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Allelopathic Effect of the Residues of *Rumex Maritimus* L. on the Yield Performance of *Boro* Rice

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Abstract
An experiment was conducted at the Agronomy Field Laboratory, BAU, Mymensingh, during the period from December 2018 to May 2019 to evaluate the effect of the residues of *R. maritimus* on the yield performance of *boro* rice. The experiment consisted of two cultivars i.e.; BRRI dhan58 and BRRI dhan74 and four rates of *R. maritimus* residues treatment such as 0, 1.0, 2.0, 3.0 t ha^{-1} and a farmers practice. The experiment was laid out in a randomized complete block design (RCBD) with three replications. Yield and yield contributing characters like number of total tillers hill^{-1}, number of effective tillers hill^{-1}, number of non-effective tillers hill^{-1}, 1000-grain weight, grain yield, straw yield, biological yield and harvest index were significantly affected by the interaction between variety and residues. BRRI dhan74 under R_4 treatment condition produced the highest grain (5.42 t ha^{-1}) and straw yield (6.71 t ha^{-1}) followed by the same variety. The lowest grain yield (5.15 t ha^{-1}) and straw yield (6.51 t ha^{-1}) resulted from BRRI dhan58 variety under R_1 treatment. The highest grain (5.42 t ha^{-1}) and straw (6.71 t ha^{-1}) yields were observed in *R. maritimus* residues @ 3.0 t ha^{-1} treatment. Results of this study indicate that *R. maritimus* residues showed potentiality to inhibit weed growth and it has a significant effect on the yield of *boro* rice. Therefore, *R. Maritimus* residues might be used as an alternative way for weed management in effective and sustainable crop production.

Keywords: Allelopathic Effect, Residues, *Rumex Maritimus*, Yield Performance, *Boro* Rice

Introduction

Rice (*Oryza sativa*) is one of the most important crops in the world, and in Bangladesh, it is the staple food for her people where rice occupies nearly 74.65% of the total net cropped area of the country. Bangladesh is an agriculture based agronomical country. The agricultural system in Bangladesh is generally characterized by intensive crop production with the rice-based cropping system. About 13.47% of the total GDP are contributed by agricultural sector (Islam *et al*. 2023) [14]. The economic development of Bangladesh is mainly based on agriculture, where agriculture sector contributes about 13.60% in GDP. In Bangladesh almost 40.6% of the labour force depends on agriculture for employment. Three major rice crops namely, *aus, aman* and *boro* constitute 100% of total rice production and grow in three different seasons. Crop productivity of Bangladesh is low in comparison to other rice producing countries. Severe weed infestation is one of the major reasons for such low yield of rice in Bangladesh. Where *boro* rice is the highest single crop (3.96 metric ton ha^{-1}) and covers about 41.71% of total rice area (BBS, 2020) [3], but weed reduced the grain yield of *boro* rice by 22-36%. Weeds compete with rice for the available moisture, nutrients and light and most of the cases weed shows dominance over rice. Hand weeding, applying chemical herbicides are the common usage methods to control weeds in Bangladesh, but hand weeding is often imperfect and/or delayed because of limited budgets for hiring labor and availability of labor during peak periods (Halder *et al*. 2024 [11]; Krupnik *et al*. 2012 [17]). On the other hand, chemical herbicides produce negative health impact both human and animal resulting serious environmental pollution (Rani *et al*. 2021) [22]. To overcome weed infestation in rice field, in this regard, researchers have been searching an environmentally safe method to manage weeds and, in this concern, plant allelopathy might be an option to control weeds Crop residues are defined as crop or its parts left in field for decomposition after it has been thrashed or harvested (Kumar and Goh, 2000) [18]. Earlier these were regarded merely as waste, but now because of their usefulness they are considered an important resource that can bring significant physical, chemical, and biological changes in the agricultural soil after amendment (O'Connor *et al*. 2021) [21]. Crop allelopathy controls weeds by the release of allelochemicals from the living plants and/or through decomposition of phytotoxic plant residues (Belz, 2004; Khanh *et al.* 2005) [4, 16]. Crop residues can interfere with weed development and growth through alteration of soil physical, chemical, and biological characteristics. Currently, researchers are giving more emphasis using different residues to suppress weed growth (Hossain *et al*. 2024) [12]. *Rumex maritimus* under the family Polygonaceae is an annual herbaceous plant found in the Southeast Asia. The species *R. maritimus* is an erect stout herb, up to 0.5-1.2 m tall and grows on the banks of water reservoirs, lakes, rivers and ponds (Nowak *et al.* 2020) [20]. The seed and leaves of *R. maritimus* are reported to have pharmacological properties. The seeds have antimicrobial, carminative, astringent and aphrodisiac properties. The seeds are used as a tonic and to treat pain in the back and lumber region, while leaves are applied to burns (Basu and Kirtikar 1980) [2].

