Indian Journal of Weed Science **51**(1): 15–22, 2019

Print ISSN 0253-8040 Online ISSN 0974-8164

Effect of crop intensification and establishment techniques on weed infestation under different cropping system

Indu Bala Sethi*, Rohitashav Singh, V.K. Singh, Sumit Chaturvedi, Ajit Pratap Singh, Dushyant Prabhakar and Jodh Pal Singh

G.B. Pant University of Agriculture & Technology, Pantnagar, Uttarakhand 263 145, India

**Email: indubalasethia2012@gmail.com*

Article information

DOI: 10.5958/0974-8164.2019.00004.2

Type of article: Research article

Received : 2 January 2019
Revised : 8 March 2019
Accepted : 17 March 2019

Key words
Intensification

Land configurations

Rice-wheat

Weed management

ABSTRACT

The field experiment was 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 management under irrigated rice-wheat system. The experiment was laid out in a randomized block design with nine treatments and replicated thrice. The nine cropping sequence were evaluated for productivity. Density of these weeds was significantly affected by crop intensification and establishment techniques during both the years. In *Kharif* season, total weed density was recorded significantly lower in treatment rice (TPR) – wheat while the highest total weed density was recorded in rice (DSR) –vegetable pea – maize grain treatment during both the years. Weed density as affected by crop rotations maize (B) (cob + fodder) + cowpea (B) + *sesbania* (F)-2:1:2 - vegetable pea (B) + toria (F)-3:1 – groundnut (B) + mentha was found to be the the superior in terms of weed suppression.

INTRODUCTION

Weeds are an important constraint in agricultural production systems, acting at same tropic level as the crop; weeds capture a part of the available resources that are essential for plant growth (Oerke 2006). Effective weed management is critical to maintaining agricultural productivity. Inevitably, leaving weeds uncontrolled will sooner or later lead to considerable reductions in crop yield and increase production cost. Manual weed control is labour intensive and therefore limits the production area. 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). 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. 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.

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, to study crop intensification and establishment techniques to enhance productivity under irrigated rice-wheat system. The soil of experimental field was loam in texture. The soil of experimental field was 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 [rice (transplanted rice) – wheat], [rice (transplanted rice) - vegetable pea – groundnut], [rice (direct seeded rice) - vegetable pea - maize (grain)], [rice (direct seeded rice) - potato -cowpea (vegetable +fodder)],

[rice (direct seeded rice) - vegetable pea - maize (cob + fodder)], [rice (direct seeded rice) - yellow sarson – cowpea], [rice (direct seeded rice) (bed) + sesbania (furrow)- 2:1-vegetable pea (bed) + toria (furrow)-2:1 - maize (bed) (cob + fodder) + mentha (furrow)1:1, (furrow irrigated raised bed, 45cm x 30 cm)], [soybean (bed) + rice (direct seeded rice) (furrow)-2:1 - wheat + mentha (3:1) – continue same cropping system (narrow bed system, 60 cm 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 105 cm 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 density/ m^2 recorded 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 m x 0.5 m (0.25 m^2) and expressed as number per meter square. Weed dry matter of all the weed species (grasses, broad leaved weeds and sedges) recorded just before the execution of firsthand weeding or before application of post emergence herbicides within an area of quadrate of 0.5 m x 0.5 m (0.25 m^2) were cut closed to ground surface, separated species wise and sun dried for first 4-5 days thereafter placed into an oven at 70 $\pm$ 1 ^{O}C temperatures till a constant weight was obtained. The dry weight of weeds was expressed as g/ m^2. Total weed dry matter was worked out by adding of all weed species.

RESULTS AND DISCUSSION

Weed density in *Kharif*

The data on density of grasses, broad leaved weeds, sedges and total weeds during *Kharif*season in 2015 and 2016 is presented in **Table 1**. Density of these weeds was significantly affected by crop intensification and establishment techniques during both the years.

