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International Journal of Agricultural Science and Food Technology

LIFE SCIENCES GROUP

ISSN: 2455-815X DOI: https://dx.doi.org/10.17352/ijasft

Research Article

Estimation of border effect on yield of rice and nutrient uptake

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Received: 29 July, 2021
Accepted: 24 August, 2021
Published: 25 August, 2021

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Keywords: Border effect; Rice; Yield and yield component; C input; Nutrient uptake

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Abstract

The experiment was conducted at Agronomy Research Field of Bangladesh Agricultural Institute, Gazipur during 2019 to quantify the border effect on rice. The experiment was set in a randomized complete block design with twelve replications. The treatment was non border (T_1) and border (T_2). Border treatment (T_2) had significant and positive influence on different parameters of rice. Grain yield and associated yield components improved in border treatment. Border effect was estimated at 8% in respect of grain yield. Increased tillers/hill (18%), filled grains/panicle (47%), grain weight/panicle (45%), grain growth (12%) weight of 1000-grain (0.97%), biological yield (4%) and harvest index (4.5%) were observed in border rows. Rice plant both flowered and matured 3 days earlier in border rows. Carbon input and uptake of N, P, K, S and Zn by rice were found higher values in border treatment. Carbon accumulation increased about 4.4% in border rice. Two lines/rows of rice hill should be excluded for harvesting of plot yield. Otherwise 8% yield will be deducted in actual yield calculation for eliminating the border area effect/border effect (for 2 lines/rows of hills around the plot).

Introduction

Border is the outer margin or side of a plot or crop field. Outer margin of crop field is exposed more as compared to inner side or centre of the plot. Plants in the outermost row next to the unplanted alley showed a general increase in yield and growth as compared to the center row [1]. This phenomenon has been referred to as ‘border effect’. Main causes of border effect are considered to be advantageous environmental factors on above the ground, such as higher solar energy, air circulation etc. Consequently, crop plants of border row get more light and more opportunity for gaseous exchange like carbon di oxide intake and release of oxygen [1]. Transpiration of crop plant is also influenced by border. Crop plants of border get more aeration as compared to inner side or centre of the plot. Consequently, the rate of transpiration decreases in a canopy due to density of foliage, shading effect and decrease of air movement inside of the rows [2,3]. More light interception enhanced total photosynthesis of crop plants of border. Leaf Area Index (LAI) in border rice increases as compared to centre due to more tillering. More tillering occurs due to advantageous environment of the outermost row [1]. As Leaf Area Index (LAI) increases so does light interception, causing increases in photosynthesis up to a critical LAI value [4]. Thus, a greater number of tillers of outer rows increased LAI resulting higher photosynthesis. More photosynthesis results in more dry matter production in the plant system ultimately contributes to higher yield of crop [5]. The greater rate of Net Assimilation Rate (NAR), Relative Growth Rate (RGR) and carbohydrate accumulation during grain ripening stage resulted in higher grain yield of rice in border [1]. They also mentioned that nutritional supply from alley and wider unplanted distance also increased yield in border rice. Hereby physiological process of yield formation of crop plant is influenced by border effect. There are scientific evidences of border effect on crop yield. A significant difference in yield (21.9 to 69.6%) and yield components was observed between outermost rows and inner rows of experimental plots, 2017) [6]. Rice plants grown in outmost first and second rows in paddy field produced averaged 30% more grain yield than that in center rows [7]. The first and the second row next to the unplanted alley consistently gave significantly higher grain yields than the centre rows but no evidence was found that border effect reach beyond the second outermost row. If the increase was very large, yield of the second outermost row were significantly decreased as compared to first row [8]. A

