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Effect of Moisture Conservation Practices on the Performance of Direct Seeded Rice–greengram Cropping Sequence in *Rainfed* Ecosystem of Assam

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A B S T R A C T

Rainfed Agriculture had played a great role in the food security of India. A field experiment on sandy loam soil was conducted during *Summer* and *kharif* season of 2016 and 2017 at Biswanath College of Agriculture, Assam Agricultural University, Biswanath Charilai to study the effect of moisture conservation practices in terms of land configuration and residue management in direct seeded rice-greengram cropping sequence. The experiment was conducted in RBD with six moisture conservation practices (Flatbed with crop residue incorporation, Flatbed without crop residue incorporation, Broad Bed Furrow (BBF) 60-30cm bed with residue incorporation, BBF 60-30cm bed without residue incorporation, BBF 120-30cm bed with residue incorporation and BBF 120-30cm bed without residue incorporation) with 4 replication. The growth, yield attributes, seed and stover yield (q ha^{-1}) of both the crop viz. direct seeded rice and greengram were better in BBF as compared to flatbed method of moisture conservation. Among the BBF, the crop residue incorporated treatments performed better over no residue incorporation. The equivalent yield of the system higher in both BBF over flatbed and BBF 120-30cm size bed showed comparatively higher net return and B:C ratio.

Keywords

BBF, Net return, grain yield, Direct seeded rice

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Introduction

Rice is the staple food of more than half of the world population and India is the second largest producer (131 million tonnes) of rice next to China (197 million tonnes). The rice productivity in India is 3.37 t ha^{-1} against the world average of 4.25 t ha^{-1}. (Sangeetha *et. al.*, 2015) The traditional method of rice establishment is the transplanting which requires high labour cost in seedbed preparation, sowing in nursery, uprooting, transplanting in the main field etc. Moreover repeated puddling adversely affects the soil physical properties by dismantling soil aggregates, reduces permeability in sub surface layers and form hard pans at shallow depths. (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). Among the pulse crop grown in Assam, greengram is a popular crop among the farmers and it is grown mostly in *kharif* season (Mid August-first of September) although in some pockets it is also grown in Feb-March as summer greengram. During *Kharif* greengram, Assam experiences heavy rainfall due to monsoon and there is records of complete failures of the crop due to water stagnation in the standing crop immediately after sowing or at vegetative stage. Therefore draining of water from the field is very much important for saving the crop from stagnation of water. Broad Bed Furrow (BBF) method is an emerging practice of land configuration in *rainfed* farming system which acts as in –situ moisture conservation during rainless periods as well as draining of water in furrows during heavy rainfall. Therefore considering the importance of direct seeded rice as compared to *sali* rice to save time, and cost in a system approach as well as moisture conservation practices in pulses grown in *kharif* season of Assam, a trial was conducted at BN College of Agriculture, Assam Agricultural University, Biswanath Chariali, Assam during summer and *kharif* season of 2016-17 and 2017-2018.

Materials and Methods

The Field experiments was conducted for two years (2016 & 2017) in sequence starting with direct seeded rice (*summer* season) followed by greengram (*Kharif* season). The experiment was conducted at BN College of Agriculture, Biswanath chariali of Assam Agricultural University, Assam. The weather condition at Biswanath charilai 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 1308.1mm during the same period distributed over 63 rainy days. Average maximum temperature range was 24.9^{0}C to 33.6^{0}C during 2016 and 25.4^{0}C to 33.2^{0}C during 2017 and the minimum temperature range was 17.0 ^{0}C to 26.7 ^{0}C and 15.8^{0}C to 26.3^{0}C during 2016 and 2017, respectively (Table 12).

During greengram growing period of 2016 and 2017 (33rd SMW to 43rd SMW) total rainfall received was 480.4mm and 526.4mm against the total evaporation of 226.6mm and 207.8, respectively. During 2016, the mean maximum and minimum temperature ranged between 29.9^{0}C to 34.3^{0}C and 21.2 ^{0}C to 26.9^{0}C, respectively while in 2017, the mean maximum temperature ranged between 27.7^{0}C to 34.1^{0}C and minimum temperature ranged between 19.1^{0}C to 25.9^{0}C. The number of rainy days during greengram growing period was 25 and 27 in 2016 and 2017, respectively (Table 13).

