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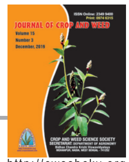

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Cropping and production systems influence on phyto-sociology and weed flora diversity

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ABSTRACT

Three cropping systems viz. maize – wheat, maize + cowpea – wheat + gram and okra + pole bean – cabbage + garden pea were evaluated under four production practices viz. integrated nutrient management (INM), organic management (OA), natural farming (NF), and conservation agriculture (CA) for appraisal on weeds floristic diversity at Palampur. Weed flora was composed of 17 species during kharif 2019, 14 during rabi 2019-20 and 15 each during kharif 2020 and rabi 2020-21. Commelina benghalensis L. (13%) was the most dominant weed during kharif 2019 followed by Persicaria hydropiper (10%), Cyperus sp (9%), Artemisia vulgaris (9%), Echinochloa colona (8%), Alternanthera philoxeroides (8%), Polygonum alatum (7%) and Galinsoga parviflora (5%). Ageratum conyzoides L. (27%) was the most dominant weed during kharif 2020 followed by Cyperus sp (19%), P. alatum (15%), C. benghalensis (8%), E. colona (7%), A. philoxeroides (4%), A. vulgaris (4%), Bidens pilosa (4%) and Trifolium repens (4%). The major weeds during rabi 2019-20 were Tulipa asiatica (18%), Stellaria media (8%), Ranunculus arvensis (8%), Poa annua (8%), Phalaris minor (7%), Coronopus didymus (7%), Anagallis arvensis (7%), Fumaria parviflora (7%), Lolium temulentum (6%) and Vicia hirsuta (6%). While, S. media (17%), P. annua (11%), Vicia sativa (10%), C. didymus (10%), T. asiatica (9%), Plantago lanceolata (7%), L. temulentum (7%), P. minor (6%) and Avena ludoviciana (6%) were the major weeds during rabi 2020-21. Irrespective of production and cropping systems, C. benghalensis was the most important weed during kharif 2019 with IVI ranging from 26.4 to 36.8 under production systems and 22.8 to 45.2 under cropping systems. This was followed by P. hydropiper, A. vulgaris and E. colona. During kharif 2020, A. conyzoides was the most important weed with IVI value of 40.9-69.8 in production systems and 60.7-69.2 in cropping systems. This was followed by Cyperus sp. and P. alatum. T. asiatica was the most important weed during the rabi 2019-20 season with IVI value ranging from 33.8 to 57.3 under production systems and 40.8 to 42.6 under cropping systems. This was followed by P. annua, R. arvensis and S. media. During rabi 2020-21. S. media was the most important weed with IVI value of 34.5-44.3 in production systems and 38.9-44.6 in cropping systems. This was followed by P. annua and V. sativa. Simpson's index of diversity and Simpson's reciprocal index indicated higher weed diversity under INM and OA treatments followed by NF (P_1) treatment during kharif 2019, while, the lower diversity as per these indices was under CA (P_4). During kharif 2020, Simpson's index of diversity and Simpson's reciprocal index were highest for the CA closely followed by INM among production systems.

Keywords: Weed floristic diversity, Phyto-sociology, Cropping systems, Production practices

Weeds compete with crop plants during entire vegetative and early reproductive stages for nutrients, water, sunlight and space, being harder they transpire a lot of valuable conserved moisture and absorb large amounts of nutrients from the soil. Thus the yield of crops become reduced because of their higher relative density. Also, slow initial growth and wider spacing encourage the growth of weeds especially in the case of maize. Not only weeds reduce sink capacity of the crop resulting in poor yield but also they reduce the photosynthetic efficiency, dry matter production and distribution to economical parts. In agro ecosystems, ideal environmental conditions provided for optimal crop productivity are being exploited by the associated weeds. Weeds not only trim down the market value of crop but also decrease the crop yield and deteriorate the quality of farm produce (Hussain *et al*., 2012). Controlling weeds fairly increases the cost of cultivation of the crop as well as evacuate resource base (Buriro *et al*., 2003). Rotation composed of a diversity of crops with different life cycles is a critical ingredient of integrated weed management (Garrison *et al*., 2014). Crop diversification is a forcible strategy to get food and nutrition security, income growth, poverty pacification, employment generation, judicious use of nutrients and water, sustainable agricultural development and environmental improvement (Rana and Rana, 2013). Only limited information on comparative evaluation of weed and soil seed bank diversity in different crops and cropping systems is available in the Indian region. There is a scarcity of information on weed shift in organic maize-based farming systems. The effect of various weed control techniques on weeds and yield of garden pea and maize under organic farming conditions was investigated (Srivastava and Singh, 2005).

The weeds are dynamic in nature and the crop(s), cropping systems, production systems and management practices mainly influence their distribution, density, abundance and shifts. Studying the weed dynamics is

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helpful to understand the dominance or absence of a particular species in a crop/cropping and production system and devise means to reduce their population through crop rotations or other agronomic practices. Thus an appraisal of weed floristic diversity was made in an ongoing experiment on newer cropping systems under varying production practices.

MATERIALS AND METHODS

Experimental site

The field experiment was carried out in an on-going experiment at the research farm of Department of Agronomy, CSK HP Krishi Vishwavidyalaya, Palampur (H.P.) during *rabi* (2019-20 and 2020-21) and *kharif* (2019 and 2020). The soil of the test site was silty clay loam in texture, moderately acidic in reaction, low in organic carbon, high in available P, medium in available K, and low in available N.

Experimental design, treatments and field techniques

The study was conducted in a split plot design with three replications. Three different cropping systems *viz*. maize – wheat, maize + cowpea – wheat + gram and okra + pole bean – cabbage + garden pea were evaluated under four production practices viz. integrated nutrient management (INM), organic farming (OA), natural farming (NF), and conservation agriculture (CA) for appraisal on weed phyto-sociology and weeds floristic diversity. The experimental field was prepared with the help of power tiller and harrow. After the layout, the experimental plots were levelled manually. The plots were ploughed individually after each season to avoid disrupting the plot bunds. Weed management measures were carried out as per the package of practices of individual crop. Herbicides such as clodinafop + metsulfuron methyl and tembotrione were used in pure wheat and maize crops, respectively under conservation and integrated crop management practices. Hoeing was done with the help of a brush weeder. Weeding was also done by hand. In the instance of crop rotation, the notion of rotating crops with distinct life cycles was adopted, which interrupted the development of weed crop associations by inhibiting weed establishment and thus weed seed generation through varied planting and harvest dates (Das *et al*., 2012), mainly by smothering and allelopathic effect (Dwivedi *et al*., 2012).

Recording of observations

Data on weeds were recorded at 30 days interval in each plot in two quadrats, each measuring 50 x 50 cm. Weeds were counted species-wise.

Phyto-sociology of weeds

a. Relative frequency

The degree of dispersion of individual species in an area in relation to the number of all the species occurred is termed as relative frequency (Odum, 1971). It was calculated as below :

$$\text{Relative frequency} = \frac{\text{Total number of occurrence of the species}}{\text{Number of occurrence of all the specis}} \times 100$$

b. Importance Value Index

The 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 (Mueller-Dombois and Ellenberget, 1974).

Weed diversity

A. Species richness (D)

Species richness was calculated as follow:

$$D = \frac{S}{\sqrt{N}}$$

Where S is equal the numbers of different species and N total number of individual organisms in a sample.

B. Species diversity

As a measure of species diversity, Shannon index (H) was calculated. It is also called Shannon Weiner index or Shannon Weir index. The proportion of species *i* relative to the total number of species (p_i) was calculated, and then multiplied by the natural logarithm of this proportion ($\ln p_i$). The resulting product was summed across species, and multiplied by -1:

$$H = -\sum_{i=0}^{n} P_i \ 1nP_i$$

C. Similarity index

In the present study, Soverson's coefficient (SC) was used for calculating community similarities as follows (Jaccard, 1908) :

$$SC = \frac{2c}{S_1 + S_2}$$

Where C is the number of species the two communities have in common, $S_1$and S_2 are the total number of species found in community 1 and 2, respectively. This coefficient gives a value between 0 to 1; the closer the value is to 1; the more the communities have in common.

D. Shannon Index

It was calculated as follow :

$$H=\frac{\sum(p_i)}{\text{Ln } P_i}$$

Where (pi) is the proportion of the total number of individuals in the population that are in species '1' (Shannon and Weaver, 1963).

