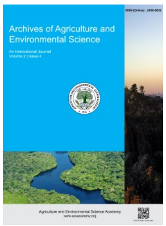
Archives of Agriculture and Environmental Science 9(3): 500-507 (2024)
https://doi.org/10.26832/24566632.2024.0903013

e-ISSN: 2456-6632

This content is available online at AESA

Archives of Agriculture and Environmental Science

Journal homepage: journals.aesacademy.org/index.php/aaes



ORIGINAL RESEARCH ARTICLE

CrossMark

# Combined hot water extract of lentil and grass pea increase weed control efficiency and yield of *boro* rice

**Mijanur Rahman, Uttam Kumer Sarker, Md. Towkir Ahmed, Meftahe Zinnat, Md. Shahin Alam and Md. Romij Uddin*** 

Department of Agronomy, Faculty of Agriculture, Bangladesh Agricultural University, Mymensingh - 2202, Bangladesh
*Corresponding author's E-mail: romijagron@bau.edu.bd

**ARTICLE HISTORY**

Received: 18 July 2024
Revised received: 30 August 2024
Accepted: 10 September 2024

**Keywords**

Boro rice
Hot water extract of grass pea and lentil
Grain yield
Weed control
Weed population

**ABSTRACT**

The agriculture sector is continuously adopting environmentally friendly and sustainable methods to reduce the harmful effects of herbicides on crop production. In this context, an experiment was conducted at the Agronomy Field Laboratory (AFL), Bangladesh Agricultural University (BAU), Mymensingh, from December 2021 to May 2022, to investigate the effect of combined hot water extracts of lentil and grass peas (ELG) on weed control efficiency and yield performance of *boro* rice. The experiment involved four varieties of *boro* rice (BAU dhan3, BRRI dhan28, BRRI dhan81, and BRRI dhan96) and four treatments of crop residues. For most weed species, varieties and crop residue extracts significantly impacted weed population (WP) and weed dry weight (DW). The highest numbers of effective tillers (NET) hill$^{-1}$, numbers of spikelets panicle$^{-1}$ (NSP), 1000-grain weight (TGW), grain yield (GY), and straw yield (SY) were observed in the three-times hand weeding treatment. This was followed by the combination of hot water ELG applied as a pre-emergence treatment three days after transplanting and post-emergence ten days after transplanting, with the lowest values found in the no-extract treatment. Considering interaction effects, the highest GY (7.07 t ha$^{-1}$) and SY (8.23 t ha$^{-1}$) were observed with hand weeding combined with the variety BAU dhan3. The results of this study indicated that hand weeding, followed by the combined application ELG crop residue, showed potential activity to suppress WP and significantly affected the yield of *boro* rice.



**Citation of this article:** Rahman, M., Sarker, U. K., Ahmed, M. T., Zinnat, M., Alam, M. S., & Uddin, M. R. (2024). Combined hot water extract of lentil and grass pea increase weed control efficiency and yield of *boro* rice. *Archives of Agriculture and Environmental Science*, 9(3), 500-507, https://dx.doi.org/10.26832/24566632.2024.0903013

## INTRODUCTION

In Bangladesh, rice (*Oryza sativa*) is the most important crop and one of the most delicate agricultural goods for local and international markets. The most essential raw material for the product is rice, which is also used to make food items throughout the country. Rice is the staple food, with an average annual consumption rate per capita of 144.5 kg year-1 (Yunus *et al.*, 2019). Bangladesh earns about 11.20% of its 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 for rice. Among the rice groups grown in our country, Boro rice, in particular, covers 4852.29 thousand 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 24–40% drop in wheat crop yield (Oad *et al.*, 2007; Akondo *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 time and effort and is impractical for more significant 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 wheat has led to significant environmental degradation and resistance in different types of weeds (Delye *et al*., 2013 and Dola *et al*., 2024).

Weed management in rice production necessitates consistent efforts to control weeds. Research has shown that aqueous extracts from various allelopathic plants effectively manage weeds in wheat and other crops (Khan *et al*., 2015; Khan *et al*., 2013). These plants produce allelochemicals that can significantly curb weed growth in organic farming systems without harming the environment, thereby enhancing crop yields (Soltys *et al*., 2013). These naturally occurring chemicals are derived from various parts of plants, such as the flowers, fruits roots, bark, leaves and root exudates (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 WP (Uddin & Pyon, 2010).

