A-5783
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Influence of Different Moisture Conservation Practices and Crop Sequence on Direct Seeded Rice based Cropping System in *Rainfed* Ecosystem of Assam, India

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10.18805/IJARe.A-5783

ABSTRACT

Background: Land configuration decides the effectiveness of crop management practices and major land configuration practice includes raised bed preparation, ridges and furrows, broad bed furrows *etc*. The farmers' practice of sowing in flatbed without proper land configuration, leads to poor growth and development of crops. A large portion of crop residues is burnt by the farmers in the fields to clear the left-over straw and stubbles. Conservation agriculture involving crop residue management can give new direction for sustaining productivity. The development issue of *rainfed* agriculture assumes critical importance in India due to slow growth and its impact on livelihood security of rural poor in India. Changes in crop establishment method in rice have significant implications in performing farm operations like tillage, seedbed preparations, transplanting, weeding and other intercultural operations including water management. The current study aimed to study the BF methods as land configuration including crop residue management in *rainfed* eco system in direct seeded rice based cropping system.

Methods: In the field experiment during 2016-17 and 2017-18, different size of bed of Broad bed Furrow (BBF) including Flatbed was made manually consisting four replication. After final land preparation the experimental field was divided into four blocks and each block was divided in to six main plots to allocate the six soil moisture conservation practices randomly, for growing summer (direct seeded *ahu* rice), *kharif* (green gram) crops. The main plots were again divided in to four sub-plots to allocate the *rabi* crops randomly following a split-plot design. Incorporation of crop residues was done in the plots as per treatments.

Result: The investigation resulted better performance of both the size of BBF beds as compared to flatbed method in respect of yield attributes and yield of the crops studied. Among the BBF, 60-30 cm size bed showed better than the BBF 120-30 cm size beds. The residue incorporation plots were shown comparatively better result than no residue incorporation treatments. The present study will be a contribution to the study of BBF particularly in pulse crops due to heavy rainfall received during *kharif* season in Assam.

Key words: Broad bed furrow, Direct seeded rice, Harvest index, Leaf area index, Net return, Rice equivalent yield.

INTRODUCTION

Land configuration is one of the most critical factors for optimizing production potentials of crops and based on weather conditions, it acted as a management practices for crops (Deshmukh *et al*., 2016). During *kharif* season, Assam experiences heavy rainfall due to monsoon and there is records of complete failures of *kharif* crops particularly pulses due to water stagnation in the standing crop at vegetative stage. Therefore draining of water from the field is important for saving the crop from water stagnation. Broad Bed Furrow (BBF) method is an emerging practice of land configuration in *rainfed* farming system which acts as in-situ moisture conservation during dry periods as well as draining of water in furrows during heavy rainfall. Transplanting of rice is the traditional method of establishment of rice crop in Assam which requires high labour cost (Sharma *et al*., 2008). The direct seeding avoids some basic operations like nursery raising, uprooting of seedlings, puddling, transplanting, maintaining standing water and thereby reduces labour requirement (Pepsico International, 2011). Direct seeding can also be profitable and can increase the net return if production is more or less comparable with the transplanted rice. Greengram is a popular pulse crop among the farmers of Assam and it is grown mostly in *kharif* season (Mid August-first of September) although in some pockets it is also grown in February-March as summer greengram. In the *rabi* season toria, linseed, niger, buckwheat, potato, lentil, pea are some

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How to cite this article: Baruah, N., Das, J.C., Bayan, H.C., Pathak, K., Basumatary, A., Goswami, R.K. and Goswami, J. (2022). Influence of Different Moisture Conservation Practices and Crop Sequence on Direct Seeded Rice based Cropping System in *Rainfed* Ecosystem of Assam, India. Indian Journal of Agricultural Research. DOI: 10.18805/IJARe.A-5783.

Submitted: 31-03-2021 **Accepted:** 25-04-2022 **Online:** 09-06-2022

of the crops that are grown under *rainfed* situation of Assam and among them, linseed, niger, buckwheat are well suited in limited water supply. Therefore considering the importance of direct seeded rice as compared to *sali* rice to save time and cost in a cropping system approach to have 300% cropping intensity, in-situ conservation of moisture in *kharif* season and residual effect of land configuration coupled with residue incorporation, a trial was conducted at BN College of Agriculture, Assam Agricultural University, Biswanath Chariali, Assam during *summer*, *kharif* and *rabi* season of 2016-17 and 2017-2018 under *rainfed* condition.

