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EFFECT OF PLANTING GEOMETRY AND INTEGRATED WEED MANAGEMENT ON THE GROWTH OF WEED AND YIELD OF *JIRASHAIL* RICE

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ABSTRACT

Managing weeds sustainably to achieve desirable crop yields is a major concern worldwide. When the same weed management strategies are used, such as using similar herbicides excessively in a certain area to control weeds for a crop, weeds become resistant to that herbicide or technique, and gene flow from that resistant weed variant makes this condition worse. In this experiment, to solve this problem through proper weed control and get the highest yield of *Jirashail* rice, planting geometry (PG) and integrated weed management (IWM) methods were evaluated in the Agronomy Field Lab of BAU from August to November 2023. The experiment was laid out in an RCBD with three replications. The experiment was conducted with *Jirashail* rice with four PG (20 cm × 10 cm) (S_1), (20 cm × 15 cm) (S_2), (25 cm × 10 cm) (S_3), (25 cm × 15 cm) (S_4) and five different IWM practices such as W_0 (unweeded control), W_1 (Two hand weedings at 15 and 30 DATs), W_2 [Application of pre-emergence herbicide (Pretilachlor) followed by one hand weeding at 30 DAT], W_3 [Application of early post-emergence (EPE) herbicide (Acetachlor + Bensulfuron methyl) followed by one hand weeding at 30 DAT), W_4 (Application of pre-emergence herbicide (PE) followed by early post-emergence herbicide). The highest weed density and dry weight were achieved when the S_3W_0 treatment was applied. Though S_1W_4 treatment showed the lowest weed density and dry weight, rice grain yield was not that desirable here. However, the highest grain yield was observed at the S_4W_4 treatment with a minimum weed interference. The lower grain yield was observed at the spacing of 20 cm × 10 cm and unweeded control treatment (S_1W_0). From the study, it may be concluded that 25 cm × 15 cm planting geometry with the application of preemergence herbicide pretilachlor followed by early post-emergence herbicide could be recommended for *Jirashail* yield maximization as well as sustainable weed management.

Keywords: *Jirashail* rice, spacing of transplanting, integrated weed management, yield

INTRODUCTION

Bangladesh earns about 11.20% of its gross domestic product (GDP) from Agriculture (BBS, 2023). For production, Bangladesh ranks third among the rice-producing countries of the world following China and India. The average paddy (unmilled rice) yield in Bangladesh is 4.81 t ha^{-1}, compared to 6.93 t ha^{-1} China, 3.69 t ha^{-1} in India, 5.41 t ha^{-1} in Indonesia, and 5.58 t ha^{-1} in Vietnam. Food demand in Bangladesh is increasing with the increase of population growth. On the other hand, agricultural land is decreasing day by day. About 220 hectares of agricultural land are decreasing per year due to urbanization, industrialization, housing and road construction purposes. *Jirashail*, an Indian rice variety, is gaining popularity in north-western districts of Bangladesh due to its good taste and fine grain type as well as higher market price. Research indicates that *Jirashail* rice is not only significant for its culinary qualities but also plays an essential role in the socio-economic landscape of the north-west region of Bangladesh. Optimum spacing can ensure the plants to grow properly with their aerial and underground parts utilizing more solar radiation and nutrients (Miah *et al*., 1990). Proper spacing may help receive maximum leaf area index (LAI) and light interceptions, which are better for photosynthesis and ultimately yield of rice. Too close a spacing may hamper intercultural operations and increase competition among the plants for light and nutrients. Optimum spacing ensures sufficient temperature, moisture and other soil factors that result in producing the

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maximum number of total tillers m^{-2}, and fertile tillers m^{-2} (Alam, 2006). The tillering habit and production of grains $panicle^{-1}$ depend to a great extent on the spacing of transplanting which is responsible for the variation in rice yield. Thus, spacing can be one of the important factors of manipulation for optimizing rice yield. (Tyeb *et al*., 2013).

