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# Weed floristic diversity in diversified cropping systems under mid-hill conditions of Himachal Pradesh

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**ABSTRACT**

The present study was carried out in a continuing experiment at the Bhadiarkhar farm of the CSK HPKV. Eight cropping systems were evaluated during 2016-17 for their effects on weed menace under mid hill conditions of Himachal Pradesh. There were 24 weed species, which invaded different cropping systems. During *Kharif*, *Ageratum* sp. (28%) *Cynodon dactylon* (20%) and *Commelina benghalensis* (19%) were the predominant weeds. In *Rabi*, *Phalaris minor* (63%) was the most dominating weed followed by *Coronopus didymus* (10%) and *Spergula arvensis* (6%). In traditional 'rice-wheat' system 14 species in *Rabi* and 8 in *Kharif* season were found associated and species richness varied with diversification of systems. In *Rabi*, the highest diversity of weed species was in rice-wheat system and in *Kharif* weed flora was more diverse in okra, turmeric and colocasia based systems and was lower in rice-based systems. During *Kharif*, *Cynodon dactylon* had the highest important value index (IVI) irrespective of the cropping system followed by *C. benghalensis*. *Monochoria vaginalis* was the important weed in rice-based cropping systems while *Ageratum* sp. was important in upland systems. *Ageratum* sp., *Polygonum* sp. and *C. dactylon* invaded the experimental field both during *Kharif* and *Rabi*. In *Rabi*, *P. minor* had the highest IVI in all the cropping systems.

Rice (*Oryza sativa* L.), wheat (*Triticum aestivum* L.), and maize (*Zea mays* L.) are the three main food crops in India, fundamental to national food security. Together these crops occupy 42.2% of the gross cropped area in India and contribute 85.7% to the total food grain production (Anonymous 2015). The crop productivity in India is low for rice (3.66 t/ha), maize (2.45 t/ha), and wheat (3.15 t/ha) as compared to their global averages of 4.53, 5.52 and 3.26 t/ha, respectively (Anonymous 2016).The mid-hill regions of Himachal Pradesh account for more than 41.01% of the cropped area of the state. The 'rice-wheat' cropping system is prevalent and occupies large area in these regions. Despite enormous growth of rice-wheat system, reports on stagnation in the productivity, with possible decline in production in future, have raised doubts on its sustainability (Ramanjaneyulu *et al.* 2006). Weeds are a major biological constraint that limits the production of rice by 10-100% and wheat by 10-60% (Yaduraju *et al.* 2015).Rotation composed of a diversity of crops with different life cycles is critical component of integrated weed management (Garrison *et al.* 2014). Cropping systems influence the crop productivity by altering the soil physical properties and changing the weed spectra in agricultural systems (Farooq and Nawaz 2014). Crop diversity can improve crop growth (Kirkegaard and Hunt 2010), thereby increasing crop competitiveness and tolerance to weeds (Anderson 2011). Therefore, an appraisal of weed floristic association in prominent crop sequences was done to have an effective strategic planning for weed management.

The present study was carried out in a continuing experiment at the Bhadiarkhar farm of the university. The experiment was started in *Kharif* 2014. The weed density was recorded in eight cropping sequences [$C_1$- 'rice – wheat', $C_2$- 'rice – pea – summer squash', $C_3$- 'okra – radish – onion', $C_4$- 'turmeric – pea – summer squash', $C_5$- 'rice – lettuce – potato', $C_6$- 'rice – palak – cucumber', $C_7$- 'rice – broccoli – radish', $C_8$- 'colocasia – pea + coriander'] during 2016-17 in RBD with four replications after 2 years. All the crops in different cropping systems were raised in accordance with recommended package of practices. The soil (0–15 cm) was acidic in reaction (pH 5.3), silty clay loam in texture, high in organic carbon (1.1%), medium in available N (362.4 kg/ha), very high in available P (73.6 kg/ha) and low in available K (115.2 kg/ha) at the initiation of the experiment (2014-15). The experimental field was under general 'rice–wheat' system prior to the commencement of the experiment.