Materials and Methods

Experiment Site and design

The experimental field was situated in the Sonatola series of the Old Brahmaputra Floodplain, which is an agro-ecological region of the Old Brahmaputra Floodplain (AEZ-9). It was 18 meters above sea level and belonged to non-calcareous dark grey floodplain soil. The location was 24°25' N latitude and 90°50' E longitude. A randomized complete block design (RCBD) with three replications was used to set up the experiment. Thirty plots in total were present. Plots were each 2.5 m by 2 m in size.

Experimental Treatments

The experimental treatment consisted of two factors. They are as follows: Factor A: Variety (2): BRRI dhan58 (V_1), BRRI dhan74 (V_2). Factor B: *Rumex maritimus* residues (5): No residues: 0 t ha^{-1} (R_1), *R. maritimus* residues @ 1.0 t ha^{-1}(R_2), *R. maritimus* residues @ 2.0 t ha^{-1}(R_3), *R. maritimus* residues @ 3.0 t ha^{-1}(R_4), Two Hand weeding @ 20 DAT and 35 DAT (R_5).

Collection and Preparation of Residues

R. maritimus (Gang Palang) residues were used in this study. The residues were collected from Agronomy field laboratory, BAU at their vegetative stage. After collection, the residues were dried under shade in the covered threshing floor. The residues were cut to small pieces by using a sickle.

Preparation of seedling nursery bed and seed sowing

A designated area of land was chosen to cultivate seedlings. The field was first leveled with a ladder and then thoroughly puddled with a country plough. On December 20, 2018, the sprouted seeds were planted in three distinct nursery beds, and great care was taken to raise the healthy seedlings there. In the nursery bed, weeds were pulled and irrigation was applied as needed.

Preparation of the experimental land

The field was prepared on 19 January, 2019. The field was ploughed with a tractor drawn plough followed by laddering. The layout of the field was made after final land preparation. Weeds and stubbles were removed and cleaned from individual plots.

Fertilizer application

The experimental plots were fertilized with Urea, Triple Super Phosphate, Muriate of potash and Gypsum @ 210, 120, 120 and 100 kg ha^{-1}, respectively. The entire amount of Triple Super Phosphate, Muriate of Potash, Gypsum and Zinc Sulphate were applied at the time of final land preparation. Urea was applied in three equal installments at 15, 30 and 45 days after transplanting (DAT).

Application of *R. maritimus* residues

R. maritimus residues were applied at 7 days before transplanting of rice at the time of final land preparation. After that crop residues were mixed well to the respective plots by a spade.

Transplanting of seedlings

Thirty-seven days old seedlings were transplanted in the well-prepared puddled field on 26 January at the rate of three seedlings hill^{-1} maintaining row and hill distance of 25 cm and l5 cm, respectively.

Sampling, Harvesting and Processing of Rice

The crops were harvested at full maturity. Maturity of crops was determined when 90% of the grains became golden yellow in color. BRRI dhan58 and BRRI dhan74 were harvested on 20 and 15 May 2019 respectively. Then the harvested crops of each plot were bundled separately, properly tagged and brought to threshing floor. The crops were then threshed and the fresh weights of grain and straw were recorded from an area of l m^2 in the middle of each plot. The grains were cleaned and finally the weight was adjusted to a moisture content of 14%. The straw was sun dried and the yields of grain and straw yield were recorded and converted to t ha^{-1}.

