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RESEARCH

Effect of Golden Dock (*Rumex maritimus*) Residues on Weed Growth Performance of *Boro* Rice (cv. BRRI dhan58 and BRRI dhan74)

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Abstract

Allelopathy plays an important role in weed control and crop productivity. We evaluated the effect of the residues of *Rumex maritimus* on the growth performance of *boro* rice comprising 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 and a farmers practice. The experiment was laid out in a randomized complete block design (RCBD) with three replications. We identified four weed species (Panikachu, Shama, Shusni, Chesra) belonging to four families. Dry weight of Shama, Shusni, Chesra except Panikachu were significantly affected by variety. The highest Shama dry weight (6.61 g/0.0625 m^2) was found in BRRI dhan74 and the lowest weed population (5.81 g/0.0625 m^2) was obtained in BRRI dhan58 at 1% level of probability and also the highest Chesra dry weight (5.58 g/0.0625 m^2) was found in BRRI dhan74 and the lowest weed population (4.89g/0.0625 m^2) was obtained in BRRI dhan58 at 1% level of probability. The highest Shusni dry weight (5.11 g/0.0625 m^2) was found in BRRI dhan58 and the lowest weed population (5.00 g/0.0625 m^2) was obtained in BRRI dhan74 at a 1% level of probability. Weed density and dry weight were also significantly affected by variety and residue treatment. Results of this study indicate that *R. maritimus* residues showed the potential to inhibit weed growth of *boro* rice. Therefore, *R. maritimus* residues might be used as an alternative way for weed management in effective and sustainable crop production.

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Statement of Sustainability: The study on *R. maritimus* residues in *boro* rice cultivation demonstrated significant inhibition of weed growth, particularly affecting weed density and dry weight. By reducing the reliance on chemical herbicides, this natural approach promotes environmentally friendly practices. The successful suppression of weeds like Shama, Shusni, and Chesra suggests that *R. maritimus* residues can be an effective and sustainable alternative for weed management. This method supports sustainable agriculture by maintaining soil health, and biodiversity, and reducing chemical inputs, thereby contributing to more effective and sustainable crop production practices.

1. Introduction

Bangladesh is a country that emphasizes agriculture and agronomy. Intensive crop production and a rice-based cropping system are the main characteristics of Bangladesh's agricultural sector. Agriculture contributes roughly 13.47% of the nation's GDP overall (BBS, 2020a). Bangladesh's agricultural productivity is low in comparison to other rice-growing countries. A major factor contributing to Bangladesh's exceptionally low rice production is a severe weed infestation. Although *boro* rice is the largest crop (3.96 Mt/ha) and makes up about 41.71% of the country's total rice area (BBS, 2020b), weeds reduced the grain yield of *boro* rice by 22–36%. The term allelopathy was first used by plant physiologist Hans Molisch of the University of Vienna, Austria. It comes from the Greek words "allelon," which means "to each other," and "pathos," which means suffering. Pathos can be used to characterize both positive (sympathetic) and negative (pathetic) interactions because it also means feeling or sensitive (Gross, 1999). Allelopathy is a branch of biology in which a single plant releases compounds called allelochemicals, which prevent the growth of surrounding plants (Islam et al., 2024). Metabolic interaction between distinct plant species is another definition of allelopathy. The main characteristic of this material is that it contains chemical components, secondary metabolites, and allelopathic chemicals, which are mostly used as carriers of information (Klejdus and Kuban, 1999). Allelopathy has gained a significant lot of attention because it has been discovered that certain rice cultivars have allelopathic action in suppressing weeds (Farhat et al., 2023).

Rumex maritimus is widespread in Southeast Asia. On the margins of water reservoirs, lakes, rivers, and ponds, the species *R. maritimus* grows as an upright, sturdy plant up to 0.5-1.2 m tall. It has been reported that the leaves and seeds of *R. maritimus* have pharmacological properties. Astringent, carminative, antibacterial, and aphrodisiac properties are among the properties of the seeds. The seeds are used as a tonic and to ease pain in the lumbar region of the back, while the leaves are applied on burns (Basu and Kirtikar, 1980). There have been reports of several biological characteristics of *R. maritimus*, but no experiments have been carried out to test its allelopathic potential. Therefore, the goal of the current study is to determine how well *boro* rice can reduce weed growth when exposed to *R. maritimus* residues.

