Indian Journal of Weed Science **51**(4): 337–343, 2019

Print ISSN 0253-8040 Online ISSN 0974-8164

Impact of diversification of rice-wheat cropping system on weed dynamics under irrigated condition of eastern Uttar Pradesh

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Article information

DOI: 10.5958/0974-8164.2019.00072.8

Type of article: Research article

Received : 28 February 2019
Revised : 24 September 2019
Accepted : 29 September 2019

Key words

Cropping Sequence

Diversification

Rice-wheat

Weed Density

Weed Dry Weight

Economic Yield

ABSTRACT

Effects of ten diversified rice based cropping sequences on weed dynamics were evaluated at Banaras Hindu University, Varanasi (Uttar Pradesh) in different season during 2016-17 and 2017-18. The results revealed that density of *Cyperus* spp., *Cynodon dactylon* and *Digitaria sanguinalis* was significantly lowest in rice-potato-greengram sequence but it remained at par with rice-berseem-cowpea fodder, rice-cabbage-cowpea fodder and rice-potato-cowpea fodder during second year in rainy season. Dry weight of *Digitaria sanguinalis* was significantly lowest under rice-potato-greengram sequence. During winter season, significantly lower density and dry weight of *Medicago denticulata*, *Chenopodium album* as well as total weeds were recorded in mustard (rice-mustard-cowpea fodder), though it was found similar with mustard (rice-mustard-sudan grass fodder), potato (rice-potato-greengram and rice-potato-cowpea fodder) and wheat (rice-wheat, rice-wheat-greengram and rice-wheat-cowpea fodder). While, density of *Cynodon dactylon* was markedly lower in wheat (rice-wheat) it was on a par with mustard (rice-mustard-sudan grass fodder), potato (rice-potato-green gram, rice-potato-cowpea fodder) and wheat (rice-wheat-greengram, rice-wheat-cowpea fodder). During summer season, cowpea grown in rice-cabbage-cowpea fodder recorded significantly lower density as well as dry weight of *Cyperus rotundus, Cynodon dactylon* as well as total weeds. Grain yield of rice was significantly higher in rice-berseem-cowpea fodder. During winter season, berseem in rice-berseem-cowpea fodder sequence out yielded all the other crops. However, in summer, sudan grass in rice-mustard-sudan grass fodder produced the highest green fodder yield.

INTRODUCTION

Rice-wheat cropping system is one of the world's largest agricultural production systems, covering an area of 26 mha extend over the Indo-Gangetic Plains (IGP) in South Asia. In India, rice-wheat system occupies around 10.5 mha area and produces almost 50% of the total food consumed in the country (Dhillon *et al*. 2010).

Diverse weed flora and excessive weed pressure is an important constraints in the way to sustainability and production potential of this system (Bhatt *et al.* 2016). Weeds are self-perpetuating and appear simultaneously with crop plants creating severe competition with the main plants for light, water and nutrients and in turn decrease overall land productivity of the system as a whole hence weeds are the main factor responsible for the yield declines in any ecosystem (Chauhan and Johnson, 2011). Due to intensive tillage in rice–wheat sequence and monoculture, increased problem of weeds are becoming serious year after year. The extent of yield reduction of rice due to weeds has been estimated up to 95% in India (Naresh *et al*, 2011), 33-80% in Pakistan (Khaliq *et al*. 2012) and 71-96% in the Philippines (Chauhan and Johnson, 2011). However, weeds accounts for more than 48% loss of potential wheat yield (Govindra *et al.* 2002; Fahad *et al*. 2015). The continuous practice of the same system over the years had an adverse effect on soil conditions (Bhatt *et al.* 2016) and increased the population of grassy weeds in both the crops. The existences of weeds in cropped lands are largely influenced by crop rotation and management practices (Mishra *et al.* 2019).

Diversification of rice-wheat system with inclusion of berseem has exhausted the seed bank of *Phalaris minor* (Tripathi and Singh 2008, Singh *et al.* 2019; Sethi *et al.* 2019). Legumes with leafy growth, succulent foliage have ability to suppress weeds and reduce weed population in succeeding season (Ali *et al.* 2012). Different rotations that include crops with different life cycles lead to additional benefits of reducing the weed seed bank. Hence, a crop diversification including legumes, oilseeds and vegetables has the potential to decreases the problems of weeds in rice-wheat systems. However, with diversification of the system, the behavior of weeds in different season as function of preceding crops may change. Therefore, a necessity was felt to study the weed dynamics in different season as influenced by diversification of rice-wheat system.