Collection of data

Data on yield and yield contributing characters were recorded from five randomly selected sample plants from each plot on the following parameters. Plant height (cm), Number of total tillers hill^{-1}, Number of effective tillers hill^{-1}, Number of non-effective tillers hill^{-1}, Panicle length (cm), Number of grains panicle^{-1}, 1000-grain weight (g), Grain yield (t ha^{-1}), Straw yield (t ha^{-1}), Biological yield (t ha^{-1}), Harvest index (%)

Harvest index (%)

Harvest index is the relationship between grains yields and biological yield.

Harvest index was calculated by using the following formula:

$$\text{Harvest index (\%)} = \frac{\text{Grain yield}}{\text{Biological yield}} \times 100$$

Here, Biological yield= Grain yield+ straw yield

Statistical analysis

The data were compiled and tabulated in proper form and subjected to statistical analysis. Analysis of variance was done with the help of computer package MSTAT-C program. The mean differences among the treatments were adjudged by Duncan's Multiple Range Test (DMRT) as laid out by Gomez and Gomez (1984) [10].

Results and Discussion

Yield and Yield Contributing Characters at Harvest

Effect of variety

The plant height varied significantly between the varieties. The tallest plant (119.21 cm) was observed in BRRI dhan74 and the shortest plant (117.08 cm) was observed in BRRI dhan58 (Fig. 1A). Plant height is a varietal character and it is the genetic constituent of the cultivar, therefore, plant height was different among the varieties. The results are consistent with the findings of Bisne *et al*. (2006) [5] who observed plant height differed significantly among the varieties. Effect of variety on number of total tillers hill^{-1} was significant at 1% level of probability. The highest number of total tillers hill^{-1} (12.80) was found in BRRI dhan74 and the lowest number of total tillers hill^{-1} was found in BRRI dhan58 (12.49) variety (Fig. 1B). Effect of variety on number of effective tillers hill^{-1} was significant at 1% level of probability. The highest number of effective tillers hill^{-1} (11.61) was found in BRRI dhan74 and the lowest number of effective tillers hill^{-1} was found in BRRI dhan58 (11.36) variety (Fig. 1C). The highest panicle length (22.26 cm) was found in BRRI dhan58 and the lowest panicle length was found in BRRI dhan74 (21.78 cm) variety (Fig. 1D). Similar results were also observed by Mia *et al*. (2023) [19]. Variety showed significant effect on number of grains panicle^{-1} at 1% level of probability. The highest number of grains panicle^{-1} (115.00) was observed in BRRI dhan74 and the lowest one (109.27) was found in BRRRI dhan58 variety (Fig. 1E).