MATERIALS AND METHODES

The field experiments was conducted for two years (2016 - 17 and 2017-18) in sequence starting with direct seeded rice (*summer* season) followed by greengram (*kharif* season) and four *rabi* crops (toria, linseed, niger and buckwheat) in *rabi* season The experiment was conducted at BN College of Agriculture, Biswanath Chariali of Assam Agricultural University, Assam The weather condition at Biswanath chariali is hot and humid during summer and cold and moist during winter. During 2016, in *ahu* rice growing season (March-July, 12th SMW to 29th SMW) total rainfall was 1112.5 mm distributed over 67 numbers of rainy days and in 2017, total rainfall was 1308.1 mm during the same period distributed over 63 rainy days. Average maximum temperature range was 24.9^{o}C to 33.6^{o}C during 2016 and 25.4^{o}C to 33.2^{o}C during 2017 and the minimum temperature range was 17.0^{o}C to 26.7^{o}C and 15.8^{o}C to 26.3^{o}C during 2016 and 2017, respectively. During growing period of greengram in the year 2016 and 2017 (33rd SMW to 43rd SMW), total rainfall received was 480.4 mm and 526.4 mm against the total evaporation of 226.6 mm and 207.8, respectively. During 2016, the mean maximum and minimum temperature ranged between 29.9^{o}C to 34.3^{o}C and 21.2^{o}C to 26.9^{o}C, respectively while in 2017, the mean maximum temperature ranged between 27.7^{o}C to 34.1^{o}C and minimum temperature ranged between 19.1^{o}C to 25.9^{o}C. The number of rainy days during greengram growing period was 25 and 27 in 2016 and 2017, respectively. During the crop growing period of *rabi* crops in 2016-17 (45th SMW to 11th SMW) and 2017-18 (45th SMW to 10th SMW) total rainfall received were 83.4 mm and 120.7 mm against the total evaporation of 264.0 mm and 261.7 mm, respectively. The mean maximum and minimum temperature ranged between 20.4^{o}C to 30.4^{o}C and 9.2^{o}C to 18.7^{o}C during 2016 and during 2017, it ranged between 24.2^{o}C to 28.8^{o}C and 8.67^{o}C to 18.9^{o}C. The number of rainy days was 9 in 2016 and 10 days in 2017.

The soil of the experimental site was sandy loam in texture with an initial pH of 5.2 and 5.4 in 2016 and 2017, respectively. The organic carbon content was 0.59% and the initial available soil nitrogen, phosphorus and potash were in the range of low (259.10 kg ha^{-1}), medium (25.65 kg ha^{-1}) and low (112.30 kg ha^{-1}). The treatments consisted of 6 moisture conservation practices consisting land configuration of Flat bed and Broad Bed Furrow (BBF) along with crop residue incorporation. Two different sizes of BBF were studied consisting 60 cm and 120 cm width with a gap of 30 cm furrowsize in between beds. The treatments were Flat bed with crop residue incorporation (M_1), Flat bed with no residue incorporation (M_2), BBF 60-30 cm with residue incorporation (M_3), BBF 60-30 cm without residue incorporation (M_4), BBF 120-30 cm with crop residue incorporation (M_5) and BBF 60-30 cm without crop residue incorporation (M_6).

The experimental plot was ploughed by tractor drawn plough followed by one harrowing. Laddering was done properly to retain water uniformly in the field. After final land preparation the experimental field was divided into four blocks and each block was divided in to six main plots to allocate the six soil moisture conservation practices randomly, for growing summer (direct seeded *ahu* rice) and *kharif* (greengram) crops in sequence. The layout of the experiment consisting of the broad bed furrows at 60 cm and 120 cm apart, with 30 cm width furrow in between them were constructed manually along with the flatbeds, before sowing of rice crop. The main plots were again divided in to four sub-plots to allocate the *rabi* crops randomly following a split-plot design. Rice crop was sown accordingly with a spacing of 20 cm in both broad bed and flatbed surface of the soil. There were 3 rows of rice crop in one 60 cm bed and 6 rows of rice in 120 cm bed, while in flatbeds seeds were sown in usual lines of 20 cm apart.

