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Research Article

Influence of Grass pea Residues Extract on Weed Control Efficacy and Performance of *Boro* Rice

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ABSTRACT

The agriculture sector is constantly adopting environmentally friendly and sustainable methods to reduce the harmful effects of herbicides on crop production. In this respect, an experiment was conducted at the Agronomy Field Laboratory (AFL), Bangladesh Agricultural University (BAU), Mymensingh to assess the allelopathic effects of grass pea crop residues on weed suppression and the growth performance of *Boro* rice from December 2021 to May 2022. The experiment consisted of four cultivars of *Boro* rice i.e. BAU dhan3, BRRI dhan28, BRRI dhan81, BRRI dhan96 along with four different treatments of weed control viz. no extract and no weeding (control), hot water extract of Grass pea residues as pre-emergence application at 3 DAT (days after transplanting), hot water extract of Grass pea residues as pre-emergence application at 3 DAT+ post- emergence at 10 DAT, hand weeding 3 times at 15, 30 and 45 DAT. The highest weed growth was noticed when no extract was added and the lowest was found when three times hand weeding was performed. The highest number of effective tillers (NET) hill^{-1}, number of spikelets panicle^{-1} (NSP) and grain yield (GY), straw yield (SY) and biological yield (BY) were recorded from the rice variety BAU dhan3. The highest NET hill^{-1}, NSP, 1000-grain weight (TGW), GY, SY and BY were recorded from three hand weeding which was followed by hot water extract of grass pea as pre-emergence application at 3 DAT+ post-emergence application at 10 DAT. From the interaction it is observed that the highest NET hill^{-1}, NSP, SY and BY were obtained from BAU dhan3 with three hand weeding which was followed by BAU dhan3 with hot water extract of grass pea as pre-emergence application at 3 DAT+ post-emergence application at 10 DAT. The findings of this study reveal that hand weeding, followed by the application of grass pea crop residues, effectively suppresses weed growth. Our research suggested leveraging the allelopathy-weed inverse relationship to address weed problems. This approach holds significant promise for weed management in the twenty-first century.

Introduction

In Bangladesh, rice (*Oryza sativa*) is the most important crop and one of the most delicate agricultural goods for both the local and international markets. The most important product's raw material is rice, which is also used to make some food items in the entire country. Rice is the staple food, with an average annual consumption rate per capita of approximately 114.6 kg year^{-1} (Paman et al. 2023). Bangladesh earns about 11.20% of her gross domestic product (GDP) from agriculture (BBS, 2023). Rice is a tropical crop cultivated in almost all parts of Bangladesh. There are three primary growing seasons exist for rice. Among the rice groups grown our country, *boro* rice in particular covers 4.85 million hectares of land with a production of 2076.76 thousand MT year^{-1} (BBS, 2023). Some challenges, such as weed and disease-pest infestations, prevent farmers from producing their maximum crop. For example, weed infestation causes a significant 21–50% drop in rice crop yield (Mostafa et al. 2024). Several weed control techniques are used in rice crops, including chemical, mechanical, and traditional methods. Each type of weed control technique has its own set of drawbacks. For example, hand weeding takes much time and effort and is impractical for larger regions (Khan et al. 2016). Mechanical weeding is usually expensive, making it unaffordable for impoverished farmers. Additionally, the excessive use of herbicides and other chemicals to control weeds in *boro* rice has led to significant environmental degradation and resistance in different types of weeds (Nur-A-Alam

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et al. 2024). Weed control is feasible without herbicides through methods such as crop rotation, cover cropping, mulching, mechanical tillage, hand weeding, and allelochemicals like sorghum, lentil and grass pea residues.

Weed management in rice production necessitates consistent efforts to control weeds. Research has shown that aqueous extracts from various allelopathic plants are effective in managing weeds not only in *boro* rice but also in other crops (Nur-A-Alam et al. 2024; Khan et al. 2015). These plants produce allelochemicals that can significantly curb weed growth in organic farming systems without harming the environment, otherwise environment may be hampered, thereby enhancing crop yields (Soltys et al. 2013). These naturally occurring chemicals are derived from various parts of plants such as the bark, flowers, leaves, roots, root exudates and fruits (Weir et al. 2004). The allelopathic activity of rotational crop residues offers an alternative strategy for weed control and crop selectivity in organic farming. All rotational crop residues effectively suppressed weed growth (Uddin and Pyon, 2010).

Plants can produce a wide variety of chemical compounds such as terpenoids, coumarins, phenolics, steroids, quinines, alkaloids, and tannins. These substances can be released into the soil through volatile emissions, root secretions, or leaching from the plant's aerial parts (Xuan et al. 2005). Mustard, widely cultivated for its seeds, oil, and greens, holds significant agricultural importance due to its potential allelopathic properties. These properties enable mustard to suppress weed growth effectively, making it a valuable crop in sustainable agriculture (Dola et al., 2024).

