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Influence of Planting Method and Weeding on the Yield of Transplanted Aman Rice

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Authors' contributions

This work was accomplished in collaboration between all authors. Author PKB planned the experiment and lead the research. Author MSAM designed the study and performed the statistical analysis. Authors MA, MMH and MEH helped in designing and performing the statistical analysis. Author MSAM carried out the research on field. Authors MSAM, SM and MAM collect the data. Author MA took the lead in writing the manuscript. Authors MSAM and MEH managed the literature searches. All authors provided critical feedback and helped shape the research, analysis and manuscript. All authors read and approved the final manuscript.

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ABSTRACT

A field experiment was conducted at the Agronomy field, Sher-e-Bangla Agricultural University, Dhaka. The experiment consisted of two factors; Factor A: Planting method viz. Rice transplanter (P_1) and Conventional method (P_2) and Factor B: Weeding viz. No Weeding (W_0), Weeding at 20 DAT (W_1), Weeding at 35 DAT (W_2), Weeding at 50 DAT (W_3), Two Weedings at 20 DAT & 35 DAT (W_4), Two Weedings at 20 DAT & 50 DAT (W_5), Two Weedings at 35 DAT & 50 DAT (W_6) and

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Three Weedings at 20 DAT, 35 DAT & 50 DAT (W_7). The maximum number of filled grains panicle^{-1} and a minimum number of unfilled grains panicle^{-1} (170.82 and 27.83 respectively) were obtained from conventional method while the minimum number of filled grains panicle^{-1} and a maximum number of unfilled grains panicle^{-1} from rice transplanter (158.31 and 41.61 respectively). Higher yield (5.38 t ha^{-1}) was obtained from the conventional method and lower yield (4.93 t ha^{-1}) from rice transplanter but they did not vary significantly. Higher biological yield (12.92 t ha^{-1}) was obtained from the conventional method and the lower from rice transplanter (10.86 t ha^{-1}). In case of weeding, the highest grain yield was obtained from Three Weedings at 20 DAT, 35 DAT & 50 DAT (W_7) (5.48 t ha^{-1}) and lowest from No Weeding (W_0) (4.13 t ha^{-1}). In case of interaction between planting method and weeding, the highest grain yield obtained from P_2W_7 (5.82 t ha^{-1}) and the lowest from P_1W_0 (3.57 t ha^{-1}). As the conventional transplanting incurs more labor, using rice transplanter and weeding either at 25 DAT or at 35 DAT might be suggested.

Keywords: Rice; Oryzae sativa; rice transplanter; T. aman; weeding.

1. INTRODUCTION

Rice (*Oryzae sativa* L.) is the staple food for nearly half of the world's population, of which more than 90% of this rice consumer is in Asia [1]. It is the grain with the second-highest worldwide production, after corn. Among the rice growing countries, Bangladesh is the fourth highest rice producing country in the world [2].

Rice is the major food of about 150 million people of Bangladesh. Total rice production in Bangladesh was about 10.59 million tons in the year 1971 when the country's population was only about 70.88 million. However, the country is now producing about 34.00 million tons rice to feed her 149.69 million people [3]. There is no reason to be complacent as the population of Bangladesh is still growing by two million every year at the rate of 1.22% and the population of the country in the year 2030 will be 186.0 million [4]. As such the country will require about 39.80 million tons of rice for the year of 2030 [3]. During this period, total rice area will also shrink to 10.28 million hectares (from present status). Rice yield, therefore, needs to be increased from the present 2.74 to 3.74 t ha^{-1} [5]. Moreover, the arable land is decreasing at the rate of 1% per annum [6]. Bangladesh has three rice growing seasons among which Transplanted *aman* (T. *aman*) rice covers about 48.97% of total rice area and it contributes to 38.13% of the total rice production in the country [7]. Transplanted *aman* covers the largest area of 5794 thousand ha with a production of 12284 thousand metric tons and average yield was about 2.9 t ha^{-1} [7] which is much lower than that of other rice-producing countries like Japan (6.8 t ha^{-1}), Korea (6.8 t ha^{-1}) and China (6.3 t ha^{-1}) [8,9]. The increasing rate of population is 1.37% [10] and decreasing rate of agricultural land by 1% per annum [11] limit the horizontal expansion of rice area. However, to meet this demand the crop should perform to its full potential. Certain factors tend to restrict the crop's potential performance. The mechanical transplanting of rice has been considered the most promising option, as increases yield, improves labor efficiency and ensures timeliness in operation and faster transplanting [12].

