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AGRONOMY | ORIGINAL ARTICLE

Comparative performance of puddled and zero till non-puddled transplant boro rice under different weed management practices

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ABSTRACT

The experiment was conducted at the Agronomy Field Laboratory, Bangladesh Agricultural University, Mymensingh to evaluate the yield of boro rice influenced by transplanting systems and different weed management practices. The experiment comprised two transplanting systems *viz.*, (i) puddled transplanted rice (PTR) and (ii) zero till non-puddled transplanted rice (ZT-NPTR), and five weed management practices *viz.*, (i) weedy, (ii) weed free, (iii) farmers' practice (3 manual weeding), (iv) application of pre-emergence herbicide Pretilachlor, and (v) application of post-emergence herbicide Penoxsulam. The experiment was laid out in randomized complete block design with three replications. Twelve weed species belonging to four families infested the experimental plots. Transplanting systems and weed management practices exerted significant influence on yield attributes and yield of boro rice. At 60 days after transplanting (DAT), maximum weed dry biomass (184.11 g m^{-2}) was found in weedy practices of ZT-NPTR, while the highest weed density (143 m^{-2}) was obtained from the weedy plots of PTR. The highest number of effective tillers $hill^{-1}$ (15.60), grains $panicle^{-1}$ (125), 1000-grain weight (22.50 g), grain (4.78 t ha^{-1}) and straw (5.16 t ha^{-1}) yield was obtained from the weed free plots of PTR. The grain yield was at par with pre- and post-emergence herbicide applied plots of PTR, and farmers' practice and post-emergence herbicide applied plots of ZT-NPTR. The maximum gross return (185650 Tk. ha^{-1}), net return (79833 Tk. ha^{-1}) and BCR (1.75) were obtained from the application of post-emergence herbicide Penoxsulam in ZT-NPTR system compared to other practices. Although, maximum grain yield was obtained from PTR under weed free condition, in terms of both grain yield and economic view point ZT-NPTR with post-emergence herbicide application might be an alternative way for sustainable crop production and weed management practices.

Keywords: Weed management, zero-till non puddle system, puddle system, herbicide

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1 Introduction

Among the three different rice (*Oryza sativa* L.) cultivation systems (puddled, non-puddled and dry direct seeded), puddled transplanting system (PTR) is the most common in South Asian countries especially in Bangladesh. However, PTR consumes huge amount of water, time and energy, and repeated puddling in PTR destroys the soil aggregates resulting in a massive structure topsoil and a shallow plow pan (Chaki et al., 2021). Migration of agricultural labor to industries or other countries for employment, causes a shortage of labor during the peak season, delays the transplanting and reduces grain yield (Shrestha et al., 2021). Moreover, recent price hike of diesel and energy crisis due to Russia-Ukraine war are also a great concern in Bangladesh. In this context, zero-till non-puddled transplanted (ZT-NPTR) system is going to be emerged as a potential technology from conservation view point. ZT-NPTR rice allows no soil disturbance, reduce tillage costs, saves water through the elimination of that required for the puddling operation, and potentially increases profit and energy efficiency without any yield penalty (Haque et al., 2016; Islam et al., 2019; Gathala et al., 2020; Chaki et al., 2021). Furthermore, ZT-NPTR also save human labor and energy that required for ploughing in other systems. But this method is not yet well-understood, especially in relation to studies addressing a systematic comparison of weed infestation, weed control efficiency, and rice yield.

Weeds are one of the major constraints to crop production in the world. Tillage has a great influence on weed composition and minimum tillage alters species diversity, but weed composition and their management in wetland rice fields under the ZT-NPTR system are not yet clearly defined (Murphy et al., 2006; Mishra and Singh, 2012). Although weed management strategies differ among countries, now-a-days it mostly relies on herbicides because of agricultural labor shortage, escalating labor wages and drudgery involved. The agricultural labor availability in Bangladesh decreased (almost 2-folds) from 70% (1991) to 37% (2021) (World Bank, 2023) which resulted the increased herbicide consumption (82-folds) from 99 MT/ kL (1991) to 8050 MT/ kL (2022) (Mou et al., 2022; BBS, 2023). It is well known that safest application time of herbicide may not always coincide with the optimum time for maximum efficacy. In addition, same herbicide may not be equally effective in different rice establishment methods (Anwar et al., 2012). To achieve low weed competition at ZT-NPTR system, a pre-planting non-selective herbicide should be applied to kill the existing weeds, and subsequently pre- or post-emergence herbicide also need to apply because of remaining viable weed seeds on the surface of the non-puddled soil still after pre-plant herbicide application (Zahan et al., 2018). The emergence of those viable seeds at the early crop growth period is caused to higher weed infestation in ZT-NPTR system compared to the conventional PTR system (Kumar and Ladha, 2011; Eager et al., 2013). Adoption of this technique may be limited if heavy weed infestation cannot successfully be controlled (Farooq et al., 2011). Study related to the comparative performance of ZT-NPTR with PTR rice in terms of yield and economics under varying weed management is very scant. Therefore, more research should be conducted to formulate an effective weed management technology keeping chemical control in the center for sustainability of the rice cultivation systems. Keeping all these in views, the present study was conducted to compare the performance of PTR and ZT-NPTR rice in terms of yield and economics under varying weed management practices.