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. Moreover, several studies have revealed the induction of phytotoxic effects by plants and their residues on various crops, including major grain crops such as rice, sorghum, rye, buckwheat, wheat, mustard, 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; Won *et al*., 2013; Uddin & Pyon, 2010). Effective weed management strategies in wheat cultivation include rotating crops, growing high-yielding wheat varieties, and utilizing phytotoxic plant extracts (Ullah *et al*., 2023).

Farmers now have to deal with workforce scarcity and rising production costs. Hand weeding could be more cost-effective due to the high price, performance difficulty, and labor availability restrictions at the right time. Due to a lack of labor, chemical weed control is getting more and more popular (Ahmed *et al*., 2018). It has become vitally necessary to use alternative weed control methods to lower the cost of rice production. There are several contemporary weed control methods besides hand weeding. Allelopathic weed management, biological weed control, mechanical weed control, chemical or herbicidal weed control, etc. Hand weeding can be substituted by mechanical weeding and herbicides. The most common way of weed control for good crop production is herbicide application. However, this practice also negatively impacts soil, water, air, and human and animal health. Alternative strategies that don't address these issues need to be considered. Crop allelopathy and allelochemicals are effective alternatives to chemical herbicides to control weeds.

Researchers are now emphasizing using various crop residues to inhibit weed development. In Bangladesh, more information is needed on using crop residues to control weeds. However, there have only been a few attempts made in Bangladesh to use the allelopathic properties of plants to reduce weeds in the agricultural sector. It is scientifically established that grass pea successfully competes with weeds in fields. These point to the grass pea's potential for allelopathy and demonstrate its effectiveness for weed biological control. However, there have only been a few attempts made in Bangladesh to use plants' crop residue to reduce weeds in the agricultural sector. Only minimal efforts have been made to harness plant crop residues for weed management in agriculture. Based on this issue, the study was designed to evaluate the aqueous ELG crop residues on weed control and yield performance of boro rice.

## MATERIALS AND METHODS

### Description of the experimental site

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

### Experimental design and treatment factors

Two components make up the experimental treatment where four rice varieties, viz. BAU dhan3 ($V_1$), BRRI dhan28 ($V_2$), BRRI dhan81 ($V_3$), BRRI dhan96 ($V_4$), and four grass pea and lentil crop residues treatment such as no weeding (control), Combined hot water ELG as a pre-emergence application at 3 DAT ($T_2$), Combined hot water ELG as a pre-emergence application at 3 DAT + post-emergence at 10 DAT ($T_3$), Three times Hand weeding ($T_4$). The experiment was arranged in a Randomized Complete Block Design (RCBD) with three replications. The total number of plots was 48 (4 ×4×3), each measuring 2.5 m × 2.0 m. A distance of 0.5 m was maintained between individual plots and 1.0 m between replications.

### Collection and preparation of experimental materials

The crops were cultivated at the AFL and BAU and harvested at the ripening stage to collect crop residues. Following collection, the crop residues were dried under shade on the covered threshing floor of the AFL. The residues were then finely cut using a sickle. The small-sized lentil and grass pea crop residues were soaked in water at a 1:10 (w/v) ratio for 24 hours at ambient room temperature. This mixture of leaves and water was then boiled for 3-4 hours and filtered using a coarse mesh to remove plant residues. Seeds of rice varieties BAU dhan3, BRRI dhan28, BRRI dhan81, and BRRI dhan96 were obtained from the AFL, BAU, and Mymensingh. Upon collection, the specific gravity technique was employed to select healthy seeds from the collected cultivars. The seeds were then submerged in water in a container for 24 hours. After soaking, the seeds were removed from the water and tightly packed in gunny bags. Gemination commenced after 48 hours, rendering the seeds ready for sowing.