Among the various factors responsible for low rice production, weeds are considered to be as one of the major limiting factors due to manifold harmful effects [13]. The infestation of weed is one of the most important constraints in the cultivation of Transplanted *aman* rice [14,15]. It is often mentioned that Agriculture is a fight against weeds [16]. Many investigators have reported a great loss in the yield of rice due to weed infestation from different parts of the world [17]. Weed depresses the normal yield of filled grains per panicle and grain weight [18].

In Bangladesh, weed infestation reduces the grain yield by 30-40% for T. *aman* rice cultivars (late summer) [19,20]. Therefore, appropriate and economical weed management technology is to be developed for the sustainable rice cultivation. The transplanting of rice through rice transplanter has been practicing in some parts of Bangladesh during *aman* season. However, information exists on the potentiality of using rice transplanter and weeding are scarce. Thus, the present study was undertaken to find out the influence of weeding for optimum yield of T. *aman* rice as well as to explore the effect of using rice transplanter under different weed management.

2. MATERIALS AND METHODS

The experiment was conducted at the Agronomy field of Sher-e-Bangla Agricultural University,

Dhaka during the period from July-December, 2013. The experimental area was situated at 23°77´ N latitude and 90°33´ E longitude at an altitude of 8.6 meters above sea level [21]. The area was under sub-tropical climate and characterized by high temperature, high relative humidity and heavy rainfall with occasional gusty winds in April to September and scanty rainfall associated with moderately low temperature during October to March. The soil of the experimental area belongs to the Agro-ecological zone 'The Modhupur Tract', AEZ-28 [22]. BRRI dhan49 was used as studied variety in this experiment. The experiment consisted of two factors, A. Planting methods viz.: Rice Transplanter (P_1) and Conventional method (P_2) and B. Weeding viz. No Weeding (W_0), Weeding at 20 days after transplanting (DAT) (W_1), Weeding at 35 DAT (W_2), Weeding at 50 DAT (W_3), Two Weedings at 20 DAT & 35 DAT (W_4), Two Weedings at 20 DAT & 50 DAT (W_5), Two Weedings at 35 DAT & 50 DAT (W_6) and Three Weedings at 20 DAT, 35 DAT & 50 DAT (W_7). All weeding was done by hand. The experiment was laid in a split-plot design with three replications having planting method in the main plots and weeding in the sub-plots. The size of the unit plot was 4.0 m × 3.0 m.

The experimental field was prepared by three successive ploughings and cross ploughings with a tractor plow and subsequently leveled by laddering. The experimental plots were fertilized with 120, 80, 80, 20 and 5 kg ha^{-1} N, P_2O_5, K_2O, S and Zn in the form of urea, triple super phosphate (TSP), muriate of potash (MoP), gypsum and zinc sulphate respectively [23]. Thirty-day-old seedlings were carefully uprooted from the seedbed. Then transplanted with 20 cm × 20 cm spacing on the well-puddled plots. The seedlings of tray were shift to the transplanter at 20 days old for transplanting in the main field. The whole field of each replication marked for transplanter was transplanted first. Then marked as per plot size by uprooting excess seedlings from drains. All intercultural operations were done as per recommendation.

Ten pre-selected hills were selected from each unit plot and uprooted before harvesting for from which different crop growth data were collected. The crops were harvested at full maturity. Then the harvested crops of each plot were threshed and the fresh weights of grain and straw were recorded plot-wise. The grains were cleaned and sun-dried to maintain the moisture of about 12%. Straw was also sun-dried properly. Finally, grain and straw yields $plot^{-1}$ were recorded and converted to t ha^{-1}.

2.1 Biological Yield (t ha^{-1})

Grain yield and straw yield were altogether regarded as biological yield. The biological yield was calculated with the following formula:

Biological yield = Grain yield + Straw yield

2.2 Harvest Index (%)

It denotes the ratio of economic yield to biological yield and was calculated with following formula [24,25].

$$\text{Harvest Index (\%)} = \frac{\text{Grain Yield}}{\text{Biological Yield}} \times 100$$

2.3 Statistical Analyses

All the data collected on different parameters were statistically analyzed following the analysis of variance (ANOVA) technique using MSTAT-C computer package program and the mean differences were adjudged by least significant difference (LSD) test at 5% level of significance [26].