For incorporation of crop residues the straw weight was recorded after harvesting the crop at the ground level followed by threshing. Then the rice straw (residue) was incorporated in the plots as per treatments by spreading them as uniformly as possible after the first opening of the plots to grow greengram in succession. The remaining plots were kept as such without crop residues. The follow up land preparation was carried out by hoeing manually without breaking the beds and furrows and greengram was also sown in all the sub-plots similar to that of direct seeded *ahu* rice.

In *rabi* season, after harvest of greengram by uprooting the plant, the remaining pods that left after field pickings were separated, weighed and incorporated in the plots as per treatments, similar to that of rice and greengram. The entire plots in each block were prepared manually, retained the broad bed furrows and four *rabi* crops *viz*. toria, linseed, niger and buckwheat were allocated randomly following split-plot design. Due to dis-similarity in biometric observations on different *rabi* crop parameters, RBD was followed for analyses of variance. The *rabi* crops were sown in lines at the recommended spacing of the crops. The fertilizer application and all other cultural practices were also performed as per recommendations of the crop.

The rice crop was sown in line with 20 cm spacing and in 60-30 cm bed, 3 rows of rice was allocated and in 120-30 cm bed, 6 rows of rice were allocated. The greengram crop was sown in 30 cm spacing in all the BBF and flat beds. The variety used for direct seeded rice was “Inglongkiri” which was developed by Regional Agricultural Research Station, Assam Agricultural University Diphu, having a average duration of 115-120 days. For greengram the variety SG-1 (Pratap) was selected for the study. In the first year rice crop was sown on 23.03.16 and in second year the rice was sown on 22.03.17 and harvested on 18.07.16 and 16.07.17, respectively. The second crop greengram crop was sown in 15.08.16 in the first year and 16.08.17 in second year and harvested on 24.10.16 and 22.10.17, respectively. The *rabi* crops were sown in the 2nd week of November and harvested in Feb (toria, linseed and niger) and march (linseed).

For all the crops, yield attributes and yield were recorded and analyzed statistically for interpretation of the data. The individual crops were analyzed in RBD and system parameters were analyzed in split plot design.

RESULTS AND DISCUSSION

Yield attributes of rice

The panicle sm^{-2} under BBF 60-30 cm with residue (113.00 and 117.69 in 2016 and 2017 and without residue (112.69 and 113.75 in 2016 and 2017 which was equal to BBF 120-30 cm with residue (109.56 and 113.63 in 2016 and 2017, respectively. The BBF 60-30 cm with residue incorporation resulted in significantly higher values of grains $panicle^{-1}$ over both flatbeds with or without residue incorporation (Table 1).

The higher number of effective panicles m^{-2} and grains $panicle^{-1}$ under BBF may be due to better growth of the crop resulting from more retention and conservation of water in the furrows which was utilised during rainless periods. Higher number of grains $panicle^{-1}$ (Kaur and Dhaliwal, 2015) and grains $panicle^{-1}$ (Hobbs and Gupta, 2003) of rice due to better growth of the crop under raised bed sowing method than the flatbed method was also reported.

Grain and straw yield

In 2016, the grain yield under the treatments BBF 60-30 cm with (23.43 q ha^{-1}) and without residue (22.72 q ha^{-1}) and BBF 120-30 cm with residue (22.81 q ha^{-1}) were at par and BBF 60-30 cm with residue produced significantly higher grain yield over rest of the treatments. In 2017, BBF 60-30cm with residue (25.70 q ha^{-1}) significantly out yielded all other treatments (Table 1). The pooled data over the years revealed that BBF 60-30 cm with residue (24.56 q ha^{-1}) produced significantly higher grain yield over rest of the treatments. In rice-wheat cropping system, the increase of rice yield by 33% and wheat yield by 60% in the permanent bed sowing method was reported by Singh *et al.* (2011).

Yield attributes of *kharif* greengram

The treatment BBF 60-30 cm both with and without residue incorporation produced significantly higher number of clusters $plant^{-1}$ over rest of the treatments during both 2016 and 2017 (Table 2). In respect to number of pods $cluster^{-1}$, in 2016, BBF 60-30 cm and BBF 120-30 cm with and without residue incorporation showed at par effect but significantly higher over both flatbed methods. While in 2017, the effect of BBF 60-30 cm with and without residue incorporation and

Table 1: Effect of moisture conservation practices on yield attributes and yields of direct seeded *ahu* rice.