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DOI: https://dx.doi.org/10.17352/2455-815X.000116

significant border effect on grain yield was observed in the outmost row, but not in the second and third outmost rows in comparison with the center rows. Higher biomass production, more panicles per m^2 and spikelets per panicle, and higher grain-filling percentage were responsible for the border effect [9]. The two external rows yielded up to 40% more than the two innermost in wheat [10]. Analysis of yield components in border rows indicated that the number of kernels per ear, 1000-kernel weight and yield per plant of corn increased in border row and stopped decreasing after the second row of the border [11]. No more than three border rows of all the cultivars had marginal superiority (border effect) under high density, but about 90% of all the cultivars had border effect no more than two border row in maize [12]. Higher number of cobs per plant in border rows of maize was also observed by Mian [5]. Border row effect was estimated at 16% in soybean in single row soybean (4.88 m long and 11.80 cm between rows) [13]. Yield of cucurbit (cv. 'M 21') was reduced 13% in central rows from that of bordered row [14]. Rice plants grown in border rows had higher number of panicles per hill and a higher number of spikelet per panicle [7]. Plants in border rows performed differently producing higher tillering from those in the centre of plots tending to depress the performance of adjacent plants [9]. Nutrient uptake also varied in borders as compared to center rows [1]. Outer rows got more nutrients facility due to unplanted alley of the border. But research on border effect of crop as well rice in Bangladesh is scanty. Therefore, the study was undertaken to quantify the border effect on rice.

Materials and method

The experiment was conducted at Agronomy Research Field of Bangladesh Agricultural Institute, Gazipur during 2019 to quantify the border effect on rice. The experiment was set in a randomized complete block design with twelve replications. The treatment was non border (T_1) and border (T_2). Unit plot size was 5 m×5 m. Plant spacing was maintained as 25 cm×15 cm (row to row 25 cm and hill to hill 15 cm). The land was prepared well by power tiller. Twenty eight day old seedling of BRRI dhan71 was transplanted on 28 July 2019 and the crop was harvested on 25 October (border) and 28 October (non border). The crop was fertilizer as per recommendation of BRRI [15]. Other intercultural operations were done as and when necessary (BRRI [15]. Date of anthesis and maturity was recorded. Data was recorded of border (2 lines around the plot) and non border (excluding 2 lines around the border) treatment. Sixty hill per treatment was cut randomly at the base of rice plant for yield component. Hundred panicles were selected for number of grains/panicle and length of panicle measurement. Grain growth was calculated on the basis of 1000-grain weight. Duration of maturity required after anthesis was recorded. Yield was recorded of border (2 lines around the plot) and non border (excluding 2 lines around the border) area of each plot. Grain yield of rice was adjusted at 12% moisture level. Dry weight of grain and straw also recorded for estimation of nutrient concentration. Nutrient concentration (C, N, P, K, S, Zn and B) was determined following the standard laboratory procedures (Organic C was determined by wet digestion method by Nelson and Sommers 1982 [16], Nitrogen through semi micro-Kjeldhal method by Bremner and mulvaney 1982 [17], P through Molybdate ascorbic acid method by Olsen and Sommers 1982 [18], K directly through flame photometer from digest, S by turbidmetric method by Tabatabi 1982, Zn through Atomic absorption spectrophotometer and Calcium chloride extraction method). Each nutrient was measured by 5 repeated number of each replication. Nutrient uptake was also computed on the basis of nutrient concentration (both grain and straw). Collected data was subjected to statistical analysis. Hence, no need of LSD value because of only two treatments since F test significance about parameters, off course indicated the variation (only higher and lower) in two treatments.

Results and Discussion

Crop character

Plant height, tillers/hill, length of panicle, total grains/ panicle, filled grains/panicle and unfilled grains/panicle of rice significantly varied between non border and border treatment (Table 1). Plant height increased in non border (122 cm) rows as compared to border rows (117 cm). Plant height increased in non border rows due to inter tiller competition for receiving light. Tall plant is advantageous in light competition [19], this is why the increased plant height in the dense treatments is depicted by Gruntman, et al. [20]. Shading effect in central rows enhanced to produce taller plant due to variation of hormonal activities. Number of tillers/hill increased (18%) in border row due to getting more space (Table 1). Advantageous environment, more available nutrient near alley helped to produce more number of tillers/hill in the outermost row [1]. Plants in border rows produced higher number of tillers from those in the centre of plots was also found by Wang, et al. [9]. Similar trend was followed in the case of length of panicle where higher value (27.92 cm) was observed in border row (Table 1). Total number of grains (193) per panicle and filled grains (179) per panicle were noticed higher in border rows but unfilled grains per panicle showed higher value (42) in central row (non border). Possibly favourable microclimatic factors (near alley), more nutrient supply from alley and higher crop growth helped in better grain filling of border rice resulting higher number filled grains per panicle. More spikelets per panicle in border rows was also reported by Wang, et al. [9]. Weight of 1000-grain (26.03 g), grain growth (0.96 g/grain/ day) and grain weight per panicle (4.47 g) were observed higher in border rows (Table 2). Better dry matter partitioning into grain and grain filling possibly enhanced 1000-grain weight. Similarly, 1000-kernel weight increased in border row of corn [11]. Grain yield (6.61 t/ha), straw yield (8.89 t/ha) and biological yield (14.50 t/ha) gave higher values in border rows of rice (Table 2). Better crop growth helped in production of higher dry matter as well as higher biological yield which ultimately contributed to higher grain yield in border rows (Table 2). The results are in agreement with the report of Wang, *et al.* [19]. Higher harvest index (46) was calculated in border rows that was possibly happened due to higher dry matter partitioning in grain as compared to non border rows. Dry weight of grain

