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AGRONOMY | ORIGINAL ARTICLE

Efficacy and Rice Phytotoxicity of Different Tank-Mix Ratios of Pre-Emergence Herbicide in Boro Rice Under Zero Till Non-Puddled Condition

Amodini Hossain[1], A K M Mominul Islam[1]✉, Md Wakilur Rahman[2], Md Parvez Anwar[1]

[1] Department of Agronomy, Bangladesh Agricultural University, Mymensingh 2202, Bangladesh

[2] Department of Rural Sociology, Bangladesh Agricultural University, Mymensingh 2202, Bangladesh

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Correspondence
A K M Mominul Islam
✉: akmmominulislam@bau.edu.bd

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ABSTRACT

It may be highly advantageous to tank-mix two or more chemical groups of either pre- or post-emergence herbicide for the efficient control of weeds in a heterogeneous population. There are a few proprietary herbicides (commercial mixtures) on the market, but they are extremely few. In this backdrop, the current research was conducted to investigate the efficacy and rice phytotoxicity of different tank-mix ratios of pre-emergence herbicides to control weeds under zero till non-puddled *Boro* rice (cv. BRRI dhan58). A total of 21 treatments were used in the experiment. Treatments comprised five pre-emergence herbicides with their 20 different tank-mix ratios and one proprietary pre-emergence herbicide as control. The experiments were conducted under randomized complete block design with three replications. The research findings suggest that various tank-mix ratios of pre-emergence herbicides effectively control weeds and the applied herbicide mixtures have not create any phytotoxicity to the rice plants. The lowest weed dry biomass was obtained from the treatment where Triafamone and Pretilachlor @ 2:3 ratios were applied in both 30 and 60 DATs, and highest weed dry biomass was from treatment Triafamone and Pretilachlor @ 3:2 ratios. Considering the yield contributing characters and yield, the highest number of effective tillers hill^{-1}, longest panicle, heaviest grain and highest grain yield of BRRI dhan58 were also obtained from the treatment where Triafamone and Pretilachlor @ 2:3 ratios were applied. Based on the results it may conclude that tank-mix pre-emergence herbicide Triafamone and Pretilachlor @ 2:3 ratios is the best in terms of weed control and rice productivity. However, these preliminary findings, based on a single-season, single-location experiment, warrant validation through multi-location and multi-season trials.

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1. Introduction

Unwanted plant species, also known as weeds, pose a serious danger to agricultural productivity and are a constant source of conflict for growers (Anwar et al. 2021). Hence, weeds are undoubtedly a significant biotic constraint to rice cultivation around the world, leading to approximately 34% of the total crop yield losses, surpassing the impact of insects (18%) and diseases (16%) (Oerke 2006, Gharde et al. 2018). Weeds can be controlled mechanically (by rice weeder or hoeing), chemically (herbicides) or by culturally (mulching, crop rotation, stale seedbed etc.). However, due to a shortage of agricultural laborers, high wages during the pick season, and the increasing time needed for manual weeding, farmers in most South Asian countries are transitioning to chemical weed control (Shrestha et al. 2021, Farhat et al., 2023). The amount of herbicides used during the year 2019 in India, Bangladesh, Sri Lanka, Pakistan, and Nepal was around 9749, 7416, 716, 245, and 164 tonnes, respectively (FAO 2020, BBS 2021). Herbicide use in last three decades of Bangladesh increased almost 84-folds, while agricultural labors decreased by around 2-folds (Mou et al. 2022, BBS 2023). Herbicidal weed control, while potentially harmful to the environment, often offers a more cost-effective and labor-saving solution compared to manual or mechanical methods. However, it's crucial to acknowledge the environmental risks associated with herbicide use and strive for sustainable alternatives when feasible (Shekhawat et al. 2022).

Typically, farmers in Bangladesh usually apply herbicides either once or in multiple applications, which can include using a pre-emergence herbicide alone, or post-emergence alone, or pre-followed by a post-application, or

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any combination of these methods, often combined with manual or mechanical weeding (Islam et al. 2024). While some proprietary herbicides (commercial mixture of pre- or post-emergence herbicide) exist, they are relatively scarce. Tank-mixing two or more chemical groups of either pre- or post-emergence herbicide may be a superior way to control weeds in a diverse population. However, three types of interactions can occur in tank mixtures of herbicides: (i) *antagonistic*: where the results of products applied in a mix are worse than those of each product applied separately; (ii) *synergistic:* when the product mixture presents better results than the application of each one separately; and (iii) *additive*: when the product mixture efficiency is comparable to that of each product individually (Ikeda 2013, Gandini et al. 2020). A non-suitable tank-mix herbicide may create phytotoxicity to the non-target crops (Islam et al., 2024), hence, this issue should be addressed accurately before recommendation. However, very few research related to the application of tank-mix herbicide in rice fields are available in literature (Menon et al. 2016, Atheena et al. 2017, Yadav et al. 2019, Islam et al. 2024).