2. Materials and Methods

2.1. Experiment Site and Design

Geographically the experimental site is located at 24°75' N latitude and 90°50' E longitude at an elevation of 18 m above sea level. The site belongs to the non-calcareous dark gray floodplain soil under the Old Brahmaputra Floodplain Agro-ecological Zone (AEZ 9) (UNDP and FAO, 1988). The experiment was laid out in a randomized complete block design (RCBD) with three replications. The total number of plots was 30. Each plot size was (2.5 × 2 m). The agroclimatic conditions during the research period are displayed in Figure 1. The majority of the silty loam soils at the experimental site are dark grey, rather sterile, and have a low organic matter level (Table 1).

2.2. Experimental Treatments

The experimental treatment consisted of two factors 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 (R_1), *R. maritimus* residues @ 1.0 t/ha (R_2), *R. maritimus* residues @ 2.0 t/ha (R_3), *R. maritimus* residues @ 3.0 t/ha (R_4), Two Hand weeding @ 20 DAT and 35 DAT (R_5).

2.3. Collection and Preparation of Residues

R. maritimus residues were used in this study. The residues were collected from the Agronomy field laboratory, BAU at their vegetative stage. Geographically the experimental site is located at 24°75' N latitude and 90°50' E longitude at an elevation of 18 m above sea level. After collection, the residues were dried under shade on the covered threshing floor. The residues were cut into small pieces by using a sickle.

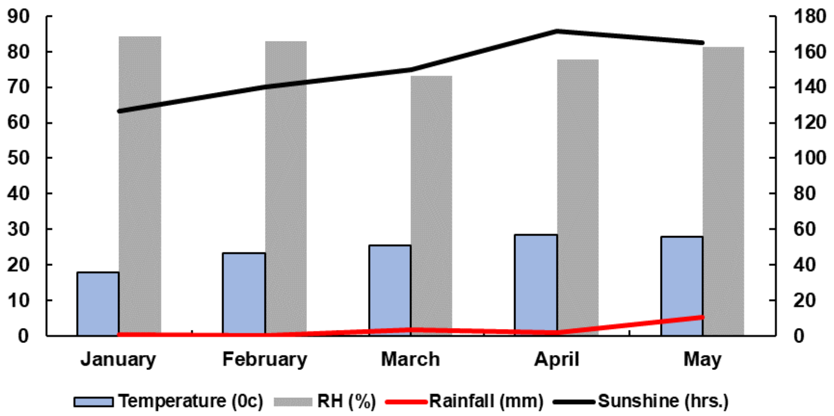

Figure 1. Distribution of monthly average air temperature relative humidity, rainfall, and sunshine hours of the experiment site during the period from January to May 2023.

Table 1. Physical and chemical properties of the experimental field.

Properties	Value
Physical	
Particle size analysis	2.57
Bulk density (g/cc)	1.42
Porosity (%)	44.7
Sand (%) (0.0-0.02 mm)	21.75
Silt (1%) (0.02-0.002 mm)	66.60
Clay (%) (<0.002 mm)	11.65
Soil textural class	Silt loam
Color	Dark grey
Consistency	Grounder
Chemical composition of the initial soil (0-15 cm depth)	
Soil pH	6.5
Organic matter (%)	1.30
Total nitrogen (%)	0.101
Available phosphorus (ppm)	27
Exchangeable potassium (me%)	0.12
Available sulphur (ppm)	22.7

Source: Department of Soil Science, Bangladesh Agricultural University, Bangladesh.

2.4. Preparation of Seedling Nursery Bed and Seed Sowing

A piece of land was selected for raising seedlings. The land was puddled well with country plow followed by leveling with a ladder. The sprouted seeds were sown in three different nursery beds on 20 December 2022. Care was taken to raise the healthy seedlings in the nursery bed. Weeds were removed and irrigation was given in the nursery bed as and when necessary.