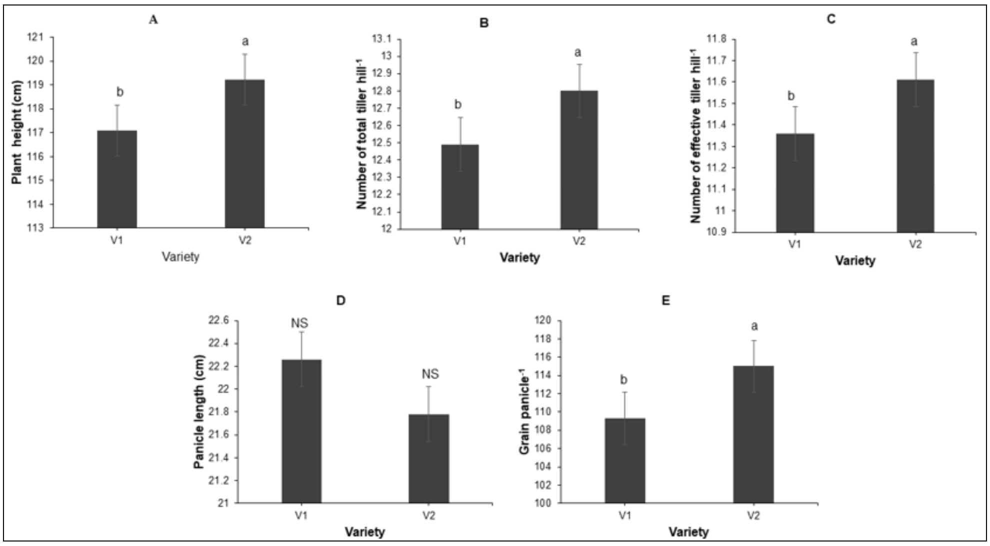

Fig 1: Effect of variety on different parameters. Means with the same letter do not differ significantly whereas figures with dissimilar letter differ significantly. V_1= BRRI dhan58, V_2= BRRI dhan74.

All the varieties under study were significant for their 1000-grain weight. The highest thousand grain weight (24.71 g) was found in BRRI dhan74 variety and the lowest one was found (23.94 g) in BRRI dhan58 (Fig. 2A). The studied variety differed significantly in respect of grain yield. The highest grain yield (5.42 t ha^{-1}) was obtained in BRRI dhan74, the increased yield might be due to the highest number of grains panicle^{-1} and the lowest grain yield (5.15 t ha^{-1}) was obtained in BRRI dhan58 variety (Fig. 2B). This difference was observed due to different varietal characteristics of rice plant. BRRI (2005) [6] also reported variation in grain yield among the varieties. Straw yield was significantly influenced by two varieties. The highest straw yield (6.71 t ha^{-1}) was found in BRRI dhan74 variety and the lowest straw yield (6.51 t ha^{-1}) was found in BRRI dhan58 variety (Fig. 2C). These results are in conformity with that obtained by Chowdhury *et al*. (1993) [7] who reported the differences in straw yield among the varieties. Biological yield had significant effect on variety. The highest biological yield (12.13 t ha^{-1}) was found in BRRI dhan74 and the lowest biological yield (11.67 t ha^{-1}) was found in BRRI dhan58 (Fig. 2D). There was significant difference in the effect of variety in respect of harvest index. The highest harvest index (44.47%) was found in BRRI dhan74 and the lowest one (43.97%) was observed in BRRI dhan58 variety (Fig. 2E). Similar results were also observed by Farhat *et al*. (2023) [8].

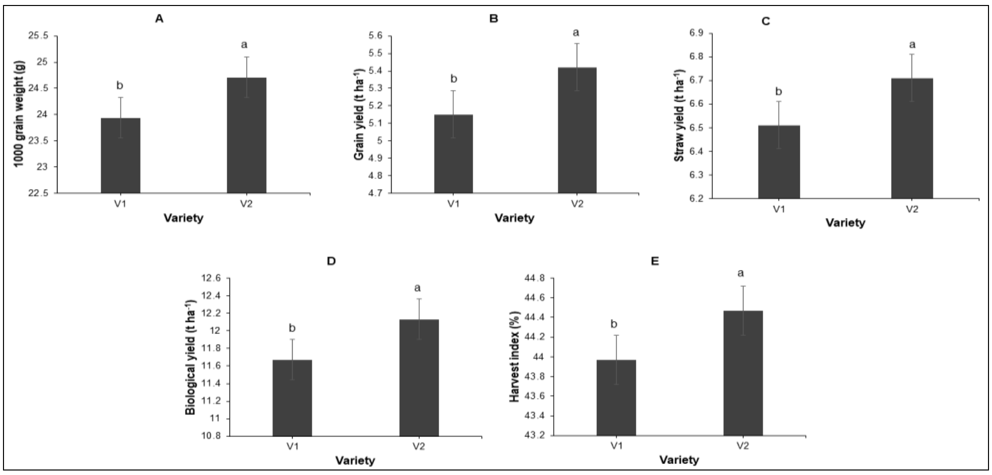

Fig 2: Effect of variety on different parameters. Means with the same letter do not differ significantly whereas figures with dissimilar letter differ significantly. V_1= BRRI dhan58, V_2= BRRI dhan74