E. Simpson's index

It was calculated as follow :

$$D=\frac{\sum_{i=1}^{s} n(n\text{-}1)}{N(N\text{-}1)}$$

Where n is total number of organism of a particular species and N is total number of organisms of all species, s is the number of species with this index, 0 represents infinite diversity and 1, no diversity (Simpson, 1949).

$$\text{Simpson's index of diversity} = 1-D = 1-\sum_{i=1}^{s} P_i^2$$

$$\text{Simpson's reciprocal index} = 1/D = 1/\sum_{i=1}^{s} P_i^2$$

F. Evenness/ Shannon's equitability (EH)

It is calculated by dividing H by H_{max} (here H_{max}= LnS). Equitability assumes values between 0 and 1 with 1 being complete evenness, i.e. EH = H/H_{max} = H/LnS (Pielou, 1969).

Statistical analysis

The data obtained were subjected to statistical treatment by analysis of variance (ANOVA) using split plot design to test the significance of the overall differences among the treatments by the "F" test and conclusion was drawn at 5% probability level as described by Gomez and Gomez (1984). Standard error of mean was calculated in each case. When the 'F' value from analysis of variance tables was found to be significant, the Least Significant Difference (LSD) was computed to test the significance of the difference between the two treatments. Weed count and dry weight data were analysed after subjecting them to square root transformation $\left[\sqrt{x+0.5}\right]$.

RESULTS AND DISCUSSION

Distribution of weed species

The experimental field was kept under meticulous care and observations during the different crop growth phases by daily farm visits. The prevalent weeds were recorded at monthly interval during *kharif* and *rabi* seasons. The weed flora was diverse with 17 and 15 species occurring in the *kharif* season of 2019 and 2020, respectively. The major flora of *kharif* seasons have been depicted in Fig. 1a and b. *C. benghalensis* L. (13%) was the most dominant weed during *kharif* 2019 which was followed by *P. hydropiper* (10%), *Cyperus sp* (9%), *A. vulgaris* (9%), *E. colona* (8%), *A. philoxeroides* (8%), *P. alatum* (7%) and *Galinsoga parviflora* (5%). The other weeds *Coronopus didymus, Digitaria sanguinalis, Chenopodium murale, Phyllanthus niruri, A. conyzoides* and *Bidens pilosa,* as a whole constituted 24% of the total weed flora. During *kharif* 2020, *A. conyzoides* (27%) was the most dominant weed followed by *Cyperus* sp. (*C. iria, C. esculentus, C. difformis*) (19%), *P. alatum* (15%), *C. benghalensis* (8%), *E. colona* (7%), *A. philoxeroides* (4%), *A. vulgaris* (4%), *B. pilosa* (4%) and *Trifolium repens* (4%). The other weeds were *D. sanguinalis, Aeschynomene indica, G. parviflora* and *C. didymus,* as a whole constituted 8% of the total weed flora. These results are in conformity with earlier findings of Chopra and Angiras (2008). They recorded similar weed flora at Palampur.

The important weed species associated during *rabi* seasons are shown in Fig. 2a and 2b. In all 14 weed species were noticed during *rabi* 2019-20 and 15 during *rabi* 2020-21. *T. asiatica* (18%), *S. media* (8%), *R. arvensis* (8%), *P. annua* (8%), *P. minor* (7%), *C. didymus* (7%), *A. arvensis* (7%), *F. parviflora* (7%), *L. temulentum* (6%) and *V. hirsuta* (6%) were the major weeds. The other weeds *viz. B. pilosa, V. sativa, P. lanceolata* and *T. repens* as a whole constituted 18% of the total weed flora. While, *S. media* (17%), *P. annua* (11%), *V. sativa* (10%), *C. didymus* (10%), *T. asiatica* (9%), *P. lanceolata* (7%), *L. temulentum* (7%), *P. minor* (6%) and *A. ludoviciana* (6%) were the major weeds during *rabi* 2020-21. The other weeds *viz*. *B. pilosa, E. heliscopia, F. parviflora, R. arvensis* and *T. repens* as a whole constituted 11% of the total weed flora.

Phyto-sociology of weeds

Phyto-sociological surveys are carried out in agro-ecosystems to investigate the links between weed plant populations and various crops and cropping systems. Control and coexistence periods between crops and weeds can be determined using phyto-sociological investigations. Thus, these are useful in determining which species are most significant during the various stages of crop growth. Seasonal observations were used to investigate phyto-sociological features in this study.

Frequency (%)

Frequency is a useful index for monitoring and comparing plant community changes over time (Bonham, 2013). Frequency reflects both a species' presence or absence and how much it is distributed

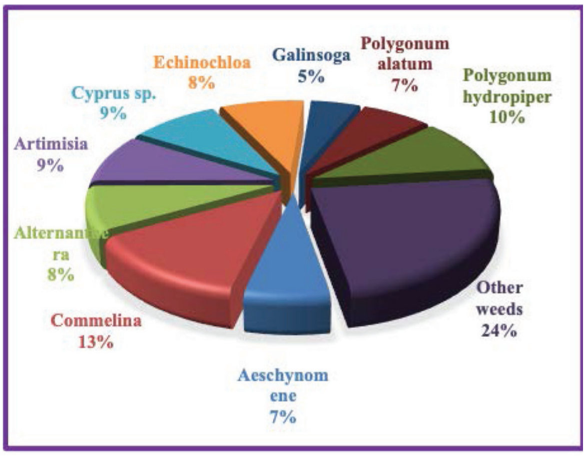

Fig. 1a: Distribution of weed species during *kharif* 2019

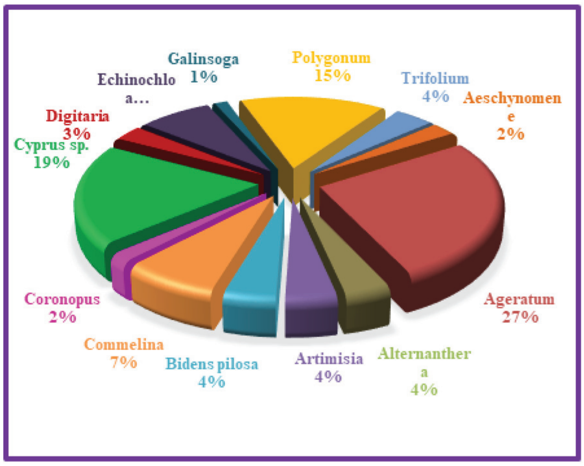

Fig. 1b: Distribution of weed species during *kharif* 2020

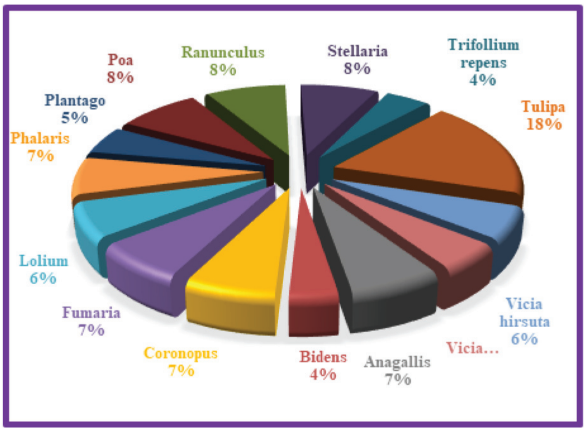

Fig. 2a: Distribution of weed species during *rabi* (2019-20)

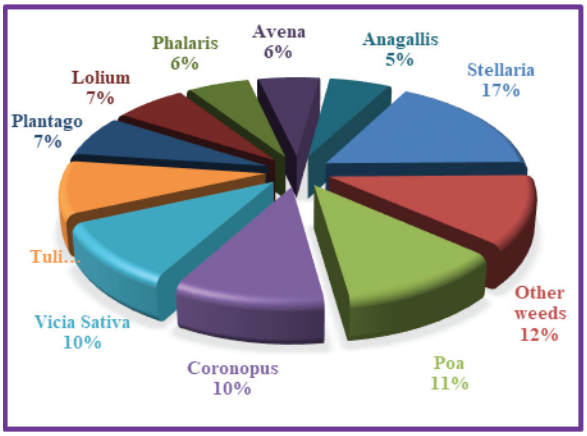

Fig. 2b: *Distribution of weed species during rabi (2020-21)*

within a community. From Table 1, it is evident that *P. hydropiper*, *Cyperus* sp and *E. colona* had the highest frequency amongst all weeds present during *kharif* 2019. *P. hydropiper* was the most frequently occurring weed in all the treatments except OA (P_2) among production systems and maize – wheat (C_1) and maize + cowpea – wheat + gram (C_2) under cropping systems where *Cyperus sp.* was most frequently occurring. Maize + cowpea – wheat + gram (C_2) had the highest frequency of *Cyperus* sp. amongst all weeds in cropping systems. *E. colona* was the most frequently occurring weed in maize + cowpea – wheat + gram (C_2). During *kharif* 2020 *P. alatum*, *Cyperus* sp and *E. colona* had the highest frequency amongst all weeds. *P. alatum* was the most frequently occurring weed in all the treatments except NF (P_3) and CA (P_4) under production systems and okra + pole bean – cabbage + garden pea (C_3) under cropping systems where *Cyperus* sp. was leading. NF (P_3) had the highest frequency of *Cyperus* sp. amongst production systems. *E. colona* was the most frequent weed with relative frequency value of 10.3-12.3 in production systems and 10.4-11.1 in cropping systems (Table 1).