The most popular method of producing rice in Bangladesh is puddled transplanting, which uses a significant quantity of water, time, and energy (Islam et al. 2023). Furthermore, frequent puddling creates shallow plow pans by dissolving the soil aggregates and capillary pores (Sharma et al. 2003). The non-puddled transplanted rice method, a promising technology, enhances both profitability and energy efficiency without sacrificing yield. It also minimizes soil disturbance, reduces tillage costs, and conserves water by eliminating the need for puddling (Chaki et al. 2021). However, zero-till non-puddled transplanted rice is considered more advantageous than non-puddled transplanted rice because it further reduces the labor and energy needed for land preparation by eliminating the need for any tillage (Islam et al. 2023). This strategy still has a lot to learn, especially in relation to studies that provide a methodological comparison of rice yield, weed infestation, and weed control efficacy. Altering crop management practices, such as land preparation and seedling establishment methods, will inevitably affect the weed species composition, their level of aggressiveness and susceptibility to control measures, ultimately impacting rice yield. Therefore, more research is required to create a weed control plan that maintains chemical control as the primary focus and guarantees the long-term viability of the zero till non-puddled transplanted rice production system. Although, non-puddled transplanted rice can achieve yields comparable to or exceeding those of puddled transplanted rice, inadequate weed control can lead to a significant drop in grain yield (Haque et al. 2016). Additionally, tillage has a significant impact on weed composition, and minimum tillage alters species diversity; nevertheless, it is yet unknown how the zero till non-puddled transplanted system defines weed composition and management in wetland rice fields.

The proposed study aimed to address all of these issues by assessing the effectiveness of different tank-mix ratios of pre-emergence herbicide for better weed control of *boro* rice under zero till non-puddled transplanted condition.

Therefore, the current study was conducted to evaluate the potentiality of applying tank-mix pre-emergence herbicide combinations in different ratios to control weeds in *boro* rice under no till non-puddled condition.

2. Materials and Methods

2.1. Description of the experimental site

The experiment was conducted at the Agronomy Field Laboratory of Bangladesh Agricultural University, Mymensingh (24.719812 N latitude, 90.426944 E longitudes) during the period from January to April 2024. This site belongs to the non-calcareous dark grey floodplain soil under Old Brahmaputra Floodplain AEZ-9 (UNDP and FAO, 1988). The soil of the experimental field was silty loam soil with pH 6.8, low in organic matter content (0.93%) and its general fertility level (0.13% total N, 16.3 ppm available P, 0.28 ppm exchangeable K and 13.9 ppm available S). There was a moderate cold air temperature during the month of January to early February and high air temperature during the rest of the months. The average maximum air temperature during the experimental period was 19.86°C to 36.7°C and minimum was 11.44°C to 25.9°C. The monthly average rainfall ranged from 0 to 72 mm and the total sunshine ranged between 187.8 to 260.7 hours' month^{-1} from January to April.

2.2. Experimental treatments and design

The experiment comprised 21 tank-mix ratios of pre-emergence herbicides *viz*., Triafamone and Pendimethalin @ 1:4 ratios (T_1), Triafamone and Pretilachlor @ 1:4 ratios (T_2), Triafamone and Triasulfuron @ 1:4 ratios (T_3), Triafamone and Oxadiazon @ 1:4 ratios (T_4), Triafamone and Pendimethalin @ 1:1 ratios (T_5), Triafamone and Pretilachlor @ 1:1 ratios (T_6), Triafamone and Triasulfuron @ 1:1 ratios (T_7), Triafamone and Oxadiazon @ 1:1 ratios (T_8), Triafamone and Pendimethalin @ 2:3 ratios (T_9), Triafamone and Pretilachlor @ 2:3 ratios (T_{10}), Triafamone and Triasulfuron @ 2:3 ratios (T_{11}), Triafamone and Oxadiazon @ 2:3 ratios (T_{12}), Triafamone and Pendimethalin @ 3:2 ratios (T_{13}), Triafamone and Pretilachlor @ 3:2 ratios (T_{14}), Triafamone and Triasulfuron @ (3:2) ratios (T_{15}), Triafamone and Oxadiazon @ 3:2 ratios (T_{16}), Triafamone and Pendimethalin @ 4:1 ratios (T_{17}), Triafamone and Pretilachlor @ 4:1 ratios (T_{18}), Triafamone and Triasulfuron @ 4:1 ratios (T_{19}), Triafamone and Oxadiazon @ 4:1 ratios (T_{20}), and Acetachlor 14% + Bensulfuron methyl 4% (T_{21}). The experiment was laid out in Randomized Complete Block design with three replications. The size of each unit plot was 4.0 m × 2.5 m. The spaces between plots and blocks were 0.50 m and 1.0m, respectively. A brief description of the pre-emergence herbicide used in this experiment to prepare the tank-mix are given below in Table 1.

