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Impact of crop intensification and establishment techniques on weed dynamics under different cropping systems

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ABSTRACT

The field experiments were conducted during 2015-16 and 2016-17 at Norman E. Borlaug Crop Research Center, Pantnagar G.B Pant University of Agriculture & Technology, Pantnagar, U.S. Nagar (Uttarakhand) India, to study the crop intensification and establishment techniques influence on weed dynamics under irrigated rice-wheat system**.** In *Kharif* season, density of total weeds as well as grasses, broad-leaved weeds and sedges was observed lowest in rice – wheat cropping system. Transplanted rice-vegatable pea- groundnut cropping sequence proved superior over those cropping systems where upland direct-seeded rice was included as one of the crop with respect to control of *Kharif* season weeds. In *Rabi* season, maize (B) (cob + fodder) + cowpea (B) + Sesbania (F)-2:1:2 - vegetable pea (B) + toria (F)-3:1 – groundnut (B) + mentha (F)-3:1(BBF 105 x 30 cm)] proved to be the most prominent cropping system for controlling broad-leaved weeds and sedges. All the cropping systems proved superior for the control of grassy weeds (*Phalaris minor* and *Avena fatua*) in which there was inclusion of either legumes or oilseed crops in place of wheat. During summer season, soybean (B) + rice (DSR) (F)-2:1 – wheat (B) + mentha (F) (3:1) - continue (NBS 60 x 30 cm) cropping system was found better for the control of complex weed flora

INTRODUCTION

Weed dynamics is severely affected by cropping system and establishment techniques. Continues cultivation of same crop year after year the weed population will be same. Crop rotations affect seed banks because weed control measures change with successive crops (Ball 1992). Weeds that survive and produce seeds in one crop contribute to the seed bank from which weed seedlings are recruited in successive crops. Because of greater variability in the type and timing of soil, crop, and weed management practices, there are more opportunities for weed mortality events in rotations than in monoculture (Martin and Felton 1993). However, this variability may also provide more chances for successful weed emergence, establishment, and seed production in rotations than in monoculture (Dorado *et al.* 1999). Manipulation of cropping systems for the purpose of improving integrated weed management requires a good understanding of weed dynamics and influences of crop- and soil-related factors on weed life cycles (Davis and Liebman 2003). Weed flora have changed over the past century, with either increasing or decreasing species abundance depending on the management (Bagmet 2000, Marshall *et al.* 2003, Stoate *et al.* 2002). Changes in crop rotation and herbicide use could change the weed seed banks in arable soils (Squire *et al.* 2000). Rotations comprised of two cool-season crops followed by two warm-season crops are the most disruptive of weed population growth. The impact of rotation design on weed community density is enhanced by no-till. Crop tolerance to weeds is improved by systems of cultural tactics. The tolerance is greatest when three tactics are combined together (Anderson 2007). Replacing spring cereals with winter cereals resulted in a 25% reduction in weed density and species diversity (Hald 1999). Considering plants with allelopathic effects such as rye and triticale permits sustainable weed management while, reducing the impact of agriculture on the environment (Tabaglio *et al.* 2008). Crop intensification and establishment techniques important to influence the weed dynamics. Keeping the above aspects in view, the present investigation

"Impact of crop intensification and establishment techniques on weed dynamics under different cropping systems" has been planned with the objective to study impact of crop intensification and establishment techniques on weed dynamics and reduce the weed dynamics by increase cop intensification and using establishment techniques.

MATERIALS AND METHODS

A field experiment was conducted during 2015-16 and 2016-17 at Norman E. Borlaug Crop Research Center, G.B Pant University of Agriculture & Technology, Pantnagar, U.S. Nagar (Uttarakhand) India, situated 29^0 1' N latitude, 79^0 29' E longitudes and an altitude of 243.83 m above mean sea level, which lies in the Tarai belt of Shivalik range of Himalayan foot hills to study crop intensification and establishment techniques to enhance productivity under irrigated rice-wheat system. The soil of experimental field was loam in texture, high in organic carbon (0.80), low in available nitrogen (260.4 kg/ ha), high in phosphorus (29.6 kg/ha) and medium in potassium (203.9 kg/ha) with neutral in pH (7.33).