During *rabi* 2019-20, *T. asiatica* with relative frequency value of 7.9 was the most frequent weed amongst all weeds which is followed by *S. media* (7.8), *P. annua*, *R. arvensis* (7.7) and *C. didymus* (7.7). *T. asiatica* was the most frequently occurring weed in CA (P_4) under production systems and maize – wheat (C_1) under cropping systems. *S. media* had the highest frequency with the value of 8.8 in INM treatment in production systems among all weeds which is followed by *T. asiatica* with relative frequency of 8.2. OA (P_2) had the highest frequency of *P. annua* 8.3 and *P. minor* 8.0 amongst all weeds in production systems (Table 2). *L. temulentum* was the most frequent weed with relative frequency value of 8.0 under production systems. *S. media* was the most frequent weed with relative frequency value of 7.3-8.8 in production systems and 7.5-8.2 in cropping systems while *P. annua* was frequent weed with relative frequency value of 7.5-8.3 in production systems and 7.4-8.3 in cropping systems. From Table 2, it is clearly evident that *S. media*, *P. lanceolata* and *C. didymus* had the highest frequency amongst all weeds present during *rabi* 2020-21. *S. media*

Table 1: Effect of production and cropping systems on relative frequency of different weed species during *kharif* 2019 and 2020

Weed species	*Kharif* 2019										*Kharif* 2020									
	P_1	P_2	P_3	P_4	Mean	C_1	C_2	C_3	Mean	Overall	P_1	P_2	P_3	P_4	Mean	C_1	C_2	C_3	Mean	Overall
Aeschynomene indica L.	8.0	7.8	7.0	7.9	7.7	7.4	7.9	7.7	7.7	7.9	9.3	5.4	4.4	7.4	6.6	7.2	6.2	6.5	6.6	6.6
Ageratum conyzoides L.	5.0	5.9	5.9	5.2	5.5	5.6	5.8	5.2	5.5	7.7	9.7	9.8	10.0	8.5	9.5	8.7	10.2	9.5	9.5	9.5
Alternanthera philoxeriodes L.	8.3	9.0	6.6	7.7	7.9	8.1	7.4	8.0	7.8	5.5	7.8	8.5	5.2	7.0	7.1	7.0	6.0	8.2	7.1	7.1
Artemisia vulgaris L.	5.2	5.6	5.5	5.5	5.4	4.7	6.0	5.6	5.5	5.4	6.3	4.9	6.0	5.7	5.7	4.6	6.5	6.1	5.8	5.7
Bidens pilosa L.	4.7	5.8	5.9	6.1	5.6	5.4	6.9	4.7	5.7	5.6	7.2	5.1	7.1	9.1	7.1	6.4	7.0	8.1	7.1	7.1
Chenopodium murale L.	4.7	4.7	6.0	5.0	5.1	2.8	3.8	8.7	5.1	5.1	-	-	-	-	-	-	-	-	-	-
Commelina benghalensis L.	9.2	7.9	8.0	7.9	8.3	9.5	7.9	7.4	8.3	8.3	9.7	8.3	8.3	8.5	8.7	9.5	7.5	9.1	8.7	8.7
Coronopus didymus L.	6.3	5.8	5.6	5.5	5.8	5.5	5.8	6.1	5.8	5.8	4.8	3.6	4.6	3.7	4.2	5.1	4.9	2.6	4.2	4.2
Cyperus sp.	9.7	9.4	9.0	8.7	9.2	9.1	9.8	8.7	9.2	9.2	10.5	12.7	13.1	11.5	12.0	11.3	12.4	12.3	12.0	12.0
Digitaria sanguinalis L.	4.4	5.0	5.9	5.0	5.1	6.9	4.5	3.8	5.1	5.1	5.5	2.9	7.3	8.0	5.9	7.0	5.2	5.7	6.0	6.0
Echinochloa colona (L.) Link	8.8	8.2	8.8	8.8	8.6	8.5	9.1	8.4	8.6	8.6	10.3	12.3	10.4	10.4	10.9	11.1	10.4	11.0	10.8	10.8
Galinsoga parviflora Cav.	5.5	5.9	6.2	6.5	6.0	7.4	6.7	4.1	6.1	6.0	3.2	3.6	4.4	2.6	3.4	4.8	2.4	3.1	3.4	3.4
Phyllanthus niruri L.	2.5	2.4	3.0	3.5	2.9	3.1	2.8	2.8	2.9	2.9	-	-	-	-	-	-	-	-	-	-
Polygonum alatum L.	8.0	7.3	7.3	7.4	7.5	7.0	6.2	9.1	7.5	7.5	11.6	13.0	12.9	11.3	12.2	11.8	12.7	12.1	12.2	12.2
Persicaria hydropiper L.	9.7	9.3	9.3	9.2	9.4	8.9	9.4	9.8	9.4	9.4	-	-	-	-	-	-	-	-	-	-
Trifolium repens L.	-	-	-	-	-	-	-	-	-	-	4.2	10.0	6.3	6.3	6.7	5.6	8.6	5.8	6.7	6.7

P_1- Integrated nutrient management, P_2- Organic farming, P_3- Natural farming, P_4- Conservation agriculture, C_1- Maize – wheat, C_2- Maize + cowpea – wheat + gram, C_3- Okra + pole bean – cabbage + garden pea

Table 2: Effect of production and cropping systems on relative frequency of different weed species during *rabi* 2019-20 and 2020-21

Weed species	*Rabi* 2019-20										*Rabi* 2020-21									
	P_1	P_2	P_3	P_4	Mean	C_1	C_2	C_3	Mean	Overall	P_1	P_2	P_3	P_4	Mean	C_1	C_2	C_3	Mean	Overall
Anagallis arvensis L.	7.8	7.3	7.4	7.7	7.6	7.5	7.5	7.7	7.6	7.6	0.0	8.0	8.7	0.0	4.2	4.6	4.6	3.9	4.4	4.3
*Avena ludoviciana*L.	-	-	-	-	-	-	-	-	-	-	6.0	5.2	4.9	6.6	5.7	8.0	10.3	0.0	6.1	5.7
Bidens pilosa L.	6.0	5.3	5.6	6.4	5.8	6.0	5.1	6.3	5.8	5.8	5.9	6.1	5.0	6.2	5.8	5.2	6.8	5.8	6.0	5.9
Coronopus didymus L.	8.1	7.3	7.8	7.7	7.7	7.5	7.5	8.0	7.7	7.7	10.5	10.3	9.4	9.4	9.9	10.2	9.5	10.7	10.1	10.0
Euphorbia heliscopia L.	-	-	-	-	-	-	-	-	-	-	3.6	4.0	4.0	4.0	3.9	4.7	0.8	6.1	3.9	4.0
Fumaria parviflora L.	7.0	7.4	7.3	7.7	7.4	7.2	6.9	7.9	7.3	7.4	3.2	3.5	2.9	3.2	3.2	0.0	0.0	9.0	3.0	3.2
Lolium temulentum L.	7.1	7.8	8.0	6.7	7.4	7.1	7.5	7.6	7.4	7.4	3.8	4.7	6.9	6.6	5.5	9.6	7.9	0.0	5.8	5.5
Phalaris minor Retz.	7.2	8.0	7.8	7.4	7.6	7.3	7.2	8.2	7.6	7.6	4.0	5.2	3.5	7.5	5.1	8.0	8.0	0.0	5.3	5.0
Plantago lanceolata L.	7.0	7.3	6.7	7.7	7.2	7.2	6.8	7.4	7.2	7.2	17.5	9.1	9.6	10.7	11.7	8.6	8.4	11.1	9.4	10.7
Poa annua L.	7.5	8.3	7.9	7.5	7.8	7.4	7.7	8.3	7.8	7.8	9.4	7.2	10.7	8.0	8.9	9.3	8.8	9.3	9.2	9.0
Ranunculus arvensis L.	7.8	7.5	7.5	7.8	7.7	7.5	7.3	8.0	7.6	7.7	4.3	4.7	3.5	5.6	4.6	3.5	4.6	5.7	4.6	4.6
Stellaria media (L.) Vill.	8.8	7.3	7.5	7.7	7.9	7.6	7.5	8.2	7.8	7.8	10.1	11.7	10.7	11.6	11.1	10.4	11.8	11.7	11.3	11.2
Trifolium repens L.	4.3	4.1	4.1	4.1	4.1	6.8	6.8	0.0	4.5	4.1	3.8	3.9	3.3	4.6	3.9	0.0	2.6	8.7	3.8	3.9
Tulipa asiatica L.	8.2	7.5	7.3	8.6	7.9	7.8	7.6	8.2	7.9	7.9	9.3	7.7	6.9	7.2	7.8	8.8	6.8	8.3	8.0	7.9
Vicia hirsute (L.) Gray	6.6	7.4	7.7	6.5	7.1	6.9	7.8	6.6	7.1	7.1	-	-	-	-	-	-	-	-	-	-
Vicia sativa L.	6.1	7.4	7.3	6.5	6.9	6.1	6.9	7.5	6.8	6.9	8.6	8.5	9.9	8.8	9.0	9.0	8.8	9.8	9.2	9.1