MATERIALS AND METHODS

A field experiment on diversification of rice-wheat system was conducted under AICRP on Integrated farming systems during 2016-17 and 2017-18 at the Agricultural Research Farm, Banaras Hindu University, Varanasi (U. P.). Varanasi is situated at an altitude of 74.4 meters above mean sea level and located between 25°15′173″ North latitude and 82°59′273″ East longitude. The impact of different cropping sequences on the weed dynamics during rainy, winter and summer season were studied. The soil of the experimental field was sandy loam (*Inceptisol*) in texture, low in organic carbon (0.41%) and available nitrogen (194.7 kg/ha), medium in phosphorus (21.7 kg/ha) and potassium (215.7 kg/ha) with slightly alkaline soil reaction (pH 7.9). The experiment was laid out in randomized block design with three replications on fixed plots with ten rice-based cropping system, *viz.* rice-wheat, rice-wheat-greengram, rice-potato-greengram, rice-wheat-cowpea (fodder), rice-potato-cowpea (fodder), rice-berseem-maize (fodder), rice-berseem-cowpea (fodder), rice-mustard-sudan grass (fodder), rice-mustard-cowpea (fodder), rice-cabbage-cowpea (fodder). All the crops were grown with recommended package of practices under irrigated condition. In rainy season, rice was sown in nursery at 16-06-2016 and 17-06-2017 during first and second year, respectively and then transplanted in the main field at 10-07-2016 and 09-07-2017. In subsequent winter season, crops were sown at optimum sowing time in the month of November, if required with pre sown irrigation. On maturity, wheat and mustard crops were harvested between 3rd week of March to 1st week of April. Whereas, potato tubers were dug out at maturity and cabbage heads were harvested at full developed stage when heads attained about 1-1.5 kg weight in the month of February. However, first cutting of berseem was done at 55-60 DAS and subsequent cutting were at 25-30 days intervals. The summer crops were sown in succession after harvesting of winter crops during both the year of experimentation. Greengram was plucked two times in rice-potato-greengram sequence but only one picking was possible in rice-wheat-greengram sequence and the remaining left over plant material was incorporated into the soil.

The recommended dose of nutrients (rice-120:60:60, wheat- 120:60:60, mustard- 120:60:60, potato-120:60:80, cabbage- 150:75:75, berseem (F) - 25:60:60, greengram- 22:56:40, cowpea (F) - 22:56:40, maize (F)- 120:60:40 and sudan grass (F)- 120:60:40 kg/ha N, P_2O_5 and K_2O) was applied to each crop except rice (50% nutrient through FYM + 50 % nutrients through fertilizers) by using inorganic sources. The half of the nitrogen requirement of the rice in each sequence was given through farm yard manure (FYM). However, with respect to phosphorus and potassium application through fertilizer was adjusted on equivalent basis as per their application as FYM. Well decomposed FYM available in the IFS model at Agricultural Research Farm was used. The desired quantity of FYM was calculated on the basis of nitrogen content and moisture percentage. The whole quantity of P_2O_5 and K_2O along with half of the nitrogen was applied as basal application through FYM, DAP and MOP in rice and urea, DAP and MOP in the remaining crop. The remaining half quantity of nitrogen was top dressed in the form of urea in one or two equal splits at recommended stages of crops. For various crops in the cropping sequences the important weed species emerged in rainy, winter and summer crops were recorded and grouped into species wise and total weeds were worked out at 25 DAT/DAS. Data on weed population (no./m^2) and their dry weight (g/m^2) were recorded at 25 DAT/DAS with the help of quadrate and subjected to square root transformation for statistical analysis and only significant data are presented in Tables.