The soil of the experiments was sandy loam in texture with an initial P^{H} 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}). Two different sizes of BBF were studied consisting 60cm and 120cm width with a gap of 30cm size furrow in between beds. The treatments were Flat bed with crop residue incorporation (M_1), Flat bed with no residue incorporation (M_2), BBF 60-30cm with residue incorporation (M_3), BBF 60-30cm without residue incorporation (M_4), BBF 120-30cm with crop residue incorporation (M_5) and BBF 60-30cm without crop residue incorporation (M_6). The experiment was laid out in randomized block design with 4 replications and plot was ploughed by tractor-drawn plough followed by one harrowing. Laddering was done properly to retain water uniformly in the field. Weeds and other stubbles were removed from the field at the time of final land preparation. The broad bed furrows were prepared manually as per treatment assigned. After harvest of direct seeded *ahu* rice, plots were prepared manually, without breaking the broad bed furrows for maintaining the incorporation of crop residues as per treatments and greengram was grown.

The rice crop was sown in line with 20 cm spacing and in 60-30cm 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. Recommended doses of fertilizers were applied in both rice and greengram as per package of practices of Assam. The variety used for direct seeded rice was "Inglongkiri" which was developed by Regional Agricultural Research Station, Assam Agricultural University Diphu, having an average duration of 115-120 days. For greengram the variety SG-1 (Pratap) was selected for the study. In the first year, the rice crop was sown on 23.03.16 and in second year crop 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. For both the crops of rice and greengram, growth parameters like plant height (cm) at 30 days interval up to harvest, dry matter accumulation (gm^2), Leaf Area Index (LAI), Yield attributes and yield (q ha^{-1}) were recorded and analyzed statistically for interpretation. The leaf area per plant was measured with the help of a leaf area meter (Model: CI-231). The area of the individual leaf was determined by taking the average of ten representative leaves covering very young, and mature leaves from the same plant. The total leaf area of a plant was calculated out by multiplying the leaf area of the individual leaf with the number of functional leaf per plant. The Leaf Area Index was determined by the method described by Williams (1946) as follows:

Leaf Area Index (LAI) = Leaf area per plant /ground area covered by the plant

Results and Discussion

Plant growth parameters of direct seeded rice

Plant height

At 30 days after sowing (DAS), no significant difference of plant height of rice was observed due to different soil moisture conservation practices but from 60 DAS onwards up to harvest of the crop, plant height was differed (Table 1). At 60 and 90 DAS, Broad Bed Furrow (BBF) 60-30 cm resulted higher plant height over other treatments.. At harvest also in both years BBF 60-30 cm and BBF 120-30cm performed better. BBF 60-30 cm with residue incorporation produced significantly higher plant height over rest of the treatments.

Dry matter production

In 2016, dry matter accumulation at 30 and 90 DAS and at harvest, the effect of BBF 60-30 and 120-30 cm both with and without residue incorporation were at par, and BBF 60-30 with residue resulted in significantly higher values over both the flat bed planting. (Table 2). In 2017, at all the growth stages (30, 60 and 90 DAS and at harvest) the effect of BBF 60-30cm and BBF 120-30cm with residue incorporation were same and BBF 60-30cm with residue produced significantly higher plant dry matter at all the crop growth stages over rest of the treatments. The lowest values were recorded under flatbed without residue incorporation.

Leaf area Index

During both the year, different moisture conservation practices did not bring about any significant variation on leaf area index of direct seeded *ahu* rice at 30DAS, while, it differed significantly from 60 DAS till harvest of the crop (Table 3).

In 2016, the highest leaf area index of direct seeded *ahu* rice at 60 and 90 DAS and at harvest were recorded under BBF 60-30 cm without residue which was being at par with BBF 60-30 cm with residue and flatbed sowings, but significantly superior to BBF 120-30 cm without residue incorporation. In 2017, BBF 60-30 cm both with and without residue produced similar and considerably higher values over other treatments.

The closure furrows in combination with incorporation of crop residues particularly in the succeeding year (2017) under the treatment BBF 60-30 cm with residue followed by without residue might have helped in retaining more rain water over the flatbeds and wider broad beds and thereby, resulted in higher plant height, dry matter accumulation and leaf area index of the crop. The increase in height of wheat crop (Akhter Ali *et al.,* 2005), dry matter production (Verma, 2017) and leaf area index of rice (Mollah *et al.,* 2015) in raised beds compared to conventionally planted crop was also reported.

In the initial year (2016) of experimentation, there was no incorporation of crop residues prior to growing rice. But, in the second year (2017), the incorporation of residues of rice and greengram in the first year experiment might have influenced in the improvement of soil water relations.

The incorporation of different locally available crop residues in the soil and thereby enhancing nutrient cycling and release to the soil resulting the higher plant height and other growth characters of Maize in South East Nigeria was reported Mbah *et al.,* (2011).