Previously considered crop residues and wastes are now recognized for their potential to alter soil properties significantly when decomposed, to supply content of potent allelochemicals. Furthermore, numerous studies have demonstrated the induction of phytotoxic effects by plants and their residues on a variety of crops, including major grain crops such as rice, rye, mustard, wheat, sorghum, buckwheat, and others (Sarker et al. 2020; Pramanik et al. 2019; Ahmed et al. 2018; Sheikh et al. 2017; Ferdousi et al. 2017; Uddin et al. 2014; Uddin et al. 2013; Won et al. 2013; Uddin and Pyon, 2010). Effective weed management strategies in Boro rice cultivation include crop rotation to disrupt weed life cycles, planting high-yielding and weed-tolerant rice varieties, and using organic mulching to suppress weed growth. Additionally, integrating cultural practices such as adjusting planting density and irrigation timing can reduce weed pressure. Utilizing natural phytotoxic plant extracts or bio-herbicides can further enhance weed control while minimizing environmental impact. These strategies, combined with periodic manual or mechanical weeding, provide a sustainable and integrated approach to weed management in *Boro* rice cultivation. (Mostafa et al. 2024 and Nur-A-Alam et al. 2024).

Researchers are now placing more emphasis on using various crop residues to inhibit weed development. In Bangladesh, there is relatively little information available on the use of crop residues to control weeds. However, there have only been a few attempts made in Bangladesh to use the allelopathic properties of plant to potentially reduce weeds in the agricultural sector. It is scientifically established; sorghum and mustard successfully compete with weeds in fields (Akondo et al. 2024 and Dola et al. 2024). These point to the grass pea's potential for allelopathy and demonstrate how effective it will be for weed biological control.

Materials and Methods

Description of the experimental site

The experiment was conducted at the Agronomy Field Laboratory (AFL), Bangladesh Agricultural University (BAU), Mymensingh from December 2021 to May 2022. In terms of location, the study is located at a longitude 90°50′ E, latitude 24°25′ N, and elevation 18 m above sea level. The test location is in the Old Brahmaputra floodplain (AEZ-9) (FAO and UNDP, 1988). The climate in this area is classified as a sub-tropical monsoon and characterized by substantial precipitation from April to October and less precipitation from October to March. Prior to the experiment, composite topsoil samples (0-15cm) were collected from the field to analyze and the morphological, chemical and physical features of the soil.

Experimental treatments and design

Two components made up the experimental treatment where four rice varieties, viz. i. BAU dhan3 (V_1), BRRI dhan28 (V_2), BRRI dhan81 (V_3), BRRI dhan96 (V_4) and four grass pea crop residue treatment such as: no extract and no weeding (control) (T_1), hot water extract of Grass pea residues as pre-emergence application at 3 DAT (T_2), hot water extract of Grass pea residues as pre-emergence application at 3 DAT+ post- emergence at 10 DAT (T_3), hand weeding 3 times at 15, 30 and 45 DAT (T_4). The experiment was structured using a Randomized Complete Block Design (RCBD) with three replications. The total number of plots was 48, calculated as 4 varieties × 4 treatments × 3 replications. Each plot measured 2.5 meters by 2.0 meters. A spacing of 0.5 meters was maintained between individual plots, and a distance of 1.0 meter was maintained between replications.

Collection and preparation of experimental materials

In this study, grass pea crop residues were utilized. The crops were cultivated at the AFL, BAU, and harvested at the ripening stage to collect the residues. After collection, these residues were dried under shade on the covered threshing floor at BAU. The residues were finely chopped using a sickle to maximize surface area exposure. Subsequently, the small-sized grass pea crop residues were soaked in water at a ratio of 1:10 (w/v) for 24 hours at ambient room temperature. The mixture was then boiled for 3-4 hours, and a coarse mesh was used to separate the plant residues from the water extract. Seeds of rice varieties BAU dhan3, BRRI dhan28, BRRI dhan81, and BRRI dhan96 were sourced from the AFL at BAU, Mymensingh. Post-collection, a specific gravity technique was employed to select healthy seeds from the gathered cultivars. These seeds were immersed in water in a container for 24 hours, after which they were removed from the water and securely packed in gunny bags. Germination commenced after 48 hours, at which point the seeds were ready for sowing.

Preparation of plots and crop husbandry

A plot of land was designated for seedling cultivation. Initially, the land was thoroughly puddled using a tractor and subsequently leveled with a ladder. The entire area was divided into two equal parts for planting germinated seeds. On December 5, 2021, the germinated seeds were sown in a wet nursery bed. Meticulous care was administered to ensure the robust growth of seedlings, including regular weeding and as-needed irrigation. The field was first opened using a power tiller and then plowed four times with a tractor, followed by laddering to prepare the land. After this final land preparation, the layout of the field was established, with weeds and stubble being removed and cleared from each plot. Fertilization of the experimental plots was performed using urea, triple superphosphate, muriate of potash, and gypsum at rates of 300, 100, 120, and 110 kg ha^{-1}, respectively. The full amounts of triple superphosphate, muriate of potash, and gypsum were applied during the final land preparation, while urea was administered in three equal installments at 15, 30, and 45 days after transplanting (DAT). The nursery bed was moistened with water one day before uprooting the seedlings. On January 20, 2022, the 45-day-old seedlings were carefully uprooted, minimizing mechanical injury to the roots, and promptly relocated to the main field. These seedlings were transplanted into the well-prepared, puddled field at a density of three seedlings per hill, maintaining a row spacing of 25 cm and a hill spacing of 15 cm.