Weeds grow in each of the crop fields throughout the world. So, it is often said that crop production is a fight against weeds (Mukhopadhay and Ghosh, 1981). Among the pests, weeds are considered an important biotic constraint to food production that reduces agricultural output (quantity and quality) of crops and increases external costs by spreading them across farm boundaries (Salam *et al*., 2024). The traditional method of weed control is hand weeding (Salam et al., 2022). Weed control techniques have been widely adopted because control is the easiest to do and often effective. The problem is known and visible, and actions can be tailored to the observed problem. Control techniques can be selected to meet short-term agricultural and economic planning objectives (Lopez, 2011). Nowadays chemical methods of weed control are gaining popularity all over the world because of their miraculous results in crop production. Pre- and early post-emergence herbicides can be more effective than traditional herbicides because they can reduce weed density and species diversity and increase crop yields (Onwuchekwa-Henry *et al.*, 2023). However, excessive or inappropriate use can cause weed resistance, soil and environmental degradation, and a great economic loss. Thus, integrating manual and chemical weed management would be helpful to control weeds at a lower cost and with minimal environmental concern.

Consequently, there is a great need for a new weed management paradigm in modern agriculture (Bajwa, 2014) based on ecological principles and non-conventional weed management approaches. These approaches may offer more durable weed management solutions to lessen problems of herbicide resistance, environmental pollution, weed diversification, weed invasion, and yield losses (Singh, 2007; Chauhan, 2013; Travlos, 2013). As the number of herbicide-resistant weed ecotypes increases and the discovery of new herbicide modes of action (MOAs) declines (Strek, 2014), the need to utilize all available weed management options is crucial. Following are three opinions to be considered for sustainable rice yield; (i) Minimizing rice yield loss by appropriate weeding; (ii) Productivity could be increased by safe use of herbicide; and, (iii) Environmentally and sustainable integrated weed management practices. The best weeding regime needs to be found to reduce losses due to weed infestation and thus get maximum yield. A few works on the productivity of transplant *aman* rice and weed growth due to cultivar and weeding regimes in rice have been done in our country. The present study was, therefore, undertaken to observe the effect of planting geometry and integrated weed management on weed growth and yield performance of *Jirashail* rice.

MATERIALS AND METHODS

Experimental site

To the Sonatala series of Old Brahmaputra Floodplain Agro-ecological Zone (AEZ-9) having non-calcareous dark grey floodplain soils with pH 6.5 (FAO, 2009). The experiment field was medium-high land having sandy loam, low in organic matter content and its general fertility was also low. The experimental site's climate is classified as sub-tropical and is distinguished by high temperature, high levels of humidity and a lot of precipitation with periodic gusty winds during the Kharif (April to September) season and little precipitation with a moderately low temperature and abundant sunshine during the Rabi season.

Experimental design

Two experimental factors were included in the experiment. These were - Factor A: Planting Geometry (PG): 20 cm × 10 cm (S_1), 20 cm × 15 cm (S_2), 25 cm × 10 cm (S_3), 25 cm × 15 cm (S_4) and Factor B: Integrated Weed Management (IWM): Unweeded control (W_0), two Hand Weedings (HW) at The experiment was conducted at the Agronomy Field Laboratory (AFLab), Bangladesh Agricultural University (BAU), Mymensingh from August to November 2023 to study the effect of PG and IWM on weed growth and yield performance of *Jirashail* rice. The location of the experiment was at 24° 75' N latitude and 90° 50' E longitude having an altitude of 18 m above the mean sea level. The experimental site belongs to the Sonatala series of Old Brahmaputra Floodplain Agro-ecological Zone (AEZ-9) having non-calcareous dark grey floodplain soils with pH 6.5 (FAO, 2009). This experiment site was located at 24° 75' N latitude and 90° 50' E longitude having an altitude of 18 m above the mean sea level. The experimental site belongs 15 and 30 DATs (W_1), application of pre-emergence herbicide (Pretilachlor @ 2 L ha^{-1}) followed by one hand weeding at 30 DAT (W_2), Application of early post-emergence herbicide Changer 18WP (Acetachlor 14% + Bensulfuron methyl 4%) @ 1 kg ha^{-1}) followed by one hand weeding at 30 DAT (W_3), application of pre-emergence herbicide followed by early post-emergence herbicide (W_4). The experiment was laid out in a randomized complete block design (RCBD) with three replications. Altogether there were 60-unit plots in the experiment. The unit plot size was 4.0 × 2.5 m.