Table 1. Trade name, common name, doses, selectivity and marketing company of pre-emergence herbicides

#	Trade name	Common name	Doses (ha^{-1})	Selectivity*	Marketing company
1	Superhit 500EC	Pretilachlor	1 L	G, B, S	ACI Formulations Ltd.
2	Sentry 25 EC	Oxadiazon	1.2 L	G, B	Haychem (Bangladesh) Ltd.
3	Panida 33 EC	Pendimethalin	2.5 L	G, B, S	Auto Crop Care Ltd.
4	Council Prime 20SC	Triafamone	150 mL	B, S	Bayer Crop Science Ltd.
5	Logran 75WG	Triasulfuron 75WG	10 g	B, S	Syngenta Bangladesh Ltd.
6	Supermix 18WP	Acetachlor 14% + Bensulfuron methyl 4%	750 g	B, S	ACI Formulations Ltd.

*G = Grass, B = Broad leaf, S = Sedge

2.3. Description of the rice variety

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

2.4. Crop Husbandry

Two weeks before the transplanting, pre-planting non-selective herbicide, Roundup® (glyphosate 41% SL-IPA salt), was applied @ 75 mL 10 L^{-1} water (2.25 L ha^{-1}) in the Zero till non-puddled field. Before transplanting, the land was inundated to 3-5 cm depth of standing water for 48 hours. However, no tillage and puddling were performed in the field to keep the land as zero till non-puddled condition. Forty-five days old rice seedlings were transplanted in the experimental plots maintaining 2-3 seedlings $hill^{-1}$ and 25 cm × 15 cm plant spacing. According to the BRRI recommendations, fertilizers were applied to the field @ 220 kg of urea, 120 kg of triple super phosphate, 75 kg of muriate of potash, 60 kg of gypsum, and 10 kg of zinc sulphate ha^{-1} (BRRI, 2022). All fertilizers were administered as basal except urea. Urea was top dressed at 15, 30, and 45 days after transplantation (DAT). According to the treatment specification, the pre-emergence herbicide was administered at 6 DAT. Since there was no noteworthy insect or disease infestation during the experimentation, no crop protection measures were implemented to keep insects and diseases under control. Irrigation was provided when necessary.

2.5. Data Collection

2.5.1. Weed Related Data

A 25 cm × 25 cm quadrate randomly placed in two locations of each experimental plots. The weed inside each quadrate were uprooted, cleaned and dried in an electrical oven for 72 hours maintaining a constant temperature of 80°C. The dry weight of each sample was taken by an electrical balance and expressed in g m^{-2}. The phytotoxicity effects of herbicides on rice were evaluated based on visual observation at 3, 6 and 9 days after application (DAA).

2.5.2. Yield related data

The crop was harvested at full maturity when 90% of the grains become golden yellow in color. Five hills (excluding border hill) were randomly selected from each plot for recording data related to yield contributing characters. Then the central 2 m^2 area of each plot was harvested, 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}.

2.6. Statistical analysis

The recorded data were compiled and tabulated for statistical analysis. The data were analyzed statistically by using Statistix10. The significant differences among the treatment means were compared by Least Significant Difference (LSD) at 5% levels of probability (Gomez and Gomez, 1984).