Harvesting and data collection

Data on weed population (WP) (30 DAT) were gathered from each rice plot using a 0.25 m × 0.25 m quadrat, following the method described by Cruz et al. (1986). The number of weeds within the quadrat was counted, converted to per square meter by multiplying by four, and then the weeds were uprooted, cleaned, and sorted by species. The weed samples were sun-dried and subsequently placed in an electric oven at 80°C for 72 hours. The dry weight (DW) of each species was measured using an electric balance and expressed in grams per square meter (g m^{-2}). Harvesting was conducted once the crops reached the appropriate maturity level. A 1 m^2 area was selected in the central section of each plot for measuring GY and SY. The GY was adjusted to a moisture content of 14% and expressed in metric tons per hectare. Data on the number of total tillers $hill^{-1}$ (NTT) and total dry weight (DW) $hill^{-1}$ were recorded for each plot, with five hills tagged. These measurements were collected at 30 DAT. During harvesting, various parameters were measured including plant height (PH), (NET) $hill^{-1}$, panicle length (PL), NSP, 1000-grain weight (TGW), GY, and SY. Subsequently, the BY and harvest index (HI%) were calculated.

Statistical Analysis

The data was arranged properly for statistical analysis. An analysis of variance was performed using the RCBD approach with the assistance of the computer program R-Studio. The mean differences were evaluated using Duncan's Multiple Range Test (DMRT) with a significance threshold of $p \leq 0.05$ (Gomez and Gomez, 1984).

Results and Discussion

The experimental field was infested with nine weed species from five different families. Among these species, four were grasses, three were broadleaf weeds, and two were sedges. Details regarding the local names, scientific names, families, morphological types, and life cycles of these weeds in the experimental plot are provided in Table 1. Notable weeds identified in the experimental plots included *Echinochloa crusgalli* and *Monochoria hastata, Leersia hexandra, Scirpus mucronatus, Scirpus articulates, Panicum repens, Digitaria ischaemum, Enhydra fluctuans* and *Oxalis europaea, Cyperus difformis.* Similar patterns of weed infestation, influenced by the use of grass pea and mustard crop residues as a growth inhibitor, were also reported by Ashraf et al. (2021) during their studies on T. *aman* rice cultivation.

Table 1. Infested weed species were found in the experimental *Boro* rice plots

Local name	Scientific name	Family	Morphological type	Life cycle
Shama	*Echinochloa crusgalli*	Poaceae	Grass	Annual
Angulee	*Digitaria sanguinalis*	Poaceae	Grass	Annual
Angta	*Panicum repens*	Poaceae	Grass	Perennial
Arail	*Leersia hexandra*	Poaceae	Grass	Perennial
Panikachu	*Monochoria hastata*	Pontederiaceae	Broad leaves	Perennial
Helencha	*Enhydra fluctuans*	Onagraceae	Broad leaves	Annual
Chechra	*Scirpus juncoides*	Cyperaceae	Sedge	Perennial
Noldog	*Scirpus articulatus*	Cyperaceae	Sedge	Annual
Sabuj nakphul	*Cyperus difformis*	Cyperaceae	Sedge	Annual

Varietal effect on WP and DW of weeds

Varietal differences significantly influenced the WP and DW of *E. crus-galli*. The highest WP of *E. crus-galli* was recorded in BRRI dhan28 (5.92), while BAU dhan3 had the lowest (3.72). Similarly, the highest DW for this weed was (2.71g) found in BRRI dhan28, and the lowest was (2.09 g) observed in BAU dhan3 (Table 2). Similarly, the rice variety significantly affected the WP and DW of other weed species. For *S. juncoides*, BRRI dhan28 exhibited the highest WP at 11.50 and the highest DW at 0.80 g, whereas BAU dhan3 showed the lowest WP (7.00) and DW (0.56 g) (Table 2). The WP and DW of *P. repens, D. sanguinalis* also varied by variety. BRRI dhan28 recorded the highest WP (2.25, 2.75) and DW (0.74 g, 0.43 g), while the lowest for BAU dhan3 were (1.25, 1.75) for WP and (0.60 g, 0.36 g) DW (Table 2). Ashraf et al. (2021) reported that the variety of transplanted *aman* rice and the residual effect of grass pea significantly influence the control efficacy of weeds and T. *aman* rice variety significantly affects weed populations, specifically for *E. crusgalli*, *Solanum torvum*, *Paspalum scrobiculatum* and *P. hydropiper*.