In *Kharif* season, total weed density was recorded significantly lower in treatment rice (TPR) – wheat while the highest total weed density was recorded in rice (DSR) –vegetable pea – maize grain treatment during both the years. The total density of grasses in *Kharif* was recorded significantly lower in

Table 1. Effect of crop intensification and establishment techniques on total weed density during *Kharif*

Treatment	Total weeds in *Kharif* (no./m^2)							
	Grassy weeds		BLWs		Sedges		Total weeds	
	2015	2016	2015	2016	2015	2016	2015	2016
Rice (TPR) – wheat	5.7 (32.0)	6.4 (40.0)	3.7 (13.3)	4.2 (17.3)	10.0 (98.7)	10.2 (104.0)	12.0 (144.0)	12.7 (161.3)
Rice (TPR) - vegetable pea – groundnut	6.4 (40.0)	6.9 (48.0)	4.7 (21.3)	5.3 (28.0)	10.1 (102.7)	10.3 (105.3)	12.8 (164.0)	13.5 (181.3)
Rice (DSR) –vegetable pea – maize grain	10.1 (102.7)	10.5 (109.3)	9.7 (94.7)	10.5 (109.3)	11.6 (133.3)	11.9 (141.3)	18.2 (330.7)	19.0 (360.0)
Rice (DSR) - potato -cowpea (vegetable)	9.0 (80.0)	9.6 (92.0)	9.3 (85.3)	10.1 (102.7)	11.4 (129.3)	11.6 (134.7)	17.2 (294.7)	18.2 (329.3)
Rice (DSR) - vegetable pea - maize (cob + fodder)	9.7 (93.3)	10.3 (106.7)	9.3 (86.7)	10.0 (100.0)	11.3 (128.0)	11.6 (133.3)	17.6 (308.0)	18.4 (340.0)
Rice (DSR) - yellow sarson – cowpea (vegetable + green manure)	9.2 (84.0)	9.9 (97.3)	9.7 (94.7)	9.9 (97.3)	11.4 (129.3)	11.5 (132.0)	17.6 (308.0)	18.1 (326.7)
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)	8.3 (68.0)	8.6 (73.3)	8.5 (72.0)	8.7 (76.0)	10.7 (114.7)	10.9 (118.7)	16.0 (254.7)	16.4 (268.0)
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	8.8 (77.3)	9.1 (82.7)	8.7 (76.0)	9.0 (81.3)	10.6 (112.0)	11.2 (124.0)	16.3 (265.3)	17.0 (288.0)
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)	9.5 (89.3)	9.9 (97.0)	8.4 (70.7)	8.3 (69.0)	10.3 (106.7)	10.7 (113.3)	16.3 (266.7)	16.7 (279.3)
LSD (p=0.05)	0.49	0.47	0.41	0.48	0.61	0.65	0.46	0.64

Original values given in parentheses was subjected to square root $(\sqrt{x+1})$transformation before analysis; BLWs =broad-leaved weeds

rice (TPR) – wheat system (5.68 and 6.36 no. /m^2) treatment during 2015 and 2016 while the highest was in rice (DSR) –vegetable pea – maize grain treatment system. Direct-seeded rice faces a potential threat from changes in the competing weed flora and with an increase in those species that are difficult to control (Johnson *et al*. 2003). These include *I. rugosum, E. crus-galli, E. colona, L. chinensis* and *Cyperus* spp. The total density of broad-leaved weeds in *kharif* during both the years was recorded significantly lower in rice (TPR) – wheat treatment while the maximum density of these weeds was recorded in rice (DSR) –vegetable pea – maize grain treatment. The total density of sedges in *Kharif* was found significantly lower in rice (TPR) – wheat treatment while highest in rice (DSR) –vegetable pea – maize grain treatment during both the years. Malik and Yadav (2008) also reported that integrated weed management, sowing sesbania with the rice and use of a selective herbicide at 30–40 days after sowing to kill the sesbania to provide mulch, which reduced the need for hand weeding.

Weed density in *Rabi*

The observation recorded to density of grasses, broad leaved weeds, sedges and total weeds during *Rabi* season in 2015-16 and 2016-17 under different treatment are presented in **Table 2.** Density of these weeds was significantly affected by crop intensification and establishment techniques during both the years.