2.5. Preparation of the Experimental Land

The field was prepared on 19 January 2023. The field was plowed with a tractor-drawn plow followed by laddering. The layout of the field was made after the final land preparation. Weeds and stubbles were removed and cleaned from individual plots.

2.6. Fertilizer Application

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

2.7. Application of *Rumex maritimus* Residues

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

2.8. Uprooting and Transplanting of Seedlings

The nursery bed was made wet by the application of water one day before uprooting the seedlings. The seedlings were uprooted on 26 January 2023, and they were immediately transferred to the main field. Healthy and similar-sized seedlings were selected for transplanting. 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.

2.9. Weed Population

Data on weed population were collected from each plot of the rice plants by using 0.25 × 0.25 m quadrate as per the method described by Cruz et al. (1986). The weeds within the quadrate were counted accordingly.

2.10. Weed Dry Weight

After counting the weeds all, the weeds inside each quadrate were uprooted, cleaned, separated species-wise, and dried first in the sun and then in an electric oven for 72 hours at a temperature of 80°C. The dry weight of each species was taken by an electric balance.

2.11. Statistical Analysis

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

3. Results and Discussion

3.1. Infested Weed Species in Experimental Field

The main crop that is widely grown in Bangladesh is rice, and the yield of transplant boro rice in our nation is significantly lower than in other nations. Four weed species belonging to four families infested the experimental field. The local name, scientific name, family, morphological type, and life cycle of the weed in the experimental plot have been presented in Table 2. The weeds of the experimental plots were *Monochoria vaginalis, Echinochloa crusgalli*, *Marsilea quadriflia*, and *Scirpus juncoides*. Parvez et al. (2013) reported that eight weed species belonging to five families infested the experimental field. Among the eight species of weeds, three were grasses, three were broad leaves and two were sedges. The important weeds of the experimental plots were *Paspalum scrobiculatum, Echinochloa crusgalli, Leersiahexandra, Oxalis europaea, Monochoria vaginalis, Ludwigia hyssopifolia, Cyperus difformis*, and *Scirpus juncoides* According to Bari et al. (1995), *Echinochloa crusgalli*, *Cyperus difformis*, and *Scirpus juncoides* were the three major weeds in rice fields, according to an experiment conducted at Bangladesh Agricultural University.

Table 2. Infested weeds species found in the experimental field of rice.

Local Name	Scientific Name	Family	Morphological type	Life cycle
Panikachu	*Monochoria vaginalis*	Pontederiaceae	Broad-leaved	Perennial
Shama	*Echinochloa crusgalli*	Poaceae	Grass	Annual
Shusni	*Marsilea quadriflia*	Marsileaceae	Grass	Annual
Chesra	*Scirpus juncoides*	Cyperaceae	Sedge	Annual

3.2. Weed Density

3.2.1. Effect of Variety

Weed density of Panikachu was non-significantly affected by variety. Shama, Shusni, and Chesra were significantly affected by variety. The highest Chesra weed density (5.18) was found in BRRI dhan74 and the lowest Shusni weed population (3.53) was obtained in BRRI dhan58 (Figure 2). The results show that, in contrast to Panikachu, the rice variety has a considerable impact on the weed densities of Shama, Shusni, and Chesra. Due to its unique development conditions or competitive advantages, BRRI dhan74 may be more vulnerable to Chesra infestation, as indicated by the increased Chesra density in this variety. In contrast, BRRI dhan58's reduced Shusni density suggests that this variety has a stronger suppressive effect on Shusni weeds, maybe as a result of its allelopathic or growth features. The significance of choosing suitable rice cultivars for efficient weed control in rice paddies is underscored by these results. To create integrated weed control techniques, more research could examine the mechanisms underlying these varietal differences. The effectiveness of allelopathic application approaches depends on environmental factors and appropriate weed management strategies, according to Hossain et al. (2024) and Cheema et al. (2013). These applications have the natural potential to reduce weed growth in addition to their ability to significantly reduce weeds.