Table 2. Effect of variety on WP and DW of weeds

Varieties	WP (no. m^{-2})				DW of weeds (g m^{-2})			
	E. crus-galli	***S. juncoides***	***P. repens***	***D. sanguinalis***	***E. crus-galli***	***S. juncoides***	***P. repens***	***D. sanguinalis***
V_1	3.92c	7.00d	1.25b	1.75c	2.09c	0.56c	0.60b	0.36d
V_2	5.92a	11.50a	2.25a	2.75a	2.71a	0.80a	0.74a	0.43a
V_3	4.75b	10.25b	1.92a	2.42ab	2.22b	0.61b	0.70ab	0.41b
V_4	4.50b	8.17c	1.50b	2.17b	2.18bc	0.61b	0.62b	0.39c
Level of Significance	**	**	**	**	**	**	*	**
CV (%)	11.35	8.28	7.68	9.89	5.42	7.25	10.51	5.57

Here, means with the same letters within the same column do not differ significantly, ** - Significant at 1% level of probability, V_1 - BAU dhan3, V_2 - BRRI dhan28, V_3 - BRRI dhan81, V_4 - BRRI dhan96

Effect of hot water extract of grass pea and hand weeding on WP and DW of weeds

The hot water extract of grass pea significantly influenced the WP and DW of *E. crus-galli*. The highest WP (9.08) was observed in the control treatment, while the lowest (0.00) occurred in the hand weeding three times treatment. Similarly, the highest DW of weeds (4.95 g) was noted in no weeding treatments, with the lowest (0.00 g) in hand weeding three times (Table 3). For *S. juncoides*, the hot water extract of grass pea also had a marked effect. The highest WP (18.92) appeared in no weeding and the lowest (0.00) in hand weeding three times. The maximum DW was 1.44 g in no weeding treatment, and the minimum was 0.00 g in hand weeding three times (Table 3). The WP and DW of *P. repens* were similarly affected. The highest WP (3.25) was found in no weeding, with the lowest (0.00) in hand weeding three times at10, 30 and 50 DAT. The highest DW was 1.46 g in no weeding, and the lowest was 0.00 g in hand weeding three times (Table 3). Lastly, the extract significantly impacted the *D. sanguinalis* WP and DW. The highest WP (4.42) and DW (0.87 g) were recorded in no weeding, while the lowest figures (0.00 WP and 0.00 g DW) were observed in hand weeding three times (Table 3). The study found that applying these residues, especially in a 50:50 crop residue-to-soil ratio, significantly suppressed weed emergence and biomass, particularly in broadleaf weed species. Sorghum residues were the most effective, enhancing both weed suppression and rice yield (Sarkar et al. 2020).

Table 3. Effect of hot water extract of grass pea on WP and DW of weeds

Treatments	WP (no. m^{-2})				DW of weeds (g m^{-2})			
	E. crus-galli	*S. juncoides*	*P. repens*	*D. sanguinalis*	*E. crus-galli*	*S. juncoides*	*P. repens*	*D. sanguinalis*
T_1	9.08a	18.92a	3.25a	4.42a	4.95a	1.44a	1.46a	0.87a
T_2	5.92b	10.83b	2.17b	2.83b	2.42b	0.67b	0.69b	0.41b
T_3	4.08c	7.17c	1.50c	1.83c	1.83c	0.47c	0.50c	0.32c
T_4	0.00d	0.00d	0.00d	0.00d	0.00d	0.00d	0.00d	0.00d
Level of significance	**	**	**	**	**	**	**	**
CV (%)	11.35	8.28	7.68	9.89	5.42	7.25	10.51	5.57

Here, means with the same letters within the same column do not differ significantly, ** - Significant at 1% level of probability, T_1 - No extract and no weeding (control), T_2 - Hot water extract of grass pea as pre-emergence at 3 days after transplanting, T_3 - Hot water extract of grass pea as pre-emergence application at 3 DAT+ post-emergence at 10 DAT, T_4 - Hand weeding three times at15, 30 and 45 DAT

Interaction effect between variety and hot water extract of grass pea on WP and DW of weeds

Significant interactions between *boro* rice varieties and the hot water extract of grass pea were observed in WP and DW. For *E. crus-galli*, the highest WP (10.67) and DW (5.90 g) were recorded in the BRRI dhan28 and no extract treatment, while the lowest numbers of weeds (0.00) and 0.00 g DW were found in BAU dhan3, BRRI dhan28, BRRI dhan81, BRRI dhan96 and hand weeding three times (Table 4). In the case of *S. juncoides*, the highest numbers of weeds were again seen in BRRI dhan28 and no weeding (23.00) and (1.82 g) DW, and the lowest was in BAU dhan3, BRRI dhan28, BRRI dhan81, BRRI dhan96 and hand weeding three times, showing 0.00 WP and 0.00 g DW of weeds (Table 4). For *P. repens*, the highest WP (4.00) and (1.66 g) DW of weeds appeared in BRRI dhan28 and no extract, and the lowest WP (0.00) and 0.00 g DW of weeds in BAU dhan3, BRRI dhan28, BRRI dhan81, BRRI dhan96 and hand weeding three times (Table 4). Lastly, *D. sanguinalis* displayed the highest WP (5.00) and DW (2.02 g) in BRRI dhan28 and no extract and the lowest number of weeds (0.00) and (0.00 g) DW in BAU dhan3, BRRI dhan28, BRRI dhan81, BRRI dhan96 and hand weeding three times (Table 4). Similarly, aqueous extracts of crop residues were effective in reducing both the WP and DW of weeds, as well as in achieving a high percent inhibition of weeds (Ahmed et al. 2018).