In *Rabi* season, total weed density was found to be significantly influenced due to different treatments during both the years. The lowest total weed density in *Rabi* season 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 while the highest value in rice (TPR) – wheat treatment during 2015-16 and 2016-17, respectively. No density of grasses in *Rabi* season 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) + menthe (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) treatment while the highest density was recorded in rice (TPR) – wheat during 2015-16 and 2016-17, respectively. The total

Table 2. Effect of crop intensification and establishment techniques on total weed density during *Rabi*

Treatment	Total weeds in *Rabi* (no./m^2)							
	Grassy weeds		BLWs		Sedges		Total weeds	
	2015-16	2016-17	2015-16	2016-17	2015-16	2016-17	2015-16	2016-17
Rice (TPR) – wheat	6.04 (36.0)	6.26 (38.7)	10.85 (117.3)	11.45 (130.7)	7.15 (50.7)	7.43 (54.7)	14.30 (204.0)	14.98 (224.0)
Rice (TPR) - vegetable pea – groundnut	0.71 (0)	0.71 (0)	9.62 (92.0)	9.96 (98.7)	6.67 (44.0)	6.77 (45.3)	11.68 (136.0)	12.02 (144.0)
Rice (DSR) –vegetable pea – maize grain	0.71 (0)	0.71 (0)	11.74 (137.3)	12.18 (148.0)	6.24 (38.7)	6.52 (42.0)	13.28 (176.0)	13.8 (190.0)
Rice (DSR) - potato -cowpea (vegetable)	1.34 (1.3)	0.71 (0)	11.33 (128.0)	11.57 (133.3)	6.04 (36.0)	6.14 (37.3)	12.87 (165.3)	13.08 (170.7)
Rice (DSR) - vegetable pea - maize (cob + fodder)	0.71 (0)	0.71 (0)	10.97 (120.0)	11.32 (127.7)	6.14 (37.3)	6.25 (38.7)	12.56 (157.3)	12.91 (166.3)
Rice (DSR) - yellow sarson – cowpea (vegetable + green manure)	0.71 (0)	0.71 (0)	8.19 (66.7)	8.67 (74.7)	5.33 (28.0)	5.69 (32.0)	9.75 (94.7)	10.35 (106.7)
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)	0.71 (0)	0.71 (0)	5.82 (33.3)	6.67 (44.0)	4.67 (21.3)	5.20 (26.7)	7.43 (54.7)	8.43 (70.7)
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	4.93 (24.0)	5.08 (25.3)	7.95 (62.7)	8.35 (69.3)	4.95 (24.0)	5.08 (25.3)	10.54 (110.7)	10.97 (120.0)
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)	0.71 (0)	0.71 (0)	5.92 (34.7)	6.45 (41.3)	4.38 (18.7)	4.52 (20.0)	7.33 (53.3)	7.85 (61.3)
LSD (p=0.05)	0.35	0.19	0.37	0.47	0.62	0.55	0.50	0.60

Original values given in parentheses was subjected to square root ($\sqrt{x+1}$)transformation before analysis; BLWs =broad-leaved weeds

density of broad-leaved weeds in *Rabi* was recorded 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 during 2015-16 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 2016-17, respectively. The total density of sedges in *Rabi* season 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 2015-16 and 2016-17, respectively which might be due to direct-seeding of rice. Similarly weed suppression is a desirable trait of a cover crop and in general, cover cropping systems have large potentials for weed management in agro ecosystems (Mohammadi 2013).

Weed density in summer

The mean values for density of grasses, broad leaved weeds, sedges and total weeds during summer season in 2015 and 2016 under different treatment are presented in **Table 3**. Density of these weeds was significantly affected by crop intensification and establishment techniques during both the years.

Total weed density in summer season was significantly influenced due to various treatments during both the years. No population of grasses, broad-leaved weeds and sedges in summer 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. The highest total density of weeds was recorded in rice (DSR) - vegetable pea - maize (cob + fodder) treatment during 2015 and 2016. The total weed density of grasses, broad-leaved weeds and sedges in summer season during both the years was recorded significantly higher in rice (DSR) - vegetable pea - maize (cob + fodder) treatment. Similarly, the cover crop within cropping systems was found to suppress weed emergence or without adversely affecting crops growth (Norsworthy 2003).

Total weed density in system

The mean values for density of total grasses, broad-leaved weeds, sedges and total weeds during *Rabi* season in 2015-16 and 2016-17 under different treatment are presented in **Figure 1**. Density of these weeds was significantly affected by crop intensification and establishment techniques during both the years.

