International Journal of Chemical Studies

P-ISSN: 2349–8528
E-ISSN: 2321–4902
IJCS 2019; SP6: 677-683

RS Pan
ICAR-Research Complex for Eastern Region, FSRCHPR, Ranchi, Jharkhand, India

Pradip Kumar Sarkar
ICAR-Research Complex for Eastern Region, FSRCHPR, Ranchi, Jharkhand, India

Reshma Shinde
ICAR-Research Complex for Eastern Region, FSRCHPR, Ranchi, Jharkhand, India

Rakesh Kumar
ICAR-Research Complex for Eastern Region, Patna, Bihar, India

JS Mishra
ICAR-Research Complex for Eastern Region, Patna, Bihar, India

AK Singh
ICAR-Research Complex for Eastern Region, FSRCHPR, Ranchi, Jharkhand, India

BP Bhatt
ICAR-Research Complex for Eastern Region, Patna, Bihar, India

Corresponding Author:
RS Pan
ICAR-Research Complex for Eastern Region, FSRCHPR, Ranchi, Jharkhand, India

(Special Issue -6)
3rd National Conference
On
PROMOTING & REINVIGORATING AGRI-HORTI, TECHNOLOGICAL INNOVATIONS [PRAGATI-2019]
(14-15 December, 2019)

Effect of diversified cropping system on weed phytosociology

RS Pan, Pradip Kumar Sarkar, Reshma Shinde, Rakesh Kumar, JS Mishra, AK Singh and BP Bhatt

Abstract
The crops like Rice, Finger millet, Black gram and Horse gram were grown as sole crops and as mixed crops in all four paired combinations in 1:1 ratio (*i.e.,* Rice + Black gram, Rice + Horse gram, Finger millet + Black gram and Finger millet + Horse gram) as treatments to estimate the effects on weed biomass and diversity and on systems' effectiveness. The study showed that, there were significant differences between different treatments in respect of total grain yield of target crops and weed diversity parameters. Significantly higher grain yield in cropping system was recorded in Finger millet (3.72 t ha^{-1}) as sole crop followed by Finger millet + Black gram (3.11 t ha^{-1}) and Finger millet + Horse gram (3.11 t ha^{-1}) as mixed crop and the lowest grain yield was recorded in Rice (1.30 t ha^{-1}) as sole crop. Compared to sole crops, weed biomass was significantly reduced by mixed crops of Finger millet + Black gram (0.20 t ha^{-1}) and Finger millet + Horse gram (0.30 t ha^{-1}). The correlation between total grain yield of cultivated crop and dry weed biomass (R= -0.860) or species richness (R= -0.319) or basal area of weeds (R = -0.518) or weed density (R= -0.567) and between Rice equivalent yield of different cropping systems and associated dry weed biomass (R= -0.468) showed that mixed cropping systems have higher natural capacity to control weeds. Among all the treatments, Finger millet + Black gram was found to be the best followed by Finger millet + Horse gram cropping system for controlling weed biomass and diversity, both naturally and biologically.

Keywords: Conventional practices, cropping system, yield, weed biomass and diversity

Introduction
In general, weeds that are associated with crops are exposed to many disruptive factors *viz.*, climate, soil, topography, *etc.*, which make their populations variable and dynamic nature over time (Booth *et al.* 2003) [4]. In case of responses to these causes of change, not all the species in an agricultural system are equally important but with differences in frequency, density, and growth habit making some species the principal ones which generate economic yield (Pitelli 2000) [22], which warrants detailed studies in predominant cropping systems. One of the more utilized methods for the analysis of weed communities in cropping systems is the phytosociological study (Ige *et al.* 2008) [16]. A quantitative phytosociological study of a weed community in a defined area and time provides a momentary analysis of the plant composition, providing a tool that supplies various inferences for a plant community (Ferriol & Merle 2006; Pandey *et al.* 2011) [8, 21], which can be approached with the description of their characteristics by employing tools such as similarity and diversity indices that clarify their performance.
Ever since man began cultivating plants, he has to fight with weeds competing with crops for space, water, mineral nutrients and sunlight.

The concept of weeds as unwanted plants was born when man started to deliberately grow plants for food (Shah *et al.* 2006) [23] and the weeds started competing with crop plants for light, water and nutrients (Wang *et al.* 2007) [29], thereby reducing yields and quality of produce. All of these ultimately end up with high monetary expenses on agronomic practices by the farmers (Abbasi *et al.* 2013) [1]. In the meantime, weeds also act as a good shelter to many detrimental pests and diseases of the crops. Therefore, weed control is must to reduce cumulative negative impacts on yields of target crops. Hence, weed control during first four weeks is very critical in many vegetable crops (Holm 1956) [15]. Marana *et al.* (1983) [17] had reported the critical period of weed competition to be as 30-40 days after sowing, otherwise their presence during that period or ahead may lead to reduced fruit yield by 70% depending on stage and duration of competition (Govindra *et al.* 1986) [13].