3. Results and Discussion

3.1. Weed dry weight

The weed dry weight (g m^{-2}) varied significantly at different sampling dates by different tank-mix ratios of pre-emergence herbicides (Table 2). The results revealed that at 30 DAT, the highest weed dry weight (3.0 g m^{-2}) was observed where pre-emergence herbicide Triafamone and Pretilachlor @ 3:2 ratios were applied. While, the lowest one (0.39 g m^{-2}) one was observed in Triafamone and Pretilachlor @ 2:3 ratios applied plot and the value was statistically similar to Triafamone and Oxadiazon @1:1 ratios, Triafamone and Pendimethalin @ 1:4 ratios, Acetachlor 14% + Bensulfuron methyl 4%, Triafamone and Pretilachlor @ 1:4 ratios, Triafamone and Oxadiazon @ 3:2 ratios (Table 2). At 60 DAT, the highest weed dry weight (10.11 g m^{-2}) was found where pre-emergence herbicide Triafamone and Pretilachlor @ 3:2 ratios were applied which was at par with Triafamone and Pretilachlor @ 1:4 ratios. At the same date of measurement, the lowest weed dry weight (3.04 g m-2) was found in Triafamone and Pretilachlor @ 2:3 ratios applied plot (Table 2). Similar type of results also obtained by Yadav et al. (2019). They observed Penoxsulam + butachlor 41% SE [Penoxsulam 0.97% w/w (1.0%w/v) + butachlor 38.8% w/w (40% w/v)] @ 820 g ha^{-1} being as good as weed free check provided almost complete control (98.1–98.5% weed control efficiency) of complex weed flora during both the years, and it was better than Penoxsulam 22.5 g ha^{-1} (87–88%), butachlor 1500 g ha^{-1} (90%) and Pretilachlor 1000 g ha^{-1} (91%). Atheena et al. (2017) reported that tank mix application of Cyhalofop-butyl (80 g ha^{-1}) and Pyrazosulfuron-ethyl (30 g ha^{-1}) at 18 days after seeding effectively controlled mixed weed flora in wet-seeded rice. Islam et al. (2024) also reported that pre-emergence herbicide as Triafamone as sole or tank-mix Triafamone + Triasulfuron or Triafamone + Pendimethalin better weed control than other herbicide used in their research.

3.2. Rice Phytotoxicity Rating

The phytotoxic effects of herbicides on rice were assessed by visually observing the plants at 3, 6, and 9 days after application (DAA) (Table 2). Different tank-mix ratios of pre-emergence herbicide showed very slight / no injuries at of all the observation dates (Table 2). The crop was constantly being monitored and it was found that phytotoxicity did not persist. A similar result was observed by Das *et al*. (2017) who reported that the application of herbicides causes very slight phytotoxic symptoms on rice plants. Yadav et al. (2019) also observed no crop phyto-toxicity of penoxsulam + butachlor 41% SE [Penoxsulam 0.97% w/w (1.0%w/v) + butachlor 38.8% w/w (40% w/v)] when applied at the rate of 820 g ha^{-1} (X) and 1640 g ha^{-1} (2X).

3.3. Yield Contributing Characters and Yield

The tank-mix ratios of pre-emergence herbicides significantly influenced all the yield contributing characters and yield of BRRI dhan58 except grains panicle^{-1} (Table 3).

3.3.1. Tillering ability

At harvest the highest number of tiller hill^{-1} (16.0) was observed where pre-emergence herbicide Triafamone and Pendimethalin @ 1:4 ratios were applied, and the lowest one (13.0) was obtained from Triafamone and Pendimethalin @ 1:1 ratios, and Triafamone and Pretilachlor @ 3:2 ratios. On the other hand, the highest number of effective tillers hill^{-1} (14.33) was found in the plots where Triafamone and Pretilachlor @ 2:3 ratios were applied followed by Triafamone and Pretilachlor @ 1:4 ratios, Triafamone and Triasulfuron @ 2:3 ratios, Triafamone and Oxadiazon @ 2:3 ratios, and Triafamone and Pretilachlor @ 4:1 ratios. The lowest number of effective tillers hill^{-1} (11.33) was found in Triafamone and Pretilachlor @ 1:1 and Triafamone and Pendimethalin @ 4:1 ratios. Yadav et al. (2019) also obtained highest number of effective tillers from the tank-mix application of Penoxsulam + butachlor 41% SE [Penoxsulam 0.97% w/w (1.0%w/v) + butachlor 38.8% w/w (40% w/v)] at the rate of 820 g ha^{-1}. Menon *et al.* (2016) also reported lowest weed dry matter production and weed control efficiency in combined application of Triafamone with Ethoxysulfuron, and Bispyribac-sodium combined with premix of (chlorimuron-ethyl+ metsulfuron-ethyl).

3.3.2. Panicle length

The longest panicle (23.33 cm) was obtained where Triafamone and Pretilachlor @ 2:3 ratios or Triafamone and Triasulfuron @ 2:3 ratios were applied, while the shortest panicle (20.33 cm) was obtained from the plots where Triafamone and Pretilachlor @ 1:1 ratios were applied (Table 3).