Effect of moisture conservation practices on Yield attributes

The yield attributes *viz.* number of effective panicles m^{-2} and grains panicle^{-1} of direct seeded *ahu* rice due to different soil moisture conservation practices differed significantly (Table 4). The panicles m^{-2} under BBF 60-30cm with (113.00 and 117.69 panicles m^{-2} in 2016 and 2017, respectively) and without residue (112.69 and 113.75 panicles m^{-2} in 2016 and 2017, respectively) which was equal to BBF 120-30cm with residue (109.56 and 113.63 panicles m^{-2} in 2016 and 2017, respectively).The BBF 60-30cm with residue incorporation resulted in significantly higher values over both flatbed with or without residue incorporation.

The number of grains panicle^{-1}, in 2016, both the BBF 60-30cm and BBF 120-30cm with and without residue incorporation were same But in 2017, BBF 60-30cm with residue incorporation produced significantly higher number of grains panicle^{-1} over all other moisture conservation practices. The higher number of effective panicles m^{-2} and grains panicle^{-1}, under BBF 60-30cm and BBF 120-30cm with residue incorporation over flat bed 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, mainly due to better growth of the crop under raised bed sowing method over flatbed method was also reported.

Grain and straw yield

In 2016, the grain yield under BBF 60-30cm with residue (23.43q ha^{-1}) and without residue (22.72q ha^{-1}) and BBF 120-30cm with residue (22.81 q ha^{-1}) incorporation were at par and

BBF 60-30cm with residue produced 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 5). The pooled data over the years, revealed that the effect of both the BBF 60-30cm (24.56 q ha^{-1}) and BBF 120-30cm with residue (23.47 q ha^{-1}) incorporation were at par and BBF 60-30cm with residue (24.56 q ha^{-1}) produced significantly higher grain yield over rest of the treatments. The increase in yield under BBF 60-30cm with residue incorporation over the flatbed without residue was 11.0 %, which was mainly due to higher number of effective panicles m^{-2} and grains $panicle^{-1}$ of the crop. 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).

In 2016, different soil moisture conservation practices did not bring about any variation on straw yield of direct seeded *ahu* rice, while it differed significantly in 2017 (Table 5). The treatment BBF 60-30cm with residue incorporation produced the highest straw yield, which was significantly higher over all the treatments.

Table.1 Effect of moisture conservation practices and crop sequences on plant height (cm) at different growth stages of direct seeded *ahu* rice

Treatment	30DAS		60DAS		90DAS		At harvest	
	2016	2017	2016	2017	2016	2017	2016	2017
Moisture conservation practies								
M_1: Flatbed with residue	20.44	23.16	46.75	52.19	98.38	103.63	135.63	140.35
M_2: Flatbed without residue	20.35	22.04	48.00	50.13	99.69	100.69	136.94	138.10
M_3: BBF 60-30cm with residue	21.94	24.97	53.94	59.38	112.19	109.21	145.69	147.66
M_4: BBF60-30cm without residue	21.88	22.72	54.63	56.31	111.63	104.81	144.81	145.31
M_5: BBF 120-30cm with residue	21.94	24.22	51.31	53.63	105.20	105.69	140.94	142.31
M_6:BBF 120-30cm without residue	21.10	22.88	50.85	51.94	103.22	102.88	141.31	142.60
SEm±	0.50	0.63	0.63	0.54	2.10	1.03	1.50	0.83
CD (0.05%)	NS	NS	1.89	1.62	6.30	3.09	4.50	2.49

Table.2 Effect of moisture conservation practices and crop sequences on plant dry matter (g m^2) at different growth stages of direct seeded *ahu* rice

Treatment	30DAS		60DAS		90DAS		At harvest	
	2016	2017	2016	2017	2016	2017	2016	2017
Moisture conservation practices								
M_1: Flatbed with residue	28.11	33.50	129.66	183.06	389.94	477.38	583.75	689.10
M_2: Flatbed without residue	28.50	32.06	128.63	174.04	388.06	461.44	575.13	655.69
M_3: BBF 60-30cm with residue	28.88	36.90	139.63	202.63	405.63	513.75	619.06	741.88
M_4:BBF60-30cm without residue	29.56	32.41	138.68	174.69	402.50	476.19	618.13	678.38
M_5: BBF 120-30cm with residue	30.13	34.41	132.63	185.81	395.63	481.88	599.06	710.21
M_6:BBF 120-30cm without residue	30.07	32.75	131.91	181.38	394.50	465.90	597.19	676.31
SEm±	0.43	0.52	2.32	5.70	5.11	10.84	7.72	17.77
CD (0.05%)	1.29	1.60	6.99	17.18	15.34	32.67	23.29	53.55