There is therefore a need for an effective weed crop management which includes cultural, biological, mechanical and chemical control. Among all, the management through chemicals or herbicide may lead to increase in the rate of toxification in soil as well as in plants, animals and human. In addition, herbicide use requires particular equipment and expertise to be sure that proper rates are used and that human health and safety are protected (Carballido *et al.* 2013) [5]. The other means of management like mechanical one are tedious, laborious, time taking and costlier. Furthermore, Cultural practices such as hoeing and mulching is a well acknowledged and effective non-chemical weed control approach. In mulching, soil surface is covered with different materials including shredded plant materials, pebbles, plastic sheets and paper (Moreno *et al.* 2011) [18] which restrict weed germination by blocking sunlight and access to atmospheric oxygen for germinating weed seeds (Fontanelli *et al.* 2013) [9]. Therefore, cultural practices along with biological control of weeds may have high impacts in improving yield of grain of crop interest and reducing the rate of weed biomass and diversity.

For such an integrated approach in controlling weeds to be visible, accurate information on the systematics of weeds, their frequency, density, growth habit, phenology (Ghersa & Holt 1995) [11] and weed crop relationships are pre-requisite. But very few information on weeds, especially in Eastern Plateau and Hill Region, is available. Because of limited recommendations available for weed managements in different conventional land use systems of this region, this study was designed for the development of an integrated weed control strategy through biological means by selecting different crop combinations. The main objective include dhow naturally the weeds can be managed through conventionally practiced system's effectiveness and efficiency without compromising the yield of interest.

Material and methods

The experiment was conducted during 2016-2018 at research farm of ICAR Research Complex for Eastern Region, Research Centre, Plandu, Ranchi (the capital of Jharkhand state) in Eastern Plateau and Hill Region (EPHR) of India, in a randomized block design with three replications in 2017, to study the effect of selected different conventional land-use systems on phytosociology of weeds and yield of the crops of respective systems. In this study, diversified cropping systems as treatments (Table 1) had been compared to know the effects of different treatments on weeds phytosociology under rainfed upland situations. The phytosociological history of weeds (at different stages of development of crop) considering a fixed time intervals was recorded at 30 days after sowing (Marana *et al.* 1983; Govindra *et al.* 1986) [17, 13] from centre of the plot by using quadrat method. In this, quadrats of size 1m X 1m were laid out to study the weed diversity parameters (Nkoa *et al.* 2015; Ahmad *et al.* 2016; Tikariha *et al.* 2016; Sinha & Banerjee 2016) [19, 2, 28, 26]. A wooden scale was used to measure the length or height of the weeds and a vernier calliper was used to measure the basal diameter of the weeds. The weed identification was done by fellows/experts of this institution and other institutions/ organizations as and when required. The number of weeds including specific number of each species was recorded from each replicated quadrats and the fresh weed biomass thus obtained were oven dried to estimate dry weed biomass. The total grain yield of the crops of respective cropping systems were also recorded and compared with to study the effect of weed infestation and to draw their correlation or relationship pattern. The average value of all the data of two years (2016-17 and 2017-18) was calculated and tabulated accordingly to reduce any error.

Data collected including crop yield and ecological parameters of weeds viz., frequency, density, diversity indices and Importance Value Index (IVI) were analyzed following Curtis and McIntosh (1950) [6] and by using Systat-12 software (Wilkinson & Coward 2007) [31], first for normalization and assumption of homoscedasticity, computation of descriptive statistics (mean, standard deviation, standard error and critical difference) and computation of ANOVA to test the significant difference. Upon significant results, correlation coefficients were also estimated to compare and to identify the significant effect of different conventional land-use systems or the crop combinations on weed biomass and diversity.

Results and discussions

The average crop yield and weed diversity under different land-use systems were enumerated and tabulated in Table 1. Significantly higher grain yield of crop was recorded in case of Finger millet (3.72 t ha^{-1}) followed by Finger millet + Black gram (3.11 t ha^{-1}) and Finger millet + Horse gram (3.11 t ha^{-1}), Horse gram (2.37 t ha^{-1}), Rice + Horse gram (2.13 t ha^{-1}), Black gram (1.93 t ha^{-1}), Rice + Black gram (1.72 t ha^{-1}) and the lowest grain yield was recorded in Rice (1.30 t ha^{-1}). Similar effect of weeds on yield of different crop combinations or cropping systems in case of intercrops like Lettuce, Favabean and Pea was reported by Sharaiha & Gliessman (1992) [24]. The results were also in accordance with the results of Smith *et al.* (2008) [27] who reported that yields of winter wheat did not get affected by weeds under diversified cropping systems included in the rotation but the yields of the same crop got reduced in monocultures. The reduction in yield of sole crop compared to mixed crop could be attributed to differences in light penetration through crop canopy (Sharaiha & Haddad 1985) [25] and also attributed to decrease in competitive effects due to distance between competing plants (Weiner 1982) [30]. Gohil (2010) [12] stated that, the innumerable weeds grow in the fields of cultivated crops which are a serious problem as they compete with neighbouring crops or plants of economic importance and reduce their yield. Moreover, increased weed diversity may have a positive impact on the functioning of agro-ecosystems (Norris & Kogan 2005; Franke *et al.* 2009) [20, 10].