3. RESULTS AND DISCUSSION

3.1 Number of Effective Tillers $hill^{-1}$

The number of effective tillers $hill^{-1}$ was not significantly influenced by the planting method (Fig. 1) along with the weeding (Table 1). Numerically the higher number of effective tillers $hill^{-1}$ (13.60) was obtained from rice transplanter (P_1) and the lower number of effective tillers $hill^{-1}$ (12.72) observed in conventional planting method (P_2).

Table 1. Effect of weeding on the number of effective tillers $hill^{-1}$ of rice

Treatments	Effective tillers (no. $hill^{-1}$)
W_0	12.23
W_1	14.53
W_2	12.43
W_3	12.07
W_4	13.97
W_5	14.8
W_6	12.4
W_7	12.87
$LSD_{(0.05)}$	NS
CV (%)	13.82

NS= Non-Significant.

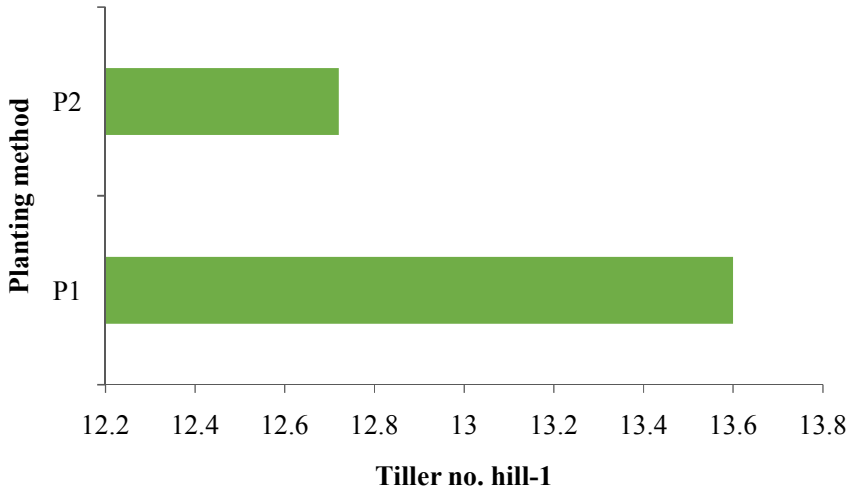

Fig. 1. Effective tillers hill^{-1} of rice as affected by planting method

Therefore, rice transplanter produced a higher number of effective tillers hill^{-1} compared to the conventional method. Manjunatha et al. [27] and Munnaf et al. [28] also reported similar results. Besides, The maximum number of effective tillers hill^{-1} (14.80) was observed in Two Weedings at 20 DAT & 50 DAT (W_5) and the minimum number of effective tillers hill^{-1} (12.7) observed in Weeding at 50 DAT (W_3). However, all weeding plots were statistically similar.

The number of effective tillers hill^{-1} was not statistically significantly influenced by planting method and weeding (Table 2). The maximum number of effective tillers hill^{-1} (15.80) was observed in P_1W_1 and the minimum number of effective tillers hill^{-1} (11.47) observed in P_1W_0.

3.2 Filled Grains Panicle^{-1}

The number of filled grains panicle^{-1} was not significantly influenced by the planting method (Fig. 2) and also by the weeding (Table 3). Numerically the higher number of filled grains panicle^{-1} (170.82) was obtained from conventional planting method (P_2) and the lower number of filled grains panicle^{-1} (158.31) observed in rice transplanter method (P_1). Three Weedings at 20 DAT, 35 DAT & 50 DAT (W_7) gave the maximum number of filled grains panicle^{-1} (173.10) and the minimum number of filled grains panicle^{-1} (159.70) observed in Two Weedings at 20 DAT & 35 DAT (W_4). So increasing number of weedings increased the filled grains panicle^{-1}. Similar findings were also reported by Polthanee et al. [29] and Sanjoy et al. [30] where the number of filled grains panicle^{-1} were increased due to weed control over no weeding.