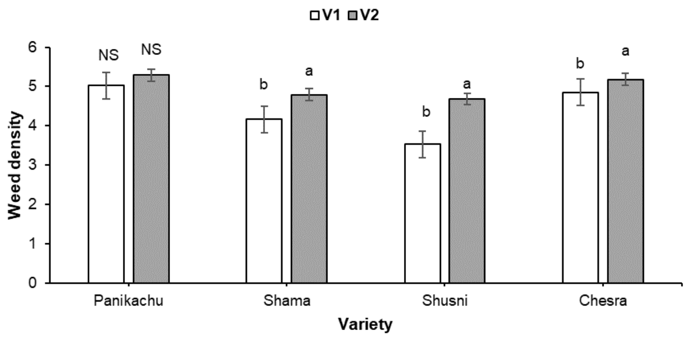

Figure 2. Effect of variety on weed density. V_1=BRRI dhan58, V_2=BRRI dhan74.

3.2.2. Effect of *R. maritimus* Residues

Weed density of Panikachu, Shama, Shusni, and Chesra was significantly affected by *R. maritimus* residues. The highest Chesra weed density (7.67) was found in the R_1 treatment and the lowest weed density was found (2.34) in the R_5 treatment. The highest Panikachu weed density (6.98) was found in the R_1 treatment and the lowest (3.16) was found in the R_5 treatment. In the case of Shama, the highest weed density (6.88) was found in the R_1 treatment, and the lowest weed density was found (2.24) in the R_5 treatment. In the case of Shusni, the highest weed density (6.04) was found in the R_1 treatment, and the lowest (2.32) was found in the R_5 treatment (Figure 3). The findings demonstrate that Panikachu, Shama, Shusni, and Chesra weed densities are considerably impacted by *R. maritimus* residues. The R_1 treatment had the highest weed densities for all four species, suggesting that *R. maritimus* residues may initially encourage weed development. On the other hand, the R_5 treatment consistently had the lowest weed densities, indicating a suppressive impact at greater residue levels. This trend suggests that one important aspect of managing *R. maritimus* residues may be weed population control. More research into the precise mechanisms underlying this suppression may aid in improving residue management strategies for more successful weed control. This result is in agreement with the findings of Salam (2020).

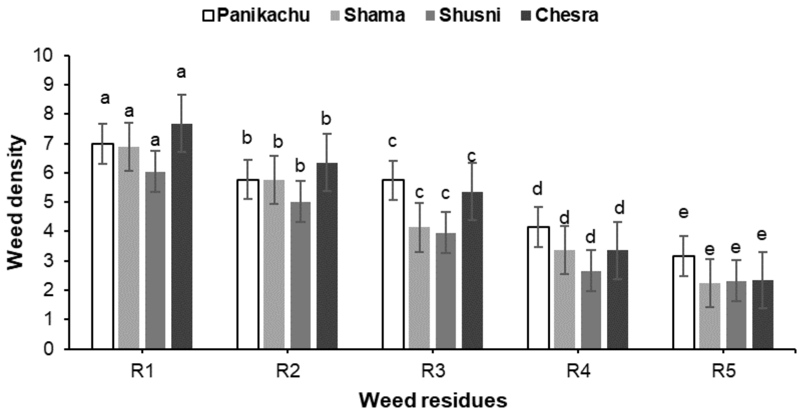

Figure 3. Effect of *R. maritimus* residues on weed density. R_1=0 t/ha, R_2=1 t/ha, R_3=2 t/ha, R_4=3 t/ha, R_5= Farmers practice.

Table 3. Effect of interaction of variety and *R. maritimus* residues on weed density.