Description of rice cultivar and crop husbandry

Jirashail is a high-yielding, Indian rice variety having long and slender grains. Its straw is resistant to rotting and the variety is less prone to lodging, so it is beneficial to farmers. Plant height is 130-135 cm, length of panicle is 22.0-23.5 cm and, grain yield is 3.5- 4.0 t ha^{-1} in *aman* season. It is a short to medium-duration rice variety.

After collecting, seeds were soaked for 72 hours on 26 July 2023. The sprouted seeds were broadcast uniformly in a well-prepared nursery bed on 3 August 2023. The nursery bed was irrigated every 72 hours at early 15 days after broadcasting sprouted seedlings. Seedlings were ready for transplanting 26 days after sowing when sixth or seventh leaves were found. The land was first opened with a tractor-driven plough, ploughing followed by laddering was done with a country plough and a ladder. Weeds and stubbles were removed from the field as much as possible after levelling.

The experimental plots were fertilized with triple super phosphate (TSP), Muriate of potash (MoP) and gypsum. Triple super phosphate, muriate of potash and gypsum were applied at the rate of 60, 80, and 60 kg ha^{-1}, respectively. The recommended dose of urea was 150 kg ha^{-1}. Nitrogen fertilizer in the form of urea was applied as per the treatment used in the experiment in three equal splits at 7, 21 and 35 DAT. All the plots were transplanted on 29 August, 2023 after 26 days of seedling. 4-5 cm water depth was maintained in the experimental field throughout the growing period and a proper drainage system was maintained.

Data collection, sampling, harvesting and processing

To determine total dry matter for three hills plot^{-1} was taken from the outside of harvest area at 15 and 30 DATs and in order to determine total dry matter for weed, the weeds were collected from the three spots plot^{-1} at 15 and 30 DAT. The plants and weeds were washed with tap water and then they were packed in labeled brown paper bags and dried in the oven at 90 °C or 80 °C for 72 hours until constant weight was reached. The samples were weighed carefully after oven drying to measure the dry weight of plant and weed.

Data on weed population were collected from each plot at vegetative growth stage of the rice plants by using 1 m^2 quadrates. The quadrate was placed in the spots at random outside 1 m^2 central areas, kept for taking yield data. The weeds within the quadrate were counted species wise and averaged. After counting the weed density, the weeds inside each quadrate were uprooted, cleaned, separated species wise and dried first in the sun and then in an electrical oven for 72 h at a temperature of 80° C. The dry weight of each species was taken by an electrical balance and expressed in gm^{-2}.

The rice crop was harvested at full maturity. The date of harvesting was confirmed when 90% of the seed became golden yellow. Three hills (excluding border rows and a central 1 m^2 area) were selected randomly from each unit plot and uprooted for recording data. After sampling, a harvest area of central 1 m ×1 m was selected from each unit plot and harvested on 10 November 2023. The harvested crop of each 1 m^2 area was separately bundled, properly tagged and then brought to the threshing floor. The crop was threshed by hand and the fresh weights of grain straw were recorded plot-wise. The grains were cleaned and sundried to a moisture content of 14%. Finally, grain and straw yields m^{-2} were recorded and converted to t ha^{-1}.

Statistical analysis

Data on different parameters were compiled and tabulated in proper form for statistical analysis. The computer package program MSTAT-C was used to analyze variance. Duncan's Multiple Range Test adjudged the mean differences among the treatments (Gomez and Gomez, 1984).

RESULTS AND DISCUSSION

Weed density and dry weight

Effect of PG

Planting geometry (PG) had a significant effect on weed density at different DAT. The highest weed density was observed in wider planting PG of 25 cm × 15 cm which was statistically identical to 25 cm × 10 cm PG. Wider spacing encouraged weed growth because of higher resource allocation for weed and hence weed density increased. Similar research finding was also repeated by (Guillermo *et al.*, 2009; Rahman *et al.*, 2022). The lowest weed density was recorded in 20 cm × 10 cm PG at all the sampling dates (Table 1). On the other hand, the highest weed dry weight was obtained in 25 cm × 10 cm PG and the lowest one was found in 20 cm × 10 cm PG (Table 1). This finding corroborates the findings of Rahman *et al.* (2022).