3.3.3. Sterile Spikelets Panicle^{-1}

The highest number of sterile spikelets panicle^{-1} (33.0) was observed from proprietary herbicides (Acetaclor14% + Bensulfuron methyl 4%) treated plots which was statistically identical with the plots where pre-emergence herbicide Triafamone and Pendimethalin or Triafamone and Oxadiazon tank-mixed with 4:1 ratios were applied. The lowest number of sterile spikelets panicle^{-1} (10.33) was produced by the Triafamone and Pretilachlor @ 1:4 ratios treated plots which was at par with Triafamone and Pretilachlor @ 3:2 ratios.

3.3.4. Grains panicle^{-1}

Numerically the highest grains panicle^{-1} (141.33) was observed from the Triafamone and Pretilachlor @ 4:1 ratios treated plots closely followed by Triafamone and Pendimethalin @ 2:3 ratios. Whereas, the lowest grains panicle^{-1} (116.33) were obtained from Triafamone and Pendimethalin @ 4:1 ratios treated plots (Table 3).

3.3.5. Weight of 1000 grains

The heaviest grain (24.21 g) was obtained from Triafamone and Pretilachlor @ 2:3 treated plots, while the lightest grain (22.30 g) was obtained from Triafamone and Pretilachlor @ 1:1 ratios treated plots.

3.3.6. Grain yield

The highest grain yield (7.64 t ha^{-1}) was obtained from T_{10} (Triafamone and Pretilachlor @ 2:3 ratios) treatment which was statistically identical to T_{11} (Triafamone and Triasulfuron @ 2:3 ratios) (7.62 t ha^{-1}) and T_{12} (Triafamone and Oxadiazon @ 2:3 ratios) (7.60 t ha^{-1}) (Figure 1). The lowest grain yield (4.90 t ha^{-1}) was obtained from T_6 (Triafamone and Pretilachlor @ 1:1 ratios) followed by T_{17} (Triafamone and Pendimethalin @ 4:1 ratios) (Figure 1). Islam et al. (2024) reported that in terms of weed control efficiency and yield increase compared to the control, the sole application of Triafamone pre-emergence herbicide provided the best results, followed by Triafamone combined with either Pretilachlor or Pendimethalin. However, for post-emergence weed control and yield enhancement, the tank-mix of Pyrazosulfuron-ethyl and Penoxsulam proved most effective, with the sole application of post-emergence Penoxsulam following behind. Yadav et al. (2019) observed highest grain yield in tank-mix application of Penoxsulam + butachlor 41% SE [Penoxsulam 0.97% w/w (1.0%w/v) + butachlor 38.8% w/w (40% w/v)] @ 820 g ha^{-1}. It was superior to its lower doses i.e. 615 and 718 g ha^{-1}, Penoxsulam 22.5 g ha^{-1}, and Butachlor 1500 g ha^{-1} during 2016. Menon *et al.* (2016) also reported highest highest grain yield from the combined application of triafamone with ethoxy sulfuron, and bispyribac-sodium with premix of (chlorimuron-ethyl+ metsulfuron-ethyl).

Table 2. Effect of tank-mix ratios of different pre-emergence herbicide on weed dry weight (g m^{-2}) and rice phytotoxicity of boro rice (cv. BRRI dhan58) at different days after transplanting (DAT)/ application (DAA)