Table 4. Combined effect of variety and hot water extract of grass pea on WP and DW of weeds

Variety x Residues	WP (no. m^{-2})				DW of weeds (g m^{-2})			
	E. crus-galli	*S. juncoides*	*P. repens*	*D. sanguinalis*	*E. crus-galli*	*S. juncoides*	*P. repens*	*D. sanguinalis*
V_1T_1	8.00cd	14.67d	2.67bc	4.67b	4.46c	1.21c	1.30c	2.03c
V_1T_2	4.33f	8.00f	1.33de	2.33cd	2.20ef	0.60ef	0.64d-f	1.02de
V_1T_3	3.33g	5.33g	1.00e	1.33de	1.69h	0.43g	0.47f	0.60e
V_1T_4	0.00h	0.00h	0.00f	0.00e	0.00i	0.00h	0.00g	0.00f
V_2T_1	10.67a	23.00a	4.00a	7.67a	5.90a	1.82a	1.66a	3.25a
V_2T_2	7.67d	14.00d	3.00b	5.00b	2.91d	0.81d	0.75d	2.02c
V_2T_3	5.33e	9.00f	2.00cd	3.00c	2.01fg	0.55f	0.55d-f	1.27d
V_2T_4	0.00h	0.00h	0.00f	0.00e	0.00i	0.00h	0.00g	0.00f
V_3T_1	9.00b	20.00b	3.33ab	7.33a	4.78b	1.36b	1.54ab	2.75ab
V_3T_2	6.00e	12.33e	2.67bc	4.67b	2.29e	0.64e	0.72de	1.93c
V_3T_3	4.00fg	8.67f	1.67de	2.67cd	1.82gh	0.44g	0.51ef	1.03de
V_3T_4	0.00h	0.00h	0.00f	0.00e	0.00i	0.00h	0.00g	0.00f
V_4T_1	8.67bc	18.00c	3.00b	6.67a	4.68b	1.36b	1.34bc	2.28bc
V_4T_2	5.67e	9.00f	1.67de	2.33cd	2.25e	0.63ef	0.65d-f	1.04de
V_4T_3	3.67fg	5.67g	1.33de	1.67cd	1.78h	0.45g	0.48f	0.76de
V_4T_4	0.00h	0.00h	0.00f	0.00e	0.00i	0.00h	0.00g	0.00f
Level of sig.	**	**	*	*	**	**	*	*
CV (%)	11.35	8.28	7.68	6.81	5.42	7.25	10.51	6.72

Here, means with the same letters within the same column do not differ significantly. ** - Significant at 1% level of probability, * - Significant at 5% level of probability, V_1 - BAU dhan3, V_2 - BRRI dhan28, V_3 - BRRI dhan81, V_4 - BRRI dhan96, T_1 - No extract and no weeding (control), T_2 - Hot water extract of Grass pea as pre-emergence at 3 days after transplanting, T_3 - Hot water extract of Grass pea as pre-emergence application at 3 DAT+ post-emergence at 10 DAT, T_4 - Hand weeding three times at 15, 30 and 45 DAT

Effect of variety on yield and yield contributing characters of boro rice

Varietal differences significantly influenced both yield and yield-related traits. BAU dhan3 exhibited the highest PH (103.92 cm), NET $hill^{-1}$ (9.25), SL (21.34 cm), NSP (100.52), TGW (22.70 g) and HI (42.99%). (Table 5). The lowest PH (90.50 cm), NET $hill^{-1}$ (5.58), SL (18.98 cm), NSP (83.86), TGW (19.36 g) and HI (39.61%) was noted in BRRI dhan28 (Table 5). Dola et al. (2024) also observed significant differences due to varietal effects in another study. Likewise, the application of sorghum crop residues in varying rates significantly influenced rice yields. The highest grain and straw yields were observed with the use of sorghum residues at a rate of 2.0 t/ha, showing a 75% increase in grain yield compared to non-treated plots. This yield increase is attributed to effective weed suppression, which allowed better resource availability was reported by Sarker et al. (2020).