2 Materials and Methods

2.1 Description of the experimental site

The experimental field was located at 24.50° N latitude and 90.75° E longitude at an average altitude of 18 m above the mean sea level. The experimental site belongs to the Old Brahmaputra Floodplain Agro-ecological zone (AEZ-9). The experiment field was medium high and the soil was silty-loam, and almost neutral in reaction (pH 6.8). The organic matter content (0.93%) and general fertility level (0.13% total N, and exchangeable P, K, and S are 16.3, 0.28 and 13.9 ppm, respectively) of the experimental field is low. The climate of the locality was tropical in nature characterized by high temperature, high humidity and heavy precipitation with occasional gusty winds in kharif season (April-September) scanty rainfall associated with moderately low average air temperature, relative humidity, rainfall and sunshine in rabi season (October-March).

2.2 Plant material

A popular high yielding boro rice variety BRRI dhan58 was used in this experiment. This variety was developed by Bangladesh Rice Research Institute and released for cultivation in 2012. It is tolerant to lodging and plant height ranges between 100-105 cm. The variety takes about 150-155 days to mature and can produce average grain yield of 7.0-7.5 t ha^{-1}. Grains are long, slender and bright in color.

2.3 Experimental treatments and design

The experiment comprised two rice transplanting systems e.g., (i) puddled transplanting system (PTR), (ii) zero till non-puddled transplanting system (ZT-NPTR); and five weed management practices e.g., (i) weedy, (ii) weed free, (iii) farmers' practice (3 hand weeding), (iv) application of pre-emergence herbicide Pretilachlor @ 1.0 L ha^{-1} at 7 days after transplanting (DAT) and (v) application of post-emergence herbicide Penoxsulam @ 93.70 mL ha^{-1} at 14 DAT. The pre- and post-emergence herbicides used in this experiment were Commit 500 EC (Pretilachlor), Granite 240 SC (Penoxsulam), respectively. A brief description of the herbicides used in the experiments along with their trade name, common name, selectivity, mode of application and their marketing company are shown in Table 1. The experiment was laid out in a randomized complete block design (RCBD) with three replications. The total number of plots were 30 (2 × 5 × 3). Each plot size was 4.0 m × 2.5 m. The distance

Table 1. Trade name, common name, selectivity, mode of application of herbicides and their marketing company

Trade name	Common name	Selectivity	MOA	Marketing Company
Commit 500 EC	Pretilachlor	Grass and broadleaf weeds of rice	Pre emergence	Auto Crop Care Ltd.
Granite 240 SC	Penoxsulam	Grass, broadleaf and sedge of rice	Post emergence	Auto Crop Care Ltd.

MOA: mode of action

maintained between two-unit plots was 0.5 m and between blocks was 1.0 m.

2.4 Crop husbandry

Sprouted seeds were sown in the wet nursery bed on 15 December, 2021. Proper care was taken to raise seedlings in the nursery bed. The PTR field was first opened on 10 January, 2022 with a power tiller. The land was irrigated on 20 January, 2022. Then the land was puddled thoroughly by ploughing and cross ploughing (three times) with a tractor driven plough followed by laddering in order to level the field. Final puddling was completed two days before the scheduled date of transplanting. The layout was done as per experimental treatments. Finally, basal doses of fertilizer were applied and the individual plots were made ready for transplanting as per design of the experiment.