Table 2. Interaction effect of planting method and weeding on the number of effective tillers hill^{-1} of rice

Treatments	Effective tillers (no. hill^{-1})
P_1W_0	11.47
P_1W_1	15.80
P_1W_2	13.27
P_1W_3	12.20
P_1W_4	15.60
P_1W_5	15.73
P_1W_6	12.67
P_1W_7	12.07
P_2W_0	13.00
P_2W_1	13.27
P_2W_2	11.60
P_2W_3	11.93
P_2W_4	12.33
P_2W_5	13.87
P_2W_6	12.13
P_2W_7	13.67
LSD $_{(0.05)}$	NS
CV (%)	13.82

NS= Non-Significant.

Interaction effect of planting method and weeding was not statistically significantly influenced the filled grains panicle^{-1} (Table 4). Numerically the maximum number of filled grains panicle^{-1} (182.20) observed in P_2W_7 (Conventional method

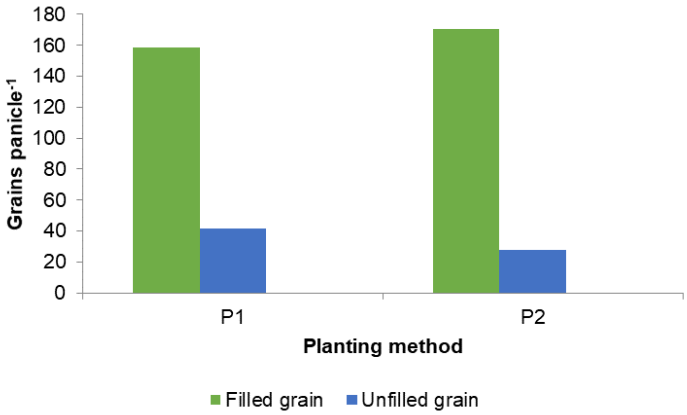

Fig. 2. Filled grains panicle^{-1} and unfilled grains panicle^{-1} of rice as affected by planting method

Table 3. Effect of weeding on different crop characters

Treatments	Filled grains panicle^{-1} (no.)	Unfilled grains panicle^{-1} (no.)	1000-grains weight (g)
W_0	167.70	29.92	18.30 c
W_1	160.20	32.83	19.25 a-c
W_2	170.40	30.32	20.30 a
W_3	160.10	33.60	19.81 ab
W_4	159.70	35.80	18.83 b
W_5	162.10	38.50	19.85 ab
W_6	163.40	39.42	18.81 bc
W_7	173.10	37.38	19.97 a
LSD $_{(0.05)}$	NS	NS	1.06
CV (%)	10.76	29.14	4.64

NS= Non-Significant. Means with the same letter(s) are not significantly different.

× Three Weedings at 20 DAT, 35 DAT & 50 DAT) and the minimum number of filled grains panicle^{-1} (147.80) observed in P_1W_4 (Rice transplanter × Two Weedings at 20 DAT & 35 DAT).

3.3 Unfilled Grains Panicle^{-1}

The number of unfilled grains panicle^{-1} was not significantly influenced by planting method (Fig. 2) and weeding (Table 3). Numerically the higher number of unfilled grains panicle^{-1} (41.60) was obtained from rice transplanter method (P_1) and the lower number of unfilled grains panicle^{-1} (27.84) observed in conventional planting method (P_2). Besides, the maximum number of unfilled grains panicle^{-1} (39.82) observed in Two Weedings at 35 DAT & 50 DAT (W_6) and the minimum number of unfilled grains panicle^{-1} (29.92) observed in No Weeding (W_0).

Interaction effect of planting method and weeding was not statistically significantly influenced the unfilled grains panicle^{-1} (Table 4). Numerically the maximum number of unfilled grains panicle^{-1} (50.30) observed in P_1W_7 (Rice transplanter × Three Weedings at 20 DAT, 35 DAT & 50 DAT) and the minimum number of unfilled grains panicle^{-1} (20.50) observed in P_2W_0 (Conventional method × No Weeding).

