	*Ageratum conyzoides* L. Com	3.45^d	45.65^a	34.12^b	28.12^c	38.78^b
3	*Alternanthera sessilis* (L.) R.Br.ex DC Ama	49.78^a	4.67^b	4.56^b	4.39^b	5.43^b
4	*Amaranthus spinosus* L.	4.78^c	64.78^a	59.45^a	3.98^c	71.65^a
5	*Amaranthus viridis* L.	3.13^d	29.78^c	60.89^b	4.67^d	79.67^a
6	*Ampelopteris prolifera* (Retz.) Copel	4.11^b	0.56^c	0.67^c	0.19^d	58.76^a
7	*Anagallis arvense* L.	1.45^b	0.89^c	0.83^c	0.33^d	56.33^a
8	*Boerhaavia diffusa* L.	24.56^a	0.07^c	0.12^c	0.13^c	14.87^b
9	*Cassia tora L*	33.78^a	19.56^b	23.67^b	2.67^c	35.67^a
10	*Chenopodium album L*	49.67^a	1.08^c	0.67^d	0.78^d	9.32^b
11	*Chromolaena odorata* (L.) King and Robinson	4.67^b	76.67^a	79.32^a	4.32^b	3.20^c
12	*Cirsium arvense* (L.) Scop.	0.78^b	0.23^b	0.29^b	0.19^c	32.03^a
13	*Coix lacryma-jobi L*	1.12^a	0.45^b	0.51^b	0.10^c	1.55^a
14	*Commelina bengalensis L*	4.34^a	0.67^b	0.71^b	0.09^c	3.88^a
15	*Convolvulus arvensis* L.	2.67^a	1.56^b	1.62^b	0.41^c	2.13^a
16	*Crotalaria pallida L.*	39.87^a	41.56^a	40.77^a	38.19^a	1.26^b
17	*Croton bonplandianum* L	3.87^a	0.89^c	0.88^c	1.56b	3.81^a
18	*Cynodon dactylon* (L.) Pers.	31.56^b	45.67^a	39.87^a	2.19^c	27.90^b
19	*Dactyloctenium aegyptium* (L.) Beauv.	57.87^a	39.78^b	39.34^b	0.69^c	64.88^a
20	*Desmodium gangeticum* DC.	2.56^a	0.67^b	0.18^c	0.27^c	2.35^a
21	*Eclipta alba* (L.) Hassk	0.34^b	0.10^c	0.15^c	0.06^c	3.48^a
22	*Eleusine indica* L.	23.45^c	33.67^b	45.78^a	2.28^d	20.03^c
23	*Euphorbia heterophylla* L.	2.45^c	3.98^b	4.14^b	4.35^b	33.54^a
24	*Euphorbia hirta* L.	1.91^a	2.08^a	2.45^a	1.56^a	2.05^a
25	*Evolvulus nummularius* (L.) L	0.55^c	0.78^c	1.23^b	1.56^b	21.43^a
26	*Fumaria indica* L	0.78^b	0.67^b	0.63^b	0.08^c	5.12^a
27	*Gnaphalium luteo-album* L.	18.98^a	21.67^a	20.21^a	19.09^a	2.86^b
28	*Lantana camara* L.	8.78^c	76.67^a	81.56^a	69.56^b	61.66^b
29	*Lathyrus aphaca* L.	34.67^b	65.56^a	63.09^a	30.15^b	1.76^c
30	*Melilotus alba* L.	4.89^c	38.67^a	40.76^a	2.54^d	26.42^b
31	*Mimosa pudica* L	0.78^c	1.56^b	1.61^b	0.81^c	11.55^a
32	*Nicotiana plumbaginifolia* L.	1.67^c	2.78^b	2.85^b	1.73^c	36.67^a
33	*Oxalis corniculata* (DC.) Raeusch	0.09^c	0.89^b	1.03^b	0.13^c	19.06^a
34	*Parthenium hysterophorus* L.	39.67^c	98.67^a	112.56^a	78.56^b	90.82^a
35	*Phalaris minor* Retz.	1.12^b	0.98^b	1.23^b	0.32^c	23.89^a
36	*Pluchea lanceolata* Peter	1.34^b	0.33^b	0.39^b	0.41^b	19.78^a
37	*Spilanthes paniculata* Wall. Ex DC.	67.56^a	1.11^b	0.98^b	0.12^c	0.09^c
38	*Synedrella nodiflora* Gaertn	5.67^b	6.15^b	7.07^b	1.56^c	29.67^a
39	*Tridax procumbens* L.	39.87^a	0.66^b	0.89^c	48.67^a	0.65^b
40	*Vernonia cinerea* (L.) Less	2.12^c	18.78^a	22.55^a	1.08^c	3.86^b
41	*Vicia hirsuta* L.	23.67^a	1.45^b	1.67^b	0.89^c	1.55^b
42	*Vicia sativa* L	43.45^a	3.56^b	4.18^b	0.95^c	1.84^c
	Mean IVI %	13.18^c	18.42^b	19.63^b	8.78^d	25.46^a

* mc1-mixed crop of lentil with mustard, mc2-with grass pea, mc3-with chickpea, and mc4-with coriander, data pooled of 1000 randomly laid square quadrats (50 sites × 4 plots/site × 5 quadrats/plot) for monocrop and of 250 quadrats (50 sites × 1 plot/site × 5 quadrats/plot) for each of the four mixed crop conditions. Values followed by different superscript lower case letters denote significant differences at $P < 0.05$ by Duncan's Multiple Range Test.