Total weed density of system was recorded significantly lower in maize (B) (cob + fodder) +

Table 3. Effect of crop intensification and establishment techniques on total weed density during summer season

Treatment	Total weeds in summer (no./m^2)							
	Grassy weeds		BLWs		Sedges		Total weeds	
	2015	2016	2015	2016	2015	2016	2015	2016
Rice (TPR) – wheat	-	-	-	-	-	-	-	-
Rice (TPR) - vegetable pea – groundnut	10.3 (105.3)	10.5 (109.3)	9.7 (94.7)	10.1 (101.3)	8.7 (76.0)	9.3 (86.7)	16.6 (276.0)	17.2 (297.3)
Rice (DSR) –vegetable pea – maize grain	10.7 (113.3)	10.8 (117.3)	10.0 (98.7)	10.1 (102.7)	11.7 (140.0)	12.0 (144.0)	18.7 (352.0)	19.1 (364.0)
Rice (DSR) - potato - cowpea (vegetable)	10.5 (110.7)	11.0 (120.0)	8.7 (74.7)	9.3 (86.7)	10.4 (108.0)	11.0 (121.3)	17.1 (293.3)	18.1 (328.0)
Rice (DSR) - vegetable pea - maize (cob + fodder)	10.7 (113.3)	11.2 (125.3)	10.3 (106.7)	10.8 (117.3)	12.2 (149.3)	12.4 (154.7)	19.2 (369.3)	19.9 (397.3)
Rice (DSR) - yellow sarson – cowpea (vegetable + green manure)	10.6 (112.0)	11.0 (121.3)	10.0 (100.0)	10.5 (109.3)	11.2 (124.0)	11.4 (129.3)	18.3 (336.0)	19.0 (360.0)
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)	9.6 (92.0)	10.1 (101.3)	9.0 (80.0)	9.5 (90.7)	8.7 (76.0)	9.2 (85.3)	15.8 (248.0)	16.6 (277.3)
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	0.7 (0)	0.7 (0)	0.7 (0)	0.7 (0)	0.7 (0)	0.7 (0)	0.7 (0)	0.7 (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)	8.7 (76.0)	9.3 (86.7)	8.0 (64.0)	8.5 (72.0)	6.0 (36.0)	6.4 (41.3)	13.3 (176.0)	14.1 (200.0)
LSD (p=0.05)	0.37	0.98	0.44	0.79	1.41	0.82	0.84	1.18

Original values given in parentheses was subjected to square root ($\sqrt{x+1}$)transformation before analysis; BLWs =broad-leaved weeds