RESULTS AND DISCUSSION

In rice crop, during rainy season, 10 different species of weeds were identified and composition of dominant weeds such as *Sagittaria guayanensis, Cyperus* spp. *Echinochloa* spp., *Digitaria sanguinalis* and *Cynodon dactylon* were 39.1, 24.7, 24.5, 6.8, 4.7 and 31.4, 25.9, 25.6, 8.4, 8.5, respectively during 2016-17 and 2017-18 (**Table 1**). During winter season; dominant weed flora were of

Medicago denticulata, Chenopodium album, Cyperus rotundus, Cynodon dactylon and other weeds were 75.1, 10.7, 7.7, 3.5, 2.8 and 74.5, 4.8, 13.5, 4.6, 2.4% respectively, during 2016-17 and 2017-18 (**Table 1**). Similarly during summer season, dominant weed flora were of *Cyperus rotundus*, *Cynodon dactylon* and other weeds were 34.2, 36.1, 29.7 and 33.1, 29.2, 37.8% respectively, during 2016-17 and 2017-18 (**Table 1**).

Table 1. Weed flora composition (%) of dominant weed during rainy, winter and summer season at 25 day after transplanting/ days after sowing of crops

Weeds	2016-17	2017-18
Rainy season		
Sagitaria guyanensis	39.06	31.44
Cyperus spp.	24.74	25.97
Echinochloa spp.	24.55	25.62
Digitaria sanguinalis	6.88	8.40
Cynodon dactylon	4.77	8.57
Winter season		
Medicago denticulate	75.11	74.57
Chenopodium album	10.73	4.83
Cyperus rotundus	7.76	13.57
Cynodon dactylon	3.54	4.60
Other weeds	2.87	2.43
Summer season		
Cyperus rotundus	34.22	33.05
Cynodon dactylon	36.12	29.17
Other weeds	29.66	37.77

Effect of cropping sequences on weed dynamics of rainy season

Weed population in different rice based cropping sequences varied during second year while, during first year, variations in different treatments was found to be non significant. In general, diversification of rice-wheat cropping sequence caused reduction in weed population as well as weed dry matter production. The density of *Cyperus* spp., *Cynodon dactylon* and *Digitaria sanguinalis* were significantly the lowest in rice-potato-greengram but it remained at par with rice-berseem-cowpea, rice-cabbage-cowpea and rice-potato-cowpea during second year of experiment (**Table 2**). This might be attributed due to intensification of sequences with legumes, which suppressed weed population during summer season and reduced the density of this perennial weed density in succeeding rice crop. The results were in conformity with Singh *et al.* (2008), who reported that weed infestation in various diversified rice-wheat cropping systems was less than that in rice-wheat system. Similarly, Ali *et al.* (2008) stated that inclusion of legumes in the existing rice-wheat cropping sequence suppresses the weed due to leafy and high vegetative cover throughout the cropping season.

Similar to weed density, the weed dry weight of most of the species did not differ significantly under different cropping sequence except dry weight of *Digitaria sanguinalis*, which was significantly lowest under rice-potato-greengram though remained statistically similar with rice-wheat-cowpea, rice-potato-cowpea, rice-berseem-cowpea, rice-mustard-cowpea and rice-cabbage-cowpea in order (**Table 2**). However, it was the highest in rice-wheat sequence during second year of study. The better performance of these sequences was mainly due to maximum coverage of ground area during summer season. Singh *et al.* (2008) reported that diversification of rice-wheat system through inclusion of green gram, cowpea fodder or *Sesbania* for green manuring in summer resulted significantly lowest population of grasses and sedges as well as weed dry matter production.

Effect of cropping sequences on weed dynamics in winter season

Density and dry weight of different species of weeds during winter season was markedly influenced by varying cropping system (**Table 3**). Significantly lower population of *Medicago denticulata*, *Chenopodium album* as well as total weed population were recorded in mustard (rice-mustard-cowpea fodder) though it was found similar with mustard (rice-mustard-sudan grass fodder), potato (rice-potato-greengram and rice-potato-cowpea fodder) and wheat (rice-wheat, rice-wheat-greengram and rice-wheat-cowpea fodder) whereas, density of *Cynodon dactylon* was markedly lower in wheat (rice-wheat). However, it was also statistically comparable with mustard (rice-mustard-sudan grass fodder, rice-mustard-cowpea fodder), potato (rice-potato-greengram and rice-potato-cowpea fodder) and wheat (rice-wheat-greengram and rice-wheat-cowpea fodder) proved distinct superior over cabbage grown (rice-cabbage-cowpea fodder) during both the year of experimentation. The lower density of weeds in these sequences might be due to establishment method of these crops which inhibited emergence of weeds under these sequences as compared to berseem and cabbage. However, comparatively higher population of all weeds were observed in cabbage (rice-cabbage-cowpea fodder) followed by berseem (rice-berseem-maize fodder and rice-berseem-cowpea fodder) sequences which could be ascribed due to establishment method of these crops, which pose favorable condition for weed