Treatments	Weed dry weight (g m^{-2}) Days after transplanting (DAT)		Phytotoxicity Rating Days after application (DAA)		
	30	60	3	6	9
Triafamone and Pendimethalin @ 1:4 ratios	0.45^{d}	4.91^{abc}	1	1	1
Triafamone and Pretilachlor @ 1:4 ratios	0.59^{d}	9.75^{a}	1	1	1
Triafamone and Triasulfuron @ 1:4 ratios	1.20^{bcd}	7.76^{abc}	1	1	1
Triafamone and Oxadiazon @ 1:4 ratios	1.09^{bcd}	5.94^{abc}	1	1	1
Triafamone and Pendimethalin @ 1:1 ratios	0.88^{cd}	6.20^{abc}	1	1	1
Triafamone and Pretilachlor @ 1:1 ratios	0.93^{bcd}	8.44^{ab}	1	1	1
Triafamone and Triasulfuron @ 1:1 ratios	1.27^{bcd}	5.96^{abc}	1	1	1
Triafamone and Oxadiazon @ 1:1 ratios	0.44^{d}	6.53^{abc}	1	1	1
Triafamone and Pendimethalin @ 2:3 ratios	1.05^{bcd}	4.44^{bc}	1	1	1
Triafamone and Pretilachlor @ 2:3 ratios	0.39^{d}	3.04^{c}	1	1	1
Triafamone and Triasulfuron @ 2:3 ratios	1.84^{bc}	6.90^{abc}	1	1	1
Triafamone and Oxadiazon @ 2:3 ratios	1.85^{bc}	7.03^{abc}	1	1	1
Triafamone and Pendimethalin @ 3:2 ratios	1.86^{bc}	10.09^{a}	1	1	1
Triafamone and Pretilachlor @ 3:2 ratios	3.00^{a}	10.11^{a}	1	1	1
Triafamone and Triasulfuron @ 3:2 ratios	1.11^{bcd}	$8.12a^{bc}$	1	1	1
Triafamone and Oxadiazon @ 3:2 ratios	0.61^{d}	6.91^{abc}	1	1	1
Triafamone and Pendimethalin @ 4:1 ratios	2.03^{ab}	8.09^{abc}	1	1	1
Triafamone and Pretilachlor @ 4:1 ratios	1.34^{bcd}	4.40^{bc}	1	1	1
Triafamone and Triasulfuron @ 4:1 ratios	1.30^{bcd}	7.80^{abc}	1	1	1
Triafamone and Oxadiazon @ 4:1 ratios	1.06^{bcd}	6.45^{abc}	1	1	1
Acetachlor14% + Bensulfuron methyl 4%	0.48^{d}	6.41^{abc}	1	1	1
Level of significance	**	*	-	-	-
CV (%)	57.65	46.29	-	-	-
LSD $_{0.05}$	1.12	5.28	-	-	-

In column, means followed by different letters are significantly different, ***means at 0.1% level of probability, CV= Coefficient of variation. Phytotoxicity rating: 1= very slightly injury, 2= slightly injury, 3= Phytotoxic, 4= severely phytotoxic, 5= 100% killed (Okafor, 1986).

Table 3. Effect of tank-mix ratios of different pre-emergence herbicide on yield attributes of BRRI dhan58

Treatments	Total tillers hill^{-1} (no.)	Effective tillers hill^{-1} (no.)	Panicle length (cm)	Sterile spikelets panicle^{-1}	Grains panicle^{-1} (no.)	1000-grain weight (g)
Triafamone and Pendimethalin @ 1:4 ratios	16.00^{a}	13.33^{abc}	21.83^{a-d}	21.00^{ab}	137.00	23.163^{ab}
Triafamone and Pretilachlor @ 1:4 ratios	15.66^{ab}	13.66^{ab}	21.66^{a-d}	10.33^{b}	140.00	23.06^{ab}
Triafamone and Triasulfuron @ 1:4 ratios	15.00^{abc}	13.33^{abc}	21.16^{cd}	15.66^{ab}	130.33	23.53^{ab}
Triafamone and Oxadiazon @ 1:4 ratios	14.00^{abc}	13.00^{abc}	22.16^{abc}	20.66^{ab}	137.33	23.23^{ab}
Triafamone and Pendimethalin @ 1:1 ratios	13.00^{c}	12.00^{bc}	22.16^{abc}	22.33^{ab}	129.00	22.49^{ab}
Triafamone and Pretilachlor @ 1:1 ratios	14.00^{abc}	11.33^{c}	20.33^{d}	24.66^{ab}	130.33	22.30^{b}
Triafamone and Triasulfuron @ 1:1 ratios	15.00^{abc}	13.00^{abc}	21.16^{cd}	16.33^{ab}	119.00	23.63^{ab}
Triafamone and Oxadiazon @ 1:1 ratios	14.66^{abc}	13.33^{abc}	20.83^{cd}	26.33^{ab}	121.00	23.15^{ab}
Triafamone and Pendimethalin @ 2:3 ratios	14.00^{abc}	12.00^{bc}	20.66^{cd}	17.00^{ab}	141.00	23.04^{ab}
Triafamone and Pretilachlor @ 2:3 ratios	15.00^{abc}	14.33^{a}	23.33^{a}	22.66^{ab}	132.00	24.21^{a}
Triafamone and Triasulfuron @ 2:3 ratios	14.66^{abc}	13.66^{ab}	23.33^{a}	17.66^{ab}	137.67	22.75^{ab}
Triafamone and Oxadiazon @ 2:3 ratios	15.00^{abc}	13.66^{ab}	22.33^{abc}	28.33^{ab}	131.00	22.96^{ab}
Triafamone and Pendimethalin @ 3:2 ratios	14.66^{abc}	12.66^{abc}	21.66^{a-d}	18.00^{ab}	132.67	22.86^{ab}
Triafamone and Pretilachlor @ 3:2 ratios	13.33^{c}	11.66^{bc}	23.00^{ab}	11.00^{b}	121.00	22.73^{ab}
Triafamone and Triasulfuron @ 3:2 ratios	13.66^{bc}	12.33^{abc}	22.00^{a-d}	23.33^{ab}	124.33	22.64^{ab}
Triafamone and Oxadiazon @ 3:2 ratios	13.66^{bc}	11.66^{bc}	21.33^{bcd}	26.66^{ab}	130.00	23.62^{ab}
Triafamone and Pendimethalin @ 4:1 ratios	15.00^{abc}	11.33^{c}	22.00^{a-d}	32.33^{a}	116.33	23.06^{ab}
Triafamone and Pretilachlor @ 4:1 ratios	15.00^{abc}	13.66^{ab}	21.83^{a-d}	15.33^{ab}	141.33	23.97^{ab}
Triafamone and Triasulfuron @ 4:1 ratios	14.00^{abc}	12.33^{abc}	20.66^{cd}	25.33^{ab}	123.67	22.81^{ab}
Triafamone and Oxadiazon @ 4:1 ratios	13.66^{bc}	13.00^{abc}	21.33^{bcd}	32.00^{a}	117.33	23.03^{ab}
Acetaclor14% + Bensulfuron methyl 4%	14.00^{abc}	12.00^{bc}	21.66^{a-d}	33.00^{a}	129.00	23.48^{ab}
Level of significance	*	*	*	*	NS	*
CV (%)	8.67	10.24	4.93	57.60	14.07	4.75
LSD $_{0.05}$	2.06	2.15	1.76	20.82	30.07	1.81

