Research Article

Estimation of border effect on yield of rice and 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 (T1) and border (T2). Border treatment (T2) 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 dioxide 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].
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 m² 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 (T1) and border (T2). Unit plot of Bangladesh Agricultural Institute, Gazipur during 2019 to procedures (Organic C was determined by wet digestion. Dry weight of grain and straw also recorded for estimation of plot. Grain yield of rice was adjusted at 12% moisture level. Duration of maturity required after anthesis was recorded. Grain growth was calculated on the basis of 1000-grain weight. Number of grains/panicle and length of panicle measurement. 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.

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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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 happened 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 dioxide (CO2) 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 border 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 (t/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| 2322      | 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     | 0.141      |
| Border    | 4805      | 114       | 28        | 128       | 11.05     | 0.153      |
| 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 yield calculation for eliminating the border area effect/border effect (for 2 lines/rows of hills around the plot).

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