Effect of *R. maritimus* residues

Plant height was significantly affected by *R. maritimus* residues. The tallest plant (125.48 cm) was found in R4 treatment and the shortest plant (109.42 cm) was found in R_1 treatment (Fig. 3A). The results revealed that *R. maritimus* residues @ 3 t ha^{-1} treatment produced the highest plant height. This might be residual effect on weed and lowest was found at 0 t ha^{-1}. Number of total tillers hill^{-1} was significantly influenced by *R. maritimus* residues. The highest number of total tillers hill^{-1} (14.46) was produced by R4 treatment and the lowest number of total tillers hill^{-1} (11.47) was produced by R1 treatment (Fig. 3B). Number of effective tillers hill^{-1} was significantly influenced by *R. maritimus* residues. The highest number of effective tillers hill^{-1} (13.28) was produced by R4 treatment and the lowest number of effective tillers hill^{-1} (10.35) was produced by R1 treatment (Fig. 3C). Panicle length (cm) was significantly influenced by *R. maritimus* residues. The highest panicle length (22.91 cm) was produced by R_4 treatment and the lowest panicle length (21.24 cm) was produced by R1 treatment (Fig. 3D). The number of grains panicle^{-1} was significantly influenced by *R. maritimus* residues. The highest number of grains panicle^{-1} (130.68) was produced by R_4 treatment while the lowest number of filled grains (93.52) was produced by R_1 treatment (Fig. 3E).

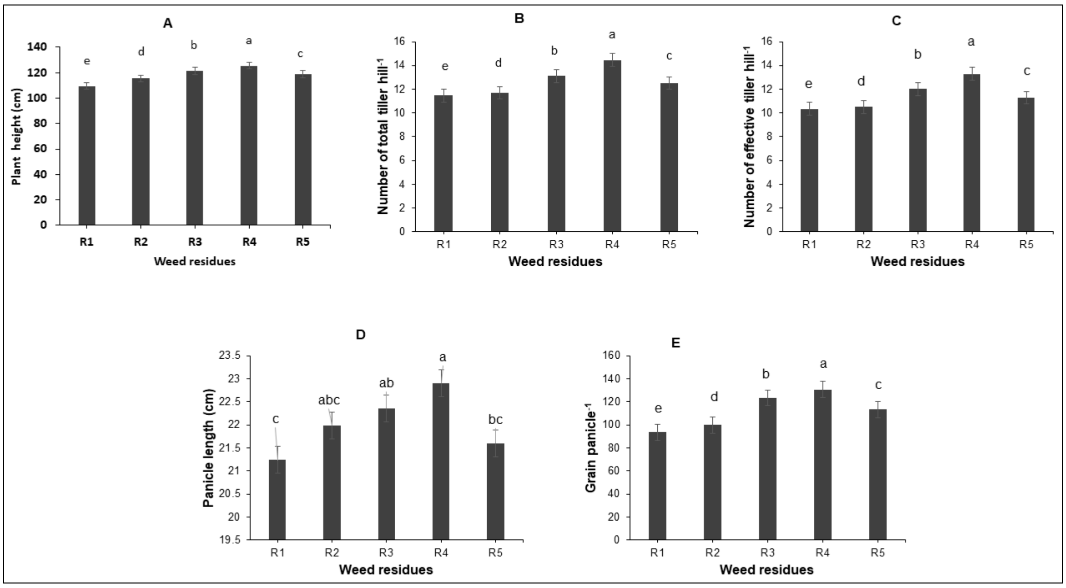

Fig 3: Effect of *R. maritimus* residues on different parameters. Means with the same letter do not differ significantly whereas figures with dissimilar letter differ significantly. $R_{1=}$ No residues: 0 t ha^{-1}, $R_{2=}$ *R. maritimus* residues @ 1.0 t ha^{-1}, $R_{3=}$ *R. maritimus* residues @ 2.0 t ha^{-1}, $R_{4=}$ *R. maritimus* residues @ 3.0 t ha^{-1}, $R_{5=}$ Two Hand weeding @ 20 DAT and 35 DAT