In column, means followed by different letters are significantly different, ***means at 0.1% level of probability, CV= Coefficient of variation, LSD = Least significant difference.

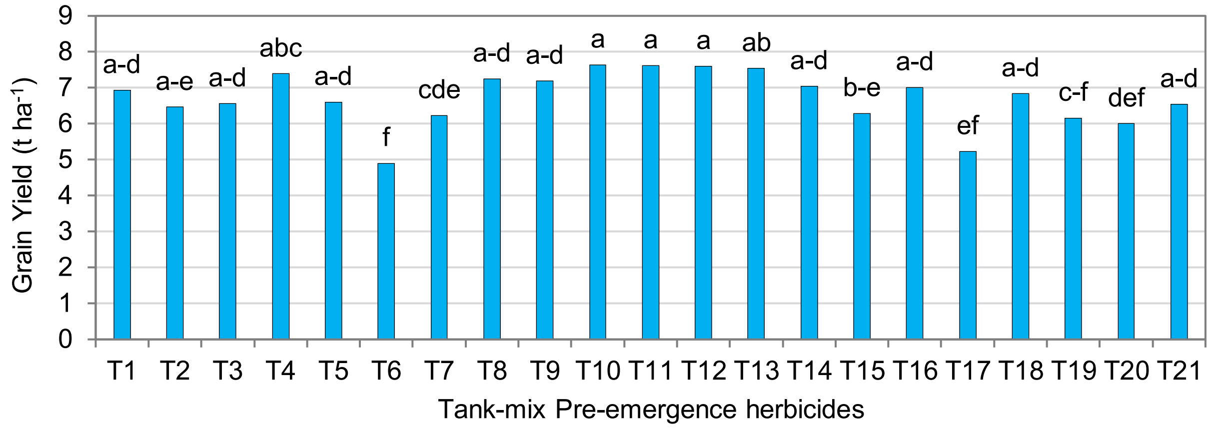

Figure 1. Effect of different tank-mix ratios of pre-emergence herbicide on grain yield of BRRI dhan58. Here, T1= Triafamone and Pendimethalin @ 1:4 ratios; T2= Triafamone and Pretilachlor @ 1:4 ratios; T3= Triafamone and Triasulfuron @ 1:4 ratios; T4= Triafamone and Oxadiazon @ 1:4 ratios; T5= Triafamone and Pendimethalin @ 1:1 ratios; T6= Triafamone and Pretilachlor @ 1:1 ratios ; T7= Triafamone and Triasulfuron @ 1:1 ratios; T8= Triafamone and Oxadiazon @ 1:1 ratios; T9= Triafamone and Pendimethalin @ 2:3 ratios; T10= Triafamone and Pretilachlor @ 2:3 ratios; T11= Triafamone and Triasulfuron @ 2:3 ratios; T12= Triafamone and Oxadiazon @ 2:3 ratios; T13= Triafamone and Pendimethalin @ 3:2 ratios; T14= Triafamone and Pretilachlor @ 3:2 ratios; T15= Triafamone and Triasulfuron @ (3:2) ratios; T16= Triafamone and Oxadiazon @ 3:2 ratios; T17= Triafamone and Pendimethalin @ 4:1 ratios; T18= Triafamone and Pretilachlor @ 4:1 ratios; T19= Triafamone and Triasulfuron @ 4:1 ratios; T20= Triafamone and Oxadiazon @ 4:1 ratios; T21= Acetachlor 14% + Bensulfuron methyl 4%.