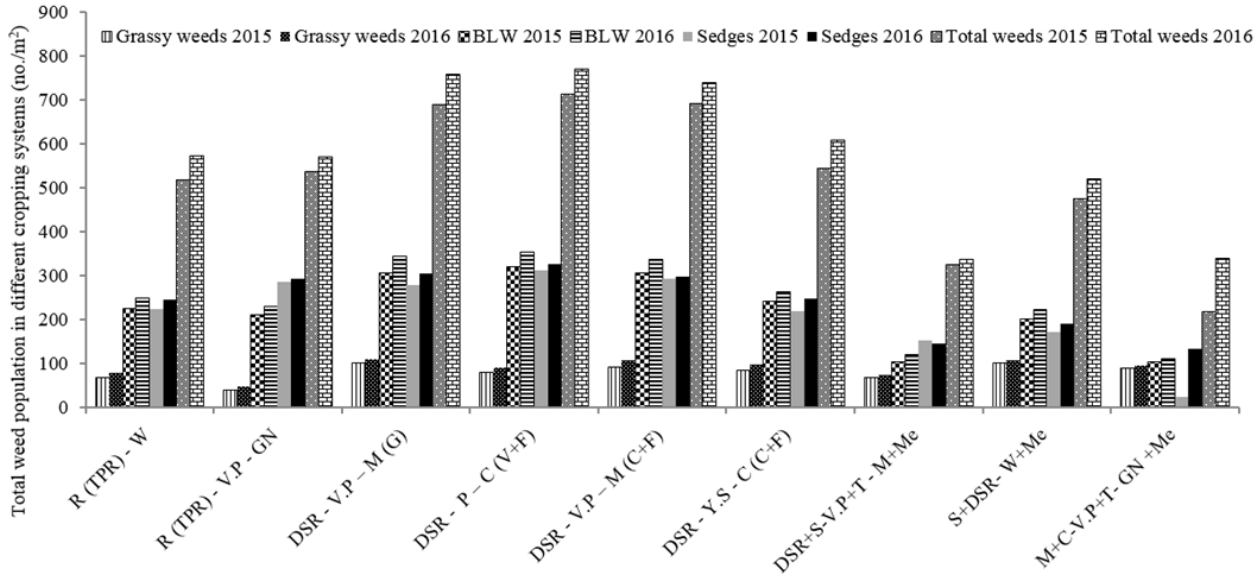

Figure 1. Effect of crop intensification and establishment techniques on weed density of total cropping systems

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 was recorded in rice (DSR) - potato -cowpea (vegetable) during both the years, respectively. The total density of grasses was recorded significantly lower in rice (TPR) - vegetable pea – groundnut treatment while the highest was recorded in rice (DSR) – vegetable pea – maize grain treatment during both the years, respectively. The total density of broad-leaved weeds recorded during 2015-16 and 2016-17 was found to be 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 in rice (DSR) - potato -cowpea (vegetable) treatment, during both years. The total population of sedges in summer 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 was recorded in rice (DSR) - potato -cowpea (vegetable) treatment during both the years. The lowest weed density 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 could be due to inclusion of different crops, *viz*. legumes, oilseeds, vegetables and fodder in cropping sequence. Similarly, Liebman and Gallandt (1997) also reported that crop rotation affects weed demography and subsequent population dynamics and hence it is considered to be a vital tool of weed management. Combinations of 25 cropping sequence reduced weed density compared to monoculture (Liebman and Ohno (1998). Mandal and Hossain (2015) observed different density of different weeds in different cropping system in winter and pre-*Kharif* seasons, maximum and minimum densities of *Digitaria sanguinalis* and *Echinochloa colona* were recorded in most of the crops.

Weed dry matter

Weeds dry matter in *Kharif, Rabi* and summer

The mean values for dry matter of total grasses, broad leaved weeds, sedges and total weeds during *Kharif, Rabi* and summer season in 2015-16 and 2016-17 under different treatment are presented in **Table 4**. Density of these weeds was significantly affected by crop intensification and establishment techniques during both the years.

In *Kharif*, dry matter accumulation of grassy, BLWs and sedges in *Kharif* was influenced significantly due to different treatments during 2015 and 2016. Significantly lower weed dry matter of grasses was recorded in rice (TPR) – wheat treatment while the highest dry matter was recorded in rice (DSR) - vegetable pea - maize (cob + fodder) treatment during 2015 and 2016, respectively. The lowest dry matter accumulation of BLWs was recorded in rice (TPR) – wheat while the highest dry matter was recorded in rice (DSR) - yellow sarson – cowpea (vegetable + green manure) during 2015 and in rice (DSR) - vegetable pea - maize (cob + fodder) during 2016, respectively. Dry matter accumulation of sedges was recorded significantly higher in rice (TPR) – wheat treatment while the highest dry matter was recorded in rice (DSR) –vegetable pea – maize grain treatment during 2015 and 2016, respectively. This might be due to direct seeding rice.

In *Rabi*, dry matter accumulation of grassy, BLWs and sedges was significantly influenced due to different treatments during 2015-16 and 2016-17, respectively. No weed dry matter of grasses was recorded in rice (TPR) - vegetable pea – groundnut, rice (DSR) –vegetable pea – maize grain, 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) -

Table 4. Effect of crop intensification and establishment techniques on weed dry matter in *Kharif, Rabi* and summer season