P_1- Integrated nutrient management, P_2- Organic farming, P_3- Natural farming, P_4- Conservation agriculture, C_1- Maize – wheat, C_2- Maize + cowpea – wheat + gram, C_3- Okra + pole bean – cabbage + garden pea

Table 3: Effect of production and cropping systems on Importance Value Index (IVI) of different weed species during *kharif* 2019

Weed species	*Kharif* 2019																						
	P_1	P_2	P_3	P_4	Mean	C_1	C_2	C_3	Mean	Overall	P_1C_1	P_1C_2	P_1C_3	P_2C_1	P_2C_2	P_2C_3	P_3C_1	P_3C_2	P_3C_3	P_4C_1	P_4C_2	P_4C_3	Overall
Aeschynomene indica L.	21.1	20.9	19.2	19.0	20.1	17.9	21.3	21.0	20.1	23.0	21.1	22.0	26.9	21.3	22.9	22.8	17.8	22.4	21.2	18.5	21.9	22.7	19.9
Ageratum conyzoides L.	14.3	16.2	17.1	14.1	15.4	14.8	16.9	14.8	15.5	19.9	16.7	18.8	6.3	17.1	18.3	9.8	16.6	17.6	12.3	15.3	17.2	9.1	15.4
Alternanthera philoxeriodes L.	25.1	25.6	22.2	20.5	23.3	23.4	21.3	24.2	23.0	15.4	25.3	20.4	23.6	27.4	23.6	20.2	26.1	23.7	11.1	24.1	21.8	13.8	23.0
Artemisia vulgaris L.	21.3	17.7	24.9	35.1	24.7	22.7	25.3	29.2	25.8	25.6	24.0	23.9	26.5	17.3	19.9	20.8	27.7	23.8	31.0	32.7	39.9	51.6	25.7
Bidens pilosa L.	14.1	16.7	16.0	14.8	15.4	15.1	18.6	12.9	15.5	15.3	7.6	11.1	14.1	9.9	13.9	16.1	9.8	13.6	14.5	11.1	12.5	13.9	15.3
Chenopodium murale L.	15.5	15.9	17.9	13.8	15.7	9.6	11.4	24.1	15.0	15.6	11.6	14.0	26.9	11.0	11.8	27.6	13.4	13.9	29.5	9.1	9.7	23.5	15.6
Commelina benghalensis L.	36.8	29.4	26.4	35.2	32.0	45.2	26.5	22.8	31.5	32.1	34.6	30.2	32.0	24.7	29.5	25.3	23.7	22.3	21.8	36.4	29.9	13.8	32.1
Coronopus didymus L.	17.1	16.2	15.5	14.5	15.8	14.9	16.8	15.8	15.8	15.7	19.7	19.6	18.2	14.9	20.6	16.9	17.2	15.5	16.9	14.9	15.5	18.5	15.7
Cyperus sp.	24.8	27.0	25.3	22.9	25.0	24.3	27.7	23.2	25.1	24.9	25.2	29.5	26.9	29.2	28.4	28.2	26.6	27.9	25.1	24.7	29.6	23.1	24.9
Digitaria sanguinalis L.	13.9	14.4	16.6	14.1	14.8	18.5	13.5	12.1	14.7	14.8	21.2	14.0	11.8	19.8	14.2	12.0	20.7	18.3	13.3	19.7	11.3	16.7	14.8
Echinochloacolona (L.) Link	23.7	23.8	24.0	23.4	23.7	22.5	26.1	23.1	23.9	23.7	24.5	30.2	24.1	25.6	24.3	26.2	22.9	26.7	26.4	25.2	27.9	25.4	23.7
Galinsoga parviflora Cav.	15.6	17.1	16.6	16.6	16.5	18.8	17.9	13.1	16.6	16.5	21.8	19.5	12.2	21.8	18.3	14.7	20.2	18.3	14.0	19.1	19.0	18.1	16.5
Phyllanthus niruri L.	9.6	10.0	9.8	10.6	10.0	10.3	10.5	9.6	10.1	10.0	10.4	6.4	10.2	13.9	4.1	8.9	11.3	10.0	10.7	12.1	4.9	13.9	10.1
Polygonum alatum L.	20.3	21.0	20.2	20.9	20.6	17.4	18.0	25.9	20.4	20.6	18.9	19.5	18.9	20.5	18.4	17.9	17.2	17.6	20.3	19.7	20.4	17.9	20.6
Persicaria hydropiper L.	26.9	28.1	28.3	24.4	26.9	24.6	28.1	28.0	26.9	26.8	17.3	20.9	21.3	25.6	31.7	32.7	29.1	28.5	31.9	17.4	18.5	18.1	26.7

P_1- Integrated nutrient management, P_2- Organic farming, P_3- Natural farming, P_4- Conservation agriculture, C_1- Maize – wheat, C_2- Maize + cowpea – wheat + gram, C_3- Okra + pole bean – cabbage + garden pea

Table 4: Effect of production and cropping systems on Importance Value Index(IVI) of different weed species during *kharif* 2020

Weed species	*Kharif* 2020																						
	P_1	P_2	P_3	P_4	Mean	C_1	C_2	C_3	Mean	Overall	P_1C_1	P_1C_2	P_1C_3	P_2C_1	P_2C_2	P_2C_3	P_3C_1	P_3C_2	P_3C_3	P_4C_1	P_4C_2	P_4C_3	Overall
Aeschynomene indica L.	16.7	10.8	9.2	13.9	12.6	13.2	11.7	12.9	12.6	12.8	18.2	14.8	17.5	10.9	9.8	11.7	9.4	7.2	11.1	15.7	16.2	10.1	12.5
Ageratum conyzoides L.	65.2	67.1	69.8	40.9	60.8	56.3	69.2	60.7	62.1	63.5	45.4	86.0	59.9	66.3	71.4	64.0	73.6	67.8	68.3	33.5	46.2	44.3	61.4
Alternanthera philoxeriodes L.	17.6	16.1	12.5	15.9	15.5	14.8	11.7	19.4	15.3	15.6	17.2	9.0	25.2	13.2	14.0	20.8	13.5	11.9	12.1	16.3	12.6	17.8	15.3
Artemisia vulgaris L.	19.9	11.4	15.0	18.0	16.1	16.3	17.0	15.6	16.3	16.6	22.5	18.2	20.2	10.1	13.1	11.2	11.9	16.3	17.2	22.3	21.6	11.9	16.0
Bidens pilosa L.	17.1	13.4	15.6	19.9	16.5	13.9	17.9	17.7	16.5	16.8	12.2	21.7	17.1	11.8	11.1	17.2	13.4	18.3	15.0	19.0	21.0	20.8	16.4
*Commelina benghalensis*L.	28.5	21.1	19.5	28.1	24.3	30.4	19.4	15.3	21.7	16.2	39.6	20.9	26.4	23.8	17.1	22.3	18.7	21.4	18.1	43.4	17.8	20.2	23.9
Coronopus didymus L.	10.7	9.0	9.2	9.0	9.5	10.7	10.6	7.1	9.4	9.7	14.1	11.7	6.6	8.2	13.3	4.4	11.4	8.9	7.4	9.9	8.5	8.5	9.4
Cyperus sp.	32.6	44.6	48.9	52.4	44.6	41.5	41.6	52.5	45.2	45.9	27.8	31.8	38.1	49.8	43.8	40.4	46.9	44.9	56.0	38.1	46.3	71.2	44.8
Digitaria sanguinalis L.	12.7	6.6	14.8	17.9	13.0	16.8	11.3	11.6	13.2	13.6	17.5	10.2	11.0	5.1	5.2	9.1	18.5	14.8	10.0	23.8	13.4	15.4	13.3
Echinochloa colona (L.) Link	22.2	26.3	23.5	27.0	24.8	24.4	23.6	26.3	24.8	25.1	24.5	21.8	21.4	24.2	27.0	27.9	22.2	19.6	29.7	28.2	28.8	24.7	24.6
Galinsoga parviflora Cav.	7.8	9.0	9.6	6.3	8.2	10.4	6.6	7.9	8.3	8.6	12.3	4.3	6.6	10.1	6.2	10.3	11.0	9.5	8.1	8.4	4.9	5.9	8.3
Polygonum alatum L.	37.9	40.9	38.9	34.9	38.1	37.3	39.3	38.6	38.4	39.0	38.9	36.2	39.6	42.7	41.5	39.1	34.8	41.3	41.2	34.5	38.9	32.3	38.1
Trifolium repens L.	11.2	24.0	13.6	15.9	16.2	14.2	20.2	14.5	16.3	16.6	9.7	13.5	10.4	23.8	26.4	21.7	14.7	18.0	5.9	7.0	23.8	17.0	16.2