Treatments	Effective panicle m^{-2}		Grains $panicle^{-1}$		1000-grain weight (g)		Grain yield (q ha^{-1})			Straw yield (q ha^{-1})		
	2016	2017	2016	2017	2016	2017	2016	2017	pooled	2016	2017	pooled
M_1: Flat bed with residue	106.35	108.19	91.33	99.13	23.60	24.05	21.85	23.69	22.77	37.94	39.88	38.91
M_2: Flat bed without residue	105.63	107.38	92.62	94.69	23.80	23.80	21.90	22.38	22.14	37.47	37.88	37.67
M_3: BBF 60-30 cm with residue	113.00	117.69	98.35	108.38	24.01	23.80	23.43	25.70	24.56	38.70	42.60	40.65
M_4: BBF 60-30 cm without residue	112.69	113.75	97.63	100.13	23.91	23.81	22.72	23.31	23.01	38.04	39.55	38.79
M_5: BBF 120-30 cm with residue	109.56	13.63	95.10	102.44	23.70	23.90	22.81	24.14	23.47	37.97	40.13	39.05
M_6: BBF 120-30 cm without residue	108.38	110.38	94.25	97.63	23.82	23.81	22.31	23.06	22.68	37.28	39.03	38.15
SEm±	1.82	2.22	1.80	1.50	0.22	0.15	0.27	0.31	0.33	0.84	0.80	0.64
CD (P=0.05)	5.48	6.69	5.43	4.41	NS	NS	0.74	0.95	1.24	NS	2.40	2.31

BBF 120-30 cm without residue incorporation on number of pod cluster^{-1} were significantly higher over rest of the treatments. In case of number of seeds pod^{-1} and 1000 seed weight, higher values were recorded under BBF 60-30 cm with residue incorporation. The optimum moisture availability due to the adequate drainage of excess rain water through the furrows in BBF methods might have resulted in better yield attributing characters compared to flatbed sowing. A similar result of increased yield attributes of *kharif* greengram *viz.*, number of clusters plant^{-1} and pod cluster^{-1} due to the land configuration of BBF compared to flatbed method was also reported by Tomar (2013).

Seed and stover yield

Both the treatment BBF 60-30 cm and BBF 120-30 cm with and without residue incorporation resulted in statistically at par seed and stover yield and produced significantly higher values over the flatbed (Table 2). The highest seed (9.58 q ha^{-1} and 10.63 q ha^{-1} in 2016 and 2017, respectively) and stover yield (27.62 q ha^{-1} and 29.26 q ha^{-1}, in 2016 and 2017, respectively) were recorded with the treatment BBF 60-30 cm with residue followed by BBF 60-30 cm without residue and BBF with and without residue incorporation. The BBF 60-30 cm with residue incorporation resulted in higher seed and stover yields by about 35.6% and 39.3% over the flatbed methods with or without residue incorporation. The higher yield attributes like number of clusters plant^{-1}, pods cluster^{-1} and seeds pods^{-1} (Table 2) under the treatment BBF 60-30 cm might have attributed to higher seed and stover yield of greengram. Increased seed and stover yield of chickpea and safflower by 12.5% and 10.7% in BBF planting over traditional flatbed method were also reported by Khambalkar, (2014).

***Rabi* crops**

Yield attributes and yields of buckwheat

The number of cymes plant^{-1} and 1000-seed weight (Table 3) of buckwheat did not vary significantly due to different moisture conservation practices in both the year. But the number of seeds cyme^{-1} was significantly higher under the treatment BBF 60-30 cm with or without crop residue incorporation over the flat bed methods and the lowest seeds cyme^{-1} was recorded in flat bed without residue.

In regards to seed and stover yields (Table 3) in both the year, BBF 60-30 cm with and without residue incorporation brought about significantly higher values over that of flatbeds with and without residue incorporation. Pooled data over the years also showed similar results in both the cases. Similar results of the increased seed yield of safflower due to different land configurations over the flat bed sowing was also reported by Khambalkar (2014).