While comparing the weed biomass and diversity, the species richness was significantly higher (ranging from 14.33 to 16.67) in case of sole crop than crop combinations (ranging from 8.00 to 10.00). But when compared within the sole crop and within crop combinations in mixed cropping, there was no significant difference. In total, 33 species of weeds had been identified and recorded. The maximum weed density was recorded in Rice plot (2313333.33 ha^{-1}) and the lowest was recorded in Finger millet + Black gram (813333.33 ha^{-1}) followed by Finger millet + Horse gram (816666.67 ha^{-1}). In case of basal area of weeds, it was found significantly higher in Black gram (2.88 m^2 ha^{-1}) and lowest in Finger millet + Black gram (0.83 m^2 ha^{-1}). The Shannon's diversity index value of weeds was found to be comparatively and significantly higher at Horse gram plot (0.99) and significantly lower in case of Finger millet + Horse gram (0.73) and Finger millet + Black gram (0.74). Among all the treatments, Rice plot constituted significantly higher dry weed biomass as 1.34 t ha^{-1} and significantly lower dry weed biomass were recorded in Finger millet + Black gram (0.20 t ha^{-1}) and Finger millet + Horse gram (0.30 t ha^{-1}) among mixed cropping and Finger millet (0.27 t ha^{-1}) among solo or mono cropping systems. The weed diversity parameters *viz.*, biomass and diversity are better controlled/reduced by mixed crop than sole crop and the result agrees with the other studies related to intercropping (Sharaiha & Gliessman 1992) [24]. The conventional farming systems show substantial variation in their relative influence on weed species diversity and community composition (Bàrberi *et al.* 1997; Doucet *et al.* 1999; Hald 1999) [3, 7, 14].

Jaccard's index (β-diversity) was computed with the view to decipher the trends of species turnover in the different weed-crop associations. The results presented in Table 2 revealed that comparatively higher value of β-diversity (83.33%) with respect to weed species composition was recorded between Black gram and Rice plot, followed by Finger millet + Horse gram and Rice + Black gram (72.73%) and Finger millet and Rice plot (72.22%). The lowest level of similarity (34.61%) was recorded between Finger millet + Horse gram and Finger millet + Black gram plot (Table 2).

The Importance Value Index (IVI) indicates the population structure of species since it takes into account collectively the structural parameters such as relative density, basal area and frequency of the species (Curtis & McIntosh 1950) [6]. The results obtained are presented in Table 3. In most of the treatments (*viz.*, Rice, Rice + Black gram and Rice + Horse gram plot), the weed '*Brachiaria deflexa*' was found to be the dominant species. On the other hand, *Dactyloctenium aegyptium* weed was found dominant in Black gram plot, *Alternanthera sessilis* weed in Finger millet and Finger millet + Black gram plot, *Cyperus rotundus* weed in Horse gram plot and *Spilanthes paniculata* was found to be dominant in Finger millet + Horse gram plot. In total, 33 different species had been identified and their distribution to their respective cropping systems had been mentioned in Table 4.

The correlation or the degree of association between weeds and its associated crops is an important statistical indicator which ultimately depicts the actual picture of the component systems as a whole in respect to their competitiveness and performances (Sharaiha & Gliessman 1992; Nkoa *et al.* 2015; Ahmad *et al.* 2016; Sinha & Banerjee 2016) [24, 19, 2, 26]. The correlation between total grain yield of cultivated crop and dry weed biomass was estimated (Fig. 1) and found that they were negatively correlated (R= -0.860). It was also revealed that in Finger millet + Black gram (as mixed crop) and Finger millet (as sole crop) had capacity to control maximum dry weed biomass. Hence, the degree of associations and their relative measure of dry weed biomass and total grain yields in crop of interest depend upon the crop combinations those were selected. While comparing the relationship between the total grain yield of cultivated crop and the species richness of associated weeds (Fig. 2), these were also negatively correlated (R= -0.319). That means the degree of associations with respect to species richness to that of target crop was very less and showed comparatively lesser control than dry weed biomass. The highest control over the species richness of weeds was found in case of the treatment Finger millet + Black gram. There was also a negative correlation (R = -0.518) between total grain yield of cultivated crops and basal area of weeds (Fig. 3). That means, the basal area of weeds was highly being controlled in the treatments like Finger millet + Black gram and Finger millet + Horse gram. The total grain yield of cultivated crop was also found to be negatively correlated (R= - 0.703) with the weed density (Fig. 4). The weed density was highly being controlled in both the treatments like Finger millet + Black gram and Finger millet + Horse gram. Also, there was a negative correlation (R= -0.567) between the Shannon's diversity index of weed and the cropping systems (Fig. 5). While estimating the degree of association between Rice equivalent yield of different cropping systems and associated dry weed biomass, there was also a negative correlation (R= - 0.468) between them (Fig. 6). The control on dry weed biomass was found to be comparatively and significantly higher in case of Finger millet + Black gram followed by Finger millet + Horse gram.