P_1- Integrated nutrient management, P_2- Organic farming, P_3- Natural farming, P_4- Conservation agriculture, C_1- Maize – wheat, C_2- Maize + cowpea – wheat + gram, C_3- Okra + pole bean – cabbage + garden pea

Table 5: Effect of production and cropping systems on Important Value Index (IVI) of different weed species during *rabi* 2019-20

Weed species	*Rabi* 2019-20																						
	P_1	P_2	P_3	P_4	Mean	C_1	C_2	C_3	Mean	Overall	P_1C_1	P_1C_2	P_1C_3	P_2C_1	P_2C_2	P_2C_3	P_3C_1	P_3C_2	P_3C_3	P_4C_1	P_4C_2	P_4C_3	Overall
Anagallis arvensis L.	21.1	21.5	20.4	20.9	21.0	20.1	20.3	22.4	20.9	21.4	22.7	20.4	21.2	19.8	20.9	23.6	19.2	19.2	22.8	20.1	21.2	21.9	20.9
Bidens pilosa L.	14.9	12.7	13.3	15.1	14.0	13.1	12.2	16.0	13.7	14.2	12.9	13.3	17.1	11.8	11.6	14.6	12.9	10.6	15.8	15.0	14.0	16.4	13.9
Coronopus didymus L.	21.3	18.9	20.7	22.9	20.9	19.6	19.2	23.3	20.7	21.3	22.7	20.0	21.9	18.0	18.3	20.5	17.9	18.3	25.0	21.6	20.8	25.9	20.8
Fumaria parviflora L.	19.4	21.7	22.2	21.0	21.1	21.0	21.0	22.0	21.3	21.7	18.0	15.9	22.4	21.4	20.9	23.1	24.4	24.1	19.8	18.4	21.6	23.0	21.2
Lolium temulentum L.	18.8	21.7	23.4	15.3	19.8	20.4	21.1	19.8	20.4	20.6	15.5	17.7	21.3	20.5	24.9	20.7	26.2	24.3	21.2	16.1	15.0	15.4	20.1
Phalaris minor Retz.	22.6	22.0	21.5	17.5	20.9	21.0	20.6	21.5	21.1	21.4	25.2	22.0	22.6	22.6	22.0	22.2	22.7	21.8	20.9	15.2	16.8	20.1	20.9
Plantago lanceolata L.	16.6	17.5	16.9	19.4	17.6	17.7	15.9	19.0	17.6	18.0	18.2	13.0	18.2	17.0	14.8	20.2	15.6	16.9	18.2	20.6	18.3	19.7	17.6
Poa annua L.	21.6	27.4	27.7	19.2	24.0	23.1	23.1	26.7	24.3	25.0	17.2	19.8	25.2	28.0	28.1	27.1	26.4	25.7	30.9	17.6	17.0	22.5	24.4
Ranunculus arvensis L.	26.0	22.5	23.0	23.4	23.7	22.2	23.4	25.2	23.6	24.2	27.6	26.8	25.7	20.5	22.0	24.9	20.6	21.6	26.4	22.6	24.8	23.7	23.6
Stellaria media (L.) Vill.	25.5	23.3	21.8	22.5	23.3	20.1	20.9	27.2	22.7	23.7	24.7	25.7	26.5	20.6	19.7	28.4	18.3	19.8	26.4	19.3	19.8	27.5	23.1
Trifolium repens L.	17.2	15.8	14.8	14.8	15.6	22.0	21.1	0.0	14.4	8.3	27.2	25.9	0.0	21.9	21.4	0.0	20.7	19.4	0.0	20.7	19.3	0.0	15.5
Tulipa asiatica L.	41.7	36.6	33.8	57.3	42.4	44.8	42.4	40.8	42.6	43.2	37.6	50.3	40.3	38.3	33.0	39.1	35.0	30.4	36.4	66.8	60.8	48.7	41.9
Vicia hirsuta (L.) Gray	17.7	20.3	21.7	15.7	18.8	19.1	21.2	18.0	19.5	19.6	16.8	16.8	19.2	21.2	24.3	17.1	21.9	25.6	18.9	15.0	15.5	16.7	19.1
Vicia sativa L.	15.4	18.2	19.0	15.0	16.9	15.7	17.6	18.1	17.2	17.5	13.7	12.5	18.2	18.3	18.1	18.6	18.4	22.4	17.3	10.9	15.0	18.5	17.1

P_1- Integrated nutrient management, P_2- Organic farming, P_3- Natural farming, P_4- Conservation agriculture, C_1- Maize – wheat, C_2- Maize + cowpea – wheat + gram, C_3- Okra + pole bean – cabbage + garden pea

Table 6: Effect of production and cropping systems on Important Value Index(IVI) of different weed species during *rabi*2020-21

Weed species	*Rabi* 2020-21																						
	P_1	P_2	P_3	P_4	Mean	C_1	C_2	C_3	Mean	Overall	P_1C_1	P_1C_2	P_1C_3	P_2C_1	P_2C_2	P_2C_3	P_3C_1	P_3C_2	P_3C_3	P_4C_1	P_4C_2	P_4C_3	Overall
Anagallis arvensis L.	0.0	22.9	30.5	0.0	13.4	16.7	23.9	22.4	21.0	19.3	0.0	0.0	0.0	32.0	21.7	19.1	18.6	40.9	34.3	0.0	0.0	0.0	19.3
Avena ludoviciana L.	22.1	16.6	15.9	21.7	19.1	22.3	27.3	0.0	16.5	18.4	29.5	30.0	0.0	14.9	31.3	0.0	15.2	26.4	0.0	30.8	26.3	0.0	18.5
Bidens pilosa L.	15.3	13.7	9.8	14.4	13.3	12.5	14.6	13.8	13.6	12.9	16.5	20.7	12.7	12.5	12.7	17.8	9.6	10.9	10.1	12.6	17.8	16.3	12.9
Coronopus didymus L.	33.2	28.4	24.3	27.2	28.3	26.5	27.1	34.0	29.2	27.7	26.4	37.6	45.8	29.1	29.2	31.4	25.3	21.4	29.8	26.8	26.9	34.2	27.8
Euphorbia heliscopia L.	10.9	9.1	8.2	10.1	9.6	10.9	4.0	14.2	9.7	9.3	11.7	0.0	20.0	12.3	0.0	12.4	10.0	6.4	9.6	10.7	0.0	18.0	9.3
Fumaria parviflora L.	11.3	13.0	9.0	13.3	11.7	0.0	0.0	24.9	8.3	11.2	0.0	0.0	27.3	0.0	0.0	26.5	0.0	0.0	19.3	0.0	0.0	31.0	11.2
Lolium temulentum L.	16.2	20.2	24.8	21.7	20.7	30.9	23.8	0.0	18.2	20.7	28.6	10.1	0.0	33.9	20.5	0.0	33.3	33.8	0.0	29.6	27.7	0.0	20.7
Phalaris minor Retz.	15.4	20.5	15.7	26.7	19.5	23.2	26.2	0.0	16.5	18.7	23.5	16.1	0.0	17.1	39.1	0.0	21.5	19.1	0.0	33.2	38.0	0.0	18.8
Plantago lanceolata L.	25.5	20.7	21.3	27.0	23.6	19.8	17.9	30.0	22.6	22.2	16.7	13.6	31.6	18.0	17.1	28.9	19.7	19.8	26.7	25.7	23.5	37.3	21.6
Poa annua L.	32.9	23.5	35.1	23.9	28.8	34.3	28.8	29.0	30.7	29.2	40.7	32.0	33.0	26.2	20.0	29.4	42.7	34.2	33.5	26.4	32.0	15.8	29.2
Ranunculus arvensis L.	10.5	10.2	7.9	12.4	10.3	8.1	10.0	13.6	10.5	9.9	8.3	13.1	14.2	8.8	9.7	13.6	5.9	8.1	10.8	10.2	11.9	18.4	10.0
Stellaria media (L.) Vill.	36.7	44.3	34.5	43.7	39.8	38.9	39.5	44.6	41.0	38.9	37.6	41.9	40.0	44.5	48.5	47.5	34.6	33.0	40.9	42.5	44.5	54.5	39.0
Trifolium repens L.	10.7	10.2	7.6	11.9	10.1	0.0	7.9	13.8	7.2	9.7	0.0	6.1	25.1	0.0	7.1	19.5	0.0	8.5	12.2	0.0	12.0	17.1	9.8
Tulipa asiatica L.	35.5	20.5	21.3	23.5	25.2	27.6	24.6	26.1	26.1	24.7	30.7	54.0	28.5	29.3	14.3	20.3	27.4	7.7	30.8	25.3	25.4	25.7	24.7
Vicia sativa L.	23.8	26.2	34.2	22.7	26.7	28.3	24.4	33.5	28.8	27.2	29.8	24.8	21.8	21.5	28.9	33.7	36.3	29.8	41.8	26.1	14.0	31.7	27.3