Table 5. Effect of variety on the yield contributing characters and harvest index of *boro* rice

Variety	PH (cm)	NET hill^{-1}	PL (cm)	NSP	TGW (g)	HI (%)
V_1	103.92a	9.25a	21.34a	100.52a	22.70a	42.99a
V_2	90.50d	5.58d	18.98d	83.86d	19.36d	39.61c
V_3	94.25c	6.67c	19.29c	87.56c	19.87c	39.99c
V_4	100.58b	7.50b	20.83b	92.80b	20.25b	42.16b
Level of Significance	**	**	**	**	**	**
CV%	12.27	9.30	6.80	11.50	6.21	11.22

Here, means with the same letters or without letters within the same column do not differ significantly as per DMRT, ** - Significant at 1% level of probability, * - Significant at 5% level of probability, V_1 - BAU dhan3, V_2 - BRRI dhan28, V_3 - BRRI dhan81, V_4 - BRRI dhan96

Effects of hot water extract of grass pea on yield and yield contributing characters of boro rice

Combining hot water extract of grass pea markedly affected yield and its contributing factors. The optimal results were observed when Hand weeding three times were used and the highest PH (105.17 cm), NET hill^{-1} (10.5), PL (20.90 cm), NSP (99.51), TGW (21.50 g) and HI (43.14%) were recorded (Table 6). In contrast, the lowest outcomes were noted when no extract was used, resulting in the lowest PH (88.17 cm), NET hill^{-1}(4.33), PL (19.52 cm), NSP (82.47), TGW (19.46 g), and HI (36.73%) (Table 6). The study shows that combining aqueous extracts of sorghum and mustard crop residues with herbicides significantly improved wheat yields. The highest grain yield (4.09 t ha^{-1}) came from using the full herbicide dose, while 80% herbicide plus crop extract achieved a close 3.92 t ha^{-1}. Crop residues also boosted straw and biological yields, suggesting that integrating them with reduced herbicide doses can enhance crop performance and weed control (Akondo et al. 2024)

Table 6. Effect of hot water extract of grass pea on the yield contributing characters and harvest index of *boro* rice

Treatment	PH (cm)	NET hill^{-1}	PL (cm)	NSP	TGW (g)	HI (%)
T_1	88.17d	4.33d	19.52d	82.47d	19.46d	36.73c
T_2	95.00c	5.92c	19.76c	88.33c	20.38c	41.78b
T_3	100.92b	8.25b	20.25b	94.44b	20.84b	43.10a
T_4	105.17a	10.5a	20.90a	99.51a	21.50a	43.14a
Level of Significance	**	**	**	**	**	**
CV%	12.27	9.30	6.80	11.50	6.21	11.22

Here, means with the same letters within the same column do not differ significantly as per DMRT, ** - Significant at 1% level of probability, T_1 - No extract and no weeding (control), T_2 - Hot water extract of Grass pea as pre-emergence at 3 days after transplanting, T_3 - Hot water extract of Grass pea as pre-emergence application at 3 DAT+ post-emergence at 10 DAT, T_4 - Hand weeding three times at 15, 30 and 45 DAT

Effects of interaction between variety and hot water extract of grass pea on the yield contributing characters and yield of boro rice

Variety has a significant effect on the total number of tillers per plant (Table 7). Among these four varieties, the Significant variations in PH, PL, TGW, NET hill^{-1}, NSP and HI were noted when different *boro* rice varieties were treated with a combination of hot water extract of grass pea. The highest PH (112.33 cm) NET hill^{-1} (12.33), PL (22.19), NSP (107.23), TGW (23.98) and HI (45.92 %) were recorded for BAU dhan3 treated with Hand weeding three times. The minimum values for PH (80.33 cm) NET hill^{-1} (3.00), PL (18.66 cm), NSP (74.25), TGW (18.68 g) and HI (38.90 %) were recorded in BRRI dhan28 and no extract treatment (Table 7). Sarker et al. (2022) identified a similar trend, highlighting the significant impact of the interaction between variety and crop residues on the weight of a thousand grains.

Table 7. Interaction effect of variety and hot water extract of grass pea on the yield contributing characters and yield of *boro* rice

Interaction	PH (cm)	NET hill^{-1}	PL (cm)	NSP	TGW (g)	HI (%)
V_1T_1	93.00fgh	6.33fg	20.71d	91.98e	21.22d	36.08h
V_1T_2	102.00d	8.00d	20.92cd	100.22c	22.49c	44.13c
V_1T_3	108.33bc	10.33bc	21.53b	102.64b	23.11b	45.82a
V_1T_4	112.33a	12.33a	22.19a	107.23a	23.98a	45.92a
V_2T_1	80.33j	3.00j	18.66j	74.25i	18.68n	38.90g
V_2T_2	90.00hi	4.33hi	18.96hi	80.45g	19.03l	39.52fg
V_2T_3	94.00efg	6.67ef	19.06f-h	87.73f	19.58k	39.97f
V_2T_4	97.67e	8.33d	19.24fg	93.02de	20.16i	40.07f
V_3T_1	87.33i	3.67ij	18.71ij	77.50h	18.94m	35.88h
V_3T_2	91.00ghi	5.33gh	18.98g-i	81.90g	19.55k	40.99e
V_3T_3	96.67ef	7.67de	19.32f	92.42e	20.08j	41.39e
V_3T_4	102.00d	10.00c	20.15e	98.43c	20.90f	41.70de
V_4T_1	92.00gh	4.33hi	20.01e	86.13f	19.01l	36.05h
V_4T_2	97.00e	6.00fg	20.20e	90.74e	20.43h	42.50d
V_4T_3	104.67cd	8.33d	21.09c	94.97d	20.58g	45.24ab
V_4T_4	108.67ab	11.33ab	22.02a	99.37c	20.98e	44.85bc
Level of sig.	*	*	**	**	**	**
CV (%)	12.27	9.30	6.80	11.50	6.21	11.22