Two weeks before the transplanting of ZT-NPTR field, pre-planting non-selective herbicide, Roundup® (glyphosate 41% SL-IPA salt), was applied @ 75 mL 10 L^{-1} water (2.25 L ha^{-1}). Before transplanting, the land was inundated to 3-5 cm depth of standing water for 48 hours. A metallic rod was used to make furrow by hand and then 40-day old rice seedlings were transplanted as per the experimental specifications. Except the above activities all others were performed as like PTR. Fertilizers were applied in the field as per recommendation of Bangladesh Rice Research Institute @ 220 kg urea, 120 kg triple super phosphate, 75 kg muriate of potash, 60 kg gypsum and 10 kg zinc sulphate ha^{-1} (BRRI, 2020). Except urea all other fertilizers were applied as basal. Urea was top dressed in three instalments at 15, 30 and 45 days after transplanting (DAT). The seedlings were transplanted both in well-prepared puddled field and zero till non-puddled field on 22 January, 2022 following the spacing of 25 cm × 15 cm with two seedlings per hill. There was no remarkable insect or diseases infestation during the experimentation and therefore, no crop protection measures were taken for controlling insects and diseases.

The crop was harvested at full maturity. The maturity date was determined when 90% of the grains become golden yellow in color. Five hills (excluding border hill) were randomly selected from each plot for recording necessary data on various plant characters. Then the harvested crop of each plot was separately bundled, properly tagged and then brought to threshing floor. The grains were then threshed using a pedal thresher. The grains were cleaned and weighed to record the grain yield per plot. Grain moisture content was recorded and adjusted to 14% for recording grain yield. Straws were cleaned, sun dried and weight to record the straw yield. Finally grain and straw yields plot-1 were converted to t ha^{-1}.

2.5 Statistical analysis

The recorded data on various plant characters were statistically analyzed. The mean of all treatments was calculated and the analysis of variance for each of the characters under study was done with the help of Statistix 10. The difference among treatment means were compared by Duncan's New Multiple Range Test (Gomez and Gomez, 1984).

3 Results and Discussion

3.1 Infested weed species

Eight species belonging to four families infested the PTR field. Among the weed species three were grasses, two broad leaves, and three sedges. Local name, scientific name, family, morphological type and life cycle of the weed in the experimental plots are presented in the Table 2. The common weeds of the experimental plots were *Paspalum scorbiculatum*, *Echinochloa crus-galli*, *Leersia hexandra*, *Monochoria vaginalis*, *Scirpus juncoides*, *Lemna perpusilla*, *Eleocharis atropurpurea* and *Eichhornia crassipes*. On the other hand, seven species infested the zero till non-puddled transplanted field belonging to three families. Among the weed species four were grasses, and three sedges. Local name, scientific name, family, morphological type and life cycle of the weed in the experimental plots are presented in Table 3. Weed species diversity in different rice cultivation system were also reported by Chhokar et al. (2014), Rahman et al. (2017) and Rahman et al. (2020).

Table 2. Infesting weed species found in the puddled transplanted rice (PTR)

#	Local name	Scientific name	Family	Morphology type	Life cycle
1	Shama	*Echinochloa crusgalli*	Poaceae	Grass	Annual
2	Angta	*Paspalum scorbiculatum*	Poaceae	Grass	Perennial
3	Arail	*Leersia hexandra*	Poaceae	Grass	Annual
4	Kachuripana	*Eichhornia crassipes*	Pontederiaceae	Broadleaf	Annual
5	Pani chaise	*Eleocharis atropurpurea*	Cyperaceae	Sedge	Annual
6	Chesra	*Scirpus juncoides*	Cyperaceae	Sedge	Annual
7	Khudi pana	*Lemna perpusilla*	Araceae	Sedge	Perennial
8	Pani kachu	*Monochoria vaginalis*	Pontederiaceae	Broadleaf	Annual

Table 3. Infesting weed species found in zero till non-puddled transplanted rice (ZT-NPTR)

#	Local name	Scientific name	Family	Morphology type	Life cycle
1	Shama	*Echinochloa crusgalli*	Poaceae	Grass	Annual
2	Angta	*Paspalum scorbiculatum*	Poaceae	Grass	Perennial
3	Khudi pana	*Lemna perpusilla*	Araceae	Sedge	Perennial
4	Sabuj nakful	*Cyperus difformis*	Cyperaceae	Sedge	Annual
5	Angulighas	*Digitaria sanguinalis*	Cyperaceae	Grass	Annual
6	Chapra	*Scirpus juncoides*	Cyperaceae	Sedge	Annual
7	Durba	*Cynodon dactylon*	Poaceae	Grass	Perennial