Table 1: Average crop yield and weed diversity under different cropping systems

Treatments	Crop components		Total grain yield (t ha^{-1})	Weed diversity parameters				
	Description	Symbol		Species richness	Density (individuals ha^{-1})	Basal area (m^2 ha^{-1})	Shannon's Index	Dry biomass (t ha^{-1})
T-1	Rice	R	1.30^{f}	16.67^{a}	2313333.33^{a}	2.41^{ab}	0.96^{ab}	1.34^{a}
T-2	Finger millet (Ragi)	FM	3.72^{a}	14.33^{a}	1663333.33^{c}	1.72^{abc}	0.87^{abc}	0.27^{d}
T-3	Black gram	BG	1.93^{de}	16.00^{a}	2256666.67^{ab}	2.88^{a}	0.95^{ab}	0.77^{b}
T-4	Horse gram	HG	2.37^{c}	14.33^{a}	1816666.67^{abc}	2.43^{ab}	0.99^{a}	0.56^{c}
T-5	Rice + black gram	R + BG	1.72^{e}	9.33^{b}	1750000.00^{bc}	1.40^{bc}	0.85^{bcd}	0.56^{c}
T-6	Rice + Horse gram	R+ HG	2.13^{cd}	10.00^{b}	1800000.00^{bc}	1.40^{bc}	0.86^{abc}	0.87^{b}
T-7	Finger millet + black gram	FM + BG	3.11^{b}	8.00^{b}	813333.33^{d}	0.83^{c}	0.74^{cd}	0.20^{d}
T-8	Finger millet + Horse gram	FM + HG	3.11^{b}	9.67^{b}	816666.67^{d}	0.86^{c}	0.73^{d}	0.30^{d}
SE(m)±			0.13	1.06	167073.91	0.40	0.04	0.05
CD (0.05%)			0.39	3.25	511676.48	1.24	0.13	0.15

Values having different superscripts within rows are significantly different at $p \leq 0.05$.

Table 2: Jaccard's index (β-diversity in %) between different cropping systems

Rice- legume systems	R	FM	BG	HG	R + BG	R+ HG	FM + BG	FM + HG
R	-	72.22	83.33	63.15	57.14	54.29	51.52	54.29
FM		-	66.67	67.65	56.67	50.00	51.72	41.18
BG			-	71.43	51.52	67.74	45.45	41.67
HG				-	42.42	45.45	46.67	41.18
R + BG					-	58.33	54.55	72.73
R + HG						-	50.00	52.94
FM + BG							-	34.61
FM + HG								-

Table 3: Importance Value Index (IVI) of five dominant weeds of associated cropping systems

	Importance Value Index of five dominant weeds of associated cropping systems							
S. N.	**R**	**FM**	**BG**	**HG**	**R + BG**	**R+ HG**	**FM + BG**	**FM + HG**
1	*Brachiaria deflexa* (33.96)	*Alternanthera sessilis* (42.27)	*Dactyloctenium aegyptium* (40.57)	*Cyperus rotundus* (43.98)	*Brachiaria deflexa* (53.08)	*Brachiaria deflexa* (47.60)	*Alternanthera sessilis* (44.96)	*Spilanthes paniculata* (50.54)
2	*Dactyloctenium aegyptium* (29.95)	*Dactyloctenium aegyptium* (40.18)	*Brachiaria deflexa* (32.33)	*Brachiaria deflexa* (38.75)	*Spilanthes paniculata* (43.46)	*Alternanthera sessilis* (34.23)	*Cynodon dactylon* (38.20)	*Alternanthera sessilis* (39.35)
3	*Alternanthera sessilis* (29.40)	*Ageratum conyzoides* (28.24)	*Alternanthera sessilis* (24.89)	*Cynodon dactylon* (24.68)	*Dactyloctenium aegyptium* (29.68)	*Spilanthes paniculata* (33.96)	*Brachiaria deflexa* (36.47)	*Brachiaria deflexa* (32.33)
4	*Cynodon dactylon* (21.63)	*Brachiaria deflexa* (27.44)	*Cynodon dactylon* (22.45)	*Alternanthera sessilis* (22.49)	*Lepidium sativum* (23.21)	*Cyperus rotundus* (29.78)	*Oxalis corniculata* (26.59)	*Dactyloctenium aegyptium* (32.27)
5	*Portulaca oleracea* (18.20)	*Cynodon dactylon* (24.02)	*Cyperus rotundus* (19.42)	*Dactyloctenium aegyptium* (22.39)	*Cyperus rotundus* (21.70)	*Dactyloctenium aegyptium* (25.81)	*Amaranthus spinosus* (22.58)	*Oxalis corniculata* (23.56)