Interaction	Weed density			
	Panikachu	Shama	Shusni	Chesra
V_1R_1	6.52ab	6.17b	5.58b	7.49a
V_1R_2	5.51c	4.91c	4.56c	6.14b
V_1R_3	5.65bc	4.01d	3.48d	5.26c
V_1R_4	4.51d	3.50e	2.07f	3.13d
V_1R_5	2.91e	2.21f	1.97f	2.21e
V_2R_1	7.44a	7.59a	6.50a	7.86a
V_2R_2	5.96bc	6.59b	5.47b	6.56b
V_2R_3	5.87bc	4.27d	4.43c	5.44c
V_2R_4	3.78de	3.24e	3.24d	3.60d
V_2R_5	3.41e	2.26f	2.68e	2.47e
$LSD_{(0.05)}$	0.93	0.47	0.39	0.62
Level of Significance	*	**	**	**
CV%	10.45	6.13	5.80	7.23

In a column, figures with the same letter do not differ significantly as per DMRT. ** = Significant at 1% level of probability, * = Significant at 5% level of probability. V_1=BRRI dhan58, V_2=BRRI dhan74, R_1=0 t/ha, R_2=1 t/ha, R_3=2 t/ha, R_4=3 t/ha, R_5= Farmers practice.

3.2.3. Effect of Interaction Between Variety and *R. maritimus* Residues

The effect of interaction between variety and *R. maritimus* residues was significantly affected by Panikachu, Shama, Shusni, and Chesra weed density (Table 3). The highest Panikachu weed density (6.52) was found in BRRI dhan58 with R_1 treatment and the lowest (2.91) was found in BRRI dhan58 with R_5 treatment. In the case of Shama the highest weed density (7.59) was found in BRRI dhan74 with R_1 treatment and the lowest (2.21) was found in BRRI dhan58 with R_5 treatment (Table 3). The highest Shusni weed density (6.50) was found in BRRI dhan74 with R_1 treatment and the lowest (1.97) was found in BRRI dhan58 with R_5 treatment. The highest Chesra weed density (7.49) was found in BRRI dhan58 with R_1 treatment and the lowest weed density was found (2.21) in BRRI dhan58 with R_5 treatment. Whatever the variety, the R_1 treatment always had the highest densities of all weeds, indicating that reduced residue levels might encourage weed growth. The combination of BRRI dhan58 and R_5 treatment consistently produced the lowest weed densities, suggesting that this combination is the most efficient at suppressing weed populations. The large interaction impact emphasizes how crucial it is to take residue management and rice variety into account for efficient weed control. To fully comprehend the underlying mechanisms and maximize these interactions for more effective weed management techniques, more research is required. Khanh et al. (2005) observed that the interaction effects of weeding regimes were significant with respect to most of the characters.

3.3. Weed Dry Weight

3.3.1. Effect of Variety

The dry weight of Shama and Shusni was significantly affected by variety but Panikachu was non-significantly affected by variety. The highest Shama dry weight (6.61 g/0.0625 m^2) was found in BRRI dhan74 and the lowest weed population (5.81 g/0.0625 m^2) was obtained in BRRI dhan58 (Figure 4) at a 1% level of probability. The highest Shusni dry weight (5.11 g/0.0625 m^2) was found in BRRI dhan58 and the lowest weed population (5.00 g/0.0625 m^2) was obtained in BRRI dhan74 (Figure 4) at a 1% level of probability. BRRI dhan74 promoted a higher dry weight of Shama, while BRRI dhan58 resulted in a higher dry weight of Shusni, suggesting varietal differences in how they influence weed biomass accumulation. The fact that Panikachu's dry weight was not significantly affected by variety may imply its growth is less influenced by the rice variety used. These findings highlight the potential for selecting specific rice varieties to manage weed biomass effectively. Further research could explore the mechanisms behind these varietal effects on weed dry weight to enhance integrated weed management strategies. Halder et al. (2024) and Uddin and Pyon (2010) observed that rotation crop residues especially hairy vetch and Chinese milk vetch have high herbicidal effects against weeds without inhibiting the growth of crop species.