Yields attributes and yield of linseed

During both the year, different moisture conservation practices significantly influenced the number of capsules plant^{-1} while the number of seeds capsule^{-1} and 1000-seed weight did not vary significantly. In both year, the seed yield (Table 4) of linseed due to BBF 60-30 both with (6.13 and

Table 2: Effect of moisture conservation practices on yield attributes and yields of greengram.

Treatment	Cluster plant^{-1}		Pods cluster^{-1}		Seed pod^{-1}		1000-seed weight (g)		Seed yield (qha^{-1})			Stover yield (qha^{-1})		
	2016	2017	2016	2017	2016	2017	2016	2017	2016	2017	Pooled	2016	2017	pooled
M_1: Flat bed with residue	1.90	2.13	3.40	3.51	7.94	7.32	30.84	30.98	6.73	7.45	7.09	19.06	22.08	20.57
M_2: Flat bed without residue	1.85	2.02	3.35	3.42	7.81	7.17	30.78	30.98	6.63	6.98	6.82	18.90	21.61	20.26
M_3: BBF 60-30 cm with residue	3.01	3.08	3.99	4.47	8.84	8.80	30.84	31.07	9.58	10.63	10.10	27.62	29.26	28.44
M_4: BBF 60-30 cm without residue	2.95	3.03	3.91	4.35	8.56	7.94	30.78	30.42	9.44	10.11	9.77	26.10	28.11	27.10
M_5: BBF 120-30 cm with residue	2.61	2.73	3.75	4.05	8.72	8.16	31.34	31.35	9.04	9.69	9.36	24.96	27.99	26.47
M_6: BBF 120-30 cm without residue	2.57	2.64	3.70	3.95	8.45	7.84	31.08	31.13	8.95	9.33	9.14	24.75	27.11	25.93
SEm±	0.10	0.08	0.11	0.16	0.30	0.29	0.46	0.31	0.36	0.41	0.19	0.97	0.75	0.41
CD (P=0.05)	0.31	0.25	0.33	0.47	NS	0.87	NS	NS	1.09	1.23	0.62	2.91	2.25	1.23

Table 3: Effect of moisture conservation practices on yield attributes and yields of buckwheat.

Treatment	Primary branches plant^{-1}		Cymes plant^{-1}		Seeds cyme^{-1}		1000-seed weight(g)		Seed yield (q ha^{-1})			Stover yield (q ha^{-1})		
	2016	2017	2016	2017	2016	2017	2016	2017	2016	2017	Pooled	2016	2017	pooled
M_1: Flat bed with residue	5.23	5.53	17.45	17.88	5.23	5.53	17.45	17.88	3.87	4.21	4.04	11.93	12.69	12.31
M_2: Flat bed without residue	5.33	5.38	17.38	17.10	5.33	5.38	17.38	17.10	3.65	3.83	3.74	11.55	11.71	11.60
M_3: BBF 60-30 cm with residue	6.10	6.40	18.13	18.38	6.10	6.40	18.13	18.38	4.93	5.35	5.14	14.19	15.43	14.81
M_4: BBF 60-30 cm without residue	6.10	6.00	17.95	17.93	6.10	6.00	17.95	17.93	4.75	5.11	4.93	13.98	14.93	14.45
M_5: BBF 120-30 cm with residue	5.93	6.20	17.50	17.63	5.93	6.20	17.50	17.63	4.43	4.73	4.58	13.41	13.55	13.48
M_6: BBF 120-30 cm without residue	5.80	6.15	17.40	17.20	5.80	6.15	17.40	17.20	4.35	4.51	4.43	13.21	13.45	13.33
SEm±	0.22	0.23	0.92	1.10	0.22	0.23	0.92	1.10	0.14	0.20	0.29	0.58	0.59	0.52
CD (P=0.05)	0.67	0.71	NS	NS	0.67	0.71	NS	NS	0.42	0.60	0.87	1.75	1.78	1.56

Table 4: Effect of moisture conservation practices on yield attributes and yield of linseed.