The experiment was laid out in a randomized block design with nine treatments, *viz.*, [rice (transplanted -TPR) – wheat], [rice (TPR) - vegetable pea – groundnut], [rice (direct seeded rice-DSR) - vegetable pea - maize (grain)], [rice (DSR) - potato -cowpea (vegetable + fodder)], [rice (DSR) - vegetable pea - maize (cob + fodder)], [rice (DSR) - yellow sarson – cowpea], [rice (DSR) (bed) + sesbania (furrow)- 2:1 -vegetable pea (bed) + toria (furrow)-2:1 - maize (bed (B)) (cob + fodder) + mentha (furrow (F))1:1, (furrow irrigated raised bed (FIRB), 45cm x 30 cm)], [soybean (bed) + rice (DSR) (furrow)-2:1 - wheat + mentha (3:1) - continue (narrow bed system (NBS), 60 x 30 cm)], [maize (bed) (cob + fodder) + cowpea (vegetable) (bed) + Sesbania (furrow)-2:1:2 - vegetable pea + toria-3:1 - groundnut + mentha-3:1(broad bed furrow (BBF) 105 x 30 cm)] and replicated thrice. The crops were sown as per the package of practices recommended for different crops. The nine cropping sequence were evaluated for productivity. '*HKR-47*' variety of rice, '*UP-2572*' variety of wheat, '*Kashi kanchan*' variety of cowpea, '*Suvarna*' variety of maize (cob + fodder), '*Arkle*' variety of vegetable pea, '*Uttara*' variety of toria, '*Kufri Bahar (3797)*' variety of potato, '*PS-1024*' variety of soybean, '*PPS-1* 'variety of yellow mustard, '*ICGS-11*' variety of groundnut and '*Kosi*' variety of mentha were used in experimentation.

Weed dynamics was observed in terms of weed density recorded species wise just before the execution of first hand weeding or before the application of post - emergence herbicides during both years by using a quadrate of size 0.5 x 0.5 m (0.25 m^2). Weed count was expressed as number per meter square.

RESULTS AND DISCUSSION

Weed flora of experimental field were collected, identified, and classified as grasses, sedges and broad-leaved weeds. There were 19 weed species (grassy 7, broad-leaved weeds 10, and sedges 2) in experimental field (**Table 1**).

Weed density

Density of individual weed was recorded before the execution of first hand weeding or application of post - emergence herbicide in crops. Large variations were observed in weed density under different cropping systems.

Grassy weeds

The data related to density of grassy weeds in *Kharif, Rabi and* summer season are given (**Table 2**). This was significantly influenced by crop intensification and establishment techniques. In *Kharif* season, among the grasses, the lowest value of density of *Echinochloa colona*, *Eleusine indica*, *Leptochloa chinensis*, *Digitaria sanguinalis* and *Echinochloa cru-galli* were recorded in treatment rice – wheat cropping system during 2015 and 2016. This was at par with treatment of rice - vegetable pea-groundnut cropping system during both years.

It might be due to rice raised through transplanting method because puddling of soil required for rice transplanting caused churning of weed flora present in the field, therefore population of weeds get minimized. Results confirmed with the findings of Bhurer *et al.* (2013) who reported that puddling benefits rice by reducing water percolation losses, controlling weeds, facilitating easy seedling establishment and creating anaerobic conditions to enhance nutrient availability. Aerobic systems are subjected to much higher weed pressure than conventional puddled transplanting system (Rao *et al.* 2007) in which weeds are suppressed by standing water and by transplanted rice seedlings, which have a "head start" over germinating weed seedlings (Moody 1983). The grasses were the most damaging weeds in the rice-pea-rice system, even more than in the rice-wheat system (Singh and Singh 2004).

Table 1. Weed flora of experimental field during 2015-16 and 2016-17

Scientific name	Family	English name	Local name
Grassy weeds			
Avena fatua	Poaceae	Wild oat	Jangli jai
Digitaria sanguinalis	Poaceae	Crab grass	Jhernia grass/Seur
Echinochloa colona	Poaceae	Jungle rice	Sai / Chhoti sai
Echinochloa cru-galli	Poaceae	Barn yard grass	Sanwa /Daura/Sawan/kodon
Eleusine indica	Poaceae	Goose grass	Jangli mandua/Mandla/ Balrara
Leptochloa chinensis	Poaceae	Red sprangle top	-
Phalaris minor	Poaceae	Little seed canary grass	Gulli danda/ Gehu ka mama
Broad-leaved weeds			
Alternanthera sessilis	Amaranthaceae	Alligator weed	Gadani
Anagallis arvensis	Primulaceae	Pimper -nel, scarlet	Krishna neel
Celosia argentia	Amaranthaceae	Cocks comb	Safed murga
Chenopodium album	Chenopodiaceae	Lambs quarter	Bathua/Bathu
Coronopus didymus	Brassicaceae	Swine cress	Jangli balu/jangli taratez
Melilotus species	Febaceae	Clover	Senji
Rumex dentatus	Polygonaceae	Sour dock	Jangli palak
Solanum nigrum	Solanaceae	Black night shade	Makoy/kakmoch
Trianthema monogyna	Aizoaceae	Giant pig weed, Horse purslane	Patherchatta /Santhi
Vicia sativa	Febaceae	Vetch	Ankari
Sedges			
Cyperus rotundus	Cyperaceae	Purple nut sedge	Motha
Cyperus iria	Cyperaceae	Yellow sedge/Flat sedge	Dachab/Gal motha