3.2 Weed density

Rice cultivation system, weed management practices and their interaction significantly influenced weed density. Due to continuous weeding in weed free plots, weed density of that plot was always zero. In PTR, maximum weed density 50.4 m^{-2} and 69.93 m^{-2} were found at 30 and 60 DAT. Minimum weed density 38.46 m^{-2} and 65.33 m^{-2} were found at 30 and 60 DAT in ZT-NPTR (Table 4). At 60 DAT, maximum weed density (101.33 m^{-2}) was found when pre-emergence herbicide Pretilachlor (Commit 500 EC) was applied, and the lowest one (63.16 m^{-2}) was observed when post-emergence herbicide Penoxsulam (Granite 240 SC) was applied @ 93.7 L ha^{-1} at 14 DAT was applied (Table 5). Chauhan et al. (2015) reported the highest total weed density (225–256 m^{-2}) in direct seeded rice (DSR) while the lowest (102–129 m^{-2}) in PTR rice. In interaction, maximum weed density (143.0 m^{-2}) was found in weedy practice under PTR at 60 DAT, while at the same stage minimum weed density was also found in the PTR field but where post-emergence herbicide Penoxsulam (Granite 240 SC) was applied (Table 6).

3.3 Weed dry biomass

Cultivation systems, weed management practices and their interaction significantly influenced weed dry biomass. Weed dry biomass in the weed free plots was always zero. Maximum dry biomass 47.72 g and 83.60 g were found in ZT- NPTR at 30 and 60 DAT, respectively. The lowest dry biomass 16.22g and 28.27 g and was found in PTR at 30 and 60 DAT, respectively (Table 4). Chauhan et al. (2015) reported that the highest total weed biomass (315–501 g m^{-2}) was recorded in DSR while the lowest (75–387 g m^{-2}) in PTR. Maximum weed dry biomass 51.35 g m^{-2} and 116.89 g m^{-2} were found in weedy condition, while the lowest 26.52 g m^{-2} and 44.18 g m^{-2} were found in farmers' practice at 30 DAT and 60 DAT, respectively. However, pre- and post-emergence herbicide Pretilachlor (Commit 500 EC) and Penoxsulam (Granite 240 SC) applied plots were statistically similar with farmers' practice at 60 DAT (Table 5). In case of interaction, the highest amount of dry biomass (184.11 g m^{-2}) was found in weedy condition at ZT-NPTR at 60 DAT. At the same DAT, the lowest amount of dry biomass 22.26 g m^{-2} was found in farmers' practice in PTR. Pre-emergence herbicide Pretilachlor and post-emergence herbicide Penoxsulam applied plots were also showed statistically similar results with farmers' practice under PTR (Table 6).

3.4 Yield attributes

Number of effective tillers $hill^{-1}$ was significantly influenced by cultivation method, weed management practices and their interaction. The highest number of effective tillers $hill^{-1}$ (13.14) was found in ZT-NPTR and the lowest one (12.01) was in PTR (Table 7). The highest number of effective tillers $hill^{-1}$ (14.9) was found in weed free practices and that of lowest one (10.33) was observed in pre-emergence herbicide Pretilachlor (Commit 500 EC) applied plots (Table 8). In case of interaction, the highest num-

Table 4. Effect of cultivation systems on weed density and weed dry biomass

Cultivation system	Weed density (no. m^{-2})		Weed dry biomass (g m^{-2})	
	30 DAT	60 DAT	30 DAT	60 DAT
PTR	50.40a	69.93a	16.22b	28.27b
ZT-NPTR	38.46b	65.33b	47.72a	83.60a
Level of sig.	**	*	*	***
CV (%)	7.92	4.63	8.67	4.58
SE (±)	2.98	1.01	1.5	1.69

In column, means followed by different letters are significantly different, *means at 5% level of probability, **means at 1% level of probability and ***means at 0.1% level of probability. PTR = Puddled Transplanted Rice; ZT-NPTR = Zero Till Non-Puddled Transplanted Rice; DAT = Days After transplanting

Table 5. Effect of weed management practices on weed density and weed dry biomass

Weed management practices	Weed density (no. m^{-2})		Weed dry biomass (g m^{-2})	
	30 DAT	60 DAT	30 DAT	60 DAT
Weedy	24.6bc	98.66a	51.35a	116.89a
Weed free	0.00c	0.00b	0.00b	0.00c
Farmers' practice	55.50ab	75.00a	26.52ab	44.18b
Pretilachlor	59.50ab	101.33a	33.74ab	61.44b
Penoxsulam	82.50a	63.16a	48.24a	57.17b
Level of sig.	*	*	*	***
CV (%)	7.92	4.63	8.67	4.58
SE (±)	2.5	1.24	1.21	1.75