Treatment	Weed dry matter (g/m^2)					
	Grassy weed		BLWs		Sedges	
	2015-16	2016-17	2015-16	2016-17	2015-16	2016-17
Kharif						
Rice (TPR) – wheat	2.82(7.5)	2.92(8.0)	3.03(8.7)	3.13(9.3)	3.52(11.9)	3.60(12.5)
Rice (TPR) - vegetable pea – groundnut	2.98(8.4)	3.08(9.0)	3.29(10.3)	3.42(11.2)	3.63(12.7)	3.78(13.8)
Rice (DSR) –vegetable pea – maize grain	3.93(15.0)	4.03(15.7)	4.21(17.2)	4.31(18.1)	3.97(15.3)	4.17(16.9)
Rice (DSR) - potato - cowpea (vegetable)	3.59(12.4)	3.72(13.4)	4.11(16.4)	4.33(18.2)	3.96(15.2)	4.09(16.3)
Rice (DSR) - vegetable pea - maize (cob + fodder)	3.96(15.2)	4.11(16.4)	4.20(17.2)	4.36(18.5)	3.97(15.3)	4.05(15.9)
Rice (DSR) - yellow sarson – cowpea (vegetable + green manure)	3.78(13.8)	3.89(14.6)	4.25(17.6)	4.30(18.0)	3.91(14.8)	4.04(15.8)
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)	3.38(10.9)	3.61(12.5)	3.82(14.1)	4.00(15.5)	3.77(13.7)	3.89(14.7)
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	3.53(12.0)	3.6(12.4)	3.87(14.5)	3.97(15.3)	3.89(14.6)	3.94(15.0)
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)	3.18(9.6)	3.36(10.8)	3.69(13.1)	3.76(13.6)	3.77(13.7)	3.85(14.4)
LSD (p=0.05)	0.13	0.23	0.20	0.18	0.26	0.21
Rabi						
Rice (TPR) – wheat	2.68(6.7)	2.91(7.9)	4.93(23.9)	5.19(26.5)	3.51(11.8)	3.54(12.1)
Rice (TPR) - vegetable pea – groundnut	0.71(0)	0.71(0)	4.28(17.8)	4.51(19.8)	3.24(10.0)	3.39(11.0)
Rice (DSR) –vegetable pea – maize grain	0.71(0)	0.71(0)	4.81(22.7)	5.02(24.7)	3.18(9.6)	3.20(9.7)
Rice (DSR) - potato - cowpea (vegetable)	0.77(0.1)	0.71(0)	4.90(23.5)	4.99(24.4)	3.05(8.8)	3.08(9.0)
Rice (DSR) - vegetable pea - maize (cob + fodder)	0.71(0)	0.71(0)	5.10(25.5)	5.31(27.7)	3.09(9.1)	3.24(10.0)
Rice (DSR) - yellow sarson – cowpea (vegetable + green manure)	0.71(0)	0.71(0)	4.06(16.0)	4.26(17.6)	2.73(7.0)	2.80(7.3)
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)	0.71(0)	0.71(0)	2.58(6.2)	2.85(7.6)	2.65(6.5)	2.72(6.9)
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	2.51(5.8)	2.65(6.5)	2.86(7.7)	2.90(7.9)	2.67(6.7)	2.75(7.1)
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)	0.71(0)	0.71(0)	2.43(5.4)	2.66(6.6)	2.47(5.6)	2.65(6.5)
LSD (p=0.05)	0.14	0.04	0.28	0.22	0.30	0.23
Summer						
Rice (TPR) – wheat	-	-	-	-	-	-
Rice (TPR) - vegetable pea – groundnut	3.55(12.1)	3.62(12.6)	3.93(15.0)	4.02(15.6)	3.04(8.8)	3.12(9.3)
Rice (DSR) – vegetable pea – maize grain	3.69(13.1)	3.78(13.8)	3.97(15.2)	4.04(15.8)	3.72(13.3)	3.60(12.4)
Rice (DSR) - potato - cowpea (vegetable)	3.64(12.8)	3.69(13.1)	3.80(13.9)	3.71(13.2)	3.35(10.7)	3.91(14.8)
Rice (DSR) - vegetable pea - maize (cob + fodder)	3.65(12.8)	3.75(13.5)	4.31(18.1)	4.43(19.2)	3.77(13.7)	3.88(14.6)
Rice (DSR) - yellow sarson – cowpea (vegetable + green manure)	3.63(12.7)	3.78(13.8)	4.00(15.5)	4.13(16.6)	3.47(11.5)	3.59(12.4)
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)	3.44(11.3)	3.54(12.0)	3.71(13.3)	3.77(13.7)	3.02(8.6)	3.12(9.2)
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	0.71(0)	0.71(0)	0.71(0)	0.71(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)	3.25(10.1)	3.36(10.8)	3.55(12.1)	3.57(12.3)	2.46(5.6)	2.62(6.4)
LSD (p=0.05)	0.48	0.46	0.37	0.50	0.25	0.47