Table 2. Effect of crop intensification and establishment techniques on grassy weed density

Treatment	Grassy weeds (no./m^2)															
	Kharif										*Rabi*				Summer	
	E. colona		*E. indica*		*L. chinensis*		*D. sanguinalis*		*E. crus-galli*		*P. minor*		*A. fatua*		*D. sanguinalis*	
	2015	2016	2015	2016	2015	2016	2015	2016	2015	2016	2015-16	2016-17	2015-16	2016-17	2015	2016
Rice (TPR) – Wheat	2.41 (5.3)	2.67 (6.7)	1.34 (1.3)	1.74 (2.7)	1.34 (1.3)	1.76 (2.7)	1.34 (1.3)	1.76 (2.7)	1.34 (1.3)	1.72 (2.7)	4.52 (20.0)	4.67 (21.3)	4.06 (16.0)	4.22 (17.3)	-	-
Rice (TPR) - Vegetable pea – Groundnut	2.91 (8.0)	3.13 (9.3)	1.74 (2.7)	2.11 (4.0)	1.77 (2.7)	2.11 (4.0)	2.12 (4.0)	2.41 (5.3)	1.74 (2.7)	2.11 (4.0)	0.71 (0)	0.71 (0)	0.71 (0)	0.71 (0)	10.29 (105.3)	10.48 (109.3)
Rice (DSR) –Vegetable pea – Maize grain	7.43 (54.7)	7.6 (57.3)	3.33 (8.0)	2.91 (10.7)	3.13 (9.3)	3.33 (10.7)	4.94 (24.0)	5.20 (26.7)	3.33 (10.7)	3.70 (13.3)	0.71 (0)	0.71 (0)	0.71 (0)	0.71 (0)	10.66 (113.3)	10.82 (117.3)
Rice (DSR) - Potato -Cowpea (vegetable)	7.24 (52.0)	7.52 (56.0)	2.67 (6.7)	2.91 (8.0)	3.13 (8.0)	2.88 (9.3)	4.79 (22.7)	5.07 (25.3)	3.13 (9.3)	3.34 (10.7)	1.34 (1.3)	0.71 (0)	0.71 (0)	0.71 (0)	10.54 (110.7)	10.98 (120.0)
Rice (DSR) - Vegetable pea - Maize (cob + fodder)	7.86 (61.3)	8.11 (65.3)	2.89 (8.0)	3.10 (9.3)	2.91 (8.0)	3.53 (12.0)	4.95 (24.0)	5.21 (26.7)	3.34 (10.7)	3.53 (12.0)	0.71 (0)	0.71 (0)	0.71 (0)	0.71 (0)	10.66 (113.3)	11.21 (125.3)
Rice (DSR) - Yellow Sarson – cowpea(vegetable + green manure)	7.41 (54.7)	7.69 (58.7)	2.67 (6.7)	2.92 (8.0)	3.34 (9.3)	3.13 (10.7)	4.81 (22.7)	4.95 (24.0)	3.13 (9.3)	3.53 (12.0)	0.71 (0)	0.71 (0)	0.71 (0)	0.71 (0)	10.61 (112.0)	11.03 (121.3)
Rice (DSR) (B) + *Sesbania* (F)- 2:1 (FIRBS 45cm * 30 cm) -Vegetable pea (B) + Toria (F)-2:1 (FIRBS) - Maize (B) (cob + fodder) + Mentha (F)1:1(FIRBS)	6.57 (42.7)	6.86 (46.7)	2.40 (5.3)	2.66 (6.7)	2.41 (5.3)	2.41 (5.3)	3.34 (10.7)	3.53 (12.0)	2.41 (5.3)	2.68 (6.7)	0.71 (0)	0.71 (0)	0.71 (0)	0.71 (0)	9.62 (92.0)	10.07 (101.3)
Soybean (B) + Rice (DSR) (F)-2:1 (NBS 60 x 30 cm) - Wheat + Mentha (3:1) (NBS 60 x 30 cm) - Continue (NBS 60 x 30 cm	6.84 (46.7)	7.43 (54.7)	2.67 (6.7)	2.67 (6.7)	2.68 (6.7)	2.91 (8.0)	3.34 (10.7)	3.53 (12.0)	2.68 (6.7)	2.91 (8.0)	4.05 (16.0)	4.22 (17.3)	2.9 (8.0)	2.91 (8.0)	0.71 (0)	0.71 (0)
Maize (B) (cob + fodder) + Cowpea (B) + *Sesbania* (F)-2:1:1 (BBF 105 x 30 cm) - Vegetable pea + Toria-3:1 (BBF) - Groundnut + Mentha-3:1(BBF)	6.47 (41.3)	6.76 (45.3)	2.08 (4.0)	2.60 (6.3)	2.11 (4.0)	2.41 (5.3)	3.12 (9.3)	3.34 (10.7)	2.40 (5.3)	2.66 (6.7)	0.71 (0)	0.71 (0)	0.71 (0)	0.71 (0)	8.75 (76.0)	9.30 (86.7)
LSD (p=0.05)	0.54	0.48	0.64	0.59	0.27	0.49	0.49	0.47	0.42	0.43	0.32	0.19	0.22	0.10	0.37	0.98