1000-grain weight was significantly affected by *R. maritimus* residues. The highest weight of 1000-grains (26.52 g) were recorded in R_4 treatment and the lowest number of 1000-grains weight (22.42 g) was produced by R_1 treatment (Fig. 4A). Grain yield was significantly influenced by *R. maritimus* residues. The highest grain yield (6.59 t ha^{-1}) was produced by R_4 (*R. maritimus* residues @ 3.0 t ha^{-1}) treatment while the lowest grain yield (3.81 t ha^{-1}) was produced by R_1 (no residues) treatment (Fig. 4B). Islam *et al*, (2024) [13] also reported the similar phenomenon. The weeds compete with the crop for nutrient, water, air, sunlight and space. The increased yield was contributed in infestation of less weed condition by higher number of effective tiller hill^{-1}, higher number of grains panicle^{-1} over no weeding treatment. These might be due to the fact that the *R. maritimus* residues kept the rice field less weed infestation and soil was well aerated which facilitated the crop for absorption of greater amount of plant nutrients, moisture and greater reception of solar radiation for better growth. Straw yield was significantly influenced by *R. maritimus* residues. The highest straw yield (7.99 t ha^{-1}) was observed in R_4 (*R. maritimus* residues 3.0 t ha^{-1}) and the lowest straw yield (5.35 t ha^{-1}) was observed in R_1 (no residues) treatment (Fig. 4C). *R. maritimus* residues had significant influence on biological yield. The highest biological yield (14.58 t ha^{-1}) was obtained in R_4 treatment and the lowest biological yield (9.17 t ha^{-1}) was obtained in R_1 treatment (Fig. 4D). Variations in biological yield among the weed control treatment were dependent upon the severity of weed infestation and climatic condition. Higher weed infestation not only reduced and finally influenced straw yield as well as biological yield. Harvest index was significantly influenced by *R. maritimus* residues. The highest harvest index (45.23%) was observed in R_4 (*R. maritimus* residues @ 3.0 t ha^{-1}) treatment and the lowest harvest index (41.58%) was obtained in R_1 (no residues) treatment (Fig. 4E).

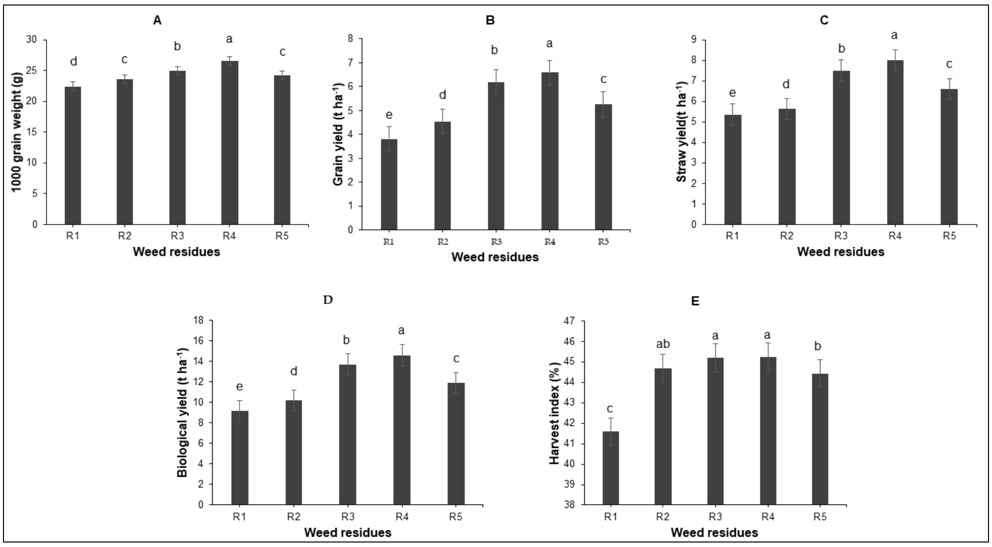

Fig 4: Effect of *R. maritimus* residues on different parameters. Means with the same letter do not differ significantly whereas figures with dissimilar letter differ significantly. R_1= No residues: 0 t ha^{-1}, R_2= *R. maritimus* residues @ 1.0 t ha^{-1}, R_3= *R. maritimus* residues @ 2.0 t ha^{-1}, R_4= *R. maritimus* residues @ 3.0 t ha^{-1}, R_5= Two Hand weeding @ 20 DAT and 35 DAT