Treatment	Capsules plant^{-1}		Seeds capsule^{-1}		1000 seed weight (g)		Seed yield (q ha^{-1})			Stover yield (q ha^{-1})		
	2016	2017	2016	2017	2016	2017	2016	2017	Pooled	2016	2017	Pooled
M_1: Flat bed with residue	38.13	39.15	9.68	9.83	4.44	4.42	4.89	4.94	4.91	15.78	16.10	15.94
M_2: Flat bed without residue	33.35	33.90	9.70	9.70	4.43	4.41	4.36	4.45	4.40	15.09	15.53	15.31
M_3: BBF 60-30 cm with residue	45.20	47.25	10.25	10.38	4.45	4.43	6.13	6.29	6.21	18.45	19.13	18.79
M_4: BBF 60-30 cm without residue	39.60	40.13	10.10	10.10	4.44	4.42	5.50	5.72	5.61	17.30	17.58	17.44
M_5: BBF 120-30 cm with residue	42.65	44.63	9.95	10.0	4.44	4.42	5.80	5.96	5.88	17.96	17.83	17.89
M_6: BBF 120-30 cm without residue	38.98	39.60	9.95	9.95	4.43	4.40	5.09	5.24	5.16	16.74	16.93	16.83
SEm±	1.33	2.20	0.49	0.32	0.04	0.04	0.22	0.20	0.11	0.42	0.35	0.35
CD (P=0.05)	4.00	6.59	NS	NS	NS	NS	0.66	0.60	0.28	1.26	1.06	0.90

Table 5: Effect of moisture conservation practices on yield attributes and yield of niger.

Treatment	Capitula plant^{-1}		Seeds capitula^{-1}		1000 seed weight		Seed yield (q ha^{-1})			Stover yield (q ha^{-1})		
	2016	2017	2016	2017	2016	2017	2016	2017	pooled	2016	2017	Pooled
M_1: Flat bed with residue	18.25	18.65	21.50	22.15	3.83	3.84	4.32	4.64	4.48	13.21	14.28	13.74
M_2: Flat bed without residue	17.90	18.35	21.10	21.35	3.80	3.83	4.21	4.45	4.33	12.93	13.41	13.17
M_3: BBF 60-30 cm with residue	19.40	20.52	23.25	24.95	3.85	3.87	5.03	5.58	5.30	14.73	15.86	15.13
M_4: BBF 60-30 cm without residue	19.00	19.20	23.00	23.20	3.84	3.84	4.94	5.05	4.99	14.52	14.03	14.12
M_5: BBF 120-30 cm with residue	18.85	19.50	22.45	23.30	3.85	3.83	4.76	4.93	4.84	14.40	14.39	14.56
M_6: BBF 120-30 cm without residue	18.75	18.98	22.25	22.70	3.85	3.82	4.65	4.76	4.70	14.21	14.13	14.32
SEm±	0.30	0.61	0.49	0.80	0.08	0.06	0.19	0.17	0.21	0.40	0.45	0.51
CD (P=0.05)	0.89	1.79	1.50	2.5	NS	NS	0.56	0.52	0.56	1.20	1.35	1.31

6.29 q ha^{-1} during 2016-17 and 2017-18) and without residue (5.50 and 5.72 q ha^{-1} during 2016-17 and 2017-18) and BBF 120-30 cm with residue incorporation (5.80 and 5.96 q ha^{-1} during 2016-17 and 2017-18) were at par and BBF 60-30 with residue produced significantly higher seed yield over rest of the treatments. From the results of a field experiment carried out at Madhya Pradesh, Gupta (2018) also observed higher yield attributes and seed and stover yields of soybean under Broad Bed Furrows compared to flat beds.

Yield attributes and yields of niger

In both the year, BBF 60-30 cm and BBF 120-30 cm with residue and without residue resulted in at par effect and recorded higher capitula plant^{-1} over flatbed methods of sowing (Table 5). Similar trend of results was also observed in regards to number of seeds capitula $^{-1}$ during both the year. The seed and stover yield of niger showed higher in both BBF 60-30 cm and BBF 120-30 cm as compared to flatbed method of moisture conservation (Table 5).

Yield attributes and yield of Toria

During both the year, different moisture conservation practices brought about significant impact on number of siliqua plant^{-1} of toria (Table 6). But it failed to show any significant variation on number of seeds siliqua^{-1} and 1000-seed weight of toria. In 2016-17, the seed yield due to BBF 60-30 cm and BBF 120-30 cmand in 2017-18, BBF 60-30 cm both with and without and BBF 120-30 cm with residue incorporation were at par and significantly higher values of seed yield were recorded under BBF 60-30 cm with residue (6.10 and 6.34 q ha^{-1} during 2016-17 and 2017-18, respectively) over other treatments (Table 6). Due to better tillering and crop growth, 12% higher wheat grain yield with ridge furrow planting in comparison to farmer's practice of flat planting was reported by Hussain (2018).