3.4 Weight of 1000-grains

The planting method (Fig. 3), as well as the weeding (Table 3), did not significantly influence the weight of 1000-grains. Numerically the maximum weight of 1000-grains (19.51 g) was obtained from conventional planting method (P_2) and the minimum weight of 1000-grains (19.26 g) observed in rice transplanter method (P_1). Munnaf et al. [28] also found similar results. Weeding at 35 DAT (W_2) gave the highest weight of 1000-grains (20.30 g) and the lowest weight of 1000-grains (18.30 g) observed in No Weeding (W_0). This may happen due to No Weeding (W_0) plot had severe plant-weed competition. That

competition may reduce the supply of proper nutrient for plant grain filling. Yuan et al. [31] observed similar finding.

Interaction effect of planting method and weeding has significantly influenced the weight of 1000-grains (Table 4). The highest weight of 1000-grains (20.65 g) observed in P_2W_2 and the lowest weight of 1000-grains (18.16 g) observed in P_1W_0.

3.5 Grain Yield

Planting method had no influence on yield (Fig. 4). Numerically the higher grain yield (5.38 t ha^{-1}) was obtained from the conventional planting method (P_2) and lower (4.93 t ha^{-1}) from the rice transplanter method (P_1). Hossain et al. [32], Manjunatha et al. [27] and Munnaf et al. [28] also reported similar results.

Weeding significantly influenced the grain yield (Table 5). The highest observation (5.48 t ha^{-1}) found in the Three Weedings at 20 DAT, 35 DAT & 50 DAT (W_7) and lowest (4.13 t ha^{-1}) found in the No Weeding (W_0). Weeding reduces the plant-weed competition. Therefore, weed-free plot has a chance to give better yield, as there was no competition for nutrients, lights and other requirements for crops. That was why Three Weedings at 20 DAT, 35 DAT & 50 DAT (W_7) plot gave the highest grain yield. Similar findings were also reported by Polthanee et al. [29], Sanjoy et al. [30], Gogoi et al. [33], Thomas et al. [34], and Attalla and Kholosy [35].

Table 4. Interaction effect of planting method and weeding on different crop characters

Treatments	Filled grains panicle^{-1} (no.)	Unfilled grains panicle^{-1} (no.)	1000-grains weight (g)
P_1W_0	162.0	39.33	18.16 g
P_1W_1	150.1	32.03	18.68 d-g
P_1W_2	158.6	35.73	19.94 a-c
P_1W_3	156.5	38.23	19.98 a-c
P_1W_4	147.8	43.10	19.05 c-g
P_1W_5	164.4	44.57	19.37 b-f
P_1W_6	155.8	48.53	19.06 c-g
P_1W_7	171.5	51.30	19.86 a-d
P_2W_0	173.4	20.50	18.44 fg
P_2W_1	170.3	33.63	19.81 a-e
P_2W_2	182.2	24.90	20.65 a
P_2W_3	163.6	28.97	19.63 a-f
P_2W_4	171.5	28.50	18.61 e-g
P_2W_5	159.8	32.43	20.34 ab
P_2W_6	171.1	30.30	18.55 fg
P_2W_7	174.7	23.47	20.07 a-c
LSD $_{(0.05)}$	NS	NS	1.19
CV (%)	10.76	29.14	4.64

NS= Non-Significant. Means with the same letter(s) are not significantly different.