Observations on species-wise weed count were taken at monthly interval at two representative locations within each plot using 25 x 25 cm quadrate. The mean weed count so obtained was converted into number per square metre by multiplying with factor 16. The data were subjected to statistical analysis using the techniques of analysis of variance as described by Gomez and Gomez (1984). Weed density data was square-root transformed ($\sqrt{x + 0.5}$) prior to analysis. The treatment differences were compared at 5 per cent level of significance. Important value index was used to determine the overall importance of each species in a cropping sequence. In calculating this index, the percentage values of the relative frequency [Total no. of occurrence of the species/no. of occurrence of all the species x 100], relative density [Total no. of individuals of the species/Number of individuals of all the species x 100] and relative abundance [Total number of individuals of a species in all quadrats/ Total no. of individuals of all species in all quadrats x 100] were summed up together and the value was designated as IVI of the species.

**Weed flora association**

During *Kharif*, the total weed count was maximum in September in okra, turmeric and colocasia, but in rice it was fairly uniform throughout the season probably due to standing water (**Figure 1**). Weed count in rice-based cropping systems varied from 80 to 200/m$^2$ but in other cropping systems it was higher than 200/m$^2$ at all the observations.It varied from 200 to 650/m$^2$. *Ageratum* sp. was the most dominant weed in *Kharif,* contributing 28% to total weed flora. *Cynodon dactylon* and *Commelina benghalensis* were next in dominance constituting 20% and 19% of total weed flora, respectively. *Brassica* sp., *Monochoria vaginalis*, *Cyperus* sp. and other weeds constituted 11, 10, 6 and 6% of total *Kharif* weed flora. *Brassica* sp., *Fimbristylis* sp., *Artimisia argyi* and *Trifolium repens* were observed for some time in the season. *Polygonum alatum*, *Scirpus juncoides*, *Eleocharis* sp., *C.benghalensis* and *Phyllanthus niruri* had sporadic appearance.

In *Rabi*, total weed count was maximum in December under most of systems, which decreased progressively due to imposition of hand weeding by mid-January (**Figure1**). From January onwards, densities of total weeds ranged from 0 to 300/m$^2$ in different systems. In *Rabi*, *P.minor* was the most dominating weed contributing 63% to total weed flora. *C. didymus* (10%), *S.rvensis* (6%), *Ageratum* sp. (4%), *T. repens* (3%), *C.dactylon* (3%), *Polygonum* sp. (4%) and other weeds (7%) were also observed. *Lathyrus aphaca*, *Ageratum* sp., *C. dactylon*, *Polygonum hydropiper*, *C. didymus*, *P. minor*, *S. rvensis*, *V. sativa*, *P. alatum*, *T. repens* were prevalent throughout the *Rabi* season. *Bidens pilosa* and *A. ludoviciana* have shown their occurrence at termination of the season. *Artimisia argyi*, *Anagallis arvensis* and *Stellaria media* were noticed on some of the observations.

**Weed diversity indices**

**Shannon weir index:** There were 24 weed species found growing in different cropping systems. Such a higher diversity in maize based cropping systems was also reported by Suresha *et al.* (2015). In traditional 'rice-wheat' system 14 species in *Rabi* and 8 in *Kharif* season were found associated. 11 to 12 weed species were common in traditional 'rice-wheat' system and the alternative cropping systems in *Rabi*. Whereas, 7 to 8 weed species were common in the traditional and new cropping systems in *Kharif*. In *Rabi*, only one weed species was different in 'turmeric – pea – summer squash' and 'rice – broccoli – radish' compared to traditional 'rice –

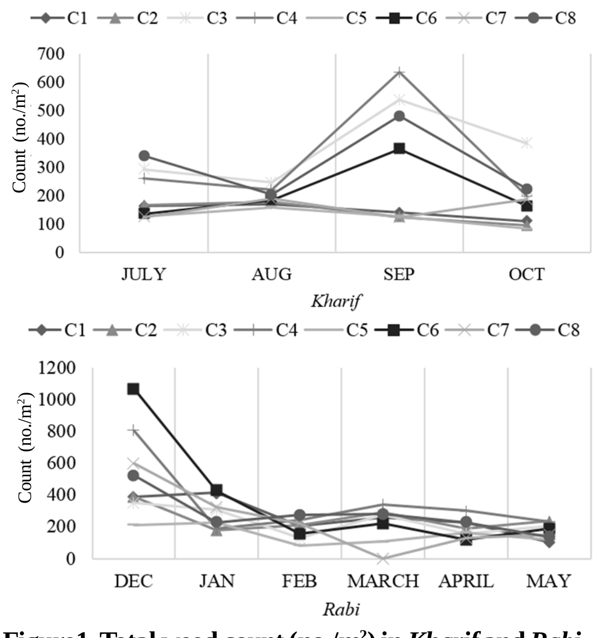


**Figure1. Total weed count (no./m$^2$) in *Kharif* and *Rabi***

wheat' system. Whereas, in *Kharif* the variation was more and 1 to 3 weed species were different from 'rice – wheat' system in new cropping systems.