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(5.81 t/ha) and straw (6.98 t/ha) were also found higher in border rows due to corresponding higher weight of grain and straw before oven dry (Table 3). Better growth at border rice plant increased dry matter of grain and straw. Flowering of rice plant occurred three days earlier in border rows possibly due to advantageous micro environment. Border rows of rice plant got advantageous environmental factors like higher solar energy and air circulation as stated by Sato and Takahashi [1]. The results also have been supported by the findings of Rezazadeh, et al. [21]. They found earlier flowering (7.5 days and 46.6 days earlier) in full sunlight as compared to shading (45% and 65% shading respectively) in firespike (*Odontonema strictum*). Central rows of rice got mutual shading as compared border rows. Hence, earlier flowering occurred in border rows as influenced by more light availability than in central rows. Moreover, better growth of rice plant might have enhanced early flowering. Three to four days early flowering of Bt. brinjal (eggplant) in higher plant growth has been reported [22,23]. As the earlier flowering resulted in earlier maturity (3 days earlier) of rice in the border whereas grain filling duration (30 days) was static both in border and non border (Table 3). Better growth also enhanced earlier flowering of rice plant has been described by Mian [5]. However, the results finally reveal that grain yield increased 8% due to border effect having some advantageous influences.

Carbon input and uptake of other nutrient

Carbon input and uptake of N, P, K, S and Zn by rice grain showed higher values in border treatment as compared to non-border treatment (Table 4). Higher dry matter rendered higher C input and other nutrients uptake in plant system [5,24]. Higher C input observed in border rows possibly happed due to higher photosynthesis in more light availability and interception of it in border rows as compared to central rows where mutual shading occurred [21]. Higher dry matter production resulted in higher C input indicating more carbon accumulation through photosynthesis from the atmospheric carbon di oxide (CO_2) in the plant system in the border rows. Similarly, higher trend of C input and uptake of N, P, K, S and Zn by rice straw was noticed in borer rows (Table 5). Total C input (4805 kg/ha), total uptake of N (114 kg/ha), P (28 kg/ha), K (128 kg/ha), S (11.05 kg/ha) and Zn (0.455 kg/ha) noticed higher values in border rows as compared to non border rows (Table 6). The results are in agreement with the findings of Mian, et al. [24]. Similar pattern of N (91.23-133.62 kg/ha), P (17.17-21.49 kg/ha), K (66.38-106.30 kg/ha), S (7.73-12.06 kg/ha) and Zn (0.288-0.618 kg/ha) uptake was observed by other investigators [25-29]. The results concluded that higher C input and nutrients uptake improved yield components of rice in border rows, contributed to higher grain yield (8%).

Table 1: Plant height, tillers/hill, length of panicle, total grains/panicle, filled grains/panicle and unfilled grains/panicle of rice under non border and border treatment (2019).