Original values given in parentheses was subjected to square root $(\sqrt{x+1})$ransformation before analysis; B - bed; F - furrow; NBS - narrow bed system; BBF - broad bed furrow; FIRB - furrow irrigated raised bed

In *Rabi* season, among the grasses, the density of *Phalaris minor* was recorded significantly higher in puddled transplanted Rice (TPR) – wheat treatment, which might be due to dominance of *P. minor* in wheat crop over the other species. Similarly, Walia *et al*. (1997) also reported that grassy weeds like *P. minor* were maintaining its dominance in wheat crop since last three decades *i.e*. from the era of

introduction of Mexican wheat crop. The density of this weed was lower in all other treatments. Density of *A. fatua* was also recorded significantly higher in TPR – wheat treatment during both the years, which might be due to inclusion of wheat crop of same nature which provides favourable environment to this weed. The other treatments recorded significantly lower weed density of *A. fatua* than TPR – wheat were soybean (bed) + rice (DSR) (F)-2:1 (NBS 60 x 30 cm) - wheat + mentha (3:1) (NBS 60 x 30 cm) - continue (NBS 60 x 30 cm. Similarly, it could be due to growth of wheat associated weed *A. fatua*, which was raised on bed, which might had helped to reduce the weeds (Das 2008).

Among the grasses, in summer season density of *Digitaria sanguinalis* was recorded significantly higher in rice (DSR) - vegetable pea - maize (cob + fodder) during 2015 and 2016. However, it was found to be at par with rice (TPR) - vegetable pea – groundnut, rice (DSR) –vegetable pea – maize grain, rice (DSR) - potato -cowpea (vegetable) and rice (DSR) - yellow sarson – cowpea (vegetable + green manure) during both the years. It might be due to direct seeding of rice. The lowest density was recorded in soybean (B) + rice (DSR) (F)-2:1 (NBS 60 x 30 cm) - wheat + mentha (3:1) (NBS 60 x 30 cm) - continue (NBS 60 x 30 cm treatment. It could be due to effect of mentha crop in cropping sequence in furrow and wheat was already raised on bed; therefore weed density reduced.

Broad-leaved weeds (BLWs)

The data pertaining to density of BLWs in *Kharif, Rabi and* summer are given in **Table 3**. Density of broad-leaved weeds was significantly influenced by crop intensification and establishment techniques.

In *Kharif*, among the broad-leaved weeds, rice – wheat cropping sequence recorded the least values of density of *Trianthema monogyna*, *Alternanthera*

Table 3. Effect of crop intensification and establishment techniques on broad-leaved weed density