With diversification of rice-based cropping system, variation in infestation of weed flora occurred **(Table 1**). In *Rabi*, *A. arvensis* was new in 'turmeric – pea – summer squash' and *B. pilosa* in 'rice – broccoli – radish'. In *Kharif*, *Scirpus juncoides* in 'rice – pea – summer squash', *Polygonum alatum*, *T.repens* and *Fimbristylis* sp. in 'okra – radish - onion' and 'turmeric – pea – summer squash', *Eleocharissp.* in 'rice – palak – cucumber', *P. alatum* and *T. repens* in 'rice – broccoli – radish' and 'colocasia – pea + coriander' and *P. niruri* in 'colocasia – pea + coriander' were the species that were absent in traditional 'rice-wheat' system but were present in the mentioned (new) systems. From the same location in maize based cropping systems, Suresha *et al.* (2015) have also reported similar effect of cropping systems on weed floristic association.

**Table 1. Cropping systems influence on shannon weir index of *Kharif* and *Rabi* weeds**

| Cropping system | No. of weed species common as $C_1$ | | No. of weed species present in new system but absent in $C_1$ | |
|---|---|---|---|---|
| | *Rabi* | *Kharif* | *Rabi* | *Kharif* |
| $C_1$ Rice – wheat | 14 | 8 | - | - |
| $C_2$ Rice – pea – summer squash | 11 | 8 | 0 | 1 |
| $C_3$ Okra – radish - onion | 11 | 7 | 0 | 3 |
| $C_4$ Turmeric – pea – summer squash | 12 | 7 | 1 | 3 |
| $C_5$ Rice – lettuce – potato | 12 | 7 | 0 | 0 |
| $C_6$ Rice – palak – cucumber | 12 | 8 | 0 | 1 |
| $C_7$ Rice – broccoli – radish | 12 | 7 | 1 | 2 |
| $C_8$ Colocasia – pea + coriander | 11 | 7 | 0 | 3 |

During *Kharif*, *C. dactylon* was most important weed having high important value index (IVI) irrespective of the cropping system followed by *C. benghalensis*. *M. vaginalis* was the important weed in rice-based cropping systems while *Ageratum* sp. was important in other cropping systems having higher IVI (**Table 2**). *Brassica* sp., *C. benghalensis, Cyprus* sp. and *P. hydropiper* were the other important weeds having higher important value index in *Kharif*. Guleria *et al.* (2018) also reported all these weeds as more aggressive in rice in the rice – wheat cropping system.

Some of the weeds like *Ageratum* sp., *Polygonum* sp. and *C. dactylon* those invaded the experimental field during *Kharif* were also present during *Rabi* **Table 2** and **3**. Suresha *et al.* (2015) also found *Ageratum houstonianum*, *A. conyzoides*, *Polygonum* sp. and *Galinsoga parviflora* invading maize based systems both during *Kharif* and *Rabi*. In *Rabi*, *P. minor* had the highest IVI in all the cropping systems. *C. didymus*, *Spergulla arvensis* and *T. repens* were other important weeds having higher IVI (**Table 3**).

### Effect of cropping systems

Cropping sequences gave significant variation in the count of *M. vaginalis* (**Table 4**). *Monochoria* sp. was found growing in rice-based cropping systems only and all were comparable to each other in influencing the population of this weed. It was absent in okra (okra-radish-onion), turmeric (turmeric-pea-summer squash) and colocasia (colocasia-pea+coriander). *Ageratum* sp., a weed of upland situations was significantly higher under 'okra-radish-onion', 'colocasia-pea+coriander' and 'turmeric-pea-summer squash' cropping systems,