P_1- Integrated nutrient management, P_2- Organic farming, P_3- Natural farming, P_4- Conservation agriculture, C_1- Maize – wheat, C_2- Maize + cowpea – wheat + gram, C_3- Okra + pole bean – cabbage + garden pea

Table 7: Effect of production and cropping systems on diversity indices of different weed species during *kharif* 2019 and 2020

	Kharif 2019										*Kharif* 2020									
Treatment	No. of species	No. of species common as P P_1 / C_1	No. of species present in new system but absent in P P_1 / C_1	Shannon Wiener index (H)	Species richness (D)	Simpson's index	Simpson's index of diversity	Simpson's reciprocal index	Similarity index	Evenness/ Shannon's equitability (EH)	No. of species	No. of species common as P P_1 / C_1	No. of species present in new system but absent in P P_1 / C_1	Shannon Wiener index (H)	Species richness (D)	Simpson's index	Simpson's index of diversity	Simpson's reciprocal index	Similarity index	Evenness/ Shannon's equitability (EH)
P_1	15	15	0	2.590	0.501	0.083	0.917	11.98	1.000	0.956	12	12	0	2.199	0.306	0.15	0.85	6.75	1.000	0.885
P_2	17	15	2	2.623	0.565	0.078	0.922	12.85	0.938	0.926	13	11	2	2.082	0.324	0.17	0.83	6.03	0.880	0.812
P_3	17	15	2	2.642	0.537	0.075	0.925	13.33	0.938	0.933	15	12	3	2.063	0.339	0.18	0.82	5.68	0.889	0.762
P_4	16	15	1	2.587	0.455	0.084	0.916	11.86	0.968	0.933	13	11	2	2.266	0.334	0.13	0.87	7.84	0.880	0.883
Overall	17	15	2	2.620	0.268	0.078	0.922	12.75	0.938	0.925	15	12	3	2.175	0.184	0.15	0.85	6.70	0.889	0.803
C_1	15	15	0	2.543	0.395	0.094	0.906	10.66	1.000	0.939	13	13	0	2.235	0.277	0.14	0.86	7.37	1.000	0.871
C_2	16	15	1	2.620	0.467	0.078	0.922	12.85	0.968	0.945	12	12	0	2.111	0.257	0.17	0.83	6.02	0.960	0.849
C_3	17	15	2	2.607	0.452	0.079	0.921	12.66	0.938	0.920	14	13	1	2.136	0.296	0.15	0.85	6.47	0.963	0.809
Overall	17	15	2	2.620	0.268	0.078	0.922	12.75	0.938	0.925	14	13	1	2.175	0.172	0.15	0.85	6.70	0.963	0.824
$P_1 C_1$	15	15	0	1.826	0.833	0.106	0.894	9.41	1.000	0.674	13	13	0	2.329	0.622	0.12	0.88	8.63	1.000	0.908
$P_1 C_2$	16	15	1	2.112	0.981	0.079	0.921	12.71	0.968	0.762	13	12	1	1.957	0.553	0.22	0.78	4.52	0.923	0.763
$P_1 C_3$	17	15	2	1.702	0.973	0.088	0.912	11.39	0.938	0.601	14	12	2	2.198	0.600	0.14	0.86	7.16	0.889	0.833
$P_2 C_1$	17	15	2	2.160	0.943	0.083	0.917	12.01	0.938	0.762	13	12	1	2.032	0.553	0.17	0.83	5.80	0.923	0.792
$P_2 C_2$	17	15	2	2.363	1.018	0.079	0.921	12.68	0.938	0.834	14	13	1	2.031	0.608	0.18	0.82	5.68	0.963	0.770
$P_2 C_3$	17	15	2	1.978	0.980	0.082	0.918	12.17	0.938	0.698	14	12	2	2.140	0.613	0.15	0.85	6.54	0.889	0.811
$P_3 C_1$	17	15	2	2.185	0.872	0.081	0.919	12.32	0.938	0.771	15	13	2	2.069	0.572	0.18	0.82	5.54	0.929	0.764
$P_3 C_2$	17	15	2	2.463	0.972	0.076	0.924	13.19	0.938	0.869	15	13	2	2.098	0.578	0.17	0.83	6.00	0.929	0.775
$P_3 C_3$	17	15	2	2.031	0.955	0.081	0.919	12.42	0.938	0.717	15	13	2	1.962	0.612	0.19	0.81	5.30	0.857	0.724
$P_4 C_1$	16	15	1	1.740	0.785	0.119	0.881	8.43	0.968	0.628	13	13	0	2.304	0.568	0.12	0.88	8.67	1.000	0.898
$P_4 C_2$	15	15	0	2.105	0.832	0.085	0.915	11.81	1.000	0.777	13	12	1	2.250	0.636	0.13	0.87	7.89	0.923	0.877
$P_4 C_3$	16	15	1	1.864	0.720	0.081	0.919	12.30	0.968	0.672	14	12	2	2.094	0.585	0.17	0.83	5.79	0.889	0.794
Overall	17	15	2	2.620	0.268	0.078	0.922	12.75	0.938	0.925	15	13	2	2.175	0.184	0.15	0.85	6.70	0.929	0.803

P_1- Integrated nutrient management, P_2- Organic farming, P_3- Natural farming, P_4- Conservation agriculture, C_1- Maize – wheat, C_2- Maize + cowpea – wheat + gram, C_3- Okra + pole bean – cabbage + garden pea

Table 8: Effect of production and cropping systems on diversity indices of different weed species during *rabi* 2019-20 and 2020-21