Effect of integrated weed management

Integrated weed management (IWM) exerted significant effect on weed density and dry weight at different DATs. The highest values were observed at unweeded control plots at 15 and 30 DATs and the lowest values were found in application of pre-emergence (PE) herbicide followed by early post-emergence herbicide (EPE) herbicide (Table 1). Weed management treatment controlled the weed successfully and hence weed density was minimal. These findings corroborate the findings of Pant *et al.* (2023) who reported that herbicide application reduced weed density than unweeded control treatment. The highest weed dry weight (3.70 g m^{-2}) was obtained in the unweeded control treatment and the lowest one (2.14 g m^{-2}) was found in the application of PE herbicide followed by EPE herbicide which was statistically identical to the application of EPE herbicide followed by one HW at 30 DAT. At 30 DAT, the highest weed dry weight (7.25 g m^{-2}) was found in the unweeded control treatment and the lowest one (3.79 g m^{-2}) with the application of EPE herbicide followed by one-hand weeding at 30 DAT (Table 1).

Effect of planting geometry and integrated weed management

The interaction effect of PG and IWM did not affect weed density. At 15 DAT, the highest weed density (14.00) was recorded in the treatment combination of S_3W_0 (25 cm × 10 cm PG and no weeding) condition which was statistically similar to S_4W_0 (25 cm × 15 cm PG and no weeding) treatment combination (Table 1).

Table 1. Effect of PG, IWM and interaction of PG and IWM on weed density and dry weight of Jirashail rice

Treatments	Weed density (no.)		Weed dry weight (g m^{-2})	
	15 DAT	30 DAT	15 DAT	30 DAT
S_1	7.33 c	10.07 b	2.66 a	4.42 c
S_2	8.87 b	10.87 ab	2.66 a	5.23 b
S_3	9.73 a	11.07 a	2.97 a	6.37 a
S_4	10.13 a	11.47 a	2.64 a	4.50 c
Level of Significance	**	*	*	**
W_0	12.92 a	14.33 a	3.70 a	7.25 a
W_1	9.33 b	11.92 b	2.90 b	5.37 b
W_2	8.17 c	10.08 c	2.48 bc	4.52 cd
W_3	7.92 c	9.50 c	2.43 c	3.79 d
W_4	6.75 d	8.50 d	2.14 c	4.73 bc
Level of significance	**	**	**	**
S_1W_0	12.00 bc	14.00 a	3.56	7.00 a-c
S_1W_1	7.67 g-j	10.67 c-e	2.83	5.23 c-g
S_1W_2	6.33 i-k	9.33 d-h	2.57	4.00 g-i
S_1W_3	6.00 jk	8.33 f-h	2.27	3.00 i
S_1W_4	4.67 k	8.00 gh	2.07	2.87 i
S_2W_0	12.67 ab	13.33 ab	3.67	6.83 a-d
S_2W_1	9.00 d-g	14.00 a	3.00	5.00 e-h
S_2W_2	8.00 f-i	10.00 c-g	2.23	5.27 c-g
S_2W_3	8.00 f-i	9.33 d-h	2.30	4.63 f-i
S_2W_4	6.67 h-j	7.67 h	2.10	4.40 f-i
S_3W_0	14.00 a	15.00 a	3.88	8.50 a
S_3W_1	10.00 de	11.33 b-d	3.17	6.07 c-f
S_3W_2	8.67 e-g	10.00 c-g	2.80	4.97 e-h
S_3W_3	8.67 e-g	10.00 c-g	2.56	4.00 g-i
S_3W_4	7.33 g-j	9.00 e-h	2.43	8.33 ab
S_4W_0	13.00 ab	15.00 a	3.70	6.67 b-e
S_4W_1	10.67 cd	11.67 bc	2.62	5.17 d-h
S_4W_2	9.67 d-f	11.00 c-e	2.32	3.83 g-i
S_4W_3	9.00 d-g	10.33 c-f	2.61	3.53 g-i
S_4W_4	8.33 e-h	9.33 d-h	1.95	3.30 hi
Level of Significance	*	*	NS	**
CV (%)	10.96	10.73	18.86	18.88