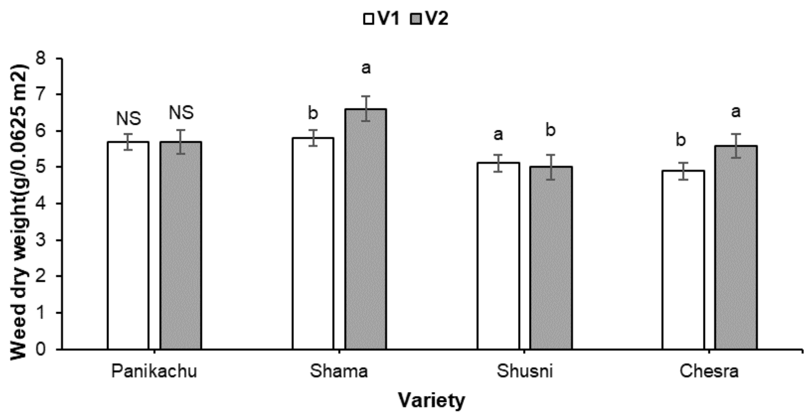

Figure 4. Effect of variety on weed dry weight. V_1=BRRI dhan58, V_2=BRRI dhan74.

3.3.2. Effect of R. maritimus Residues

The dry weight of Panikachu, Shama, Shusni, and Chesra was significantly affected by *R. maritimus* residues at a 1% level of probability. The highest Panikachu dry weight (10.48 g/0.0625 m^2) was found in R_1 treatment and the lowest (1.75 g/0.0625 m^2) was found in the R_5 treatment. In the case of Shama, the highest dry weight (11.26 g/0.0625 m^2) was found in the R_1 treatment, and the lowest (1.82 g/0.0625 m^2) was found in the R_5 treatment (Figure 5). The highest Shusni dry weight (9.34 g/0.0625 m^2) was found in the R_1 treatment and the lowest (1.47 g/0.0625 m^2) was found in the R_5 treatment and the highest Chesra dry weight (9.56 g/0.0625 m^2) was found in R_1 treatment and the lowest (1.590 g/0.0625 m^2) was found in R_5 treatment (Figure 5). The results reveal that *R. maritimus* residues significantly affect the dry weight of all weed species studied, with the highest biomass recorded in the R1 treatment and the lowest in the R_5 treatment. This trend suggests that lower residue levels (R_1) enhance weed growth, whereas higher residue levels (R_5) provide a more effective suppression of weed biomass. The substantial reduction in dry weight across all species in R_5 indicates its strong suppressive impact, likely due to increased competition or allelopathic effects. These findings highlight the potential of managing *R. maritimus* residues to control weed growth. Future research should focus on optimizing residue application to maximize its benefits for weed management. Bertholdsson (2011) observed the allelopathic effect of wheat on weeds showed a significant effect.

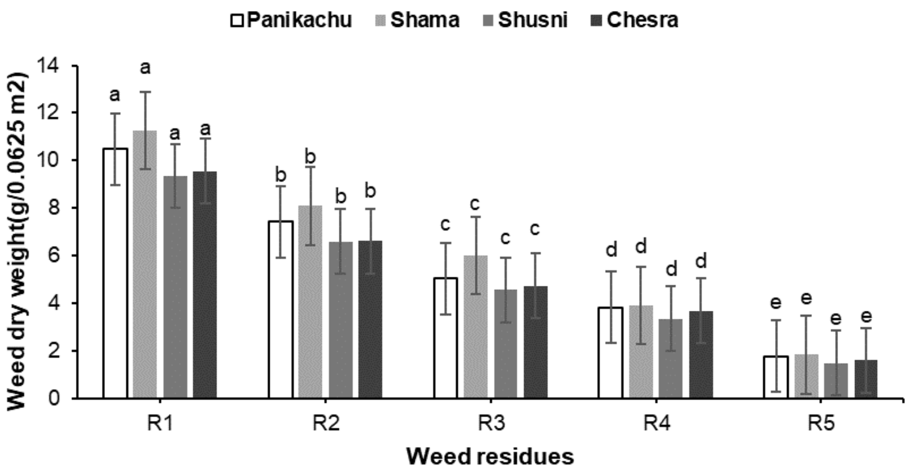

Figure 5. Effect of *R. maritimus* residues on weed dry weight. R_1=0 t/ha, R_2=1 t/ha, R_3=2 t/ha, R_4=3 t/ha, R_5= Farmers practice.