Here, means with the same letters within the same column do not differ significantly as per DMRT, ** - Significant at 1% level of probability, * - Significant at 5% level of probability, V_1 - BAU dhan3, V_2 - BRRI dhan28, V_3 - BRRI dhan81, V_4 - BRRI dhan96, T_1 - No extract and no weeding (control), T_2 - Hot water extract of Grass pea as pre-emergence at 3 days after transplanting, T_3 - Hot water extract of Grass pea as pre-emergence application at 3 DAT+ post-emergence at 10 DAT, T_4 - Hand weeding three times at15, 30 and 45 DAT

Effect of variety on GY, SY and BY

The study revealed that different varieties significantly influenced both GY, SY and BY. The highest GY (5.81 t ha^{-1}) for BAUdhan3. The lowest number of sterile spikelets panicle^{-1} is the main reason for highest yield. The lowest GY (3.63 t ha^{-1}) was observed in BRRI dhan28 due to genetic potential (Figure 1). Similarly, the highest SY and BY (7.57 t ha^{-1}, 13.39 t ha^{-1}) was found in BAU dhan3 and the lowest SY and BY (5.52 t ha^{-1}, 9.16t ha^{-1}) was found in BRRI dhan28 (Figure 1). This trend aligned with the observations of Dola et al. (2024), who noted that crop varieties could significantly affect the crop performance.

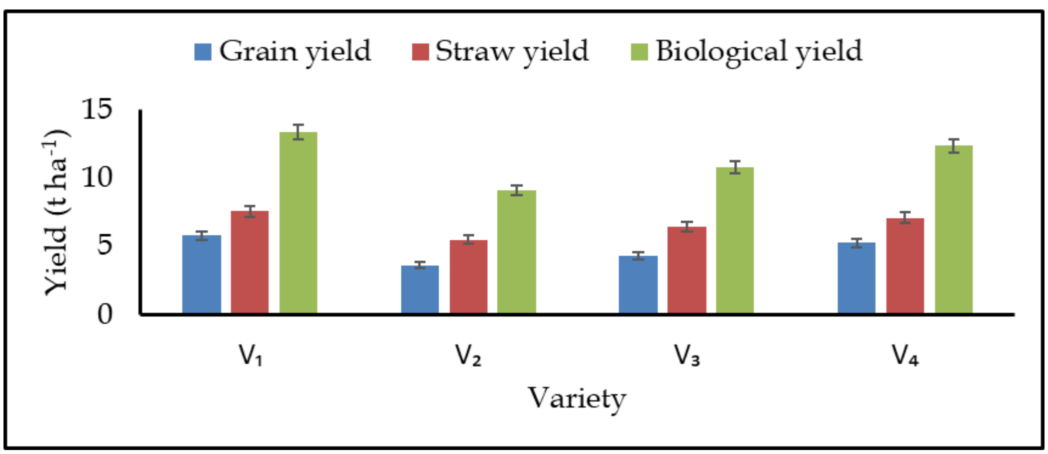

Figure 1. Effect of variety on GY, SY and BY of *boro* rice. Here, V_1 - BAU dhan3, V_2 - BRRI dhan28, V_3 - BRRI dhan81, V_4 - BRRI dhan96

Effect of hot water extract of grass pea on GY, SY and BY

The application of the hot water extract of grass pea had a significant impact on GY, SY and BY. The highest GY (5.70 t ha^{-1}) was observed in three times hand weeding and lowest GY (3.41 t ha^{-1}), was observed in no extract treatment (Figure 2). Similarly, SY, BY were significantly affected, with the highest SY and BY (7.43 t ha^{-1},13.12 t ha^{-1}) recorded in three times hand weeding treatment. The lowest SY and BY (5.92 t ha^{-1}, 9.33 t ha^{-1}), was noted in no extract treatment (Figure 2). This trend aligned with the observations of Sarker et al. (2022), who noted that crop residues could significantly affect the crop performance. The study found that combining 90% of the recommended herbicide dose with aqueous mustard extract effectively controlled weeds and boosted wheat yields. The highest grain yield (5.02 t ha^{-1}) and straw yield (6.93 t ha^{-1}) were achieved with this method, suggesting that using crop residues can reduce reliance on synthetic herbicides and sustainably improve wheat production (Dola et al. 2024).