Effect of interaction between variety and *R. maritimus* residues

The plant height was significantly affected by interaction between variety and *R. maritimus* residues at 1% level of provability. The tallest plant (126.50 cm) was obtained from BRRI dhan74 in *R. maritimus* residues 3 t ha^{-1} treatment and the shortest plant (108.30 cm) was obtained from BRRI dhan58 in *R. maritimus* residues 0 t ha^{-1} treatment (Table 1). Significant variation was found in number of total tillers hill^{-1} due to interaction between variety and *R. maritimus* residues. The highest number of total tillers hill^{-1} (14.49) was produced by BRRI dhan74 and *R. maritimus* residues 3.0 t ha^{-1} combination, while the lowest number of total tillers hill^{-1} (11.18) was found from BRRI dhan58 with no residue's combination (Table 1). Significant variation was found in number of effective tillers hill^{-1} due to interaction between variety and *R. maritimus* residues. The highest number of effective tillers hill^{-1} (13.34) was produced by BRRI dhan74 and *R. maritimus* residues 3.0 t ha^{-1} combination, while the lowest number of effective tillers hill^{-1} (10.10) was found from BRRI dhan58 with no residue's combination (Table 1). Non-significant variation was found in panicle length (cm) due to interaction between variety and *R. maritimus* residues. The highest panicle length (23.09 cm) was produced by BRRI dhan74 and *R. maritimus* residues @ 3.0 tha^{-1} combination, while the lowest panicle length (20.62 cm) was found from BRRI dhan74 with no residue's combination (Table 1). There was significant difference in the number of grains panicle^{-1} due to interaction between varieties and *R. maritimus* residues. Numerically, the highest number of grains (133.37) was produced in BRRI dhan74 with *R. maritimus* residues @ 3.0 t ha^{-1} (V_2R_4) treatment and the lowest number of grains panicle^{-1} (90.70) was produced in BRRI dhan58 with no residues (V_1R_1) treatment (Table 1). There was significant difference in the weight of 1000-grains due to interaction between variety and *R. maritimus* residues. The highest weight of 1000-grains (26.87 gm) was recorded in BRRI dhan74 with *R. maritimus* residues @ 3.0 t ha^{-1} (V_2R_4) treatment and the lowest weight of 1000-grains (21.99gm) was recorded in BRRI dhan58 with no residues (V_1R_1) (Table 1). Grain yield was significantly influenced by the interaction between variety and *R. maritimus* residues. The highest number of grain yield **(**6.75 t ha^{-1}) was produced in BRRI dhan74 with *R. maritimus* residues (V_2R_4) @ 3.0 t ha^{-1}) combination and the lowest number of grain yield (3.65 t ha^{-1}) was produced in BRRI dhan58 with no residues (V_1R_1) combination (Table 1). The lowest grain yield ha^{-1} in the no use of residues might be due to the poor performance of yield contributing characters like number of tillers hill^{-1} and grain panicle^{-1}. Because severe weed infestation occurred in the plots and competition for moisture, nutrients between weed and rice plants. Similar results were also observed by Gogoi *et al*. (2000) [9]; Islam (2001) [15]; Attalla and Kholosy (2002) [1]. Straw yield was significantly influenced by the interaction between variety and *R. maritimus* residues. The highest straw yield (8.02 t h a^{-1}) was produced in BRRI dhan74 with *R. maritimus* residues @ 3.0 t ha^{-1} (V_2R_4) treatment and the lowest straw yield (5.21 t ha^{-1}) was produced in BRRI dhan58 with no residues treatment (V_1R_1) (Table 1). Biological yield was significantly influenced by the interaction between variety and *R. maritimus* residues. The highest biological yield (14.77 t ha^{-1}) was produced in BRRI dhan74 with *R. maritimus* residues @ 3.0 t ha^{-1} (V_2R_4) treatment combination and the lowest biological yield **(**8.87 t ha^{-1}) was produced in BRRI dhan58 with no residues (V_1R_1) treatment combination (Table 1). The harvest index was not significantly influenced by the interaction between variety and *R. maritimus* residues. The highest harvest index (45.69%) was observed in BRRI dhan74 with *R. maritimus* residues @ 3.0 t ha^{-1}(V_2R_4) combination and the lowest harvest index (41.21%) was observed in BRRI dhan58 with no residues combination (V_1R_1) (Table 1).