Treatment				T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	T_9	LSD (p=0.05)
Broad-leaved weeds (no./m^2)	*Kharif*	*T. monogyna*	2015-16	2.9(8.0)	3.3(10.7)	5.3(28.0)	4.9(24.0)	5.2(25.3)	4.9(24.0)	3.7(13.3)	3.7(13.3)	3.5(12.0)	0.40
			2016-17	3.1(9.3)	3.9(14.7)	5.6(30.7)	5.3(28.0)	5.1(26.7)	5.6(30.7)	3.9(14.7)	3.9(14.7)	4.0(15.7)	0.53
		A. sessilis	2015-16	1.3(1.3)	1.7(2.7)	3.3(10.7)	2.9(8.0)	3.1(9.3)	3.5(10.7)	2.1(4.0)	2.4(5.3)	2.7(6.7)	0.36
			2016-17	1.8(2.7)	2.1(4.0)	3.5(12.0)	3.1(9.3)	3.3(10.7)	3.3(12.0)	2.7(6.7)	2.9(8.0)	2.9(8.0)	0.61
		Celosia argentea	2015-16	2.1(4.0)	2.9(8.0)	7.9(62.7)	7.5(56.0)	7.9(58.7)	7.3(53.3)	7.1(49.3)	7.2(52.0)	6.9(46.7)	0.48
			2016-17	2.4(5.3)	3.1(9.3)	8.2(66.7)	8.1(65.3)	7.7(62.7)	7.8(61.3)	7.4(54.7)	7.7(58.7)	6.8(45.3)	0.56
	Rabi	*S. nigrum*	2015-16	3.3(10.7)	3.3(10.7)	3.5(12.0)	3.7(13.3)	3.1(9.3)	3.3(10.7)	2.9(8.0)	2.7(6.7)	2.4(5.3)	0.30
			2016-17	3.5(12.0)	3.3(10.7)	3.9(14.7)	3.9(14.7)	3.3(10.3)	3.7(13.3)	3.3(10.7)	2.9(8.0)	2.7(6.7)	0.47
		C. didymus	2015-16	3.3(10.7)	3.13(9.3)	3.7(13.3)	3.5(12.0)	3.9(14.7)	2.9(8.0)	2.4(5.3)	2.9(8.0)	2.7(6.7)	0.36
			2016-17	3.5(12.0)	3.3(10.7)	3.9(13.3)	3.9(13.3)	3.3(16.0)	3.7(9.3)	3.3(8.0)	2.9(9.3)	2.7(8.0)	0.47
		Melilotus. species	2015-16	3.5(12.0)	4.1(16.0)	5.3(28.0)	5.7(28.0)	5.3(28.0)	4.5(20.0)	2.7(6.7)	2.4(5.3)	2.1(4.0)	0.37
			2016-17	3.7(13.3)	4.2(17.3)	5.5(29.3)	5.3(32.0)	5.5(29.3)	4.7(21.3)	2.9(8.0)	2.4(5.3)	2.1(4.0)	0.39
		C. album	2015-16	4.1(16.0)	4.9(24.0)	5.3(28.0)	4.1(17.3)	4.9(24.0)	4.1(16.0)	2.7(6.7)	3.5(12.0)	2.4(5.3)	0.70
			2016-17	4.2(17.3)	5.1(25.3)	5.5(29.3)	4.4(18.7)	5.1(25.3)	4.2(17.3)	2.9(8.0)	3.7(13.3)	2.7(6.7)	0.30
		C. arvense	2015-16	2.9(8.0)	3.5(12.0)	3.5(12.0)	5.3(28.0)	4.5(20.0)	3.5(12.0)	2.4(5.3)	2.1(4.0)	2.7(6.7)	0.39
			2016-17	2.9(8.0)	3.7(13.3)	3.7(13.3)	5.6(30.7)	4.7(21.3)	3.7(13.3)	2.7(6.7)	2.1(4.0)	2.9(8.0)	0.43
		T. monogyna	2015-16	2.9(8.0)	0.7(0.0)	2.9(8.0)	2.1(4.0)	2.9(8.0)	0.7(0.0)	1.3(1.3)	0.7(0)	2.7(6.7)	0.33
			2016-17	3.1(9.3)	0.7(0)	3.1(9.3)	2.1(4.0)	2.9(8.0)	0.7(0.0)	1.8(2.7)	0.7(0.0)	2.9(8.0)	0.27
		R. dentatus	2015-16	3.5(12.0)	0.7(0)	0.7(0)	1.3(1.3)	0.7(0)	0.7(0)	0.7(0)	3.3(10.7)	0.7(0)	0.19
			2016-17	3.7(13.3)	0.7(0)	0.7(0)	1.8(2.7)	0.7(0)	0.7(0)	0.7(0)	3.3(10.7)	0.7(0.0)	0.29
		V. sativa	2015-16	3.5(12.0)	4.5(20.0)	5.3(28.0)	0.7(0.0)	4.1(16.0)	0.7(0)	0.7(0)	0.7(0)	0.7(0)	0.18
			2016-17	3.7(13.3)	4.7(21.3)	5.5(29.3)	0.7(0)	4.2(17.3)	0.7(0)	0.7(0)	0.7(0)	0.7(0)	0.21
		A. arvensis	2015-16	3.5(12.0)	0.7(0)	0.7(0)	0.7(0)	0.7(0)	0.7(0)	0.7(0)	2.9(8.0)	0.7(0)	0.20
			2016-17	3.7(13.3)	0.7(0)	0.7(0)	0.7(0)	0.7(0)	0.7(0)	0.7(0)	3.1(9.33)	0.7(0)	0.17
		M. alba	2015-16	4.1(16.0)	0.7(0)	2.9(8.0)	4.5(20.0)	0.7(0)	0.7(0)	0.7(0)	2.9(8.0)	0.7(0)	0.24
			2016-17	4.4(18.7)	0.7(0.0)	3.1(9.3)	4.7(21.3)	0.7(0)	0.7(0)	0.7(0)	3.1(9.3)	0.7(0)	0.20
	Summer	*T. monogyna*	2015	-	9.7(95)	10.0(99)	8.7(75)	10.3(107)	10.0(100)	9.0(80.0)	0.7(0.0)	8.0(64)	0.44
			2016	-	10.1(101)	10.1(103)	9.3(87)	10.8(117)	10.5(109)	9.5(90.7)	0.7(0)	8.5(72)	0.79