*In this column with same letters or without letters do not differ significantly whereas figures with dissimilar letters differ significantly as per DMRT. ** = Significant at 1% level of probability, *= Significant at 5% level of probability and NS = Not significant. Here, S_1 = 20 cm × 10 cm, S_2 = 20 cm × 15 cm, S_3 = 25 cm × 10 cm, S_4 = 25 cm × 15 cm, W_0 = Unweeded control, W_1 = Two Hand weedings at 15 and 30 DATs, W_2 = Application of pre-emergence herbicide followed by one hand weeding at 30 DAT, W_3 = Application of early post-emergence herbicide followed by one hand weeding at 30 DAT, W_4 = Application of pre-emergence herbicide followed by early post-emergence herbicide

The lowest value (4.67) at 15 DAT was observed in the treatment combination of S_1W_4 (20 cm × 10 cm PG and application of PE herbicide followed by EPE herbicide. At 30 DAT, the highest value (15.00) was found in the treatment combination of 25 cm × 15 cm PG with unweeding control condition (S_4W_0) which was statistically identical to S_3W_0 (25 cm × 10 cm PG with unweeded control) treatment combination at 30 DAT. The lowest value (7.67) was found in 20 cm × 15 cm PG with application of PE herbicide followed by EPE herbicide (S_2W_4) treatment combination (Table 1). However, the interaction effect of PG and IWM had no significant effect on weed dry weight at 15 DAT but had a significant effect at 30 DAT. At 15 DAT, numerically the highest weed dry weight

(3.88 g m^{-2}) was observed in 25 cm × 10 cm PG and unweeded control condition and the lowest one (1.95 g m^{-2}) was found in 25 cm × 15 cm PG with application of PE herbicide followed by EPE herbicide. At 30 DAT, the highest (8.50 g m^{-2}) was observed in 25 cm × 10 cm PG with an unweeded control condition and the lowest one (2.87 g m^{-2}) was recorded in 20 cm × 10 cm PG with the application of PE herbicide followed by EPE herbicide (Table 1).

Yield and yield components

Effect of planting geometry

Planting geometry (PG) had a significant effect on plant height, total tillers hill^{-1}, effective tillers hill^{-1}, grains panicle^{-1}, grain yield, straw yield, and harvest index. From Table 2 it is observed that the longest plant (94.29 cm) was obtained with a spacing of 25 cm × 15 cm and the shortest Ph (89.22 cm) was obtained at a spacing of 25 cm × 10 cm which was statistically identical to S_1 (20 cm × 10 cm) and S_2 (20 cm × 10 cm) PGs (Table 2).

Table 2. Effect of PG and IWM on the yield and yield attributes of *Jirashail* rice

Treatment	Plant height (cm)	Total tillers hill^{-1}	Effective tillers hill^{-1} (no.)	Grains panicle^{-1}	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Harvest index (%)
Planting geometry							
S_1	90.52 b	8.82 c	7.78 c	84.22 b	3.39 b	4.52b	42.79 ab
S_2	91.47 b	9.85 ab	9.22 ab	84.89 b	3.52 b	4.81ab	43.17 ab
S_3	89.22 b	9.35 bc	8.63 b	85.44 b	3.44 b	5.02a	40.60 b
S_4	94.29 a	10.53 a	9.42 a	91.03 a	3.82 a	4.83ab	43.95 a
Level of significance	**	**	**	**	*	*	*
Integrated weed management							
W_0	89.36 b	8.89 b	7.90 b	75.47 d	2.72 c	4.63	38.26 b
W_1	92.03 a	9.64 ab	8.72 a	86.01 c	3.55 b	4.60	43.63 a
W_2	91.23 a	10.07 a	9.31 a	88.37 bc	3.80 ab	5.13	42.55 a
W_3	91.03 a	9.61 ab	8.72 a	89.04 b	3.74 ab	4.95	43.13 a
W_4	93.22 a	9.97 a	9.17 a	93.10 a	3.91 a	4.68	45.58 a
Level of significance	**	**	**	**	*	NS	*
CV (%)	3.99	10.14	9.67	3.49	11.35	12.64	