	Rabi 2019-20									*Rabi* 2020-21									
Treatment	No. of species	No. of species common as P P_1 / C_1	No. of species present in new system but absent in P P_1 / C_1	Shannon Wiener index (H)	Species richness (D)	Simpson's index	Simpson's index of diversity	Simpson's reciprocal index	Similarity index	Evenness/ Shannon's equitability (EH)	No. of species	No. of species common as P P_1 / C_1	No. of species present in new system but absent in P P_1 / C_1	Shannon Wiener index (H)	Species richness (D)	Simpson's index	Simpson's index of diversity	Simpson's reciprocal index	Similarity index	Evenness/ Shannon's equitability (EH)
P_1	13	13	0	2.548	0.269	0.09	0.91	11.46	1.000	0.994	14	14	0	2.420	0.329	0.104	0.90	9.63	1.000	0.917
P_2	14	13	1	2.573	0.256	0.08	0.92	12.23	0.963	0.975	15	14	1	2.511	0.342	0.097	0.90	10.32	0.966	0.927
P_3	13	13	0	2.583	0.223	0.08	0.92	12.55	1.000	0.967	15	14	1	2.441	0.299	0.100	0.90	9.96	0.966	0.902
P_4	13	13	0	2.442	0.246	0.11	0.89	8.82	1.000	0.952	14	14	0	2.471	0.347	0.098	0.90	10.25	1.000	0.936
Overall	14	13	1	2.555	0.131	0.09	0.91	11.59	0.963	0.968	15	14	1	2.522	0.169	0.092	0.91	10.85	0.966	0.931
C_1	14	14	0	2.544	0.243	0.09	0.91	11.24	1.000	0.964	13	13	0	2.401	0.248	0.100	0.90	9.98	1.000	0.936
C_2	13	13	0	2.555	0.226	0.09	0.91	11.62	0.963	0.996	14	13	1	2.437	0.272	0.096	0.90	10.38	0.963	0.923
C_3	13	13	0	2.497	0.187	0.09	0.91	11.22	0.963	0.973	12	12	0	2.342	0.240	0.108	0.89	9.30	0.880	0.942
Overall	14	14	0	2.555	0.131	0.09	0.91	11.59	1.000	0.968	14	13	1	2.522	0.158	0.092	0.91	10.85	0.963	0.956
$P_1 C_1$	14	14	0	2.543	0.604	0.09	0.91	11.61	1.000	0.964	13	13	0	2.325	0.501	0.106	0.89	9.41	1.000	0.907
$P_1 C_2$	13	13	0	2.475	0.517	0.10	0.90	9.88	0.963	0.965	14	13	1	2.171	0.559	0.079	0.92	12.71	0.963	0.823
$P_1 C_3$	13	13	0	2.504	0.382	0.09	0.91	11.37	0.963	0.976	13	12	1	2.261	0.575	0.088	0.91	11.39	0.923	0.882
$P_2 C_1$	14	14	0	2.566	0.474	0.08	0.92	12.05	1.000	0.972	13	13	0	2.364	0.515	0.083	0.92	12.01	1.000	0.922
$P_2 C_2$	14	14	0	2.579	0.472	0.08	0.92	12.50	1.000	0.977	15	13	2	2.307	0.608	0.079	0.92	12.68	0.929	0.852
$P_2 C_3$	14	14	0	2.499	0.400	0.09	0.91	11.35	1.000	0.947	12	11	1	2.333	0.460	0.082	0.92	12.17	0.880	0.939
$P_3 C_1$	14	14	0	2.578	0.435	0.08	0.92	12.41	1.000	0.977	13	13	0	2.325	0.457	0.081	0.92	12.32	1.000	0.907
$P_3 C_2$	13	13	0	2.588	0.410	0.08	0.92	12.80	0.963	0.981	15	13	2	2.346	0.504	0.076	0.92	13.19	0.929	0.866
$P_3 C_3$	13	13	0	2.503	0.352	0.09	0.91	11.49	0.963	0.976	14	13	1	2.254	0.486	0.081	0.92	12.42	0.963	0.854
$P_4 C_1$	14	14	0	2.358	0.472	0.14	0.86	7.32	1.000	0.893	13	13	0	2.338	0.519	0.119	0.88	8.43	1.000	0.912
$P_4 C_2$	13	13	0	2.417	0.458	0.12	0.88	8.30	0.963	0.942	14	13	1	2.321	0.611	0.085	0.92	11.81	0.963	0.879
$P_4 C_3$	13	13	0	2.450	0.392	0.10	0.90	10.04	0.963	0.955	13	12	1	2.234	0.593	0.081	0.92	12.30	0.923	0.871
Overall	14	14	0	2.555	0.131	0.09	0.91	11.59	1.000	0.968	15	13	2	2.522	0.169	0.078	0.92	12.75	0.929	0.931

P_1- Integrated nutrient management, P_2- Organic farming, P_3- Natural farming, P_4- Conservation agriculture, C_1- Maize – wheat, C_2- Maize + cowpea – wheat + gram, C_3- Okra + pole bean – cabbage + garden pea

was the most frequently occurring weed in all the treatments under production and copping systems except INM (P_1) under production systems where *P. lanceolata* was leading with relative frequency value of 17.5. *C. didymus* was the most frequent weed with relative frequency value of 9.4-10.5 in production systems and 9.5-10.7 in cropping systems while *P. lanceolata* was frequent weed with relative frequency value of 9.1-17.5 in production systems and 8.4-11.1 in cropping systems. Maize – wheat (C_1) and okra + pole bean – cabbage + garden pea (C_3) had the highest frequency of *S. media* and *C. didymus,* respectively while maize + cowpea – wheat + gram (C_2) had the highest frequency of *S. media* and *A. ludoviciana*.

Importance value index (IVI) of kharif seasons

The IVI of weed species during the *kharif* season of 2019 given in Table 3 indicated that *C. benghalensis* was the most important weed having overall value of 32.1 which was followed by *P. hydropiper* (26.8) and *A. Vulgaris* (25.6). The weeds *A. indica, Cyperus* sp and *E. colona* were second in importance weeds and had the same values. *C. benghalensis* was most important having highest IVI value in all treatments under production systems except NF (P_3). *A. Vulgaris* was the most important weed in okra + Pole bean – cabbage + garden pea (C_3) among cropping systems which was followed by *P. hydropiper*. *P. hydropiper* was the most important weed in NF (P_2) and the second importance after *C. benghalensis* in all treatments except CA (P_4) in all production and cropping systems. In CA (P_4), it was third in importance after *A. Vulgaris*. Overall, *C. benghalensis* was having highest IVI value followed by *P. hydropiper*, *A. Vulgaris, A indica, Cyperus* sp, *E. colona* and *A. philoxeriodes* under production x cropping systems.

The IVI of weed species during the *kharif* season of 2020 given in Table 4 indicated that *A. conyzoides* was the most important weed having overall value of 63.5. Except CA (P_4), it was the most important weed in all the other production and cropping systems. In CA (P_4), it was second in importance after *Cyperus* sp. (*C. iria, C. esculentus, C. difformis*). *Cyperus* sp. together were second in importance after *A. conyzoides* in OA (P_2), NF (P_3) and CA (P_4) among production practices and maize – wheat (C_1), maize + cowpea – wheat + gram (C_2) and okra + pole bean – cabbage + garden pea (C_3) among the cropping systems. *P alatum* was second most important weed after *Ageratum* in INM (P_1) treatment. Overall, *A. conyzoides* was having highest IVI value followed by *Cyperus* sp. *P. alatum, E. colona, B. pilosa*, *T. repens, A. Vulgaris* and *C beghalensis*.

Importance value index (IVI) of rabi seasons

The IVI of the species during *rabi*2019-20 given in Table 5 revealed higher importance of *Tulipa asiatica, Poa annua, Ranunculus arvensis* and *Stellaria media* under different cropping and production system. It is evident that *T. asiatica* was the most important weed as it was present in large number and had greater importance in CA (P_4) among the production systems and, maize – wheat (C_1) and maize + cowpea – wheat + gram (C_2) amongst cropping systems. *P. annua* was most important in NF (P_3), and OA (P_2) under production systems and okra + pole bean – cabbage + garden pea (C_3) under cropping systems. *R. arvensis* was present in largest amount in INM (P_1) and okra + pole bean – cabbage + garden pea (C_3) under different treatments. *S. media* had highest IVI in okra + pole bean – cabbage + garden pea (C_3) among cropping systems.

The IVI of the species during *rabi* 2020-21 given in Table 6 showed that *S. media* was the most important weed having overall value of 39.0. Except NF (P_3), it was the most important weed in all the other production and cropping systems. In NF it was the second important weed after *P. annua* which was lead. The weeds present in different cropping and production system during *rabi* 2019-20 having highest IVI were *S. media, P. annua, C. didymus* and *V. sativa* with 38.9, 29.2, 27.7 and 27.3, respectively. *P. minor, L. temulentum* and *A. ludoviciana* had highest IVI in okra + pole bean – cabbage + garden pea (C_3) among cropping systems. *C. didymus* was present in largest amount in INM (P_1) under production system and okra + pole bean – cabbage + garden pea (C_3) under cropping system. *V. sativa* had highest IVI in NF (P_3) under production system okra + pole bean – cabbage + garden pea (C_3) among cropping systems. Overall *E. heliscopia* had lowest IVI with 9.3 value among all treatments.

Diversity indices

There were 17 and 15 weed species found growing in different cropping/production systems during *kharif* 2019 and 2020, respectively (**Tables 7**). During *kharif* 2019, fifteen species were found common in 'INM' and other production systems and 0 to 2 weed species were different. Similarly, among the cropping systems 15 species were common and only 0-2 species different. It clearly indicated that with changes in production and cropping systems, variation in infestation of weed flora occurred. With controlling/limiting one species, another species finds its way to invade the agro-ecosystem indicating that successful weed control is a never ending process rather a continuous effort and care must be taken to control weeds at critical period of crop weed competition. Shannon Weiner index accounting for the order or abundance of a species within a community was highest for the NF treatment followed by OA. It was lowest under CA followed by INM treatment under production systems. Shannon's equitability which revealed more evenness under INM (P_1) and minimum under the OA (P_2) treatment. The other two treatments i.e. (NF and CA) were having similar evenness. Among the cropping systems it assumed more evenness under maize + cowpea – wheat + gram (C_2). Simpson's index of diversity and Simpson's reciprocal index were highest for the NF closely followed by OA treatment. Among the cropping systems, these were highest in maize + cowpea – wheat + gram which was at per with okra + pole bean – cabbage + garden pea. Similarity index following Soverson's coefficient (SC) showed weed communities high in INM (P_1) treatment. However, the lowest similarity index was obtained for OA (P_2) and natural farming (P_3) treatments among production systems.