Table 2. Effect of different cropping sequences on weed density (no./m^2) and weed dry wt. (g/m^2) at 25 DAT of rice in rainy season

Treatment	Weed density(no./m^2)								Weed dry wt. (g/m^2)			
	Cyperus spp.		*Digitaria sanguinalis*		*Cynodon dactylon*		Total weeds		*Digitaria sanguinalis*		Total weeds	
	2016-17	2017-18	2016-17	2017-18	2016-17	2017-18	2016-17	2017-18	2016-17	2017-18	2016-17	2017-18
Rice-wheat	1.64	2.19	1.16	1.44	1.04	1.42	3.53	3.97	0.753	0.812	1.153	1.284
	(2.44)	(4.32)	(0.89)	(1.56)	(0.59)	(1.53)	(12.15)	(15.29)	(0.068)	(0.160)	(0.837)	(1.148)
Rice-Wheat-greengram	1.83	2.17	1.09	1.42	1.07	1.40	3.52	3.94	0.742	0.794	1.152	1.239
	(3.11)	(4.22)	(0.7)	(1.52)	(0.67)	(1.45)	(12.04)	(15.30)	(0.051)	(0.130)	(0.829)	(1.036)
Rice-potato-greengram	1.97	1.75	1.13	1.11	1.02	1.16	3.60	3.65	0.746	0.772	1.225	1.238
	(3.44)	(2.56)	(0.78)	(0.75)	(0.56)	(0.84)	(12.44)	(12.87)	(0.057)	(0.097)	(1.090)	(1.032)
Rice-wheat-cowpea (F)	1.76	2.09	1.11	1.21	0.91	1.32	3.50	3.76	0.738	0.783	1.164	1.253
	(2.78)	(3.89)	(0.73)	(0.96)	(0.33)	(1.24)	(11.84)	(13.7)	(0.046)	(0.113)	(0.858)	(1.074)
Rice-potato- cowpea (F)	1.72	1.84	1.02	1.20	1.08	1.18	3.55	3.64	0.726	0.773	1.169	1.244
	(2.67)	(2.88)	(0.56)	(0.94)	(0.67)	(0.90)	(12.28)	(12.83)	(0.027)	(0.098)	(0.867)	(1.049)
Rice-berseem-maize (F)	1.90	2.11	1.22	1.37	0.97	1.35	3.42	3.74	0.769	0.792	1.191	1.232
	(3.33)	(3.96)	(1.00)	(1.38)	(0.44)	(1.32)	(11.30)	(13.56)	(0.091)	(0.129)	(0.920)	(1.019)
Rice-berseem- cowpea (F)	1.76	1.82	1.02	1.18	1.01	1.17	3.45	3.62	0.740	0.774	1.166	1.219
	(2.67)	(2.83)	(0.56)	(0.901)	(0.53)	(0.88)	(11.42)	(12.6)	(0.048)	(0.099)	(0.861)	(0.988)
Rice-mustard-sudan grass (F)	1.76	2.15	1.07	1.39	1.07	1.38	3.46	3.91	0.739	0.791	1.126	1.234
	(2.78)	(4.14)	(0.67)	(1.44)	(0.67)	(1.42)	(11.59)	(14.78)	(0.046)	(0.127)	(0.678)	(1.023)
Rice-mustard-cowpea (F)	1.83	2.04	1.18	1.25	0.97	1.28	3.36	3.82	0.750	0.780	1.099	1.216
	(3.11)	(3.66)	(0.89)	(1.07)	(0.44)	(1.15)	(10.89)	(14.1)	(0.063)	(0.109)	(0.726)	(0.982)
Rice-cabbage-cowpea (F)	1.90	1.88	1.36	1.20	1.12	1.22	3.75	3.54	0.755	0.777	1.169	1.212
	(3.22)	(3.06)	(1.44)	(0.95)	(0.77)	(0.99)	(13.65)	(12.0)	(0.071)	(0.104)	(0.871)	(0.969)
LSD (p= 0.05)	NS	0.15	NS	0.09	NS	0.10	NS	NS	NS	0.017	NS	NS