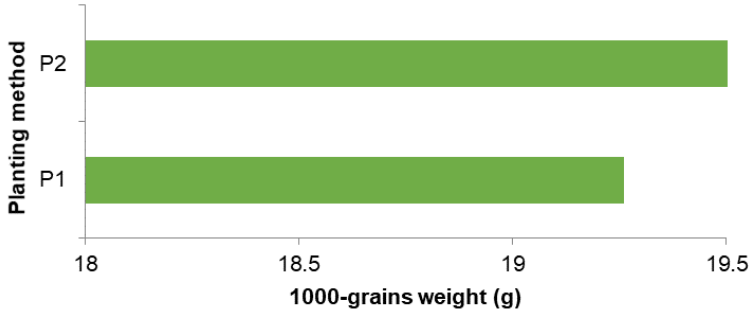

Fig. 3. 1000-grains weight of rice as affected by planting method

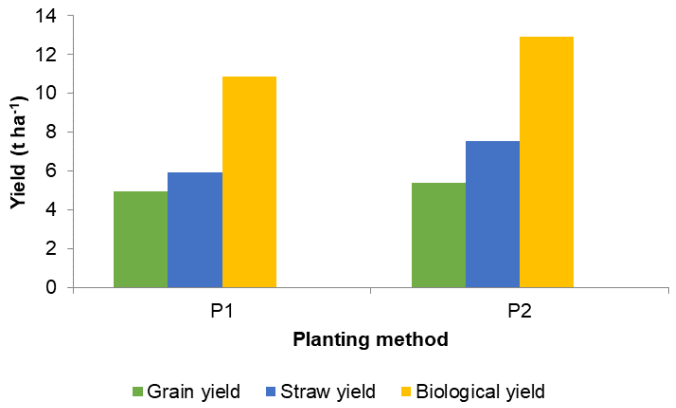

Fig. 4. Grain yield, Straw yield and Biological yield of rice as affected by planting method
$LSD_{(0.05)}$ = 0.94 for Biological yield.

Table 5. Effect of weeding on yield and other crop characters of rice

Treatments	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
W_0	4.13 b	6.49	10.62	39.05 c
W_1	5.04 a	6.89	11.94	42.79 a-c
W_2	5.44 a	6.73	12.17	44.63 ab
W_3	5.33 a	6.99	12.32	43.50 a-c
W_4	5.23 a	7.43	12.67	41.39 bc
W_5	5.32 a	6.20	11.53	46.71 a
W_6	5.26 a	6.66	11.93	44.14 ab
W_7	5.48 a	6.46	11.95	46.66 a
$LSD_{(0.05)}$	0.61	NS	NS	9.08
CV (%)	10.13	13.71	9.40	8.68

NS= Non-Significant. Means with the same letter(s) are not significantly different.

Grain yield was significantly influenced by the interaction effect of planting method and weeding (Table 6). The highest grain yield (5.82 t ha^{-1}) observed in P_2W_7 (Conventional method × Three Weedings at 20 DAT, 35 DAT & 50 DAT) and the lowest (3.57 t ha^{-1}) observed in P_1W_0 (Rice transplanter × No Weeding). That might happen because the Conventional method has lesser line-to-line distance than Rice transplanter method. Lesser spacing may help to control weed population and supply more nutrition to crop.

3.6 Straw Yield

Straw yield was not significantly influenced by the planting method (Figure 4) and also by weeding (Table 5). The conventional planting method (P_2) gave the higher straw yield (7.55 t ha^{-1}) and lower (5.93 t ha^{-1}) from the rice transplanter method (P_1). On the other hand, the maximum straw yield (7.44 t ha^{-1}) observed in Two Weedings at 20 DAT & 35 DAT (W_4) and minimum straw yield (6.21 t ha^{-1}) observed in Two Weedings at 20 DAT & 50 DAT (W_5).

Straw yield was not also significantly influenced by the interaction effect of planting method and weeding (Table 6). Numerically the maximum straw yield (7.85 t ha^{-1}) observed in P_2W_4 (Conventional method × Two Weedings at 20 DAT & 35 DAT) and minimum (5.12 t ha^{-1}) observed in P_1W_7 (Rice transplanter × Three Weedings at 20 DAT, 35 DAT & 50 DAT).

3.7 Biological Yield

Planting method significantly influenced biological yield (Fig. 4). The result revealed that higher biological yield (12.92 t ha^{-1}) obtained from the conventional transplanting method (P_2) and lower biological yield (10.86 t ha^{-1}) observed in rice transplanter method (P_1).

Biological yield was not significantly influenced by weeding (Table 5). Two Weedings at 20 DAT & 35 DAT (W_4) gave the maximum biological yield (12.67 t ha^{-1}) and No Weeding (W_0).gave the minimum (10.62 t ha^{-1}).

The interaction effect of planting method and weeding significantly influenced biological yield (Table 6). The highest observation (13.63 t ha^{-1}) was in P_2W_7 (Conventional method × Three Weedings at 20 DAT, 35 DAT & 50 DAT) and the lowest (8.97 t ha^{-1}) was in P_1W_0 (Rice transplanter × No Weeding). Weed-free condition may help to increase biological yield.

3.8 Harvest Index (%)

Harvest index was not significantly influenced by the planting method (Fig. 5). Numerically higher harvest index (45.52 %) was obtained from the rice transplanter method (P_1) and lower (41.69%) from the conventional transplanting method (P_2). Similar results also observed by Munnaf et al. [28].