**Table 2. IVI (important value index) of weed species in *Kharif***

| Weed species | Rice – wheat | Rice – pea – summer squash | Okra – radish – onion | Turmeric – pea – summer squash | Rice – lettuce – potato | Rice – palak – cucumber | Rice – broccoli – radish | Colocasia – pea + coriander |
|---|---|---|---|---|---|---|---|---|
| *Cyprus* sp. | 28.4 | 26.9 | 27.4 | 22.7 | 15.5 | 26.6 | 10.1 | 24.6 |
| *Polygonum alatum* | 0.0 | 0.0 | 7.2 | 7.3 | 0.0 | 0.0 | 4.7 | 6.1 |
| *Trifolium repens* | 0.0 | 0.0 | 6.7 | 6.8 | 0.0 | 0.0 | 4.7 | 7.2 |
| *Fimbristylis* sp. | 0.0 | 0.0 | 4.4 | 12.8 | 0.0 | 0.0 | 0.00 | 0.0 |
| *Monochoria vaginalis* | 62.1 | 76.3 | 0.0 | 0.0 | 70.5 | 43.8 | 57.6 | 0.0 |
| *Polygonum hydropiper* | 8.6 | 14.8 | 5.6 | 6.8 | 18.2 | 7.9 | 17.7 | 10.9 |
| *Ageratum* sp. | 30.3 | 8.6 | 102.2 | 88.1 | 18.2 | 12.4 | 55.1 | 105.1 |
| *Cynodon dactylon* | 57.9 | 51.0 | 49.9 | 57.1 | 95.9 | 50.9 | 65.3 | 49.0 |
| *Echinochloa* sp. | 5.2 | 7.0 | 5.6 | 10.7 | 0.0 | 7.5 | 0.00 | 13.1 |
| *Brassica* sp. | 55.1 | 61.9 | 32.0 | 25.4 | 28.9 | 48.0 | 47.5 | 27.0 |
| *Commelinabenghalensis* | 52.2 | 47.9 | 59.1 | 62.3 | 52.8 | 99.2 | 37.2 | 51.3 |
| *Scirpus juncoides* | 0.0 | 5.5 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| *Eleocharis* sp. | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 3.7 | 0.0 | 0.0 |
| *Phyllanthus niruri* | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 5.7 |

where upland crops *viz*. okra, colocasia and turmeric, respectively had occupied the land.

There was significant variation in the count of *Cyperus* sp. (*C. iria*, *C. difformis* and *C. esculentus*) due to cropping systems. 'Rice – broccoli – radish' remaining at par with 'rice – lettuce – potato' had significantly lower count of *Cyperus* sp. as compared to other cropping systems. Farooq and Nawaz (2014) had also reported significant influence of cropping systems in changing the weed spectra in agricultural systems.

Cropping systems also brought about significant variation in the count of *P. alatum,* but the weed had very low intensity. The weed was found only in upland cropping systems where okra, turmeric and colocasia were grown. It was absent in rice. *Fimbristylis* sp. count was also affected significantly due to cropping systems but the weed was present in low intensity. The population of the weed was significantly higher in 'rice – palak – cucumber' cropping system. But this cropping system was at par with 'rice – pea – summer squash' and 'turmeric – pea – summer squash' cropping systems. The population of *T. repens*, *P. hydropiper*, *C. dactylon*, *Echinochloa* sp., *Brassica* sp. and *C.benghalensis* was not significantly influenced due to cropping systems probably owing to their sporadic occurrence.

*Phalaris minor* was the most troublesome weed in *Rabi* and cropping systems brought about significant variation in its count. The count of *P. minor* was significantly higher in 'rice – palak – cucumber' and 'turmeric – pea – summer squash' and was lowest in okra – radish – onion (**Table 5**). *S. media* had low population but was significantly affected due to cropping systems. Its population was higher in upland rotations in contrast to the lowland where rice was cultivated during *Kharif* under