*In this column with same letters or without letters do not differ significantly whereas figures with dissimilar letters differ significantly as per DMRT. ** = Significant at 1% level of probability, *= Significant at 5% level of probability and NS = Not significant. S_1 = 20 cm × 10 cm, S_2 = 20 cm × 15 cm, S_3 = 25 cm × 10 cm, S_4 = 25 cm × 15 cm, W_0 = Unweeded control, W_1 = Two Hand weedings at 15 and 30 DATs, W_2 = Application of pre-emergence herbicide followed by one hand weeding at 30 DAT, W_3 = Application of early post-emergence herbicide followed by one hand weeding at 30 DAT, W_4 = Application of pre-emergence herbicide followed by early post-emergence herbicide.

In their research, Ferdousy *et al.* (2020) and Yumnam *et al*. (2021) reported similar research findings that PG exerted a significant effect on plant height. The highest number of total tillers in hill^{-1} (10.53) was observed with 25 cm × 15 cm which was statistically similar (9.85) with 20 cm × 15 cm PG and the lowest number of total tillers hill^{-1} (8.82) was observed in the spacing of 20 cm × 10 cm (Table 2). This result showed that wider spacing produced the highest number of total tillers. This might be because wider spacing had less competition from nutrients and other growth factors which enhanced tiller production. A similar result was reported by Sarker (2001) who found a higher number of tillers in wider spacing in his study. The highest number of effective tillers hill^{-1} (9.42) was recorded in 25 cm × 15 cm PG which was statistically similar (9.22) with 20 cm × 15 cm PG and the lowest number of effective tillers hill^{-1} (7.78) was observed in the spacing of 20 cm × 10 cm (Table 2). This result was in agreement with the findings of Salahuddin *et al.* (2009). The highest number of grains panicle^{-1} (91.03) was obtained from 25 cm × 15 cm PG. A similar research finding was also reported by Rahman *et al.* (2022) who found the highest number of grain panicle^{-1} with 25 cm × 15 cm PG in their research. The lowest number of grains panicle^{-1} (84.22) was found with 20 cm × 10 cm PG which was statistically similar to 20 cm × 10 cm and 25 cm × 10 cm PG (Table 2). The highest grain yield (3.82 t ha^{-1}) was observed in 25 cm × 15 cm PG. The observed highest grain yield in this treatment might be due highest number of effective tillers per unit area and the highest number of grains panicle^{-1}. A similar research finding was also reported by Bhowmik et al. (2012) who found the highest grain yield of 3.13 t ha^{-1} using 20 cm × 10 cm spacing using the NERICA 1 variety. The lowest grain yield (3.39 t ha^{-1}) was statistically identical to 25 cm × 10 cm and 20 cm × 10 cm (Table 2). The highest straw yield (5.02 t ha^{-1}) was found with 25 cm × 10 cm PG and the lowest value (4.52 t ha^{-1}) was observed in PG of 20 cm × 10 cm (Table 2). The highest harvest index (43.95%) was observed in 25 cm × 15 cm PG which was statistically similar with S_1 (20 cm × 10 cm) and S_2 (20 cm × 15 cm) treatments and the lowest one (40.60) was observed in 20 cm × 10 cm PG.