Table 4: List of the weed species and their distribution

S.N.	Species name	Family	Cropping systems							
			R	**FM**	**BG**	**HG**	**R + BG**	**R+ HG**	**FM + BG**	**FM + HG**
1.	*Ageratum conyzoides*	Asteraceae	-	*	*	-	-	-	-	-
2.	*Ageratum houstonianum*	Asteraceae	-	-	-	-	-	-	*	*
3.	*Alternanthera sessilis*	Amaranthaceae	*	*	*	*	*	*	*	*
4.	*Alternanthera tenella*	Amaranthaceae	*	*	*	-	-	-	-	-
5.	*Amaranthus spinosus*	Amaranthaceae	*	-	*	-	*	*	*	*
6.	*Amaranthus viridis*	Amaranthaceae	-	-	-	-	*	-	*	*
7.	*Bidens pilosa*	Asteraceae	-	-	*	-	-	-	-	-
8.	*Brachiaria deflexa*	Poaceae	*	*	*	*	*	*	*	*
9.	*Cassia tora*	Caesalpiniaceae	-	-	*	-	-	-	-	-
10.	*Commelina benghalensis*	Commelinaceae	*	*	*	-	-	-	-	-
11.	*Conyza* sp.	Asteraceae	*	*	-	-	-	-	-	-
12.	*Cynodon dactylon*	Poaceae	*	*	*	*	*	*	*	*
13.	*Cyperus kyllingia*	Cyperaceae	*	*	-	-	-	-	-	-
14.	*Cyperus rotundus*	Cyperaceae	*	*	*	*	*	*	-	-
15.	*Dactyloctenium aegyptium*	Poaceae	*	*	*	*	*	*	-	*
16.	*Digitaria ciliaris*	Poaceae	*	*	-	-	-	*	-	-
17.	*Digitaria sanguinalis*	Poaceae	-	*	-	-	-	-	-	-
18.	*Echinochloa crus-galli*	Poaceae	*	-	-	*	-	-	-	-
19.	*Eleusine indica*	Poaceae	-	-	*	*	-	*	-	-
20.	*Emilia sonchifolia*	Asteraceae	-	-	-	*	-	-	-	-
21.	*Eragrostis unioloides*	Poaceae	-	-	-	*	-	-	-	-
22.	*Euphorbia hirta*	Euphorbiaceae	-	-	-	*	-	-	-	-
23.	*Hedyotis corymbosa*	Rubiaceae	-	-	-	*	-	-	-	-
24.	*Hygrophila spinosa*	Acanthaceae	*	-	-	-	-	-	-	-
25.	*Ipomoea* sp.	Convolvulaceae	-	-	-	-	-	-	-	*
26.	*Lepidium sativum*	Cruciferae	*	*	-	-	*	-	-	-
27.	*Mimosa pudica*	Fabaceae	-	-	-	*	-	-	-	-
28.	*Oxalis corniculata*	Oxalidaceae	*	-	-	*	-	-	*	*
29.	*Portulaca oleracea*	Portulacaceae	*	-	*	-	*	*	-	-
30.	*Scoparia dulcis*	Scrophulariaceae	-	*	*	-	-	-	-	-
31.	*Sida cordifolia*	Malvaceae	-	-	-	*	-	-	-	-
32.	*Solanum torvum*	Solanaceae	-	-	*	-	-	-	-	-
33.	*Spilanthes paniculata*	Asteraceae	*	*	*	*	*	*	*	*

* =Presence of particular weeds, - = Absence of particular weeds

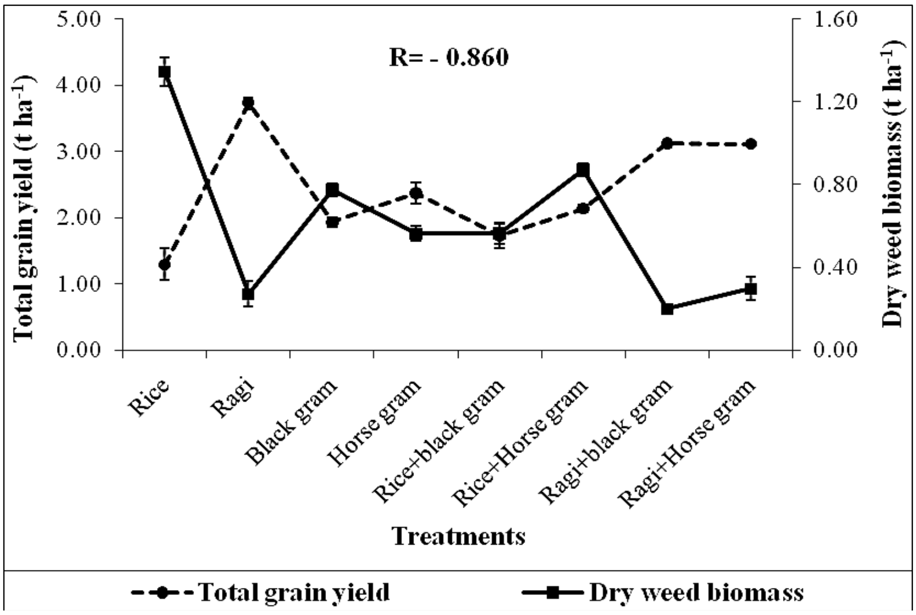

Fig 1: Correlation between total grain yield of cultivated crop and dry weed biomass