### Preparation of plots and crop husbandry

A plot of land was selected for raising seedlings, which was thoroughly puddled using a country plough and then leveled with a ladder. The area was divided into two equal sections for sowing the germinated seeds. On December 5, 2021, the germinated seeds were planted in a wet nursery bed. Care was taken to ensure healthy seedling growth through timely weeding and necessary irrigation. The main field was initially prepared using a power tiller and then ploughed four times with a country plough, followed by laddering. Final land preparation included completing the field layout and removing weeds and stubbles from each plot. The experimental plots were fertilized with urea, triple super phosphate (TSP), muriate of potash (MoP), and gypsum ($CaSO_4.2H_2O$) at rates of 300, 100, 120, and 110 kg ha$^{-1}$, respectively. TSP, MoP, and $CaSO_4.2H_2O$ were applied during final land preparation, while urea was applied in three equal installments at 15, 30, and 45 days after transplanting (DAT). The nursery bed was wetted with water one day before uprooting the seedlings. On January 20, 2022, 45-day-old seedlings were carefully uprooted to minimize mechanical damage to the roots and were immediately transferred to the main field. The seedlings were transplanted into the well-prepared, puddled field at a density of three seedlings hill$^{-1}$, with a row spacing of 25 cm and a hill spacing of 15 cm.

### Harvesting and data collection

Data on WP at 30 DAT were collected from each rice plot using a 0.25 m × 0.25 m quadrat, following the methodology outlined by Cruz *et al.* (1986). The number of weeds within each quadrat was counted and converted to a per square meter value by multiplying by four. After measuring weed density, the weeds within each quadrat were uprooted, cleaned, and sorted by species. The weed samples were initially air-dried and then further dried in an electric oven at 80°C for 72 hours. The DW of each weed species was measured using an electric balance and expressed in grams per square meter (g m$^{-2}$). Harvesting was performed when the crops reached full maturity. A 1 m² area was selected in the central section of each plot to measure 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 (NTT) hill$^{-1}$ and total DW hill$^{-1}$ were recorded for each plot, with five hills tagged for measurement. This data was collected at 30 DAT. During harvest, measurements were taken for plant height (PH), NET hill$^{-1}$, panicle length (PL), NSP, TGW, GY, and SY. Subsequently, biological yield (BY) and harvest index (HI%) were calculated.

### Statistical analysis

The data was correctly arranged for statistical analysis. An analysis of variance (ANOVA) 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 & Gomez, 1984).

## RESULTS AND DISCUSSION

The experimental field was infested by nine weed species from five different families. Of 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. The predominant weeds observed in the experimental plots included: *Echinochloa crusgalli*, *Monochoria hastata*, *Leersia hexandra*, *Scirpus mucronatus*, *Scirpus articulatus*, *Panicum repens*, *Digitaria ischaemum*, *Enhydra fluctuans*, and *Oxalis europaea*. Similar patterns of weed infestation, influenced by the use of AES crop residues as a growth inhibitor, were also reported by Ahmed *et al.* (2018) in their studies on wheat 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 |
| Chotoangulee | *Digitaria ischaemum* | Poaceae | Grass | Annual |
| Angta | *Panicum repens* | Poaceae | Grass | Perennial |
| Arail | *Leersia hexandra* | Poaceae | Grass | Perennial |
| Panikachu | *Monochoria hastate* | Pontederiaceae | Broad leaves | Perennial |
| Helencha | *Enhydra fluctuans* | Onagraceae | Broad leaves | Annual |
| Chechra | *Scirpus mucronatus* | Cyperaceae | Sedge | Perennial |
| Noldog | *Scirpus articulatus* | Cyperaceae | Sedge | Annual |
| Motka | *Oxalis europaea* | Oxalidaceae | Leaves | perennial |