A total of 42 weed species belonging to 15 families and 39 genera were recorded in a total of 400 plots with 2000 randomly laid square quadrats during flowering stage of lentil. Asteraceae was the dominant family (11 spp.), followed by Fabaceae (8 spp.), Poaceae (5 spp.), Amaranthaceae (4 spp.), Euphorbiaceae (3 spp.), Convolvulaceae (2 spp.), and Verbenaceae, Solanaceae, Chenopodiaceae, Nyctaginaceae, Oxalidaceae, Fumariaceae, Commelinaceae, Primulaceae with one each. One fern, *Ampelopteris prolifera* belonging to Thelypteridaceae was also documented with angiospermic composition. Among the 42 species, *Lantana camara* L. was the shrub while *Crotalaria pallida* L. and *Coix lacryma-jobi* L. represented under-shrubs. Rest of the species was herbaceous. Among the taxa, *Ageratum conyzoides* L., *Chromolaena odorata* (L.) King and Robinson, *Cirsium arvense* (L.) Scop., and *Parthenium hysterophorus* L. in Asteraceae, *L. camara* L. in Verbenaceae, *Boerhaavia diffusa* L. in Nyctaginaceae, *Cynodon dactylon* (L.) Pers, *Dactyloctenium aegyptium* (L.) Beauv. *Eleusine indica* L. in Poaceae, *Melilotus alba* L. and *Lathyrus aphaca* L. in Fabaceae, *Anagallis arvense* L. in Primulaceae was identified with other taxa in both monocrop and mixed crop fields. Frequency, density and dominance and their relative values were calculated (data not presented) and used to calculate IVI % of each of the 42 taxa and mean IVI % (Table 1).

The IVI % thus obtained varied significantly between monocrop and mixed cropping conditions, and also, within four mixed cropping conditions (Table 1). Mean IVI % strongly indicated that both monocropping and mixed cropping of lentil are equally prone to weed infestations, but monocropping invited more weed flora and the mc4 condition was comparatively safer than the others (Table 1). It was also indicative that mean IVI % of mc2 varied non-significantly ($P > 0.05$) with mc3, although both varied significantly ($P < 0.05$) with mc1, mc4 as well as with monocropping (Table 1). This suggested rather homogeneous ecological indices of weed diversity in legume-legume mixed cropping than legume-othercrop and monocropping. High IVI value of *A. conyzoides*, *C. odorata*, *P. hysterophorus*, *C. tora*, *A spinosus*, *A. viridis*, *C. dactylon*, *D. aegypticum*, *E. indica*, and *L. aphaca* in both mixed and monocropping systems was mainly due to their high relative frequency and/or relative density. By contrast, high IVI of *L. camara* was mainly due to high relative dominance value (data not shown). Among the rest 31 species, 12 taxa showed high IVI value solely in monocropping, while 11 species acquired high IVI only in mixed cropping (Table 1). The phytosociological composition of these 11 taxa revealed a peculiar scenario; four species namely *Alternanthera sessilis*, *Spilanthes paniculata*, *Vicia sativa* and *V. hirsuta* showed high IVI value only in mc1 (lentil-mustard), three species *Chromolaena odorata*, *Melilotus alba* and *Vernonia cinerea* in both mc2 (lentil-grasspea) and mc3 (lentil-chickpea), one species (*Tridax procumbens*) in both mc1 and mc4 (lentil-coriander), three species *Crotalaria pallida*, *Lathyrus aphaca* and *Gnaphalium luteo-album* manifested high IVI % in all the four mixed cropping systems (Table 1). However, high number of individuals was not the sole reason for rise in IVI value as high basal area coverage by a particular taxa even in low frequency may lead to high IVI value, as explained in an earlier report on suppressive action of *Cassia occidentalis* on *Parthenium hysterophorus* [25]. In the present study, high IVI value in some weed taxa, especially *L. camara*, *A. conyzoides*, *C. odorata*, and *P. hysterophorus* is alarming because of their strong allelopathic effect, which often led to inhibition of growth and yield of target crops as well as loss of taxonomic diversity and floral compositions in the invaded areas [17, 26, 27], and suggested aggressiveness of these weed taxa in lentil field. To the contrary, detection of *Cassia tora* and two spp. of *Amaranthus* with high IVI value in the present study is also worth mentioning, as these taxa reportedly have the capacity to counter the invasions of weeds like *Parthenium* through high degree of sociability at first and then gradually replacement of the daisy [28, 29]. The dominance of Asteraceae over other families has been attributed to their efficient seed dispersal mechanisms, and high seed germination along with potent allelopathic effect on neighboring community [28]. Dominance of leguminous weeds such as *L. aphaca*, *M. alba*, spp. of *Vicia* and *Cassia* in the present study might be due to their high rate of seed germination, hardiness in adverse situations, alleopathic potential and/or highly efficient antioxidant defense systems, as explained earlier under diverse experimental conditions [10, 18, 25]. The low IVI values in eight taxa could be due to the sharing of resource spaces to minimize interactions among the species and to facilitate access to resources [27].