In column, means followed by different letters are significantly different, *means at 5% level of probability and ***means at 0.1% level of probability. DAT = Day After Transplanting

Table 6. Interaction effect of cultivation systems and weed management practices on weed density and weed dry biomass (g m^{-2})

CM × WMP		Weed density (no. m^{-2})		Weed dry biomass (g m^{-2})	
		30 DAT	60 DAT	30 DAT	60 DAT
PTR	Weedy	45.66ab	143.00a	27.52a-d	49.68bcd
	Weed free	0.00b	0.00d	0.000d	0.000e
	Farmers' practice	65.00a	74.33bc	13.57bcd	22.26de
	Pretilachlor	53.33ab	97.66ab	11.20cd	36.45cde
	Penoxsulam	88.00a	34.66cd	28.82a-d	32.98cde
ZT-NPTR	Weedy	3.66b	54.33bcd	75.18a	184.11a
	Weed free	0.00b	0.00d	0.000d	0.00e
	Farmers' practice	46.00ab	75.66bc	39.46a-d	66.10bc
	Pretilachlor	65.66a	105.00ab	56.29abc	86.42b
	Penoxsulam	77.00a	91.66ab	67.65ab	81.36b
Level of sig.		*	**	*	**
CV (%)		7.92	4.63	8.67	4.58
SE (±)		1.99	2.85	2.75	1.45

In column, means followed by different letters are significantly different, *means at 5% level of probability and **means at 1% level of probability. CM = cultivation method, WMP = weed management practices, PTR = Puddled Transplanted Rice; ZT-NPTR = Zero Till Non-Puddled Transplanted Rice; DAT = Days After Transplanting ber of effective tillers hill^{-1} (15.60) was found in weed free practices under ZT-NPTR condition, which was statistically similar with farmers' practice (14.86) and post-emergence herbicide Penoxsulam (14.73) applied plots. The lowest number of effective tillers hill^{-1} (9.60) was found in ZT-NPTR plots where pre-emergence herbicide Pretilachlor (Commit 500 EC) was applied, which was statistically similar with weedy practice of PTR (Table 9).

Number of non-effective tillers hill^{-1} was not significantly influenced by cultivation systems. The highest number of non-effective tillers hill^{-1} (1.40) was observed in weedy plot and the lowest one (1.0) was observed in pre-emergence herbicide Pretilachlor (Commit 500 EC) applied plots (Table 8). Number of non-effective tillers hill^{-1} significantly influenced due to the interaction effect between cultivation systems and weed management practices. The maximum number of non-effective tillers hill^{-1} (1.46) was observed in weedy practice of both PTR and ZT-NPTR systems while the minimum number of non-effective tillers hill^{-1} (1.0) was obtained from pre-emergence herbicide Pretilachlor (Commit 500 EC) applied plots of both PTR and ZT-NPTR systems (Table 9).

Number of grains panicle^{-1} varied significantly by cultivation systems, weed management practices and their interaction. The maximum number of grains panicle^{-1} (107.2) was found in PTR and the minimum (101.8) was from ZT-NPTR (Table 7). On the other hand, the maximum number of grains panicle^{-1} (114.50) was found when post-emergence herbicide Penoxsulam (Granite 240 SC) was applied @ 93.73 mL ha^{-1} at 14 DAT, and the minimum number (78.50) was found in weedy condition (Table 8). Sarkar et al. (2017) also observed highest number of grains panicle^{-1} (86.14) in the plots where pre-emergence herbicide (Panida 33 EC) was applied. Maximum number of grains panicle^{-1} (125.0) was found in PTR under weed free condition which was statistically similar to the plots where post-emergence herbicide Penoxsulam (Granite 240 SC) was applied. The lowest number of grains panicle^{-1} (67.0) was found in PTR under weedy condition which was statistically similar to the same condition of ZT-NPTR (Table 9).