Table.3 Effect of moisture conservation practices and crop sequences on Leaf Area Index at different growth stages of direct seeded *ahu* rice

Treatment	30DAS		60DAS		90DAS		At harvest	
	2016	2017	2016	2017	2016	2017	2016	2017
Moisture conservation practices								
M_1: Flatbed with residue	1.40	1.50	3.50	3.69	2.65	2.60	1.73	2.03
M_2: Flatbed without residue	1.41	1.45	3.51	3.53	2.62	2.48	1.77	1.81
M_3: BBF 60-30cm with residue	1.47	1.64	3.65	3.94	2.79	3.08	1.95	2.33
M_4:BBF60-30cm without residue	1.46	1.48	3.68	3.75	2.81	2.88	1.99	2.06
M_5: BBF 120-30cm with residue	1.44	1.57	3.28	3.44	2.47	2.75	1.61	1.75
M_6:BBF120-30cm without residue	1.43	1.47	3.25	3.29	2.44	2.67	1.58	1.61
SEm±	0.06	0.06	0.07	0.11	0.07	0.12	0.13	0.15
CD (0.05%)	NS	NS	0.22	0.35	0.22	0.36	0.39	0.46

Table.4 Effect of moisture conservation practices and crop sequences on yield attributes of direct seeded *ahu* rice

Treatment	Effective panicle m^{-2}		Grains $panicle^{-1}$		1000-grain weight (g)		Length of panicle (cm)	
	2016	2017	2016	2017	2016	2017	2016	2017
Moisture conservation practices								
M_1: Flatbed with residue	106.35	108.19	91.33	99.13	23.60	24.05	23.14	24.56
M_2: Flatbed without residue	105.63	107.38	92.62	94.69	23.80	23.80	23.37	24.00
M_3: BBF 60-30cm with residue	113.00	117.69	98.35	108.38	24.01	23.80	24.21	24.72
M_4: BBF 60-30cm without residue	112.69	113.75	97.63	100.13	23.91	23.81	24.15	23.81
M_5: BBF 120-30cm with residue	109.56	113.63	95.10	102.44	23.70	23.90	23.73	24.60
M_6: BBF120-30cm without residue	108.38	110.38	94.25	97.63	23.82	23.81	23.80	24.10
SEm±	1.82	2.22	1.80	1.50	0.22	0.15	0.29	0.31
CD (0.05%)	5.48	6.69	5.43	4.41	NS	NS	NS	NS

Table.5 Effect of moisture conservation practices and crop sequences on grain and straw yields and harvest index of direct seeded *ahu* rice

Treatment	Grain yield (q ha^{-1})			Straw yield (q ha^{-1})			Harvest index (%)	
	2016	2017	Pooled	2016	2017	Pooled	2016	2017
Moisture conservation practices								
M_1: Flat bed with residue	21.85	23.69	22.77	37.94	39.88	38.91	36.55	37.27
M_2: Flat bed without residue	21.90	22.38	22.14	37.47	37.88	37.67	36.88	37.13
M_3: BBF with residue 60-30 cm	23.43	25.70	24.56	38.70	42.60	40.65	37.71	37.62
M_4: BBF without residue 60-30 cm	22.72	23.31	23.01	38.04	39.55	38.79	36.96	37.08
M_5: BBF with residue 120-30 cm	22.81	24.14	23.47	37.97	40.13	39.05	37.43	37.56
M_6: BBF without residue 120-30 cm	22.31	23.06	22.68	37.28	39.03	38.15	37.95	37.13
SEm±	0.27	0.31	0.33	0.84	0.80	0.64	0.46	0.49
CD (P=0.05)	0.74	0.95	1.24	NS	2.40	2.31	NS	NS

Table.6 Effect of soil moisture conservation practices and crop sequences on plant height (cm) at different growth stages of greengram

Treatment	30DAS		60 DAS		At Harvest	
	2016	2017	2016	2017	2016	2017
Moisture conservation practices						
M_1: Flat bed with residue	21.62	23.67	64.31	65.22	64.93	65.52
M_2: Flatbed without residue	21.13	22.20	64.15	65.78	64.52	66.08
M_3: BBF with residue 60-30 cm	25.33	26.90	72.57	74.29	73.02	74.72
M_4: BBF without residue 60-30 cm	25.61	26.65	72.19	73.26	72.69	73.49
M_5: BBF with residue 120-30 cm	23.62	25.60	68.33	70.29	68.51	70.59
M_6: BBF without residue 120-30 cm	23.82	24.63	68.92	70.33	69.36	70.48
SEm±	0.60	0.49	1.92	1.89	1.85	2.09
CD (P=0.05)	1.80	1.49	5.79	5.82	5.56	6.27