Table 3. Effect of cropping sequences on weed density (no./m^2) and weed dry wt. (g/m^2) at 25 DAS in winter season

Treatment	Weed density (no./m^2)								Weed dry wt. (g/m^2)					
	Medicago denticulata		*Chenopodium album*		*Cynodon dactylon*		Total weeds		*Medicago denticulata*		*Cynodon dactylon*		Total weeds	
	2016-17	2017-18	2016-17	2017-18	2016-17	2017-18	2016-17	2017-18	2016-17	2017-18	2016-17	2017-18	2016-17	2017-18
Rice-wheat	8.7	8.9	3.6	1.9	2.0	1.6	10.3	10	1.52	1.54	1.21	0.96	2.20	2.10
	(76.4)	(79.8)	(12.6)	(3.3)	(3.3)	(2.2)	(106)	(100)	(1.83)	(1.93)	(0.95)	(0.43)	(4.73)	(3.96)
Rice-Wheat-greengram	10.4	8.7	3.7	2.1	2.1	1.8	11.9	9.9	1.54	1.40	1.26	0.93	2.39	2.06
	(108)	(78.8)	(13.3)	(3.6)	(3.7)	(2.9)	(142)	(99)	(1.89)	(1.47)	(1.09)	(0.36)	(5.21)	(3.78)
Rice-potato-greengram	10.9	8.9	3.9	1.8	2.4	2.1	12.7	10	1.62	1.26	1.56	0.86	2.50	1.86
	(118)	(80)	(14.8)	(3.3)	(5.6)	(3.6)	(160)	(100)	(2.13)	(1.09)	(1.92)	(0.24)	(5.79)	(2.97)
Rice-wheat-cowpea (F)	10.2	9.2	3.6	2.1	2.4	1.8	11.7	10.3	1.53	1.47	1.43	0.96	2.46	2.09
	(103)	(84.6)	(12.6)	(3.6)	(5.3)	(2.8)	(136)	(106)	(1.85)	(1.66)	(1.55)	(0.43)	(5.55)	(3.88)
Rice-potato- cowpea (F)	10.8	9.1	4.0	2.2	2.5	1.7	12.2	10.5	1.59	1.44	1.54	0.90	2.40	1.80
	(117)	(81)	(15.5)	(4.1)	(5.7)	(2.4)	(144)	(110)	(2.04)	(1.59)	(1.88)	(0.31)	(5.25)	(2.76)
Rice-berseem-maize (F)	12.1	9.5	4.4	3.1	2.5	2.8	13.6	11.4	1.85	1.64	1.55	1.03	2.71	2.31
	(146)	(90)	(19)	(8.6)	(6.1)	(7.6)	(187)	(132)	(2.95)	(2.22)	(1.91)	(0.57)	(6.84)	(4.88)
Rice-berseem- cowpea (F)	11.8	9.8	4.3	2.9	2.5	2.8	13.4	11.6	1.83	1.70	1.39	1.05	2.50	2.35
	(139)	(96)	18.6)	(8)	(5.7)	(7.3)	(179)	(136)	(2.85)	(2.24)	(1.18)	(0.60)	(5.79)	(5.06)
Rice-mustard-sudan grass (F)	8.5	8.6	3.5	2.14	2.2	2.6	10.1	9.9	1.51	1.31	1.46	1.03	2.37	2.09
	(71.4)	(74.4)	(12)	(4.12)	(4.3)	(6.3)	(102)	(99)	(1.81)	(1.22)	(1.66)	(0.56)	(5.12)	(3.90)
Rice-mustard-cowpea (F)	8.3	8.5	3.4	1.8	2.2	2.6	9.8	9.8	1.48	1.21	1.29	1.02	2.34	2.13
	(68.5)	(73.4)	(11.7)	(2.8)	(4.4)	(6.6)	(96)	(95)	(1.70)	(0.97)	(1.15)	(0.55)	(4.99)	(3.88)
Rice-cabbage-cowpea (F)	12.4	10.2	5.2	3.7	3.1	2.9	13.9	12.4	3.13	3.21	1.64	1.19	2.93	3.65
	(153)	(104)	(26.3)	(13.6)	(8.7)	(8.3)	(207)	(153)	(4.81)	(5.29)	(1.28)	(0.91)	(8.13)	(8.39)
LSD (p= 0.05)	2.7	0.8	0.6	0.45	0.42	0.50	2.09	1.55	0.21	0.35	0.14	0.16	0.27	0.37