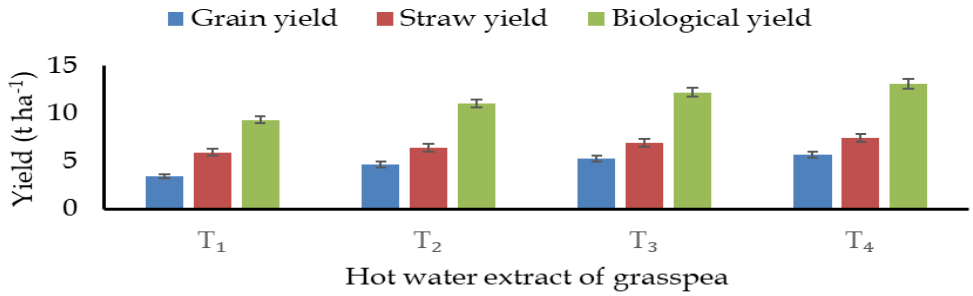

Figure 2. Effect of hot water extract of grass pea on GY, SY and BY of *boro* rice. Here, T_1 - No extract and no weeding (control), T_2 - Hot water extract of Grass pea as pre-emergence at 3 days after transplanting, T_3 - Hot water extract of Grass pea as pre-emergence application at 3 DAT+ post-emergence at 10 DAT, T_4 - Hand weeding three times at15, 30 and 45 DAT

Interaction effect on GY, SY and BY

The interaction between varieties and hot water extract of grass pea significantly influenced GY, SY and BY. The highest GY (6.91 t ha^{-1}) was produced by BAUdhan3 and three times hand weeding treatment, and the lowest GY (2.79 t ha^{-1}) was produced by BRRI dhan28 and no extract treatment (Figure 3). The highest SY and BY (8.13 t ha^{-1}, 15.04 t ha^{-1}) was observed in BAUdhan3 ×three times hand weeding treatment. The lowest SY and BY (4.39 t ha^{-1}, 7.18 t ha^{-1}) was observed in BRRI dhan28 and no extract treatment (Figure 3). These findings underscore the critical role of treatment interactions in optimizing wheat crop yields. Similar conclusions were drawn by Sarker et al. (2022) reported that the combination of variety and aqueous crop residue extracts effectively enhanced yield. Similar conclusions were drawn by Afroz et al. (2018), who noted the significant impact of marsh pepper and buckwheat crop residue extracts on yield and related traits of T. *aman* rice.

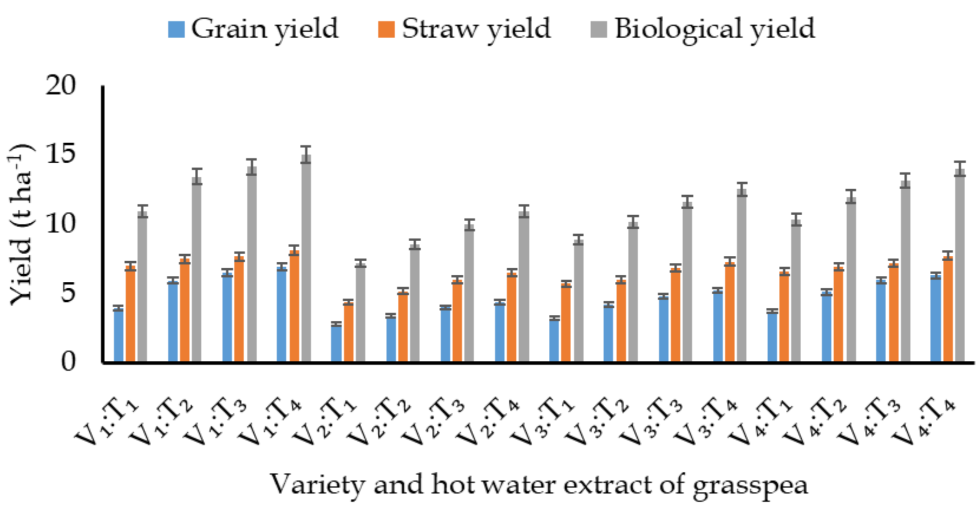

Figure 3. Interaction effect of variety and hot water extract of grass pea on GY, SY and BY of *boro* rice. Here, V_1 - BAU dhan3, V_2 - BRRI dhan28, V_3 - BRRI dhan81, V_4 - BRRI dhan96, T_1 - No extract (control), T_2 - Hot water extract of Grass pea as pre-emergence at 3 days after transplanting, T_3 - Hot water extract of Grass pea as pre-emergence application at 3 DAT+ post-emergence at 10 DAT, T_4 - Hand weeding three times at 15, 30 and 45 DAT

Conclusion

The experimental findings indicate that the application of hot water extract from grass pea residues positively affects yield across most of the studied traits. Additionally, the extract demonstrates the ability to suppress weed growth and exhibits significant herbicidal activity. Therefore, the hot water extract of grass pea crop residues has the potential to serve as an effective method for weed control and increase crop yield. Its act as a modern technology in agricultural science as well as environment friendly because it has no residual effect. So, we can use crop residues of grass pea to suppress weeds and increase the yield of *Boro* rice.

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