### 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, BRRI dhan81 (4.08), while BAU dhan3 had the lowest (3.58). Similarly, the highest DW for this weed was (2.36 g, 2.38 g) found in BRRI dhan28, BRRI dhan8 and the lowest was (1.80 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 (16.92) and the highest DW at 0.76 g, whereas BAU dhan3 showed the lowest WP (11.25) and DW (0.60 g) (Table 2). The WP and DW of *P. repens*, *D. sanguinalis* also varied by variety. BRRI dhan28 recorded the highest WP (2.00, 3.92) and DW (.99 g, 1.63 g), while the lowest for BAU dhan3 were (1.42, 2.08) for WP and (0.67 g, 0.91 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. Also, Uddin *et al.* (2012) found that sorgoleone significantly reduced the Fv/Fm ratio and chlorophyll fluorescence in all tested weed species, particularly in *Galium spurium*, *Aeschynomene indica*, and *Rumex japonicus*. Ahmed *et al.* (2018) and Akondo *et al.* (2024) found similar results, stating that wheat variety significantly affects weed populations, specifically for *E. crusgalli*, *Solanum torvum*, *Paspalum scrobiculatum* and *P. hydropiper*.

### Effect of combined hot water ELG on WP and DW of weeds

The hot water ELG significantly influenced the WP and DW of *E. crus-galli*. The highest WP (8.50) 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 (4.55 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 ELG also had a marked effect. The highest WP (34.67) appeared in no weeding and the lowest (0.00) in hand weeding three times. The maximum DW was 1.46 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 (3.17) was found in no weeding, with the lowest (0.00) in hand weeding three times. The highest DW was 1.56 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 (6.58) and DW (2.58 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). These findings are consistent with observations by Sarkar *et al.* (2020) and Akondo *et al.* (2024). All rotation crop residues effectively suppressed weed growth, particularly at a 90:10 crop-to-soil ratio, completely inhibiting all tested weed species (Uddin & Pyon, 2010).

**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* |
| $V_1$ | 3.58b | 11.25d | 1.42b | 2.08b | 1.80b | 0.60d | 0.67b | 0.91b |
| $V_2$ | 4.08a | 16.92a | 2.00a | 3.92a | 2.36a | 0.76a | 0.99a | 1.63a |
| $V_3$ | 4.08a | 15.92b | 1.67ab | 3.67a | 2.38a | 0.72b | 0.84ab | 1.43a |
| $V_4$ | 4.00a | 13.25c | 1.50b | 2.67b | 1.92b | 0.68c | 0.72b | 1.02b |
| Level of Significance | * | ** | * | ** | * | ** | * | ** |
| CV (%) | 13.11 | 7.74 | 12.74 | 6.81 | 6.91 | 5.16 | 13.95 | 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.

**Table 3.** Effect of hot water extract of lentil and 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* |
| $T_1$ | 8.50a | 34.67a | 3.17a | 6.58a | 4.55a | 1.46a | 1.56a | 2.58a |
| $T_2$ | 4.25b | 12.83b | 2.08b | 3.58b | 2.07b | 0.71b | 1.03b | 1.50b |
| $T_3$ | 3.00c | 9.83c | 1.33c | 2.17c | 1.49b | 0.59c | 0.63c | 0.91c |
| $T_4$ | 0.00d | 0.00d | 0.00d | 0.00d | 0.00c | 0.00d | 0.00d | 0.00d |
| Level of significance | ** | ** | ** | ** | ** | ** | ** | ** |
| CV (%) | 13.11 | 7.74 | 12.74 | 6.81 | 6.91 | 5.16 | 13.95 | 6.72 |

Here, means with the same letters within the same column do not differ significantly, ** - Significant at 1% level of probability, $T_1$ - No extract (control), $T_2$ - Combined hot water extract of lentil and grasspea as pre-emergence at 3 days after transplanting, $T_3$ - Combined hot water extract of lentil and grasspea as post-emergence at 10 days after transplanting, $T_4$ - Hand weeding three times.