3.3.3. Effect of Interaction Between Variety and R. Maritimus Residues

The effect of interaction between variety and *R. maritimus* residues was significantly affected by Panikachu, Shama, Shusni, and Chesra weed dry weight at a 1% level of probability (Table 4). The highest Panikachu dry weight (10.53 g/0.0625 m^2) was found in BRRI dhan58 with R_1 treatment and the lowest (1.83 g/0.0625 m^2) was found in BRRI dhan74 with R_5 treatment. In the case of Shama, the highest dry weight (11.72 g/0.0625 m^2) was found in BRRI dhan74 with R_1 treatment, and the lowest (1.68 g/0.0625 m^2) was found in BRRI dhan58 with R_5 treatment (Table 4). The highest Shusni dry weight (9.54 g/0.0625 m^2) was found in BRRI dhan58 with R_1 treatment and the lowest (1.43 g/0.0625 m^2) was found in BRRI dhan58 with R_5 treatment. The highest Chesra dry weight (10.69g/0.0625 m^2) was found in BRRI dhan74 with R_1 treatment and the lowest (1.54 g/0.0625 m^2) was found in BRRI dhan58 with R_5 treatment (Table 4). The highest dry weights for all weed species were observed in the R_1 treatment, indicating that lower residue levels can enhance weed biomass. Notably, different rice varieties affected weed growth differently; for instance, BRRI dhan58 with R_1 treatment led to the highest dry weight of Panikachu and Shusni, while BRRI dhan74 with R_1 treatment resulted in the highest dry weight of Shama and Chesra. Conversely, the lowest dry weights were consistently found in the R_5 treatment, highlighting its effectiveness in suppressing weed biomass across varieties. These results suggest that both residue management and rice variety selection are crucial for effective weed control, and optimizing these factors could improve weed management strategies. A similar phenomenon was also reported by Chakrabortty et al. (2014).

Table 4. Effect of interaction of variety and *R. maritimus* residues on Weed dry weight.

Interaction	Weed dry weight			
	Panikachu	Shama	Shusni	Chesra
V_1R_1	10.53a	10.80b	9.54a	8.44b
V_1R_2	7.48b	7.33d	6.64c	6.50d
V_1R_3	4.95e	5.33f	4.63d	4.24f
V_1R_4	3.86f	3.93g	3.34f	3.74g
V_1R_5	1.67h	1.68i	1.43g	1.54h
V_2R_1	10.44a	11.72a	9.13b	10.69a
V_2R_2	7.34c	8.84c	6.53c	6.72c
V_2R_3	5.09d	6.66e	4.48e	5.22e
V_2R_4	3.78f	3.86g	3.33f	3.62g
V_2R_5	1.83g	1.95h	1.52g	1.65h
$LSD_{(0.05)}$	0.12	0.15	0.14	0.19
Level of Significance	**	**	**	**
CV%	1.25	1.46	1.60	2.07

In a column, figures with the same letter do not differ significantly as per DMRT. ** = Significant at 1% level of probability. V_1=BRRI dhan58, V_2=BRRI dhan74, R_1=0 t/ha, R_2=1 t/ha, R_3=2 t/ha, R_4=3 t/ha, R_5= Farmers practice.

4. Conclusion

The study's findings demonstrated that applying *R. maritimus* residues to *boro* rice may help to prevent weed growth while also improving growth for the majority of weed-related attributes. It also demonstrates that *R. maritimus* residue has herbicidal action to inhibit the growth of weeds. For crop production in contemporary agriculture, *R. maritimus* residues may therefore represent a potential supply of weed management tools.

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Data Availability/Sharing: The authors confirm that the data supporting the findings of this study are available within the article (and/or) its supplementary materials.

Supplementary Information Availability: Not applicable.

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