Treatment	Plant height (cm)	Tillers/hill (no.)	Length of panicle (cm)	Total grains/panicle (no.)	Filled grains/panicle (no.)	Unfilled grains/panicle (no.)
Non Border	122	12.03	26.57	164	121	42
Border	117	14.20	27.92	193	179	12
SDV	3.23	1.53	0.95	20.50	41.01	21.21
LS	*	*	*	**	**	**
CV (%)	1.57	9.52	3.58	2.53	4.27	17.05

SDV: Standard Deviation; LS: Level of Significance; **Significant at 1% level of probability and * Significant at 5% level of probability

Table 2: Weight of 1000-grain, grain growth, grain weight/panicle, grain yield, straw yield, biological yield and harvest index of rice under non border and border treatment (2019).

Treatment	Weight of 1000-grain (g)	Grain growth (mg/grain/day)	Grain weight/ Panicle (g)	Grain yield (t/ha)	Straw yield (t/ha)	Biological yield (/ha)	HI (%)
Non Border	25.78	0.86	3.09	6.12	7.81	13.93	44
Border	26.03	0.96	4.47	6.61	8.89	14.50	46
SDV	0.18	0.07	0.98	0.35	0.76	0.40	1.41
LS	*	*	*	**	*	**	*
CV(%)	1.62	9.22	6.13	8.56	10.25	9.41	2.64

SDV=Standard deviation, LS=Level of significance, **Significant at 1% level of probability and * Significant at 5% level of probability

Table 3: Dry weight of grain, dry weight of straw, days to flowering, duration of maturity after anthesis and total life period of rice under non border and border treatment (2019).

Treatment	Dry weight of grain (t/ha)	Dry weight of straw (t/ha)	Days to flowering	Duration of maturity after anthesis (day)	Total life period (day)
Non Border	5.38	6.91	90	30	120
Border	5.81	6.98	87	30	117
SDV	0.30	0.05	2.12	0.00	2.12
LS	*	*	*	NS	*
CV(%)	8.42	9.07	5.11	0.00	5.19

SDV=Standard deviation, LS=Level of significance, * Significant at 5% level of probability and NS=Not significant

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Table 4: C input and uptake of N, P, K, S and Zn by rice grain under non border and border treatment (2019).

Treatment	C(kg/ha)	N(kg/ha)	P (kg/ha)	K(kg/ha)	S(kg/ha)	Zn(kg/ha)
Non Border	2232	62	17.75	16.14	3.77	0.141
Border	2411	67	19.17	17.43	4.07	0.153
SDV	127	3.54	1.00	0.91	0.21	0.01
LS	**	**	**	*	*	*
CV(%)	8.75	6.55	6.86	7.92	11.24	10.05

SDV= Standard Deviation, LS= Level of Significance; **Significant at 1% level of probability and * Significant at 5% level of probability

Table 5: C input and uptake of N, P, K, S and Zn by rice straw under non border and border treatment (2019).

Treatment	C (kg/ha)	N (kg/ha)	P (kg/ha)	K(kg/ha)	S(kg/ha)	Zn(kg/ha)
Non Border	2370	46.30	8.29	109	6.91	0.297
Border	2394	46.77	8.38	110	6.98	0.302
SDV	17	0.33	0.06	0.71	0.05	0.00
LS	*	*	*	*	*	NS
CV(%)	9.33	9.09	5.37	8.11	10.84	0.01

SDV= Standard deviation, LS= Level of significance, * Significant at 5% level of probability and NS= Not significant

Table 6: Total C input and uptake of total N, P, K, S and Zn by rice (grain +straw) under non border and border treatment (2019).

Treatment	C (kg/ha)	N (kg/ha)	P (kg/ha)	K(kg/ha)	S(kg/ha)	Zn(kg/ha)
Non Border	4602	109	26	125	10.68	0.438
Border	4805	114	28	128	11.05	0.455
SDV	144	3.54	1.41	2.12	0.26	0.01
LS	**	**	**	*	*	*
CV(%)	8.75	6.55	6.86	7.92	11.24	10.05

SDV=Standard deviation, LS=Level of significance, **Significant at 1% level of probability and * Significant at 5% level of probability

Conclusion

Yield components and grain yield of rice improved in border rows. Border effect was estimated at 8% in grain of border rice. Two lines/rows of rice hills should be excluded for harvesting of plot yield. Otherwise 8% yield will be deducted in actual yield calculation for eliminating the border area effect/border effect (for 2 lines/rows of hills around the plot).

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