**Table 3. IVI (important value index) of weed species in *Rabi***

| Weed species | Rice – wheat | Rice – pea – summer squash | Okra – radish – onion | Turmeric – pea – summer squash | Rice – lettuce – potato | Rice – palak – cucumber | Rice – broccoli – radish | Colocasia – pea + coriander |
|---|---|---|---|---|---|---|---|---|
| *Phalaris minor* | 110.7 | 107.7 | 60.5 | 151.1 | 109.3 | 168.5 | 153.0 | 102.7 |
| *Stellaria media* | 6.4 | 0.0 | 7.6 | 14.0 | 4.4 | 3.2 | 3.6 | 9.0 |
| *Spergulla arvensis* | 29.1 | 32.5 | 47.5 | 10.8 | 18.7 | 11.8 | 17.4 | 28.0 |
| *Polygonum alatum* | 12.4 | 17.6 | 20.0 | 8.2 | 21.5 | 7.4 | 10.0 | 14.1 |
| *Trifolium repens* | 14.9 | 17.0 | 22.7 | 17.9 | 11.8 | 20.4 | 10.0 | 27.1 |
| *Coronopus didymus* | 16.7 | 48.1 | 52.8 | 26.5 | 42.4 | 27.0 | 20.8 | 52.7 |
| *Vicia sativa* | 43.5 | 19.1 | 14.7 | 12.0 | 18.5 | 8.9 | 6.9 | 21.4 |
| *Polygonum hydropiper* | 15.6 | 14.7 | 10.7 | 10.5 | 17.1 | 6.1 | 10.0 | 14.7 |
| *Ageratum* sp. | 3.9 | 13.8 | 40.3 | 18.6 | 11.7 | 24.6 | 28.0 | 9.7 |
| *Cynodon dactylon* | 5.5 | 17.9 | 17.4 | 20.9 | 25.4 | 14.8 | 19.6 | 10.6 |
| *Lathyrus aphaca* | 9.7 | 4.5 | 5.8 | 3.2 | 12.0 | 4.2 | 3.6 | 9.9 |
| *Artemisia argyi* | 14.1 | 7.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| *Anagallis arvensis* | 0.0 | 0.0 | 0.0 | 3.2 | 0.0 | 0.0 | 0.0 | 0.0 |
| *Commelina benghalensis* | 3.1 | 0.0 | 0.0 | 3.2 | 0.0 | 3.2 | 0.0 | 0.0 |
| *Avena ludoviciana* | 14.5 | 0.0 | 0.0 | 0.0 | 7.3 | 0.0 | 10.8 | 0.0 |
| *Bidens pilosa* | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 6.2 | 0.0 |

**Table 4. Species-wise mean count (no./$m^2$) of weeds in *Kharif*.**

| Cropping system | *Cyprus sp.* | *Polygonum alatum* | *Trifolium repens* | *Fimbristylis* sp. | *Monochoria vaginalis* | *Polygonum hydropiper* | *Ageratum* sp. | *Cynodon dactylon* | *Echinochloa* sp. | *Brassica* sp. | *Commelina benghalensis* |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Rice – wheat | 2.8(7) | 0.7(0) | 0.7(0) | 0.7(0) | 4.8(24) | 1.2(1) | 2.3(8) | 4.6(21) | 0.9(0) | 4.5(20) | 4.0(17) |
| Rice – pea – summer squash | 3.7(15) | 0.7(0) | 1.5(3) | 1.8(3) | 5.7(33) | 2.0(4) | 2.9(9) | 4.7(23) | 1.0(1) | 4.8(23) | 3.4(13) |
| Okra – radish - onion | 3.9(17) | 1.3(2) | 1.3(1) | 1.0(1) | 0.7(0) | 1.1(1) | 10.7(115) | 6.1(38) | 1.1(1) | 4.3(20) | 6.4(49) |
| Turmeric – pea – summer squash | 3.3(11) | 1.4(2) | 1.1(1) | 1.4(3) | 0.7(0) | 1.1(1) | 9.2(87) | 6.7(45) | 1.7(3) | 3.5(14) | 6.7(51) |
| Rice – lettuce – potato | 1.6(2) | 0.7(0) | 0.7(0) | 0.7(0) | 4.7(22) | 1.5(3) | 1.6(3) | 5.8(34) | 0.7(0) | 2.4(6) | 3.5(13) |
| Rice – palak – cucumber | 4.1(18) | 0.7(0) | 1.5(2) | 2.2(5) | 4.7(23) | 1.2(1) | 3.4(12) | 5.4(29) | 1.3(1) | 5.1(26) | 6.9(54) |
| Rice – broccoli – radish | 1.3(1) | 0.9(0) | 0.9(0) | 0.7(0) | 4.8(23) | 1.9(4) | 3.7(21) | 5.2(26) | 0.7(0) | 3.3(17) | 2.9(12) |
| Colocasia – pea + coriander | 3.4(12) | 1.1(1) | 1.3(1) | 0.7(0) | 0.7(0) | 1.5(2) | 10.0(102) | 5.7(34) | 2.0(4) | 2.9(13) | 5.9(37) |
| LSD (p=0.05) | 1.5 | 0.5 | NS | 1.0 | 1.0 | NS | 2.8 | NS | NS | NS | NS |