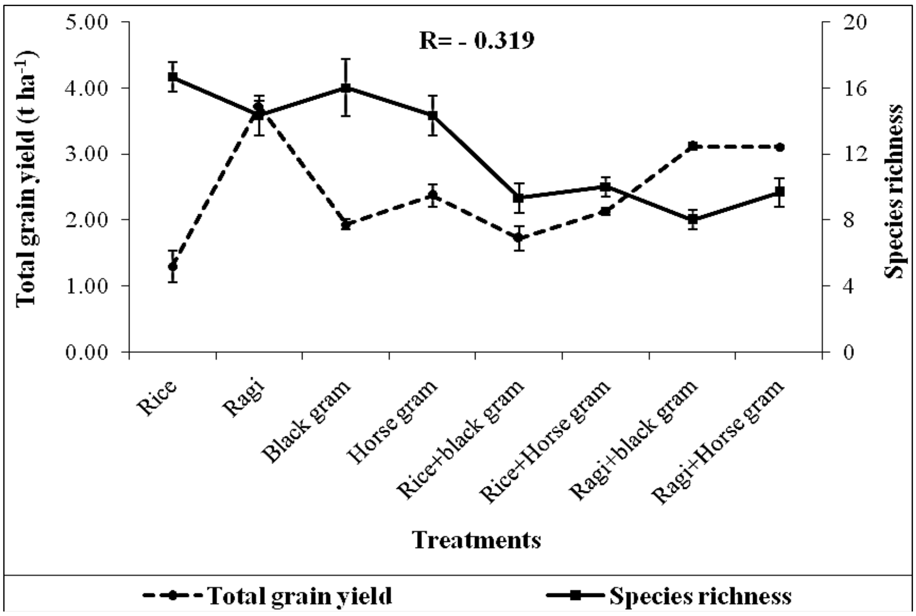

Fig 2: Correlation between total grain yield of cultivated crop and associated weed's species richness

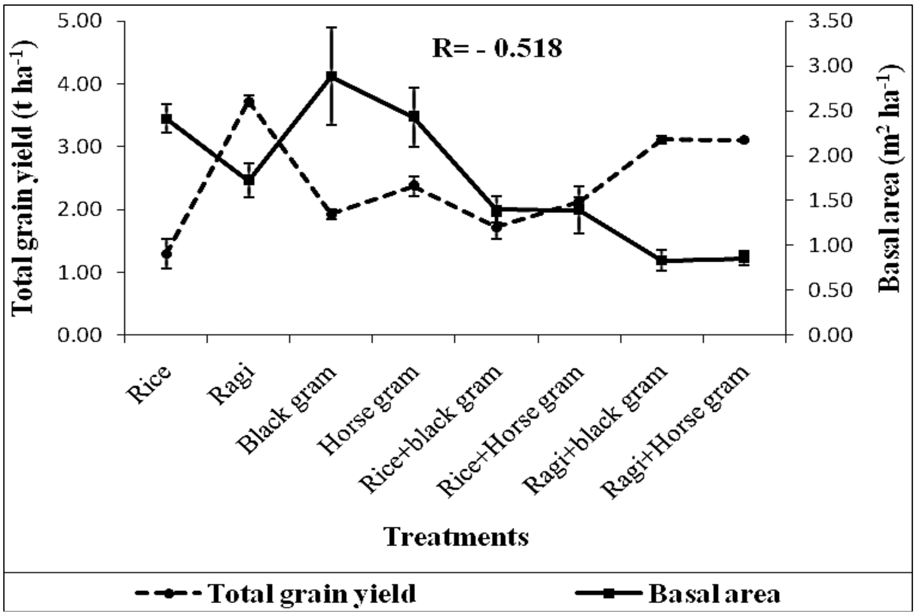

Fig 3: Correlation between total grain yield of cultivated crop and basal area of weeds

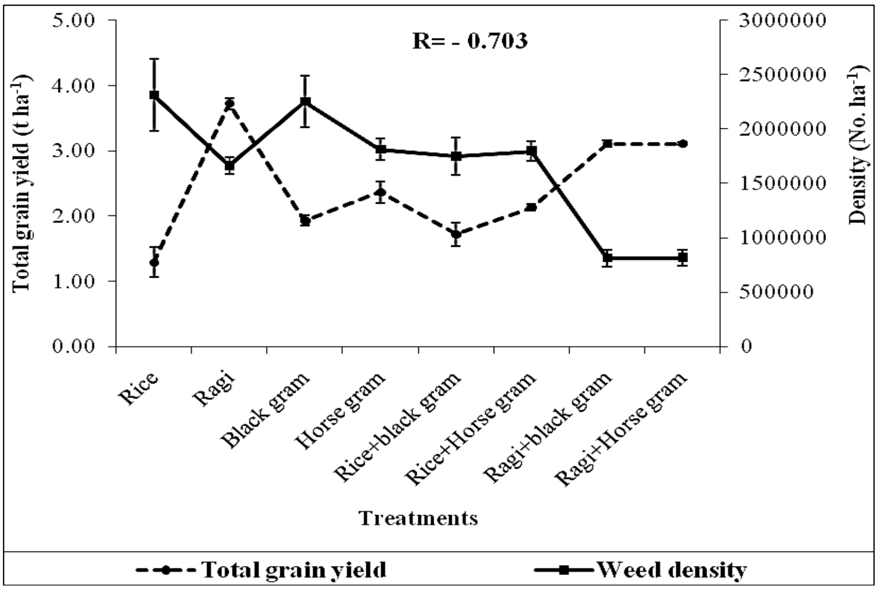

Fig 4: Correlation between total grain yields of cultivated crop and associated weed density