Effect of integrated weed management

Different methods of IWM had a significant effect on plant height, total tillers hill^{-1}, effective tillers hill^{-1}, grains panicle^{-1}, grain yield and harvest index. The tallest plant (93.22 cm) was obtained with the W_4 (application of PE herbicide followed by EPE herbicide) treatment and the shortest one (89.36 cm) was found in the unweeded control treatment (Table 2). In the W_4 treatment plant grew vigorously due to less or no competition of rice crops with weeds and hence plant height increased. On the other hand, the shortest plant was found in no weeding treatment due to the highest crop-weed competition and the weed absorbed more nutrients than rice hence shortest plant was observed in this treatment. Onna *et al.* (2024) also found similar research findings in her study. The highest number of total tillers hill^{-1} (10.07) was observed with the application of pre-emergence herbicide followed by one-hand weeding at 30 DAT which was statistically similar with other weed management practices except no weeding (Table 2). Sultana *et al.* (2023) also observed a significant relation of total tillers hill^{-1} with weed management and showed that the highest number of total tillers hill^{-1} was recorded in the plots that were treated with EPE herbicide followed by one-hand weeding at 30 DAT. The lowest number of total tillers hill^{-1} (8.89) was observed at unweeded control treatment due to crop-weed competition and weed absorbed more nutrients than rice hence shortest plant was observed in this treatment. The highest number of effective tillers hill^{-1} (9.17) was recorded in W_4 (application of PE herbicide followed by EPE herbicide) treatment which was statistically identical to other weed management practices except control. The conformity of this result was also observed by Sultana *et al.* (2023) who recorded a positive influence of weed management on the number of effective tillers hill^{-1}. The lowest number of effective tillers hill^{-1} (7.90) was obtained in the W_0 treatment (Table 2). The highest number of grains panicle^{-1} (93.10) was observed with the application of PE herbicide followed by EPE herbicide and the lowest one (75.47) was observed from the unweeded control treatment (Table 2). Herbicide applied plot-controlled weed effectively and rice growth was vigorous, hence a greater number of grains was formed than the unweeded control plot. Similar findings were also reported by Kheya *et al.* (2024) (Table 2). The highest grain yield (3.91 t ha^{-1}) was found in the application of PE herbicide followed by EPE herbicide. A similar research finding was also reported by Onna *et al.* (2024) in her research. In comparison to an un-weeded control treatment, weed management techniques effectively reduced weed growth, giving the crop an advantage over its competition and ultimately increasing the grain yield. The lowest value (2.72 t ha^{-1}) was found with unweeded control treatment (Table 2). The highest harvest (45.58%) was found in the application of PE herbicide followed by EPE herbicide which was statistically identical to two hand weedings at 15 and 30 DATs, application of EPE herbicide followed by one hand weeding at 30 DAT and application of PE herbicide followed by one hand weeding at 30 DAT. The lowest harvest index (38.26%) was found in the unweeded control treatment.

Interaction effect of planting geometry and method of integrated weed management

The interaction of PG and IWM exerted a significant effect on plant height, total tillers hill^{-1} and grains panicle^{-1}. The tallest plant (97.89 cm) was observed in the PG spacing of (25 cm × 15 cm) and the application of pre-emergence herbicide followed by one-hand weeding at 30 DAT (Table 3). The highest number of total tillers hill^{-1} (11.22) was found in S_4W_2 treatment which was statistically identical to S_4W_1 (25 cm × 15 cm PG with two hand weedings at 15 and 30 DATs).

Table 3. Interaction effect of PG and IWM on the yield and yield attributes of *Jirashail* rice