Original values given in parentheses was subjected to square root ($\sqrt{x+1}$)transformation before analysis; BLWs =broad-leaved weeds

vegetable pea (B) + toria (F)-2:1 (FIRBS) - maize (B) (cob + fodder) + mentha (F) 1:1(FIRBS), 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) while the highest dry matter was recorded in rice (TPR) – wheat treatment during 2015-16 and 2016-17, respectively. Significantly lower weed dry matter 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) during 2015-16 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 while the highest dry matter accumulation was recorded in rice (TPR) – wheat during 2015-16 and rice (DSR) - vegetable pea - maize (cob + fodder) during 2016-17, respectively. The lowest dry matter accumulation of sedges 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 while significantly higher dry matter was recorded in rice (TPR) – wheat treatment during 2015-16 and 2016-17, respectively.

In summer, dry matter accumulation of grassy, BLWs and sedges was significantly influenced due to different treatments during 2015 and 2016, respectively. Significantly lower dry matter accumulation of grassy, BLWs and sedges 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 summer season. The highest dry matter of grasses was recorded in rice (DSR) – vegetable pea – maize grain treatment during 2015 and rice (DSR) –vegetable pea – maize grain and rice (DSR) - yellow sarson – cowpea (vegetable + green manure) treatments during 2016. rice (DSR) - vegetable pea - maize (cob + fodder) treatment recorded the highest values of dry matter accumulation of BLWs during both years and sedges during 2015 while the highest dry matter accumulation in sedges during 2016 was found in rice (DSR) - potato -cowpea (vegetable) treatment.

Total weeds dry matter in system

The data regarding to total dry matter of grassy, BLWs and sedges weeds in the system during 2015-16 and 2016-17 under different treatment are presented in (**Figure 2**). Density of these total weeds was significantly affected by crop intensification and establishment techniques during both the years.

Total dry matter was recorded significantly lower 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 dry matter was recorded in rice (DSR) - vegetable pea - maize (cob + fodder) treatment during 2015-16 and 2016-17, respectively. Significantly lower dry matter accumulation of grassy weeds was recorded in rice (TPR) – wheat treatment whereas the highest dry matter was recorded in rice (DSR) – vegetable pea – maize grain during 2015-16 and rice (DSR) - vegetable pea - maize (cob + fodder) during 2016-17, respectively. The lowest total dry matter