Number of sterile spikelets panicle^{-1} varied significantly between the cultivation systems, weed management practices and their interaction. The maximum number of sterile spikelet panicle^{-1} (11.5) was found in PTR and the minimum (11.1) was found from ZT-NPTR (Table 7). The variation in sterile spikelet between two cultivation systems might be due to their weed management practices (Table 7). The maximum number of sterile spikelets panicle^{-1} (15.16) was found in weedy condition and that of minimum (9.83) was found in post–emergence herbicide Penoxsulam (Granite 240 SC) application (Table 8). In interaction, maximum number of sterile spikelets panicle^{-1} (15.33) was found in weedy plots of PTR while the minimum number of sterile spikelet panicle^{-1} (9.66) was found in both pre-emergence herbicide Pretilachlor (Commit 500 EC) and post-emergence herbicide Penoxsulam (Granite 240 SC) applied plots of ZT-NPTR (Table 9).

Thousand grains weight varied significantly due to cultivation systems, weed management practices and their interaction. The highest 1000–grain weight (22.39 g) was found in ZT-NPTR and the lowest one (22.30 g) in PTR (Table 7). Hugar et al. (2009) also found highest 1000-grain weight (27.5 g) in ZT-NPTR system of rice cultivation. On the other hand, the highest 1000–grain weight (22.55 g) was found in weed free condition and the lowest one (22.21 g) in pre-emergence herbicide Pretilachlor (Commit 500 EC) applied plots (Table 8). In interaction, highest 1000–grain weight (22.60 g) was found in ZT-NPTR under weed free condition which was statistically similar with the same condition of PTR (22.50 g). In addition, application of pre- and post-emergence herbicides, farmers practice at both PTR and ZT-NPTR systems of cultivation gave the statistically similar results. The lowest 1000–grain weight was found in weedy condition of both PTR and ZT-NPTR systems (Table 9).

Grain yield was not significantly influenced by cultivation systems. However, the weed management practices, and its interaction with cultivation systems were significant. The highest grain yield (4.61 t ha^{-1}) was found in post-emergence herbicide Penoxsulam (Granite 240 SC) applied plots and the lowest one (2.56 t ha^{-1}) in weedy plots (Fig. 1). In interaction, the highest grain yield (4.78 t ha^{-1}) was found in both weed free condition in PTR and farmers' practice in ZT-NPTR. The lowest grain yield (2.48 t ha^{-1}) was found in weedy condition in PTR (Table 9). Similar type of results was also reported by Chauhan et al. (2015) and Aslam et al. (2008).

Straw yield was significantly influenced by the cultivation systems, weed management practices and their interaction. Between two cultivation systems, the highest straw yield (4.79 t ha^{-1}) was found in ZT-NPTR and the lowest one (4.55 t ha^{-1}) in PTR (Table 7). The highest straw yield (5.28 t ha^{-1}) was found in post-emergence herbicide Penoxsulam (Granite 240 SC) applied plots and the lowest one (3.01 t ha^{-1}) in weedy condition. In interaction, the highest straw yield (5.42 t ha^{-1}) was found in ZT-NPTR when post-emergence herbicide Penoxsulam (Granite 240 SC) was applied which was statistically similar to farmers' practice (5.41 t ha^{-1}) of the same condition and weed free condition of PTR. While the lowest straw yield (2.84 t ha^{-1}) was found in weedy condition of PTR which was statistically at par with weedy condition of ZT-NPTR (Table 9).

Table 7. Effect of different cultivation method on yield attributes and yield of Boro rice

Cultivation method	ET	NET	GP	SP	WTS	GY	SY
PTR	12.01ab	1.21	107.20a	11.53a	22.30ab	4.17	4.55b
ZT-NPTR	13.14a	1.2	101.80b	11.06ab	22.39a	4.17	4.79a
Level of sig.	***	NS	*	*	**	NS	*
CV (%)	6.07	8.49	6.66	7.22	5.06	7.91	6.28
SE (±)	1.87	0.12	0.83	0.27	0.08	0.12	0.1

In column, means followed by different letters are significantly different. In column, means followed by same letters are not significantly different *means at 5% level of probability, **means at 1% level of probability, ***means at 0.1% level of probability. PTR = Puddled Transplanted Rice; ZT-NPTR = Zero Till Non-Puddled Transplanted Rice; NS = Not Significant; ET = number of effective tillers hill^{-1}, NET = number of non-effective tillers hill^{-1}, GP = number of grains panicle^{-1}, SP = number of spikelets panicle^{-1}, WTS = weight of 1000-grains (g), GY = grain yield (t ha^{-1}), and SY = straw yield (t ha^{-1})

Table 8. Effect of weed management practices on yield attributes and yield of Boro rice