emergence. Berseem was sown in puddled condition, whereas cabbage was irrigated after planting which createed conducive environment for germination, emergence as well as growth of weeds.

Similar to weed density, the dry matter production (**Table 3**) of most of the weed species under mustard grown in rice grown in (rice-mustard-sudan grass fodder and rice-mustard-cowpea fodder), wheat grown in (rice-wheat, rice-wheat-greengram and rice-wheat-cowpea fodder) and potato grown in (rice-potato-greengram and rice-potato-cowpea fodder) sequences, remained statistically comparable among themselves and recorded lower dry matter production as compared to cabbage (rice-cabbage-cowpea fodder). Lower population of weeds as well as crop smothering effect due to closer spacing and broad leaf of mustard, in turn, might have reduced the growth of weeds, which resulted in reduced dry matter production of weeds under these sequences. However, highest dry weights of weeds were observed in cabbage (rice-cabbage-cowpea fodder). These findings might be due to its wide spacing accompanied with slow initial growth and establishment build favorable environment for vigorous growth of weeds. Similarly, dry weight of weeds was higher in berseem as compared to wheat, mustard and potato during both the years. These results could be attributed to higher density of weeds under berseem resulting in higher dry matter production.

Effect of cropping sequences on weed dynamics in summer season

The density and dry weight of different weed species during summer season varied under different cropping sequences during both the years (**Table 4**). Cowpea grown in rice-cabbage-cowpea fodder recorded significantly lower density as well as dry weight of *Cyperus rotundus* and *Cynodon dactylon* as well as total weeds, but it remained at par with rice-berseem-cowpea fodder and rice-berseem-maize fodder during both the years. The lower density and dry matter of these perennial weed under these sequence might be due to smothering effect of preceding crops and which reduced the population of weeds, which did not offer favorable environment for germination of weeds particularly *Cyperus rotundus* and *Cynodon dactylon.* However, the annual weeds did not differ significantly by different cropping sequences during both the years of study. These results were conformity with finding of Tripathi and Singh (2008) who reported that minimum dry weight was recorded under rice-vegetable pea-wheat-green gram, subsequently, rice-berseem-rice-wheat-rice-wheat cropping sequence. Singh (2008) working on different rice based cropping sequences recorded lower weed density in cowpea as compared to other crops during summer season and stated that cowpea with its good canopy coverage had better smothering effect on weeds resulting in lower density as well as dry matter production of all the three groups of weeds.

Grain yield of rice

Data on grain yield of rice under different cropping sequences are presented in **Table 5**. In general, as compared to rice-wheat sequence, the

Table 4. Effect of different cropping sequence on weed density (no./m^2) and weed dry wt. (g/m^2) at 25 DAS in summer crops