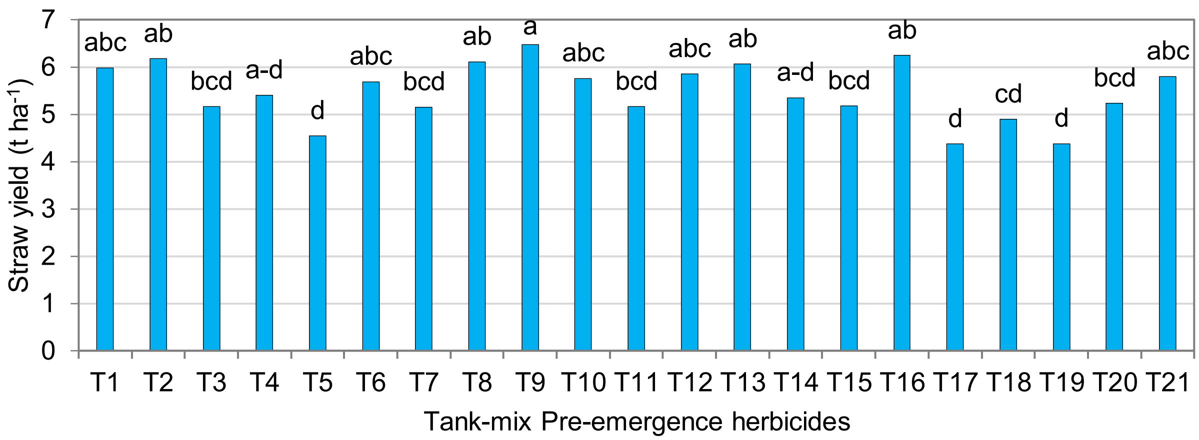

Figure 2. Effect of different tank-mix ratios of pre-emergence herbicide on straw yield of BRRI dhan58. Here, T1= Triafamone and Pendimethalin @ 1:4 ratios; T2= Triafamone and Pretilachlor @ 1:4 ratios; T3= Triafamone and Triasulfuron @ 1:4 ratios; T4= Triafamone and Oxadiazon @ 1:4 ratios; T5= Triafamone and Pendimethalin @ 1:1 ratios; T6= Triafamone and Pretilachlor @ 1:1 ratios ; T7= Triafamone and Triasulfuron @ 1:1 ratios; T8= Triafamone and Oxadiazon @ 1:1 ratios; T9= Triafamone and Pendimethalin @ 2:3 ratios; T10= Triafamone and Pretilachlor @ 2:3 ratios; T11= Triafamone and Triasulfuron @ 2:3 ratios; T12= Triafamone and Oxadiazon @ 2:3 ratios; T13= Triafamone and Pendimethalin @ 3:2 ratios; T14= Triafamone and Pretilachlor @ 3:2 ratios; T15= Triafamone and Triasulfuron @ (3:2) ratios; T16= Triafamone and Oxadiazon @ 3:2 ratios; T17= Triafamone and Pendimethalin @ 4:1 ratios; T18= Triafamone and Pretilachlor @ 4:1 ratios; T19= Triafamone and Triasulfuron @ 4:1 ratios; T20= Triafamone and Oxadiazon @ 4:1 ratios; T21= Acetachlor 14% + Bensulfuron methyl 4%.

4. Conclusion

This experiment concludes that when Triafamone and Pretilachlor were tank-mixed @2:3 ratios in zero till non-puddled transplanted condition has given the superior performance among the most traits under this study. So, it could be concluded that Triafamone and Pretilachlor @ 2:3 ratios would be most effective combination for better weed management along with higher yield of BRRI dhan58 under zero till non-puddled transplanted condition. However, as this experiment had been conducted in a single season and location, future research should incorporate multi-location and multi-season trials to validate these preliminary findings.

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Conflict of Interests

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

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