WMP	ET	NET	GP	SP	WTS
Weedy	11.90bc	1.40a	78.50c	15.16a	22.33ab
Weed free	14.90a	1.20ab	114.00a	10.33bc	22.55a
Farmers' practice	12.33abc	1.30a	101.50b	10.83b	22.30ab
Pretilachlor	10.33c	1.00b	114.00a	10.33bc	22.21b
Penoxsulam	13.43ab	1.03b	114.50a	9.83c	22.35ab
Level of sig.	***	*	*	*	**
CV (%)	6.07	8.49	6.66	7.22	5.06
SE (±)	1.22	0.19	1.31	0.43	0.13

In column, means followed by different letters are significantly different, *means at 5% level of probability, **means at 1% level of probability and ***means at 0.1% level of probability; WMP = weed management practices, PTR = Puddled Transplanted Rice; ZT-NPTR= Zero-Till Non-Puddled Transplanted Rice; ET = number of effective tillers hill^{-1}, NET = number of non-effective tillers hill^{-1}, GP = number of grains panicle^{-1}, SP = number of spikelets panicle^{-1}, WTS = weight of 1000-grains (g); Sig. = Significance; CV = Co-efficient Variance; SE = Standard Error

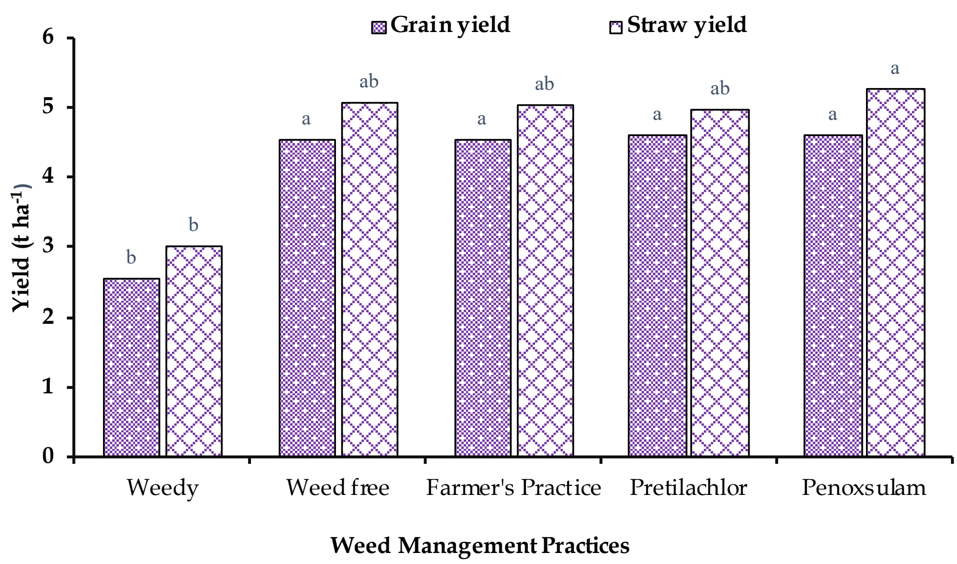

Figure 1. Effect of weed management practices on grain and straw yield of boro rice

Table 9. Interaction effect of different cultivation method and weed management practices on yield attributes and yield of Boro rice

CM × WMP		ET	NET	GP	SP	WTS	GY	SY
PTR	Weedy	9.80c	1.46a	67.00f	15.33a	22.03b	2.48d	2.84c
	Weed Free	15.60a	1.26abc	125.00a	10.33bc	22.50a	4.78a	5.16a
	Farmers' practice	12.86abc	1.33ab	102.00d	11.00b	22.33ab	4.28cd	4.66b
	Pretilachlor	11.06bc	1.00c	120.00b	11.00b	22.26ab	4.56ab	4.95ab
	Penoxsulam	12.13abc	1.00c	122.00ab	10.00bc	22.40ab	4.76a	5.14ab
ZT-NPTR	Weedy	10.93bc	1.46a	90.00e	15.00a	22.05b	2.65d	3.18c
	Weed Free	14.20ab	1.00bc	103.00d	10.33bc	22.60a	4.31cd	5.01ab
	Farmers' practice	14.86ab	1.33ab	101.00d	10.66bc	22.40ab	4.78a	5.41a
	Pretilachlor	9.60c	1.13ab	108.00c	9.66c	22.40ab	4.46bc	4.96ab
	Penoxsulam	14.73ab	1.06bc	107.00c	9.66c	22.30ab	4.63ab	5.42a
Level of sig.		**	***	*	*	**	*	*
CV (%)		6.07	8.49	6.66	7.22	5.06	7.91	6.28
SE (±)		1.95	0.28	1.86	0.61	0.19	1.26	0.22