Treatment = T_1 - Rice (TPR) – Wheat; T_2- Rice (TPR) – Wheat; T_3 - Rice (TPR) - Vegetable pea – Groundnut; T_4 - Rice (DSR) – Vegetable pea – Maize grain; T_5 - Rice (DSR) - Potato -Cowpea (vegetable); T_6 - Rice (DSR) - Vegetable pea - Maize (cob + fodder); T_7 - Rice (DSR) – Yellow Sarson – cowpea (vegetable + green manure); T7 - Rice (DSR) (B) + Sesbania (F)- 2:1 (FIRBS 45cm * 30 cm) -Vegetable pea (B) + Toria (F)-2:1 (FIRBS) - Maize (B) (cob + fodder) + Mentha (F)1:1(FIRBS); T_8 - Soybean (B) + Rice (DSR) (F)-2:1 (NBS 60cm * 30 cm) - Wheat + Mentha (3:1) (NBS 60cm * 30 cm) - Continue (NBS 60cm * 30 cm; T_9 - Maize (B) (cob + fodder) + Cowpea (B) + Sesbania (F)-2:1:1 (BBF 105cm * 30 cm) - Vegetable pea + Toria-3:1 (BBF) - Groundnut + Mentha-3:1 (BBF)

Original values given in parentheses was subjected to square root $(\sqrt{x+1})$ransformation before analysis; B - bed; F - furrow; NBS - narrow bed system; BBF - broad bed furrow; FIRB - furrow irrigated raised bed

sessilis and *Celosia argentia* during both the years, which might be due to puddling operation performed in transplanted rice. The density of all these weeds was significantly more when rice raised through direct seeding or in other cropping sequences.

In *Rabi* season, among the broad leaved weeds, significantly lower weed density of *Solanum nigrum*, *Coronopus didymus*, *Melilotus* sp. and *Chenopodium album* was recorded in maize (B) (cob + fodder) + cowpea (B) + *Sesbania* (F)-2:1:1 (BBF 105 x 30 cm) - vegetable pea + toria-3:1 (BBF) - groundnut + mentha-3:1 (BBF) treatment during both the years except during 2015-16 where density of *C. didymus* was significantly lower in rice (DSR) (B) + sesbania (F)- 2:1 (FIRBS 45 x 30 cm) -vegetable pea (B) + toria (F)-2:1 (FIRBS) - maize (B) (cob + fodder) + mentha (F)1:1(FIRBS) treatment. Significantly higher density of these weeds was found rice (DSR) – vegetable pea – maize grain and rice (DSR) - potato - cowpea (vegetable) treatment where rice was raised through direct seeding in upland condition. No infestation of *T. monogyna* was reported in rice (TPR) - vegetable pea – groundnut, rice (DSR) - yellow sarson – cowpea (vegetable + green manure) and soybean (B) + rice (DSR) (F)-2:1 (NBS 60 x 30 cm) - wheat + mentha (3:1) (NBS 60 x 30 cm) - continue (NBS 60 x 30 cm during both years, whereas the highest density of this weed was recorded in rice (DSR) –vegetable pea – maize grain treatment which was at par with rice (DSR) - vegetable pea - maize (cob + fodder) and maize (B) (cob + fodder) + cowpea (B) + *Sesbania* (F)-2:1:1 (BBF 105 x 30 cm) - vegetable pea + toria-3:1 (BBF) - groundnut + mentha-3:1(BBF) treatment during 2015-16 while rice (TPR) – wheat treatment recorded the highest being at par with rice (DSR) – vegetable pea – maize grain, rice (DSR) - vegetable pea - maize (cob + fodder) and maize (B) (cob + fodder) + cowpea (B) + *Sesbania* (F)-2:1:1 (BBF 105 x 30 cm) - vegetable pea + toria-3:1 (BBF) - groundnut + mentha-3:1(BBF) during 2016-17. No density of *Rumex dentatus* was recorded in rice (TPR) - vegetable pea – groundnut, rice (DSR) – vegetable pea – maize grain, rice (DSR) - vegetable pea - maize (cob + fodder), rice (DSR) - yellow sarson – cowpea (vegetable + green manure), rice (DSR) (B) + sesbania (F)- 2:1 (FIRBS 45 x 30 cm) -vegetable pea (B) + toria (F)-2:1 (FIRBS) - maize (B) (cob + fodder) + mentha (F)1:1(FIRBS), maize (B) (cob + fodder) + cowpea (B) + Sesbania (F)-2:1:1 (BBF 105 x 30 cm) - vegetable pea + toria-3:1 (BBF) - groundnut + mentha-3:1(BBF) treatments during both the years, while the highest density of this weed of was recorded in rice (TPR) – Wheat treatment during both the years.