Treatment	Weed density (no./m^2)						Weed dry wt. (g/m^2)					
	Cyperus rotundus		*Cynodon dactylon*		Total weeds		*Cyperus rotundus*		*Cynodon dactylon*		Total weeds	
	2016-17	2017-18	2016-17	2017-18	2016-17	2017-18	2016-17	2017-18	2016-17	2017-18	2016-17	2017-18
Rice-wheat	-	-	-	-	-	-	-	-	-	-	-	-
Rice-wheat-greengram	2.12 (4.01)	2.11 (3.95)	2.26 (4.62)	2.04 (3.67)	3.53 (11.94)	3.46 (11.47)	1.087 (0.682)	1.117 (0.748)	1.054 (0.612)	0.923 (0.353)	1.514 (1.794)	1.582 (2.006)
Rice-potato-greengram	2.10 (3.90)	2.09 (3.87)	2.11 (3.98)	1.96 (3.36)	3.48 (11.63)	3.50 (11.75)	1.060 (0.625)	1.072 (0.650)	1.053 (0.615)	0.914 (0.336)	1.489 (1.718)	1.580 (1.998)
Rice-wheat-cowpea (F)	2.15 (4.12)	2.15 (4.15)	2.13 (4.12)	2.03 (3.65)	3.49 (11.72)	3.54 (12.06)	1.165 (0.860)	1.150 (0.823)	1.059 (0.621)	0.946 (0.395)	1.554 (1.918)	1.636 (2.145)
Rice-potato- cowpea (F)	2.11 (3.90)	2.09 (3.89)	2.14 (4.10)	1.93 (3.24)	3.49 (11.57)	3.36 (12.81)	1.051 (0.606)	1.054 (0.611)	1.064 (0.639)	0.983 (0.468)	1.477 (1.681)	1.506 (1.773)
Rice-berseem-maize (F)	1.93 (3.24)	1.91 (3.17)	1.90 (3.14)	1.72 (2.46)	3.18 (9.66)	3.11 (9.22)	1.025 (0.551)	1.072 (0.650)	0.990 (0.489)	1.011 (0.523)	1.498 (1.491)	1.475 (1.678)
Rice-berseem- cowpea (F)	1.94 (3.27)	1.90 (3.12)	1.98 (3.45)	1.68 (2.34)	3.22 (9.89)	3.34 (10.69)	1.027 (0.555)	0.985 (0.471)	1.077 (0.661)	1.009 (0.518)	1.462 (1.528)	1.501 (1.758)
Rice-mustard-sudan grass (F)	2.25 (4.57)	2.18 (4.24)	2.47 (5.61)	2.19 (4.29)	3.71 (13.33)	3.62 (12.62)	1.204 (0.950)	1.155 (0.835)	1.190 (0.919)	1.046 (0.595)	1.663 (2.274)	1.629 (1.156)
Rice-mustard-cowpea (F)	2.18 (4.24)	2.13 (4.05)	2.11 (3.97)	2.16 (4.15)	3.41 (11.19)	3.60 (12.51)	1.092 (0.694)	0.975 (0.451)	1.073 (0.953)	1.055 (0.614)	1.598 (1.747)	1.523 (1.821)
Rice-cabbage-cowpea (F)	1.90 (3.12)	1.84 (2.87)	1.85 (2.94)	1.65 (2.24)	3.07 (8.91)	3.19 (9.68)	1.015 (0.530)	0.908 (0.437)	0.972 (0.445)	0.906 (0.322)	1.333 (1.279)	1.437 (1.566)
LSD (p= 0.05)	0.17	0.20	0.23	0.24	0.27	0.24	0.070	0.056	0.085	0.055	0.091	0.117

S- Sequence, the figure in the parentheses were original grain yield of rice was enhanced in sequences having legume crops during winter and summer season. However, the yield differences were significant only during the second year of experimentation. Rice-berseem-cowpea fodder cropping sequences being at par with rice-potato-green gram, rice-wheat-greengram and rice-potato-cowpea fodder produced significantly higher grain yield of rice than rest of the sequences and the lowest was recorded in rice-wheat cropping sequence. The grain yield of rice was improved in sequences having legume crops during winter and summer season, which might have positive effect of preceding legume (green gram, berseem and cowpea fodder) on growth characters and yield attributes. The results are in conformity with Prasad *et al.* (2013), who reported that rice-potato-greengram sequence produced higher grain and straw yield of rice. They attributed this to residual effect of nutrients by growing potato during winter and the beneficial effect of legumes grown in summer season.

Economic yield of winter crops

Growth and yield of the component crops was found to differ under variation cropping sequences. It is clear from the data (**Table 5**) that, in general, slightly higher yield of winter season crops were recorded in 2017-18 as compared to 2016-17 in most of the sequences. Though, wheat and mustard yield were declined during second year as compared to first year of experiment in rice-wheat and rice-mustard-sudan grass fodder sequences, respectively. The better performance during second year might be due to better soil fertility condition in sequences having legume component might be due to legume effect of previous year.