Table 1: Interaction effect of variety and residues on yield and yield contributing characters at harvest

Interaction	Plant height (cm)	Number of total tiller hill^{-1}	Number of effective tiller hill^{-1}	Number of non-effective tiller hill^{-1}	Panicle length (cm)	Grain panicle^{-1}	Number of sterile spikelets	1000 grain weight (g)	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
V_1R_1	108.30g	11.18h	10.10g	1.08	21.85	90.70g	15.3	21.99f	3.65i	5.21g	8.87j	41.21c
V_1R_2	113.29f	11.44g	10.28f	1.16	22.4	97.81ef	15.25	23.36e	4.45g	5.53f	9.99h	44.58b
V_1R_3	120.39cd	12.99c	11.97b	1.02	21.99	119.29c	16.24	24.66cd	6.05c	7.44b	13.50d	44.85ab
V_1R_4	124.44ab	14.42a	13.21a	1.21	22.73	127.99b	12.14	26.18ab	6.43b	7.95a	14.39b	44.70ab
V_1R_5	118.97de	12.43d	11.27c	1.16	22.32	110.55d	15.97	23.51e	5.16e	6.43d	11.59f	44.52b
V_2R_1	110.53g	11.75f	10.60e	1.15	20.62	96.34f	14.62	22.85ef	3.97h	5.50f	9.47i	41.96c
V_2R_2	117.61e	11.96e	10.74d	1.21	21.59	101.96e	14.95	23.75de	4.65f	5.74e	10.39g	44.77ab
V_2R_3	122.40bc	13.22b	12.07b	1.14	22.73	127.44b	15.66	25.25bc	6.33b	7.55b	13.89c	45.61a
V_2R_4	126.50a	14.49a	13.34a	1.15	23.09	133.37a	11.34	26.87a	6.75a	8.02a	14.77a	45.69a
V_2R_5	118.99de	12.59d	11.31c	1.27	20.87	115.90c	16.05	24.84c	5.39d	6.77c	12.16e	44.34b
LSD (0.05)	2.42	0.20	0.14	0.18	1.42	4.83	4.74	0.94	0.17	0.19	0.27	1.03
Level of Significance	**	**	**	NS	NS	**	NS	**	**	**	**	**
CV%	1.20	0.94	0.71	8.95	3.75	2.51	18.71	2.25	1.87	1.74	1.31	1.35

In a column, means with the same letter do not differ significantly whereas figures with dissimilar letter differ significantly. ** = Significant at 1% level of probability, *= Significant at 5% level of probability. $V_{1=}$ BRRI dhan58, $V_{2=}$ BRRI dhan74, $R_{1=}$ No residues: 0 t ha^{-1}, $R_{2=}$ *R. maritimus* residues @ 1.0 t ha^{-1}, $R_{3=}$ *R. maritimus* residues @ 2.0 t ha^{-1}, $R_{4=}$ *R. maritimus* residues @ 3.0 t ha^{-1}, $R_{5=}$ Two Hand weeding @ 20 DAT and 35 DAT.

Conclusion

From the above results it was found that the variety BRRI dhan74 treatment exhibited the superior effect followed by R_4 treatment (3.0 t ha^{-1} *R. maritimus* residues). Results of the study showed that application of *R. maritimus* residues for *boro* rice may reduce weed and it has positive effect on yield for most of the weed traits. It also shows that *R. maritimus* residue has herbicidal activity for suppressing weed growth. Therefore, *R. maritimus* residues could be a prospective source of weed management tool for crop production in modern agriculture.

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