Species diversity, dominance and equitability

Significantly higher Shannon–Weaver index and species richness was observed in monocropping and in mc2 and mc3 compared with mc1 and mc4 (Table 2), suggesting high degree of weed diversity both in lentil-monocropping and legume-legume mixed cropping. This richness may be attributed to capacity of N_2-fixation by legume plants, resulting in enrichment of soil nutrients which is being utilized by weed flora. As competitive fitness of weed flora is far greater due to hardiness, better adaptability and allelopathic potentials than crop plants [15, 17, 27, 30], the monocropping and grasspea-lentil (mc2) and chickpea-lentil (mc3) may not be suitable for growth and yield of lentils, but can be effective if extensive weeding can be done during flowering stage of the crop. By contrast, mc1 (lentil-mustard) and mc4 (lentil-coriander) showed low weed diversity, and can be better managed. The dominance of some invasive taxa like *Ageratum, Chromolaena*, *Lantana*, *Parthenium* and *Vernonia* along with spp. of *Amaranthus* in mc2 and mc3 conditions might be responsible for significantly higher dominant index in these two cropping systems than the others. High monoculture of particular taxa may often lead to reduction in species diversity and concomitant increase in evenness of population [27]. In this condition, high IVI value of these taxa may enhance the overall IVI value of particular condition/s, as observed in the present mc2, mc3 and monocropping, but does not necessarily reflect the high species diversity and may be inversely proportional to diversity indices, as observed earlier in *Parthenium* infested areas [25, 31]. In the present case, diversity indices were significantly increased in both mc2 and mc3 despite very high IVI value of the invasive weeds in these two cropping systems. Furthermore, there was no significant increase in species evenness in mc2 and mc3 as compared with mc1, mc4 and monocropping (Table 2).

Unlike different peas, where number of desirable genetic and cytogenetic mutations/genotypes with greater adaptability and better breeding perspectives has been isolated [32-35], no ideotype breeding has been undertaken in lentil although lentil is a close relative of peas [36]. Phytotoxicity of some weeds identified in the present study is a paramount problem in lentil breeding and yield due to their invasiveness [37]. The present study revealed differential floristic composition in monocropping and four mixed cropping patterns of lentil growing areas. Altogether, 42 weed taxa were documented, and Asteraceae dominated over other families. Higher weed diversity was observed in monocropping, mc2 and mc3 conditions than mc1 and mc4. High weed diversity based on Shannon's index and species richness was observed in all the five cropping systems, but the infestation was the severest in mc2 and mc3 fields. Based on the present result, it is concluded that lentil-fields are highly rich in weed flora and floral compositions. Lentil-mustard and lentil-coriander are better suitable for crop growth than lentil-grasspea/chickpea conditions in terms of composition and distribution of weed taxa.

Table 2. Diversity indices of weed flora in monocropping and four different mixed cropping (mc1, mc2, mc3 and mc4) of lentil.

Indices	mc1*	mc2*	mc3*	mc4*	monocropping
Shannon's index (H')	3.48^{b}	4.89^{a}	5.05^{a}	3.12^{b}	5.19^{a}
Species dominance (C)	0.67^{c}	0.98^{a}	0.93^{a}	0.55^{d}	0.81^{b}
Species richness (D)	4.61^{b}	5.94^{a}	6.08^{a}	4.78^{b}	5.85^{a}
Equitability (E)	0.61^{a}	0.74^{a}	0.79^{a}	0.73^{a}	0.68^{a}

* mc1-mixed crop of lentil with mustard, mc2-with grass pea, mc3-with chickpea, and mc4-with coriander, data calculated from primary data obtained from 1000 randomly laid square quadrats (50 sites × 4 plots/site × 5 quadrats/plot) for monocrop and of 250 quadrats (50 sites × 1 plot/site × 5 quadrats/plot) for each of the four mixed crop conditions. Values followed by different superscript lower case letters denote significant differences at $P < 0.05$ by Duncan's Multiple Range Test.

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