Table.7 Effect of moisture conservation practices and crop sequences on plant dry matter (gm^{-2}) at different growth stages of greengram

Treatment	30DAS		60 DAS		At Harvest	
	2016	2017	2016	2017	2016	2017
Moisture conservation practices						
M_1: Flat bed with residue	35.35	40.32	240.33	297.34	270.31	330.35
M_2: Flatbed without residue	35.26	37.61	244.39	278.66	273.65	309.61
M_3: BBF with residue 60-30 cm	38.91	45.33	355.31	401.09	390.56	445.60
M_4: BBF without residue 60-30 cm	38.38	40.65	327.34	369.34	363.24	410.32
M_5: BBF with residue 120-30 cm	36.37	42.82	350.31	386.43	386.34	429.31
M_6: BBF without residue 120-30 cm	36.39	38.32	330.26	356.71	360.63	396.32
SEm±	0.90	1.12	10.95	10.33	11.96	11.53
CD (P=0.05)	2.72	3.35	32.72	30.89	35.60	34.69

Table.8 Effect of soil moisture conservation practices and crop sequences on leaf area Index at different growth stages of greengram

Treatment	30DAS		60 DAS		At Harvest	
	2016	2017	2016	2017	2016	2017
Moisture conservation practices						
M_1: Flat bed with residue	0.53	0.58	2.35	2.53	2.09	2.23
M_2: Flatbed without residue	0.50	0.54	2.33	2.41	2.07	2.13
M_3: BBF with residue 60-30 cm	0.66	0.73	2.59	2.75	2.33	2.51
M_4: BBF without residue 60-30 cm	0.61	0.65	2.47	2.67	2.23	2.36
M_5: BBF with residue 120-30 cm	0.65	0.67	2.56	2.68	2.33	2.45
M_6: BBF without residue 120-30 cm	0.60	0.63	2.45	2.53	2.21	2.37
SEm±	0.02	0.03	0.06	0.07	0.06	0.07
CD (P=0.05)	0.07	0.09	0.17	0.20	0.17	0.20

Table.9 Effect of soil moisture conservation practices and crop sequences on primary branch and yield attributing characters of greengram

Treatment	Primary branch plant^{-1}		Cluster plant^{-1}		Pod cluster^{-1}		Length of pod (cm)		Seed pod^{-1}		1000 seed weight (g)	
	2016	2017	2016	2017	2016	2017	2016	2017	2016	2017	2016	2017
Moisture conservation practices												
M_1: Flat bed with residue	0.53	0.58	2.35	2.53	2.09	2.23	7.62	7.93	7.94	7.32	30.84	30.98
M_2: Flatbed without residue	0.50	0.54	2.33	2.41	2.07	2.13	7.39	7.88	7.81	7.17	30.78	30.98
M_3: BBF with residue 60-30 cm	0.66	0.73	2.59	2.75	2.33	2.51	7.88	8.02	8.84	8.80	30.84	31.07
M_4: BBF without residue 60-30cm	0.61	0.65	2.47	2.67	2.23	2.36	7.72	7.98	8.56	7.94	30.78	30.42
M_5: BBF with residue 120-30 cm	0.65	0.67	2.56	2.68	2.33	2.45	7.70	8.02	8.72	8.16	31.34	31.35
M_6: BBF without residue 120-30 cm	0.60	0.63	2.45	2.53	2.21	2.37	7.67	7.83	8.45	7.84	31.08	31.13
SEm±	0.02	0.03	0.06	0.07	0.06	0.07	0.16	0.12	0.30	0.29	0.46	0.31
CD (P=0.05)	0.07	0.09	0.17	0.20	0.17	0.20	NS	NS	NS	0.87	NS	NS

Table.10 Effect of soil moisture conservation practices and crop sequences on seed and stover yield and harvest index of greengram