Rice equivalent yield (REY) of rice-based cropping systems

The rice equivalent yields of the system (Table 7) were significantly influenced by different moisture conservation practices. In 2016-17, BBF 60-30 cm and BBF120-30 cm both with residue (81.77 q ha^{-1} and 77.80 q ha^{-1}) and without residue (79.03 q ha^{-1} and 76.47 q ha^{-1}) produced statistically similar REY and all being significantly higher over flatbed method of sowing both with (64.29 q ha^{-1}) and without residue incorporation (63.56 q ha^{-1}). In 2017-18, the highest REY was recorded with the treatment BBF 60-30 cm with residue (89.64 q ha^{-1}) which was at par with BBF 60-30 cm without residue (82.56 q ha^{-1}) and BBF 120-30 cm with residue incorporation (82.47 q ha^{-1}), but significantly higher over rest of the treatments. The lowest value was recorded under flatbed without residue incorporation (66.05 q ha^{-1}).

During both the year, the REY (Table 7) due to different crop sequences varied significantly. In 2016-17, the REY of direct seeded rice-greengram-toria (78.13 q ha^{-1}) and direct seeded *ahu* rice-greengram-linseed (74.75 q ha^{-1}) were at par and the effect of direct seeded rice-greengram-toria was significantly higher over direct seeded *ahu* rice-greengram-

Table 6: Effect of moisture conservation practices on yield attributes and yield of toria.

Treatment	Siliqua plant^{-1}		Seeds Siliqua^{-1}		1000-seed weight (g)		Seed yield (q ha^{-1})			Stover yield (q ha^{-1})		
	2016	2017	2016	2017	2016	2017	2016	2017	pooled	2016	2017	Pooled
M_1: Flat bed with residue	42.50	48.11	10.38	10.43	3.29	3.31	4.96	5.21	5.08	11.83	14.31	13.07
M_2: Flat bed without residue	41.75	44.25	10.00	10.13	3.32	3.30	4.73	4.81	4.77	11.13	13.28	12.20
M_3: BBF 60-30 cm with residue	48.00	51.60	11.95	12.13	3.33	3.35	6.10	6.34	6.22	13.75	16.18	14.96
M_4: BBF 60-30 cm without residue	46.75	47.13	11.15	11.88	3.33	3.33	5.71	5.80	5.75	13.50	15.43	14.71
M_5: BBF 120-30 cm with residue	47.50	50.13	11.85	11.50	3.31	3.31	5.65	5.73	5.69	13.63	15.03	14.46
M_6: BBF 120-30 cm without residue	46.25	48.50	11.00	10.75	3.30	3.30	5.40	5.48	5.44	13.43	14.88	14.15
SEm±	1.85	2.06	0.58	0.66	0.02	0.03	0.23	0.20	0.32	0.45	0.33	0.74
CD (P=0.05)	5.55	6.18	NS	NS	NS	NS	0.70	0.61	0.82	1.35	1.01	1.90

niger (72.58 q ha^{-1}) and direct seeded *ahu* rice-greengram-buckwheat (69.80 q ha^{-1}). In 2017-18, the crop sequences *viz.* direct seeded *ahu* rice-greengram-toria (81.97 q ha^{-1}), followed by direct seeded *ahu* rice-greengram-linseed (79.28 q ha^{-1}) and direct seeded *ahu* rice-greengram-niger (77.29 q ha^{-1}) resulted in similar values and direct seeded rice-greengram-toria showed significantly higher rice equivalent yield over direct seeded *ahu* rice-greengram-buckwheat (74.90 q ha^{-1}).

It was observed that, direct seeded *ahu* rice, being the base and uniform crop, the REY of different crops of the cropping systems mostly influenced by both *kharif* greengram and *rabi* crops. Besides, the higher production potential of toria as compared to the other *rabi* crops and the better market price of toria contributed much for attaining higher REY under the sequence. This is in conformity with the findings of Kalita (2015) and Baishya (2016).