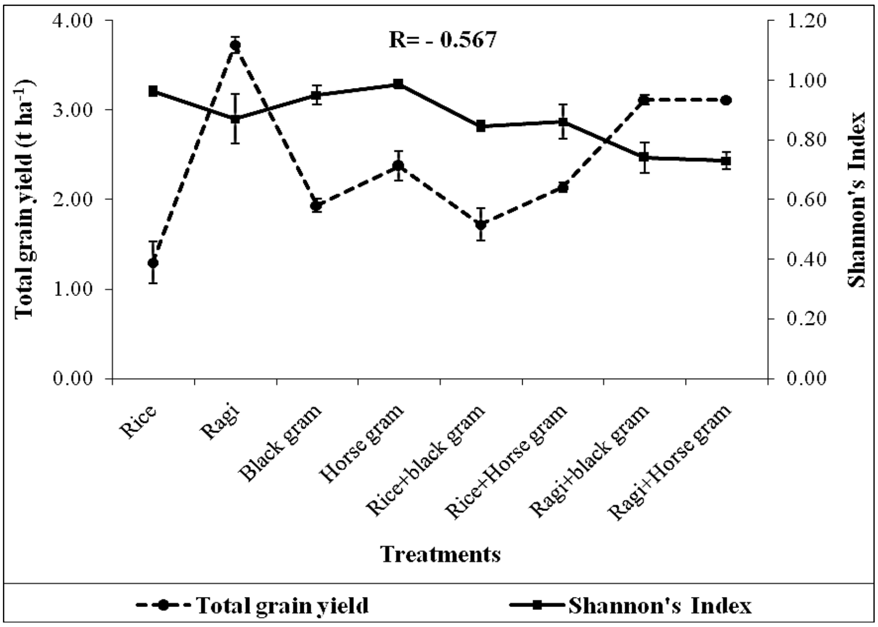

Fig 5: Correlation between total grain yield of cultivated crop and associated weed diversity

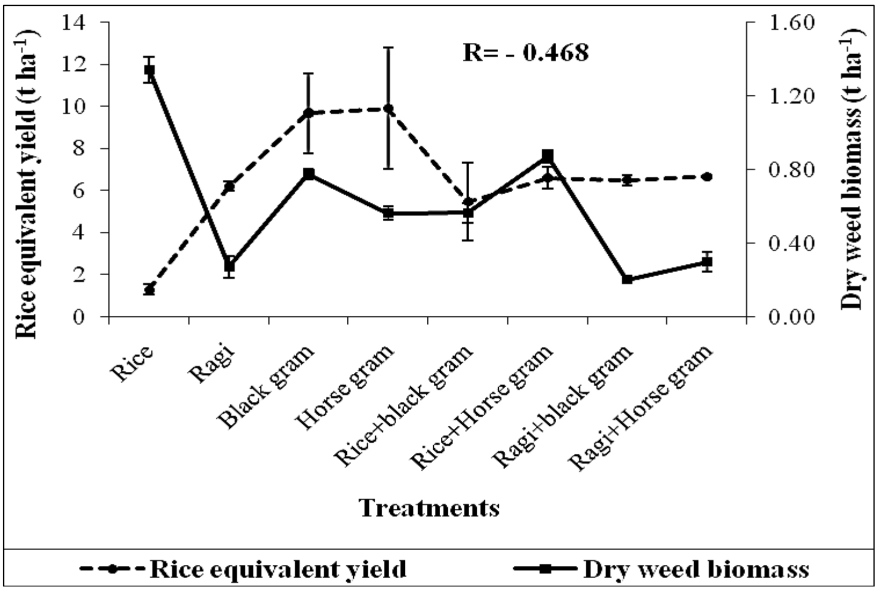

Fig 6: Correlation between Rice equivalent yield of cultivated crop and associated dry weed biomass

Conclusion

Among all the treatments (cropping systems), Finger millet + Black gram (T_7) and Finger millet + Horse gram (T_8) were found to be the best conventionally practiced cropping systems or land-use systems for controlling weed biomass and diversity naturally without compromising the yield of interest. While considering the sole crops or monocropping systems, the treatment Finger millet (T_2) can be considered the best among others in getting the highest grain yield of interest without controlling the weed infestation. But management of weeds are very crucial since its infestations may lead to severity in terms of deterioration of land productivity through lower grain yield and soil nutrient loss. Hence, farmers can be advised to select the different crop combinations as mixed cropping for controlling weed infestations as well as getting higher grain yield from the target crops.