Treatment	Seed yield (q ha^{-1})			Stover yield (q ha^{-1})			Harvest Index (%)	
	2016	2017	Pooled	2016	2017	pooled	2016	2017
Moisture conservation practices								
M_1: Flat bed with residue	6.73	7.45	7.09	19.06	22.08	20.57	26.09	25.22
M_2: Flat bed without residue	6.63	6.98	6.82	18.90	21.61	20.26	25.96	24.41
M_3: BBF 60-30cm with residue	9.58	10.63	10.10	27.62	29.26	28.44	25.75	26.64
M_4: BBF 60-30 cm without residue	9.44	10.11	9.77	26.10	28.11	27.10	26.56	26.45
M_5: BBF 120-30 with residue	9.04	9.69	9.36	24.96	27.99	26.47	26.58	25.71
M_6: BBF 120-30 without residue	8.95	9.33	9.14	24.75	27.11	25.93	26.55	25.60
SEm±	0.36	0.41	0.19	0.97	0.75	0.41	0.56	0.47
CD (P=0.05)	1.09	1.23	0.62	2.91	2.25	1.23	NS	1.40

Table.11 Rice equivalent yield (q /ha) and economics of the system

Treatment	REY (q ha^{-1})			Cost of cultivation		Gross return		Net return		B:C ratio	B:C ratio
	2016	2017	pooled	2016	2017	2016	2017	2016	2017	2016	2017
Moisture conservation practices											
M_1: Flat bed with residue	51.42	57.44	54.43	42530	44030	56562	63184	14032	19154	1.32	1.43
M_2: Flat bed without residue	52.21	54.03	53.12	41030	41030	57431	59433	16401	18403	1.39	1.44
M_3: BBF 60-30cm with residue	64.47	69.62	67.04	45530	47030	70917	76582	25387	29552	1.55	1.62
M_4: BBF 60-30cm without residue	63.20	65.70	64.45	44030	44030	69520	72270	25490	28240	1.57	1.64
M_5: BBF 120-30cm with residue	65.54	72.42	68.98	44530	46030	72094	79662	27564	33632	1.61	1.73
M_6: BBF 120-30 without residue	66.27	68.94	67.60	43030	43030	72897	75834	29867	32804	1.69	1.76
SEm±	2.47	2.74	2.14	-	-	-	-	-	-	-	-
CD (P=0.05)	7.45	8.24	7.81	-	-	-	-	-	-	-	-

Price of rice: Rs.1100/q and price of greengram: Rs. 5000/q

Table.12 Weekly meteorological data during *Ahu* rice growing period (March to July)

SMW	Period	Rainfall (mm)		Evaporation(mm)		Temperature (^oC)				Number of rainy days	
		2016	2017	2016	2017	2016		2017		2016	2017
						Max.	Min.	Max.	Min.		
12	19-25 March	2.8	12.2	23.2	21.6	28.60	17.00	26.8	15.8	0	2
13	26-01 April	22.1	17.8	22.2	17.8	28.40	18.20	26.8	19.7	4	3
14	2-8 April	31.4	60.2	22.6	15.1	29.70	20.80	25.4	19.2	3	4
15	9-15 April	29.8	0.40	33.2	31.4	29.30	20.50	31.9	19.5	2	1
16	16-22 April	149.5	38.0	15.5	24.0	24.90	19.60	28.5	20.4	6	4
17	23-29 April	74.8	168.6	19.4	24.4	27.30	20.60	28.6	21.3	4	6
18	30-6 May	7.2	22.80	25.4	23.8	28.80	20.70	28.1	20.4	2	3
19	7-13 May	25.6	59.80	23.5	25.6	32.60	22.60	30.9	22.2	2	3
20	14-20 May	108.8	29.20	15.8	30.2	26.40	21.40	31.6	23.0	5	3
21	21-27May	64.2	102.7	25.3	27.5	30.10	23.30	29.4	23.2	4	4
22	28-3 June	27.6	81.40	25.2	21.5	31.00	23.60	30.2	23.9	3	4
23	4-10 June	53.6	78.20	29.4	28.1	33.60	26.70	32.1	24.2	2	3
24	11-17 June	174.6	75.20	27.7	22.8	33.00	25.60	31.8	25.1	4	3
25	18-24 June	52.5	90.40	17.0	21.6	30.70	25.70	30.8	24.9	5	5
26	25-01 July	20.2	188.0	23.6	16.0	32.90	26.70	31.9	25.1	3	5
27	02-08 July	116.2	109.2	20.4	25.1	31.10	25.30	31.6	25.7	6	4
28	09-15 July	37.0	150.0	26.6	12.6	33.00	26.00	30.1	23.9	5	3
29	16-22 July	114.6	24.0	10.8	31.6	30.20	25.20	33.6	26.3	7	3
Total		**1112.5**	**1308.1**	**406.8**	**420.7**	**-**	**-**	**-**	**-**	**67**	63
Mean		**-**	**-**	**22.5**	**-**	**30.0**	**22.7**	**30.0**	**22.4**		