Planting geometry × Integrated weed management	Plant height (cm)	Total tillers hill^{-1} (no.)	Effective tillers hill^{-1} (no.)	Grains panicle^{-1} (no.)	1000-grain weight (g)	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Harvest index (%)
S_1W_0	89.33 b-d	8.78 cd	7.11 h	72.88 g	18.32	2.603 d	3.74	41.09
S_1W_1	89.00 b-d	8.78 cd	7.67 gh	84.72 ef	18.64	3.24b cd	4.38	42.43
S_1W_2	89.48 b-d	8.89 cd	8.00 e-h	87.22 c-f	18.21	3.71 ab	5.13	42.01
S_1W_3	90.79 b-d	9.00 b-d	8.11 d-h	85.98 d-f	18.42	3.64 a-c	4.84	42.95
S_1W_4	94.00 a-c	8.67cd	8.00 e-h	90.33 b-e	18.47	3.75 ab	4.50	45.45
S_2W_0	91.56 a-d	8.11d	7.78 f-h	76.39g	18.34	2.90 cd	4.74	42.09
S_2W_1	94.89 a-c	9.67 a-d	9.11 a-g	82.51f	18.26	3.56 a-c	4.40	44.96
S_2W_2	89.33 b-d	10.22 a-c	9.89 ab	86.98 c-f	18.35	3.70 ab	5.11	41.93
S_2W_3	89.33 b-d	10.33 a-c	9.45 a-e	87.65 c-f	18.22	3.59 a-c	5.16	41.44
S_2W_4	92.22 a-d	10.89 ab	9.89 ab	90.93 b-d	18.24	3.85 ab	4.64	45.44
S_3W_0	85.89 d	8.56 cd	7.61 gh	76.16 g	18.33	2.68 d	5.07	34.56
S_3W_1	90.55 b-d	9.00 b-d	8.33 b-h	89.28 c-e	18.28	3.56 a-c	4.66	43.36
S_3W_2	88.22 cd	9.96 a-d	9.33 a-f	86.49 d-f	18.32	3.62 a-c	5.35	40.47
S_3W_3	90.78 b-d	8.78 cd	8.22 c-h	87.04 c-f	18.57	3.62 a-c	5.14	41.30
S_3W_4	90.67 b-d	10.45 a-c	9.67 a-d	88.25 c-f	18.48	3.72 ab	4.90	43.34
S_4W_0	90.67 b-d	10.11 a-c	9.11 a-g	76.46 g	18.52	2.69 d	4.97	35.30
S_4W_1	93.67 a-c	11.11 a	9.78 a-c	87.51 c-f	18.42	3.84 ab	4.94	43.75
S_4W_2	97.89 a	11.22 a	10.00 a	92.78 bc	18.39	4.15 a	4.91	45.78
S_4W_3	93.22 a-c	10.33 a-c	9.11 a-g	95.49 b	18.58	4.10 a	4.65	46.85
S_4W_4	96.00 ab	9.89 a-d	9.11 a-g	102.9 a	18.57	4.32 a	4.69	48.08
CV (%)	3.99	10.14	9.67	3.49	1.27	11.35	12.64	9.54
Level of significance	*	*	*	**	NS	*	*	NS

*In this column with same letters or without letters do not differ significantly whereas figures with dissimilar letters differ significantly as per DMRT. ** = Significant at 1% level of probability, *= Significant at 5% level of probability and NS = Not significant. Here, S_1 = 20 cm × 10 cm, S_2 = 20 cm × 15 cm, S_3 = 25 cm × 10 cm, S_4 = 25 cm × 15 cm, W_0 = Unweeded control, W_1 = Two Hand weedings at 15 and 30 DATs, W_2 = Application of pre-emergence herbicide followed by one hand weeding at 30 DAT, W_3 = Application of early post-emergence herbicide followed by one hand weeding at 30 DAT, W_4 = Application of pre-emergence herbicide followed by early post-emergence herbicide

The lowest number of total tillers hill^{-1} (8.11) was found in the S_2W_0 (20 cm × 15 cm planting geometry with unweed control treatment (Table 3). The highest number of grains panicle^{-1} (102.90) was observed in S_4W_4 (25 cm × 15 cm PG and application of PE herbicide followed by EPE herbicide) treatment. This was might be due to the of 25 cm × 15 cm spacing allowed the plants enough room to grow without competition for light, water and nutrients which helped the plant to promote better root development as well as shoot growth leading to more productive panicles and consequently, a higher number of grains per panicle^{-1}. The combination of proper spacing and effective weed management allowed rice plants to grow in a less stressful, resource-rich environment which helped increased grain production. The finding corroborates the finding of Salam *et al.* (2020).

The lowest number of grains panicle^{-1} (72.88) was attained with S_1W_0 (20 cm × 10 cm PG and unweeded control) treatment.

CONCLUSION

Though 20 cm × 10 cm planting geometry with application of PE herbicide followed by EPE herbicide(S_1W_4) showed the lowest weed density and dry weight, but rice grain yield was not desirable in this treatment combination. The highest grain yield was recorded in 25 cm × 15 cm planting geometry with application of PE herbicide followed by EPE herbicide (S_4W_4) with a minimum weed interference. Therefore, it could be concluded that 25 cm × 15 cm planting geometry with the application of PE herbicide followed by EPE herbicide could be recommended for yield maximization as well as sustainable weed management.

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