The weeding (Table 5) and the interaction effect of planting method & weeding (Table 6) both significantly influenced the harvest index. The highest harvest index (46.71%) observed in Two

Table 6. Interaction effect of planting method and weeding on yield and other crop characters of rice

Treatments	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
P_1W_0	3.57 d	5.40	8.97 f	39.89 c
P_1W_1	4.80 c	6.09	10.89 de	44.74 a-c
P_1W_2	5.09 a-c	6.42	11.52 b-e	44.15 a-c
P_1W_3	4.94 bc	6.25	11.19 c-e	44.38 a-c
P_1W_4	5.24 a-c	7.02	12.26 a-d	42.78 a-c
P_1W_5	5.15 a-c	5.15	10.30 ef	50.18 a
P_1W_6	5.53 a-c	5.95	11.48 b-e	47.97 ab
P_1W_7	5.15 a-c	5.12	10.27 ef	50.07 a
P_2W_0	4.69 c	7.58	12.27 a-d	38.21 c
P_2W_1	5.29 a-c	7.69	12.99 a-c	40.83 c
P_2W_2	5.78 ab	7.04	12.82 a-c	45.10 a-c
P_2W_3	5.73 ab	7.73	13.46 a	42.62 bc
P_2W_4	5.22 a-c	7.85	13.08 ab	39.99 c
P_2W_5	5.50 a-c	7.26	12.76 a-d	43.34 a-c
P_2W_6	4.99 a-c	7.38	12.38 a-d	40.30 c
P_2W_7	5.82 a	7.81	13.63 a	43.26 a-c
LSD $_{(0.05)}$	0.87	NS	1.87	7.44
CV (%)	10.13	13.71	9.40	9.08

NS= Non-Significant. Means with the same letter(s) are not significantly different.

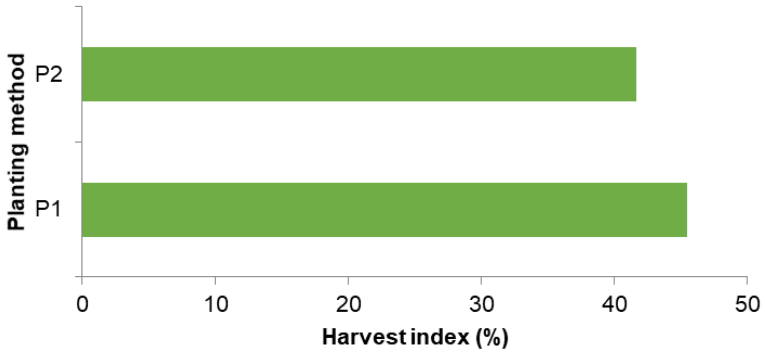

Fig. 5. Harvest Index of rice as affected by planting method

Weedings at 20 DAT & 50 DAT (W_5) and the lowest harvest index (39.07%) observed in No Weeding (W_0). P_1W_5 (Rice transplanter × Two Weedings at 20 DAT & 50 DAT) gave the highest harvest index (50.18%) and P_2W_0 (Conventional method × No Weeding) gave the lowest (38.21 %).

4. CONCLUSION

From this study, it is observed that three times weedings can increase grain yield. The weeding showed a significant effect on all the agronomic parameters except effective tillers hill^{-1} and straw yield. The highest grain yield (5.48 t ha^{-1}) observed in Three Weedings at 20 DAT, 35 DAT & 50 DAT (W_7) and lowest grain yield (4.13 t ha^{-1}) observed in No Weeding (W_0). Interaction effect of planting method and weeding was not significantly influenced the grain yield. The highest grain yield (5.82 t ha^{-1}) observed in P_2W_7 (Conventional method × Three Weedings at 20 DAT, 35 DAT & 50 DAT) and the lowest grain yield (3.57 t ha^{-1}) observed in P_1W_0 (Rice Transplanter × No Weeding).

Based on the results of the present study, the conclusions may draw- No weeding reduced the grain yield of transplanted rice due to crop-weed competition and rice transplanter have no influence on grain yield as both, the rice transplanter and conventional method, gave similar yield.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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