Table.13 Weekly meteorological data during *kharif* greengram growing period (August to October)

SMW	Period	Rainfall (mm)		Evaporation(mm)		Temperature (^oC)				Number of rainy days	
		2016	2017	2016	2017	2016		2017		2016	2017
						Max.	Min.	Max.	Min.		
33	13-19 Aug	107.2	85.4	25.6	15.1	34.6	26.8	30.70	25.10	2	4
34	20-26 Aug	14.40	2.40	28.1	25.0	35.4	26.9	34.10	25.90	1	0
35	27-02 Sep	21.40	43.4	26.8	18.9	34.3	26.5	32.30	25.50	3	3
36	03-09 Sep	32.20	154.8	24.4	20.3	33.1	26.0	31.90	25.40	5	4
37	10-16 Sep	84.60	43.0	16.3	18.5	32.1	25.3	32.30	24.90	2	2
38	17-23Sep	80.60	35.4	17.2	19.0	31.2	24.7	33.30	25.60	4	3
39	24-30 Sep	44.60	38.8	18.1	20.5	32.7	24.8	32.30	24.70	2	3
40	01-07Oct	0.00	19.6	19.4	20.6	34.2	25.6	32.60	24.70	0	2
41	08-14Oct	91.20	32.2	12.0	20.0	29.9	23.5	33.40	24.70	5	2
42	15-21Oct	0.00	11.8	19.9	16.8	32.2	21.2	30.40	23.00	0	1
43	22-28 Oct	4.20	59.6	18.8	13.1	31.2	20.0	27.70	19.10	1	3
Total		**480.4**	**526.4**	**226.6**	**207.8**	**-**		**-**	**-**	**25**	**27**
Mean		**-**	**-**	**20.6**	**18.8**	**32.8**	**24.6**	**31.9**	**24.4**	**-**	**-**

Pooled data showed that the effect of BBF 60-30cm with and without residue and that due to BBF 120-30cm and flatbed both with residue incorporation were at par and BBF 60-30cm with residue recorded significantly higher values over other treatments. The increase of yield of grain, as well as straw of wheat crop grown after maize due to the residual effect of crop residue as mulching, was also reported by Sharma *et al.,* (2010).

Growth parameters of *kharif* Greengram

Plant height: The plant height of greengram during 2016 and 2017, at 60 DAS and at harvest, BBF 60-30cm and BBF 120-30cm with and without rice residues incorporation resulted in similar effect and proved significantly superior to flatbed methods (Table 6).

Dry matter accumulation: In case of dry matter accumulation (Table 7), at 30 DAS and 60 DAS and at harvest in 2016, and 30 DAS in 2017, the effect of both the BBF at 60-30cm and 120-30cm with and without rice residues incorporation were statistically at par but significantly higher over the flatbed methods, However, dry matter accumulation at 60 DAS and at harvest in 2017, both BBF at 60-30cm and 120-30cm with residues incorporation produced higher values over rest of treatments.

Leaf area index: During both the year, at all the crop growth stages, significantly higher leaf area index (LAI) was recorded under the treatment BBF at 60-30 cm with residue incorporation (Table 8). This was followed by BBF at 120-30 cm with residue incorporation and BBF at 60-30cm without residue incorporation, all being at par in effect and proved significantly superior to flatbed methods. It was evident that during the *kharif* seasons of both the year 2016 and 2017, rainfall exceeded the ET needs of the crop by 258.6mm and 318.6 mm, respectively. The provision of furrows in both the BBF method served as a drainage channel and helped in draining out of excess rain water from the crop field. The increased plant height, dry matter accumulation and LAI at different crop growth stages under the treatment particularly with closure furrows *i.e.,* BBF at 60-30 cm with residue incorporation, might have attributed from the favourable root rhizosphere achieved through adequate aeration due to proper drainage. Increased plant height (Raut *et al.,* 2000), growth characters including dry matter accumulation (Verma *et al.,* 2017) under ridge and furrow sowing and growth characters including LAI (Ram *et al.,* 2011) under broad bed furrow compared to normal (conventional) flatbed sowing in rainfed soybean have also been reported.