In column, means followed by different letters are significantly different. In column, means followed by same letters are not significantly different *means at 5% level of probability, **means at 1% level of probability, ***means at 0.1% level of probability. CM = cultivation method, WMP = weed management practices, PTR = Puddled Transplanted Rice; ZT-NPTR = Zero Till Non-Puddled Transplanted Rice; NS = Not Significant; ET = number of effective tillers hill^{-1}, NET = number of non-effective tillers hill^{-1}, GP = number of grains panicle^{-1}, SP = number of spikelets panicle^{-1}, WTS = weight of 1000-grains (g), GY = grain yield (t ha^{-1}), and SY = straw yield (t ha^{-1})

Table 10. Cost effectiveness of PTR and ZT-NPTR methods under different weed management practice†

CM	WCP	Variable cost	Herbicides cost	Labor cost	Total cost	Gross income	Net income	BCR
PTR	Weedy	103625	0	0	103075	107190	4115	1.03
	Weed free	103625	0	20900	124525	185100	60575	1.49
	Farmers' practice	103625	0	5500	109125	167880	58755	1.54
	Pretilachlor	103625	1000	550	105175	174790	69615	1.66
	Penoxsulam	103625	2642	550	106817	179970	73153	1.68
ZT-NPTR	Weedy	102625	0	0	102625	113640	11015	1.1
	Weed free	102625	0	20900	123525	180370	56845	1.46
	Farmers' practice	102625	0	5500	108125	166200	58075	1.54
	Pretilachlor	102625	1000	550	104175	173450	69275	1.66
	Penoxsulam	102625	2642	550	105817	185650	79833	1.75

†All values are cost in Tk. ha^{-1}, where 1 USD = 85 Tk; PTR = Puddled Transplanted Rice; ZT-NPTR = Zero Till Non-Puddled Transplanted Rice; BCR = benefit-cost ratio

3.5 Economics

Analysis of economic factors like cost of cultivation, gross return, net return and benefit cost ratio (BCR) are important to evaluate the effect of treatment from practical point of view to the farming community as well as the to the planner. Grain yield was major factors which caused differences in net income and net return per taka invested. The highest total cost of production was found in weed free practices (124525 Tk. ha^{-1}) of PTR followed by the same condition (123525 Tk. ha^{-1}) of ZT-NPTR (Table 9). While, the minimum cost (102625 Tk. ha^{-1}) was found in weedy condition of ZT-NPTR followed by the same condition (103075 Tk. ha^{-1}) of PTR. Maximum gross return (185650 Tk. ha^{-1}) was recorded in post-emergence herbicide Penoxsulam (Granite 240 SC) under ZT-NPTR followed by weed free condition (185100 Tk. ha^{-1}) under PTR. But maximum net return (79833 Tk. ha^{-1}) and benefit cost ratio (BCR, 1.75) was obtained from post-emergence herbicide Penoxsulam (Granite 240 SC) under ZT-NPTR system followed by the same herbicidal treatment in PTR (Table 10).

4 Conclusion

In this study the comparative performance of zero till non-puddled transplanted rice cultivation system (ZT-NPTR) was compared with the conventional puddled transplanted system (PTR) in terms of weed control, grain yield and cost effectiveness. It was observed that weedy practices under ZT-NPTR system gave the highest weed dry biomass, while the highest weed density was observed in the weedy plots of PTR. The highest grain yield was obtained from the farmers' practice of ZT-NPTR and weed free practice of PTR. In addition, the value was statistically similar with the pre- (Pretilachlor) and post-emergence (Penoxsulam) herbicide application plots of PTR, and post- (Penoxsulam) emergence herbicide application plots ZT-NPTR. However, considering the cost effectiveness, maximum gross return, net return and BCR were obtained from the post-emergence herbicide Penoxsulam applied plots of ZT-NPTR. Although a number of weed management practices showed better performance considering the grain yield, in terms of both grain yield and economic view point post-emergence herbicide Penoxsulam application in ZT-NPTR system is the best, and might be an alternative for better weed control and saving labor and energy. However, this experiment was conducted in a single season and in a single location, and soil related data was not considered for analysis, so it is not possible to draw a final conclusion. Multi-location and multi-season trial considering both crop and soil should be conducted to draw a concrete conclusion based on this preliminary study.

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Conflict of Interest

The authors declare that there is no conflict of interests regarding the publication of this paper.

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