No population of *Vicia sativa* was recorded in rice (DSR) - yellow sarson – cowpea (vegetable + green manure), rice (DSR) (B) + sesbania (F)- 2:1 (FIRBS 45 x 30 cm) -vegetable pea (B) + toria (F)-2:1 (FIRBS) - maize (B) (cob + fodder) + mentha (F)1:1(FIRBS), soybean (B) + rice (DSR) (F)-2:1 (NBS 60 x 30 cm) - wheat + mentha (3:1) (NBS 60 x 30 cm) - continue (NBS 60 x 30 cm, maize (B) (cob + fodder) + cowpea (B) + sesbania (F)-2:1:1 (BBF 105 x 30 cm) - vegetable pea + toria-3:1 (BBF) - groundnut + mentha-3:1(BBF) treatment, while the highest density of this weed was found in rice (DSR) –vegetable pea – maize grain treatment during both years.

No population of *Anagallis arvensis* was recorded in rice (DSR) - potato -cowpea (vegetable), rice (DSR) - vegetable pea - maize (cob + fodder), rice (DSR) - yellow sarson – cowpea (vegetable + green manure), rice (DSR) (B) + *Sesbania* (F)- 2:1 (FIRBS 45 x 30 cm) -vegetable pea (B) + toria (F)-2:1 (FIRBS) - maize (B) (cob + fodder) + mentha (F)1:1(FIRBS), maize (B) (cob + fodder) + cowpea (B) + sesbania (F)-2:1:1 (BBF 105 x 30 cm) - vegetable pea + toria-3:1 (BBF) - groundnut + mentha-3:1(BBF) treatments, while the highest density of this weed was recorded in rice (TPR) – wheat treatment during both the years.

No population of *Melilotus alba* was recorded in rice (DSR) - vegetable pea - maize (cob + fodder), rice (DSR) - yellow sarson – cowpea (vegetable + green manure), rice (DSR) (B) + *Sesbania* (F)- 2:1 (FIRBS 45 x 30 cm) -vegetable pea (B) + toria (F)-2:1 (FIRBS) - maize (B) (cob + fodder) + mentha (F)1:1(FIRBS), rice (DSR) (B) + *Sesbania* (F)- 2:1 (FIRBS 45 x 30 cm) -vegetable pea (B) + toria (F)-2:1 (FIRBS) - maize (B) (cob + fodder) + mentha (F)1:1(FIRBS) treatments, while the highest density of this weed was found in rice (DSR) - potato - cowpea (vegetable) treatment during both the years.

In summer season, among the broad-leaved weeds, no population of *T. monogyna* was recorded in soybean (B) + rice (DSR) (F)-2:1 (NBS 60 x 30 cm) - wheat + mentha (3:1) (NBS 60 x 30 cm) - continue (NBS 60 x 30 cm) treatment which might be due to sowing spreading type crop like mentha, while the highest density of this weed was recorded in rice (DSR) - vegetable pea - maize (cob + fodder) treatment during both the years. Teasdale (1996) reported that cover crop control the weeds and control increased with greater amounts of crop residue biomass; however, weed suppression was species specific in terms of both the cover crop and weed. A more recent review stated that those

Table 4. Effect of crop intensification and establishment techniques on density of sedges