Yield attributes and yield of *kharif* greengram

The treatment BBF 60-30cm 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 9). In respect to number of pods cluster^{-1}, in 2016, BBF 60-30cm and BBF 120-30cm with and without residue incorporation showed at par effect but significantly higher over both flatbed methods. While in 2017, the effect of BBF 60-30cm with and without residue incorporation and BBF 120-30cm without residue incorporation on such number of pod cluster^{-1} were significantly higher over rest of the treatments. During both the year, higher values were recorded in respect of number of seeds pod^{-1} and 1000 seed weight under BBF 60-30cm with residue incorporation and the lowest values were observed under the flatbed without residue incorporation. The better crop growth coupled with optimum moisture availability due to the adequate drainage of excess rain water through the provision of furrows in BBF methods might have resulted in better yield attributing characters compared to flatbed sowing. A similar result of increased yield attributes of 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 *et al.,* (2013). Increased number of pods under the raised bed in chickpea was also reported by Shrivastava *et al.,* (2018).

Seed and stover yield

Both the treatment BBF 60-30 cm and BBF 120-30cm with and without residue incorporation resulted in statistically similar seed and stover yield and produced significantly higher values over the flat methods with and without residue incorporation.(Table 10). The highest seed yield (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 120-30cm with and without residue incorporation. The flat bed method of sowing recorded significantly the lower seed and stover yields in both the year.

The data pooled over the years (Table 10) also revealed that the treatment BBF 60-30cm with residue (10.10 qha^{-1}) followed by BBF 60-30cm without residue (9.77 qha^{-1}) incorporation out yielded rest of the treatments, in respect to seed and stover yield. BBF 60-30cm 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 crop growth throughout the growing season *viz.,* plant height (Table 6), dry matter accumulation (Table 7) and leaf area index (Table 8) and higher yield attributes like number of clusters plant^{-1}, pods cluster^{-1} and seeds pods^{-1} (Table 9) under the treatment BBF 60-30cm with and without residue incorporation might have attributed to produce higher seed and stover yield of the crop. Due to the drainage of excess rain water through the broad bed furrows led to adequate aeration even during the rainy days (25 days in 2016 and 27 days in 2017) and saved the crop suffering from depletion of oxygen in the root zone by reducing water stagnation in the crop field and thereby, resulted in significantly higher seed and stover yields under the treatment BBF. 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, *et al.,* (2014). In 2017, Harvest Index varied significantly and BBF 60-30cm and BBF120-30cm with and without residue incorporation resulted in similar effect and all being significantly higher over flatbed methods with or without residue incorporation. Higher biological yield of wheat from land configuration treatment as compared to the conventional system was also reported by Jat and Singh (2003).

Equivalent yield and economics

The equivalent yield of the rice-greengram sequence was calculated (Table 11) and pooled analysis was also done. Results showed that in both year of experimentation, the BBF method of moisture conservation irrespective of the size of the bed (60-30cm and 120-30cm) was significantly better than the flatbed. The pooled data over the years also showed in the same trend. Among the BBF (60-30cm bed and 120-30cm bed), the net return and B:C ratio was more in BBF 120-30cm size bed due to comparatively better yield and less cost of cultivation in terms of mandays required in preparing bed as number of furrow requirement is less in BBF 120-30cm as compared to BBF 60-30cm bed.

Although cost of cultivation is more in residue incorporation treatments as compared to no residue incorporation, the cost was compensated by the higher yield obtained in both the crop of rice and greengram. The better yield of the rice and greengram particularly in second year was perhaps due to the better retention of moisture in rainless period by the residue which acted as mulch for better conservation of moisture.

In conclusion, from the study it has been seen that the moisture conservation practice BBF 60-30cm with residue and BBF 60-30cm without residue and BBF 120-30cm with residue incorporation treatments resulted almost similar effect on plant height, dry matter accumulation and leaf area index of rice and BBF 60-30cm with residue incorporation resulted higher values over rest of the treatments. Higher grain yield of rice was recorded under BBF 60-30cm with and without residues residue and BBF 120-30cm with residue and both BBF 60-30cm and BBF 120-30 cm resulted better over rest of the treatments. Similar trend of superiority of BBF over flatbed was observed in growth and yield attributes of *kharif* greengram. The seed and stover yield of greengram due to both the BBF with or without residue was at par in effect and being significantly higher over flatbed method of moisture conservation practices.

Pooled data showed also superiority of BBF irrespective of the size of the beds over flatbeds. We can conclude that BBF method of moisture conservation practices along with residue incorporation is suitable practices for better growth, and yield as well as net income of farmers. During *kharif* greengram the furrows of the BBF helps in draining of excess rainfall during monsoon period (July to Sept) in Assam thereby saved the crop from water stagnation. From economic point of view BBF 120-30cm bed size is the better although yield is somewhat less than the BBF 60-30cm as cost of cultivation is less during furrow preparation.

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