During *kharif* 2020, twelve species were found growing in 'INM' (Table 7). Eleven to twelve weed species were common in 'INM' and other production systems. In production systems, 0 to 3 weed species were found different from 'INM'. Similarly, among the cropping systems 12-13 species were common and only 0-1 species was different. It is clearly indicated that with changes in production and cropping systems, variation in infestation of weed flora occurred. Shannon Weiner index was highest for the CA treatment followed by INM treatment. It was lowest under NF followed by OA treatment among production systems. Simpson's index of diversity and Simpson's reciprocal index were highest for the CA closely followed by INM. Among the cropping systems, these were highest in maize – wheat followed by okra + pole bean – cabbage + garden pea. Species richness was highest under NF followed by CA and INM treatments. Similarity index following Soverson's coefficient (SC) showed weed communities under all the treatments less in common as INM treatment. However, the lowest similarity index was obtained for OA and CA treatments among production systems. This may absolutely happen under Palam valley conditions in crops like maize and okra which are widely spaced allowing luxuriant weed growth owing to frequent heavy rains in *kharif.*

As mentioned earlier there were 14 and 15 weed species found growing in different cropping systems under different production management during *rabi* 2019-20 and 2020-21, respectively (Tables 8). In 'INM' production system all the 14 weed species were found associated during *rabi* 2019-20. Thirteen weed species were common in INM and other production systems. Wider spacing in peas provides ample opportunities for weed infestation (Singh *et al*., 1991; Kundra *et al*., 1993; Banga et al. 1998). Shannon Weiner index accounting for order or abundance of a species within a sample plot was highest under INM followed by OA treatment. Lowest values of this index were obtained under CA followed by NF. Simpson's index of diversity and Simpson's reciprocal index indicated higher weed diversity under INM and OA treatments followed by NF treatment, while, the lower diversity as per these indices was under CA. Species richness was highest under INM among production systems. Whereas, the lowest Species richness was under okra + pole bean – cabbage + garden pea followed by maize + cowpea – wheat + gram among cropping systems. The evenness index showed a little variation in weed community structure under different production and cropping system treatments. It varied from 0.893 to 0.995 (value equal to one means complete evenness).

During *rabi* 2020-21, all the 15 weed species were found associated in 'INM' production system (Table 8). Fourteen weed species were common in INM and other production systems. Shannon Weiner index was highest under OA (P_2) followed by conservation agriculture (P_4) treatment among production systems. Lowest values of this index were obtained under INM (P_1) followed by NF (P_3). Among the cropping systems, the highest value of this index was under maize + cowpea – wheat + gram (C_2) while the lowest value of this index was under the okra + pole bean – cabbage + garden pea (C_3) cropping system. Simpson's index of diversity was similar in all treatments under production and cropping systems but the Simpson's reciprocal index indicated higher weed diversity under OA (P_2) treatment followed by conservation agriculture (P_2) treatment, while, the lower diversity as per these indices was under INM (P_1). Maize + cowpea – wheat + gram (C_2) had the similar Simpson's index of diversity and Simpson's reciprocal index among cropping systems which was followed by maize – wheat (C_1) and okra + pole bean – cabbage + garden pea (C_3) treatments. Species richness was highest under CA (P_4) among production systems that is followed by OA (P_2) treatment among the production systems. Whereas, the lowest Species richness was under NF (P_3) treatment. Okra + pole bean – cabbage + garden pea (C_3) treatment had lowest Species richness followed by maize – wheat (C_1) treatment among cropping systems. The evenness index showed a little variation in weed community structure under different production and cropping system treatments. It varied from 0.823 to 0.956 (value equal to one means complete evenness).

CONCLUSION

Weed flora was composed of diverse species and were dynamic in nature. Their distribution, density, abundance and importance were varied due to production practices and cropping systems. Irrespective of production and cropping systems, *C. benghalensis* was the most important weed during *kharif* 2019 which was followed by *P. hydropiper, A. vulgaris* and *E. colona*. During *kharif* 2020, *A. conyzoides* was the most important weed and was followed by *Cyperus sp.* and *P. alatum*. *T. asiatica* was the most important weed during the *rabi* 2019-20 followed by *P. annua, R. arvensis* and *S. media*. While, *S. media* was the most important weed during *rabi* 2020-21 which was followed by *P. annua* and *V. sativa*. Simpson's index of diversity and Simpson's reciprocal index indicated higher weed diversity under INM and OA treatments followed by NF treatment during *kharif* 2019, while, the lower diversity was under CA. During *kharif* 2020, Simpson's index of diversity and Simpson's reciprocal index were highest for CA closely followed by INM among production systems.

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REFERENCES

Banga, R.S., Yadav, A., Malik, R.S. and Malik, R.K. 1998.Evaluation of different herbicides for weed control in pea (*Pisumsativum L.*). *Indian J.Weed Sci.,* **30** : 145-148

Buriro, U.A., Oad, F.C., Agha, S.K. and Solangi, G.S. 2003.Post emergence weed control in wheat. *J. Appl. Sci.,* **3** : 424-427

Chopra, P. and Angiras, N.N. 2008.Influence of tillage and weed control methods on weeds, yield and yield attributes of maize (*Zea mays* L.). *Indian J. Weed Sci.,* **40** : 47-50

Das, T.K., Tuti, M.D., Sharma, R., Paul, T. and Mirija, P.R. 2012.Weed management research in India: An overview. *Indian J. Agron.,* **573** (3 IAC Special Issue) : 148-156

Dwivedi, S.K., Shrivastava, G.K., Singh, A.P. and Lakpale, R. 2012.Weeds and crop productivity of maize + blackgram intercropping system in Chhattisgarh plains. *Indian J. Weed Sci.,* **44**: 26-29

Garrison, A.J., Miller, A.D., Ryan, M.R., Roxburgh, S.H. and Shea, K. 2014.Stacked crop rotations exploit weed-weed competition for sustainable weed management. *Weed Sci.,* **62**:166-176

Gomez, K.A. and Gomez, A.A. 1984. Statistical Procedures for Agricultural Research. John Wiley and Sons, New York p. 680.

Hussain, Z., Munsif, F., Shah, S.I.A., Khan, G.B., Kakar, N., Siraj-ud-din and Ahmad, A. 2012.Assessment of weed problems in wheat crop of Peshawar (Pakistan). *Pakistan J. Weed Sci.,* **18**(3): 357-366

Jaccard, P. 1908.Nouvelles recherches sur la distribution floral. *Bull. de la Société vaudoise des Sci. Naturelles.,* **44**: 223-270

Kundra, H.C., Singh, G. and Brar, L.S. 1993.Nutrient uptake by pea (*Pisum sativum* L.) and associated weeds under different weed management practices. Integrated weed management for sustainable agriculture. *Proceedings of Indian Society of Weed Science International Symposium*, Hisar, India. (2) : 49-51

Mueller-Dombois, D. and Ellenberget, H. 1974.Aims and methods of vegetation ecology. John Wiley and Sons. p. 574

Odum, E.P. 1971.Fundamentals of Ecology (Saunders WP eds). Philadelphia. p. 574

Pielou, E.C. 1969.An introduction to mathematical ecology. Wiley Inter science. John Wiley and Sons, New York. p. 286

Rana, S.S. and Rana, M.C. 2013.Modern Concepts in Crop Production. Department of Agronomy, College of Agriculture, CSK Himachal Pradesh Krishi Vishvavidyalaya, Palampur, pp.144. (DOI: 10.13140/RG.2.2.18685.97769)

Shannon, C.E. and Weaver, W. 1963.The Mathematical Theory of Communication*.* University of Illinois Press Urbana. p. 19

Simpson, E.H. 1949. Measurement of diversity. *Nature,* **163**:688-694

Singh, B., Singh, C.M., Bhargava, M. and Sood, R.D. 1991.Integrated weed control in rainfed maize. *Himachal J.Agric. Res.,* **17**(1):1-2

Srivastava, R. and Singh, K.P. 2005.Integrated weed management studies in maize based intercropping system. *Indian J. Weed Sci.,* **37**(3&4) : 205-208