Economics

In both year, the highest cost of cultivation was associated with the treatment BBF 60-30cm (Rs. 56,815/ha and 58,315/ha, in 2016-17 and 2017-18) (Table 8). This was mainly due to the cost involved in preparation of broad bed furrows as per closure and widened sizes of the beds and associated cost of residues and labour engaged in incorporation. During both the year, considerably higher gross (Rs.94,035 ha^{-1} and 1,03,086 ha^{-1}, in 2016-17 and 2017-18, respectively) and net return (Rs.37,220 ha^{-1} and 44771 ha^{-1}, in 2016-17 and 2017-18, respectively) were recorded with the treatment BBF 60-30 cm with residue incorporation compared to other

Table 7: Effect of moisture conservation practices on rice equivalent yield of the system.

Treatments	Rice equivalent yield (q ha^{-1})		
	2016-17	2017-18	Pooled
Moisture conservation practices			
M_1: Flat bed with residue	64.29	70.48	67.38
M_2: Flat bed without residue	63.56	66.05	64.80
M_3: BBF 60-30 cm with residue	81.77	89.64	85.70
M_4: BBF 60-30 cm without residue	79.03	82.56	80.79
M_5: BBF 120-30 cm with residue	77.80	82.47	80.13
M_6: BBF 120-30 cm without residue	76.47	78.95	77.71
SEm±	2.47	2.96	2.06
CD (P=0.05)	7.45	8.94	7.50
Crop sequences			
S_1: Rice-greengram-toria	78.13	81.97	80.05
S_2: Rice-greengram-linseed	74.75	79.28	77.01
S_3: Rice-greengram-niger	72.58	77.29	74.93
S_4: Rice-greengram-buckwheat	69.80	74.90	72.35
SEm±	1.56	2.01	2.43
CD (P=0.05)	4.42	5.68	6.41

Price of rice: Rs.1150/q; Greengram: Rs.5000/q; Toria: Rs.4000/q; Linseed: Rs.3500/q; Niger: Rs.3500/q; Buckwheat: Rs.3000/q.

Table 8: Effect of moisture conservation practices and crop sequences on economics.

Treatment	Cost of cultivation (Rs. ha^{-1})		Gross return (Rs. ha^{-1})			Net return (Rs. ha^{-1})			B:C ratio		
	2016-17	2017-18	2016-17	2017-18	Mean	2016-17	2017-18	Mean	2016-17	2017-18	Mean
Moisture conservation practices											
M_1	53815	55315	73934	81052	77493	20119	25737	22928	1.37	1.46	1.41
M_2	50815	50815	73094	75957	74525	22279	25142	23710	1.43	1.49	1.46
M_3	56815	58315	94035	103086	98560	37220	44771	40995	1.65	1.76	1.70
M_4	53815	53815	90919	94944	92931	37104	41129	39116	1.68	1.76	1.72
M_5	55815	57315	89470	94840	92155	33655	37525	35590	1.60	1.65	1.62
M_6	52815	52815	87940	90793	89366	35125	37978	36551	1.66	1.71	1.68
Crop sequences											
S_1	56917	57666	89849	94265	92057	32932	36599	34765	1.58	1.63	1.60
S_2	53697	54446	85962	91172	88567	32265	36726	34495	1.60	1.67	1.63
S_3	52657	53406	83467	88883	86175	30810	35477	33143	1.58	1.66	1.62
S_4	52657	53406	80270	86135	83202	27613	32729	30171	1.52	1.61	1.56

treatments. The lowest gross return of Rs. 74,525 ha^{-1} was obtained under flatbed without residue incorporation.

CONCLUSION

The moisture conservation practices of Broad Bed Furrow system of land configuration along with residue incorporation was beneficial in regards to yield attributes and yield of summer, *kharif* and *rabi* crops grown as rice-based cropping systems under the soils and climatic conditions in *rainfed* situation of Assam. Among the BBF, the bed size of 60-30cm was better as compared to the 120-30 cm size bed. The BBF coupled with residue incorporation had not only influenced the crop performance but also helped in getting higher economic return. Among the crop sequences, Direct seeded *ahu* rice-greengram-toria was the most performing crop sequence in terms of higher rice equivalent yield, less cropping duration with better production efficiency, employment generation and economic return. However the linseed and niger can also be advocated as an alternative to toria as their performance was also better under *rainfed* situation in *rabi* season of Assam.

Conflict of interest: None.

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