Treatment	Sedges (no./m^2)							
	Kharif				*Rabi*		Summer	
	C. rotundus		*C. iria*		*C. rotundus*		*C. rotundus*	
	2015	2016	2015	2016	2015-16	2016-17	2015	2016
Rice (TPR) – Wheat	9.9(97)	10.1(101)	1.34(1.3)	1.74(2.7)	7.15(50.7)	7.43(54.7)	-	-
Rice (TPR) - Vegetable pea – Groundnut	10.0(100)	10.1(101)	1.77(2.7)	2.10(4.0)	6.67(44.0)	6.77(45.3)	8.75(76)	9.30(87)
Rice (DSR) –Vegetable pea – Maize grain	11.3(128)	11.6(133)	2.39(5.3)	2.86(8.0)	6.24(38.7)	6.52(42.0)	11.69(140)	12.0(144)
Rice (DSR) - Potato -Cowpea (vegetable)	11.2(124)	11.3(128)	2.41(5.3)	2.66(6.7)	6.04(36.0)	6.14(37.3)	10.42(108)	11.0(121)
Rice (DSR) - Vegetable pea - Maize (cob + fodder)	11.1(121)	11.0(125)	2.68(6.7)	2.91(8.0)	6.14(37.3)	6.25(38.7)	12.24(149)	12.4(155)
Rice (DSR) - Yellow Sarson – cowpea(vegetable + green manure)	11.2(121)	11.0(123)	2.91(8.0)	3.13(9.3)	5.33(28.0)	5.69(32.0)	11.16(124)	11.4(129)
Rice (DSR) (B) + Sesbania (F)- 2:1 (FIRBS 45cm * 30 cm) -Vegetable pea (B) + Toria (F)-2:1 (FIRBS) - Maize (B) (cob + fodder) + Mentha (F)1:1(FIRBS)	10.4(108)	10.5(111)	2.65(6.7)	2.90(8.0)	4.67(21.3)	5.20(26.7)	8.75(76)	9.23(85)
Soybean (B) + Rice (DSR) (F)-2:1 (NBS 60 cm * 30 cm) - Wheat + Mentha (3:1) (NBS 60cm * 30 cm) - Continue (NBS 60cm * 30 cm	10.3(105)	10.7(115)	2.67(6.7)	3.12(9.3)	4.95(24.0)	5.08(25.3)	0.71(0)	0.71(0)
Maize (B) (cob + fodder) + Cowpea (B) + Sesbania (F)-2:1:1 (BBF 105cm * 30 cm) - Vegetable pea + Toria-3:1 (BBF) - Groundnut + Mentha-3:1(BBF)	10.1(101)	10.3(105)	2.40(5.3)	2.91(8.0)	4.38(18.7)	4.52(20.0)	6.04(36)	6.45(41)
LSD (p=0.05)	0.63	0.62	0.53	0.64	0.62	0.55	1.41	0.82

Original values given in parentheses was subjected to square root $(\sqrt{x+1})$ransformation before analysis; B - bed; F - furrow; NBS - narrow bed system; BBF - broad bed furrow; FIRB - furrow irrigated raised bed

alternative methods such as the use of allelopathy, cover crops, and living mulches are low cost, effective and eco-friendly practices for sustainable weed management in cropping systems (Mohammadi 2013).

Sedges

The data regarding to density of sedges is given in **Table 4**. Density of sedges was significantly affected by crop intensification and establishment techniques before the post-emergence application of herbicides during both the years.

In *Kharif*, among the sedges, significantly lower density of *Cyperus rotundus* and *C. iria* was recorded in rice-wheat cropping system being at par with rice-vegetable pea- groundnut cropping system during both the years which might be due to puddling operation in transplanted rice, while the highest density of *C. rotundus* and *C. iria* was recorded in rice (DSR) –vegetable pea – maize grain and rice (DSR) - yellow sarson – cowpea (vegetable + green manure) treatments during both the years. It might be due to direct seeding of rice similar to as reported by Singh and Singh (2004) that in rice –wheat system weed density was the highest for sedges (>60%) followed by grasses and broadleaved weeds, but in biomass, grasses had a >60% share, followed by sedges and non-grasses. In *Rabi*, among the sedges, density of *C. rotundus* was recorded significantly lower in maize (B) (cob + fodder) + cowpea (B) + sesbania (F)-2:1:1 (BBF 105 x 30 cm) - vegetable pea + toria-3:1 (BBF) - groundnut + mentha-3:1(BBF) treatment while the highest density was recorded in rice (TPR) – wheat treatment during both the years. It could be due to inclusion of cereals crops like wheat in *Rabi* season which don't cause smothering effect on weeds therefore weed density resulted the highest.

In summer, among the sedges, no density of *C. rotundus* was recorded in soybean (B) + rice (DSR) (F)-2:1 (NBS 60 x 30 cm) - wheat + mentha (3:1) (NBS 60 x 30 cm) - continue (NBS 60 x 30 cm treatment while the highest density was recorded in rice (DSR) - vegetable pea - maize (cob + fodder) treatment during both the years.

In *Kharif* season density of total weeds as well as grasses, broad-leaved weeds and sedges was observed the lowest in rice – wheat cropping system. In *Rabi* season, [maize (B) (cob + fodder) + cowpea (B) + sesbania (F)-2:1:2 - vegetable pea (B) + toria (F)-3:1 – groundnut (B) + mentha (F)-3:1(BBF 105 x 30 cm)] proved to be the most prominent cropping system for controlling total weeds likewise broad leaved weeds and sedges. All the cropping systems proved superior for the control of grassy weeds (*Phalaris minor* and *Avena fatua*) in this season in which there was inclusion of either legumes or oilseed crops over those cropping systems in which wheat was raised. During summer season, soybean (B) + rice (DSR) (F)-2:1 – wheat (B) + mentha (F) (3:1) - continue (NBS 60 x 30 cm) cropping system was found better for the control of complex weed flora

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