Among the all cropping sequences berseem grown in rice-berseem-maize fodder and rice-berseem-cowpea fodder as winter crop out yielded rest of the other crops during both the years of experimentation. It was followed by cabbage in rice-cabbage-cowpea fodder sequence followed by potato in rice-potato-greengram and rice-potato-cowpea fodder. Among grain/seed crops, wheat yield was considerably higher than mustard grown in sequences rice-sudan grass fodder and rice-mustard-cowpea fodder this may be attributed to their high yield potential and harvesting of economic produce fresh at high moisture contents. These results are in conformity with the findings of Bohra *et al.* (2007) who reported that potato out yielded other crops followed by maize + vegetable pea intercropping. Further examination of the data indicated that among three sequences involving wheat as winter crop, wheat grown in rice-wheat-cowpea fodder produced 4.8 per cent higher grain yield than rice-wheat sequence during second year of study. Similarly, wheat in rice-wheat-greengram sequence registered 3.14 per cent higher yield over rice-wheat sequence during second year of experimentation. This could be because of beneficial effect of the inclusion of cowpea and greengram in the cropping sequences which added a significant amount of biomass and nitrogen in the soil. Ali *et al.* (2012) found a significant higher yield of wheat under rice-wheat-cowpea and rice-wheat-greengram than rice-wheat sequence.

Grain/fodder yield of summer crops

Grain yield of greengram was higher in rice-potato-greengram sequence than rice as compared to rice-wheat-greengram (**Table 5**). Greengram performed better when taken after potato (rice-potato-green gram) as compared to after wheat (rice-wheat-green gram). This was mainly due to timely sowing of greengram after potato that provided

Table 5. Economic yield (t/ ha) of rainy, winter and summer crops in different cropping sequences

Treatment	Rainy		Winter		Summer	
	2016-17	2017-18	2016-17	2017-18	2016-17	2017-18
Rice-wheat	3.84	3.73	4.29	4.25	-	-
Rice-Wheat-greengram	3.87	4.06	4.36	4.39	0.63	0.67
Rice-potato-greengram	3.97	4.21	23.51	23.84	1.26	1.29
Rice-wheat-cowpea (F)	3.67	3.95	4.40	4.46	36.46	36.92
Rice-potato- cowpea (F)	3.87	4.02	23.34	23.54	40.74	41.04
Rice-berseem-maize (F)	3.92	3.91	41.31	41.36	59.26	59.79
Rice-berseem- cowpea (F)	3.79	4.25	41.48	41.75	41.14	41.59
Rice-mustard-sudan grass (F)	3.94	3.82	2.06	2.03	63.54	64.05
Rice-mustard-cowpea (F)	3.90	3.93	2.01	2.07	36.57	37.16
Rice-cabbage-cowpea (F)	3.78	3.95	32.22	32.49	34.72	35.14
LSD (p= 0.05)	NS	0.29	NA	NA	NA	NA

S- Sequence, NA- Not analyzed

favorable weather conditions for initial growth and development as well as sufficient period for two pickings before the onset of monsoon. Whereas, in rice-wheat-greengram sequence only one picking were possible in greengram due to delayed sowing of greengram.

Among the different summer crops, sudan grass grown in sequence rice-mustard-sudan grass fodder produced highest economic yield as compared to other crops. However, lowest yield were noted in greengram grown after wheat in rice-wheat-greengram sequence during both the years of experiment. As regards the cowpea grown in different cropping sequences, cowpea in rice-berseem-cowpea fodder sequence produced highest yield followed by cowpea in rice-potato-cowpea, rice-mustard-cowpea and rice-wheat-cowpea. However, the lowest yield was recorded in rice-cabbage-cowpea fodder sequence during both the years of study. The higher yield of cowpea in rice-berseem-cowpea fodder might be due to legume effect of preceding berseem. Similar, result were obtained by Yadav *et al.* (2013). The variation in the yield of crop might be attributed to the biological and environmental complexity and interaction in the cropping system (Francis 1989).

Therefore, the results of the experiment clearly indicated that diversification of rice-wheat system through substitution of wheat by other winter crops and inclusion of summer grain/fodder legumes might be one of the possible ways to reduce weed infestation and enhanced crop productivity in irrigated condition of eastern U.P.

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