References

1. Abbasi NA, Zafar L, Khan HA, Qureshi AA. Effects of naphthalene acetic acid and calcium chloride application on nutrient uptake, growth, yield and post-harvest performance of tomato fruit. Pak. J Bot. 2013; 45:1581-1587.
2. Ahmad Z, Khan SM, Abd Allah EF, Alqarawi AA, Hashem A. Weed species composition and distribution pattern in the maize crop under the influence of edaphic factors and farming practices: A case study from Mardan, Pakistan. Saudi Journal of Biological Sci. 2016; 23:741-748.
3. Bàrberi P, Silvestri N, Bonari E. Weed communities of winter wheat as influenced by input level and rotation. Weed Res. 1997; 37:301-313.
4. Booth DB, Murphy SD, Swanton CJ. Weed ecology in natural and agricultural systems. Editorial CABI Publishing, Wallingford, UK, 2003.
5. Carballido J, Rodríguez-Lizana A, Agüera J, Pérez-Ruiz M. Field sprayer for inter and intra-row weed control: Performance and labor savings. Span. J Agric. Res. 2013; 11:642-651.
6. Curtis JT, McIntosh RP. The interrelations of certain analytic and synthetic phytosociological characters. Ecology, 1950, 434-455.
7. Doucet C, Weaver SE, Hamill AS, Zhang J. Separating the effects of crop rotation from weed management on weed density and diversity. Weed Sci. 1999; 47:729-735.
8. Ferriol M, Merle HBF. El Inventario fitosociologico. In: Universitat Politecnica de Valencia, 2006. http://hdl.handle. Net/10251/16818; Accessed 05 March 2015.
9. Fontanelli M, Raffaelli M, Martelloni L, Frasconi C, Ginanni M, Peruzzi A. The influence of non-living mulch, mechanical and thermal treatments on weed population and yield of rainfed fresh-market tomato (*Solanum lycopersicum* L.). Span. J Agric. Res. 2013; 11:593-602.
10. Franke AC, Lotz LAP, Van Der Burg WJ, Van Overbeek L. The role of arable weed seeds for agroecosystem functioning. Weed Res. 2009; 49:131-141.
11. Ghersa CM, Holt JS. Using phenology prediction on weed management: a Review. Weed Res. 1995; 35:461-470.
12. Gohil TG. A study of weed occurrence and crop association of valsad district in south Gujarat. Life sciences Leaflets, Published on 1st, 2010.
13. Govindra S, Bhan VM, Tripathi SS. Effect of herbicde alone and combination with weeding on tomato and association with weeds. Indian Journal of Weed Sci. 1986; 16:262-266.
14. Hald AB. Weed vegetation (wild flora) of long established organic versus conventional cereal fields in Denmark. Annals of Applied Biol. 1999; 134:307-314.
15. Holm L. Some quantitative aspects of weed competition in vegetable crops. Weeds. 1956; 4:111-123.
16. Ige OE, Olumekun VO, Olagbadegun JO. A phytosociological study of weed flora in three abandoned farmlands in owo area, ondo state, Nigeria. Pak. J Weed Sci. Res. 2008; 14(1-2):81-89.
17. Marana J, Gongola R, Paredes E, Labrada R. Critical period for competition from weeds and direct-sown tomato. Cienciay Tecnica en la Agricoltura, Hortizalas, Papa, Granosy Fibra. 1983; 2:73-83.
18. Moreno M, Morenom A, Mancebo I. Comparison of different mulch materials in a tomato (*Solanum lycopersicum* L.) crop. Span. J Agric. Res. 2011; 7:454-464.
19. Nkoa R, Owen MDK, Swanton CJ. Weed Abundance, Distribution, Diversity, and Community Analyses. Weed Sci. 2015; 63:64-90.
20. Norris RF, Kogan M. Ecology of interactions between weeds and arthropds. Annual Review of Entomology. 2005; 50:479-503.
21. Pandey DD, Pandey K, Kumar SS. Phytosociological studies of grassland in the Vicinity of pataratu thermal power, hazaribagh, Jharkhand. Journal of Phytology. 2011; 3(12):63-66.
22. Pitelli RA. Estudos fitossociologicos em comunidades infestantes de agroecossistemas. J Conser. 2000; 1:1-7.
23. Shah SRU, Qasim M, Khan IA, Shah SAU. Study of medicinal plants among weeds of wheat and maize in Peshawar region. Pak. J Weed Sci. Res. 2006; 12(3):191-197.
24. Sharaiha R, Gliessman S. The Effects of Crop Combination and Row Arrangement in the intercropping of Lettuce, Favabean and Pea on Weed Biomass and Diversity and on Crop Yields. Biological Agriculture and Horticulture: An International Journal for Sustainable Production Systems. 1992; 9(1):1-13.
25. Sharaiha R, Haddad N. Potential of intercropping of cabbage, broad bean and corn under Jordan Valley conditions. Dirasat Agricultural Science. 1985; XII(4):45-56.
26. Sinha MK, Banerjee A. Studies on weed diversity and its associated phytosociology under direct dry seeded rice systems. Communications in Plant Sciences. 2016; 6(3-4):47-54.
27. Smith RG, Gross KL, Robertson GP. Effects of crop diversity on agroecosystem function: Crop yield response. Ecosystems. 2008; 11:355-366.
28. Tikariha A, Shrivastava AK, Patra S. Phytosociological Analysis of Weeds in Durg District of Chhattisgarh. IOSR Journal of Environmental Science, Toxicology and Food Technology. 2016; 10(10):14-21.
29. Wang S, Duan L, Li J, Tian X, Li Z. UV-B radiation increases paraquat tolerance of two broad leaved and two grass weeds in relation to changes in herbicide absorption and photosynthesis. Weed Res. 2007; 47(2):122-128.
30. Weiner J. A neighborhood model of annual-plant interference. Ecol. 1982; 63:1237-1241.
31. Wilkinson L, Coward M. SYSTAT: Statistics-II. (Version 12) Systat software Inc., Sanjose, CA-95110, 2007.