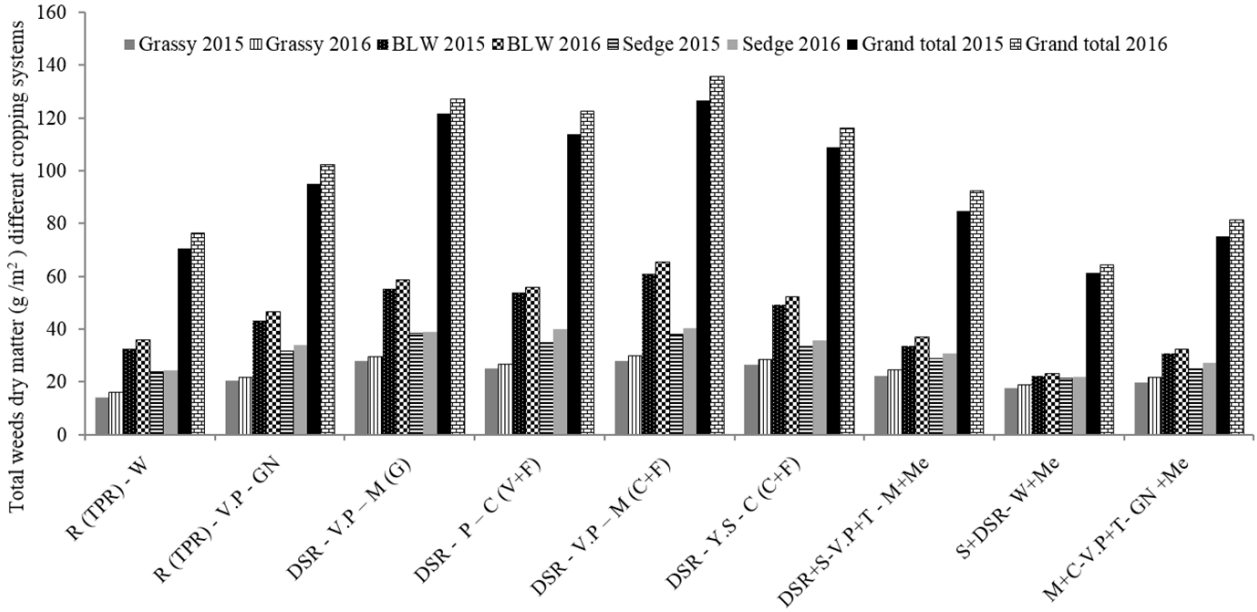

Figure 2. Effect of crop intensification and establishment techniques on total weed dry matter in cropping systems

accumulation of BLWs 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 while the highest total dry matter was recorded in rice (DSR) - vegetable pea - maize (cob + fodder) during 2015-16 and 2016-17, respectively. Significantly lower dry matter accumulation of sedges 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) during both years while the highest dry matter was recorded in rice (DSR) – vegetable pea – maize grain during 2015-16 and rice (DSR) - vegetable pea - maize (cob + fodder) during 2016-17, respectively. It might be due to inter-cropping effect. Inter-cropping can reduce both weed density and biomass to a great extent due to decreased light transmission through the canopy (Baumann *et al.* 2000). Inter-cropping with *Sesbania* for 30 days were found effective in controlling weeds in DSR (Singh *et al.* 2007).

REFERENCES

Ball DA. 1992. Weed seed bank response to tillage, herbicides, and crop rotation sequence. *Weed Science* **40**: 654–659.

Baumann D, Kropff M, Bastiaans L. 2000. Intercropping leeks to suppress weeds. *Weed Research* **40**: 359–374. Doi: 10.1046/j.1365-3180.2000.00197.x.

Johnson BC and Young BG. 2002. Influence of temperature and relative humidity on the foliar activity of mesotrione. *Weed Science.* **50**: 157–161. 10.1614/0043-17452002050[0157: IOTARH]2.0.CO;2

Liebman M and Gallandt ER. 1997. Many little hammers: ecological management of crop-weed interactions. In: *Ecology in Agriculture* (ed. LE Jackson), 291-343. Academic Press, San Diego, CA, USA.

Liebman M and Ohno T. 1998. Crop rotation and legume residue effects on weed emergence and growth: implications for weed management. In: *Integrated Weed and Soil Management* (eds JL Hat®eld, DD Buhler and BA Stewart), 181-221. Ann Arbor Press, Chelsea, MI, USA.

Malik RK and Yadav A. 2008. Direct-seeded rice in the Indo-Gangetic Plain: progress, problems and opportunities. p. 124–132. In: *Proceedings of Permanent Beds and Rice Residue Management for Rice–Wheat Systems in the Indo-Gangetic Plains*. (Eds. Humphreys E and Roth CH), ACIAR Workshop Proceedings No. 127, ACIAR, Canberra, Australia.

Martin RJ and Felton WL. 1993. Effect of crop rotation, tillage practice, and herbicides on the population dynamics of wild oats in wheat. *Australian Journal of Experimental Agriculture* **33**: 159–165.

Mohammadi GR. 2013. Alternative weed control methods: a review, *Weed and Pest Control - Conventional and New Challenges*, Dr. Sonia Soloneski (Ed.), ISBN: 978-953-51-0984-6, In Tech, doi: 10.5772/54164.

Mandal DC and Hossain A. 2015. Density, survival and seed production potential of important weeds of lateritic belt of West Bengal. *Indian Journal of Weed Science* **47**(1): 103–105.

Norsworthy JK. 2003. Small-grain cover crop interaction with glyphosate-resistant corn. *Weed Technology* **18**(1): 52–59.

Oerke EC. 2006. Crop losses to pests. *The Journal of Agricultural Science* **144**: 31–43.

Singh TK, Mehta RK, Kumar V and Singh PP. 2007. Effect of weed management practices on direct-seeded rice under puddle lowlands. *Indian Journal of Agronomy* **50**: 35–37.

Squire GR, Rodgers S and Wright G. 2000. Community-scale seed bank response to less intense rotation and reduced herbicide input at three sites, *Annals of Applied Biology* **136**: 47–57.