*Figures in the parentheses are the means of original values. Data transformed to square root transformation ($\sqrt{x+0.5}$)

**Table 5. Species-wise mean count (no./m$^2$) of weeds in *Rabi***

| Cropping system | *Phalaris minor* | *Stellaria media* | *Spergula arvensis* | *Trifolium repens* | *Coronopus didymus* | *Vicia sativa* | *Ageratum* sp. | *Cynodon dactylon* | *Lathyrus aphaca* | *Artemisia argyi* | *Anagallis arvensis* | *Avena ludoviciana* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Rice – wheat | 12.4(155) | 1.1(1) | 4.3(23) | 2.8(7) | 2.3(7) | 6.2(40) | 1.0(1) | 1.2(1) | 1.7(4) | 2.4(7) | 0.7(0) | 2.5(7) |
| Rice – pea – summer squash | 11.6(135) | 0.7(0) | 4.4(24) | 2.8(8) | 6.3(44) | 3.0(9) | 2.3(6) | 2.7(8) | 1.0(1) | 1.0(1) | 0.7(0) | 0.7(0) |
| Okra – radish - onion | 7.7(62) | 1.5(2) | 6.4(44) | 3.6(13) | 7.1(51) | 2.6(7) | 5.8(34) | 3.0(9) | 1.3(1) | 0.7(0) | 0.7(0) | 0.7(0) |
| Turmeric – pea – summer squash | 16.4(272) | 2.6(7) | 1.9(5) | 3.0(9) | 4.4(19) | 2.3(5) | 3.3(12) | 3.5(14) | 0.9(0) | 0.7(0) | 0.9(0) | 0.7(0) |
| Rice – lettuce – potato | 9.2(84) | 0.9(0) | 2.4(6) | 1.8(3) | 4.5(22) | 2.4(6) | 1.1(1) | 3.3(11) | 1.8(3) | 0.7(0) | 0.7(0) | 1.1(1) |
| Rice – palak – cucumber | 17.3(303) | 0.9(0) | 2.0(5) | 3.4(11) | 3.9(16) | 1.7(3) | 4.0(16) | 2.5(7) | 1.0(1) | 0.7(0) | 0.7(0) | 0.7(0) |
| Rice – broccoli – radish | 13.5(186) | 0.9(0) | 2.4(7) | 1.7(3) | 2.7(7) | 1.3(1) | 3.7(16) | 2.7(9) | 0.9(0) | 0.7(0) | 0.7(0) | 1.7(3) |
| Colocasia – pea + coriander | 12.0(145) | 1.7(3) | 4.3(22) | 4.5(20) | 6.7(54) | 3.4(12) | 1.8(3) | 1.3(2) | 2.0(4) | 0.7(0) | 0.7(0) | 0.7(0) |
| LSD (p=0.05) | 2.7 | 1.0 | 2.0 | 0.8 | 2.0 | 1.3 | 1.7 | NS | NS | 0.7 | NS | 0.9 |

Figures in the parentheses are the means of original values. Data transformed to square root transformation ($\sqrt{x+0.5}$)

submergence. The highest population of *S. arvensis* was recorded in 'okra – radish – onion'. Significantly lower population of Trifolium repens was recorded in 'rice – lettuce – potato' and 'rice – broccoli – radish'. All the new cropping systems resulted in significantly lower population of *V. sativa* as compared to conventional 'rice – wheat' cropping system. 'Rice – broccoli – radish' remaining at par with 'rice – palak – cucumber', 'turmeric – peas – summer squash' and 'rice – lettuce – potato' resulted in significantly lower count of *V. sativa*. There was significant variation in the count of *Ageratum* sp. due to cropping systems. But in the 'rice – wheat' system there was invasion of *Artimissia arzvi* and *A. ludoviciana* significantly higher than all the new cropping systems.

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