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

| Variety × 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* |
| $V_1T_1$ | 7.33b | 24.00d | 2.67bc | 4.67b | 3.96b | 1.14d | 1.28b-d | 2.03c |
| $V_1T_2$ | 4.00cd | 12.00fg | 1.67d | 2.33cd | 1.85c | 0.68f | 0.82de | 1.02de |
| $V_1T_3$ | 3.00d | 9.00h | 1.33d | 1.33de | 1.37c | 0.56h | 0.59e | 0.60e |
| $V_1T_4$ | 0.00e | 0.00i | 0.00e | 0.00e | 0.00d | 0.00i | 0.00f | 0.00f |
| $V_2T_1$ | 9.33a | 43.00a | 4.00a | 7.67a | 5.69a | 1.70a | 1.99a | 3.25a |
| $V_2T_2$ | 4.00cd | 14.00e | 2.67bc | 5.00b | 2.17c | 0.74e | 1.33bc | 2.02c |
| $V_2T_3$ | 3.00d | 10.67gh | 1.33d | 3.00c | 1.60c | 0.62g | 0.66e | 1.27d |
| $V_2T_4$ | 0.00e | 0.00i | 0.00e | 0.00e | 0.00d | 0.00i | 0.00f | 0.00f |
| $V_3T_1$ | 9.00a | 40.67b | 3.33ab | 7.33a | 4.5ab | 1.57b | 1.70ab | 2.75ab |
| $V_3T_2$ | 4.33cd | 12.67ef | 2.00cd | 4.67b | 2.05c | 0.73e | 1.01c-e | 1.93c |
| $V_3T_3$ | 3.00d | 10.33gh | 1.33d | 2.67cd | 1.55c | 0.60gh | 0.65e | 1.03de |
| $V_3T_4$ | 0.00e | 0.00i | 0.00e | 0.00e | 0.00d | 0.00i | 0.00f | 0.00f |
| $V_4T_1$ | 8.33ab | 31.00c | 2.67bc | 6.67a | 4.03b | 1.43c | 1.29bc | 2.28bc |
| $V_4T_2$ | 4.67c | 12.67ef | 2.00cd | 2.33cd | 2.21c | 0.68f | 0.94c-e | 1.04de |
| $V_4T_3$ | 3.00d | 9.33h | 1.33d | 1.67cd | 1.43c | 0.59gh | 0.63e | 0.76de |
| $V_4T_4$ | 0.00e | 0.00i | 0.00e | 0.00e | 0.00d | 0.00i | 0.00f | 0.00f |
| Level of sig. | * | ** | * | * | * | ** | * | * |
| CV (%) | 13.11 | 7.74 | 12.74 | 6.81 | 6.91 | 5.16 | 13.95 | 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 (control), $T_2$ - Combined hot water extract of lentil and grasspea as pre-emergence at 3 days after transplanting, $T_3$ - Combined hot water extract of lentil and grasspea as post-emergence at 10 days after transplanting, $T_4$ - Hand weeding three times.

**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 (%) |
|---|---|---|---|---|---|---|
| $V_1$ | 103.5a | 8.50a | 20.83a | 78.50a | 23.10a | 43.38a |
| $V_2$ | 87.08c | 6.58c | 18.75c | 74.17d | 19.88d | 38.07c |
| $V_3$ | 93.17b | 7.67b | 19.50c | 75.92c | 21.68b | 41.38b |
| $V_4$ | 93.83b | 8.08ab | 19.92b | 76.75b | 20.32c | 43.21a |
| Level of Significance | ** | ** | ** | ** | ** | ** |
| CV% | 5.31 | 10.72 | 6.68 | 7.31 | 7.98 | 12.03 |

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, $V_1$ - BAU dhan3, $V_2$ - BRRI dhan28, $V_3$ - BRRI dhan81, $V_4$ - BRRI dhan96.

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

Significant interactions between boro rice varieties and the hot water ELG were observed in WP and DW. For E. crus-galli, the highest WP (9.33) and DW (5.69 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 (43.00) and (1.70 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 (1.33 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).

## 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 (103.5 cm), NET $hill^{-1}$ (8.50), SL (20.83 cm), NSP (78.59), TGW (23.10 g) and HI (43.38%) (Table 5). The lowest PH (87.08 cm), NET $hill^{-1}$ (6.58), SL (18.75 cm), NSP (74.17), TGW (19.88 g) and HI (38.07%) was noted in BRRI dhan28 (Table 5). Dola *et al.* (2024) also observed significant differences due to varietal effects in another study. Likewise, significant variation in yield and yield-contributing characters of wheat crops grown with the application of mustard crop residues was reported by Sarkar *et al.* (2020).

## Effects of hot water ELG on yield and yield contributing characters of *boro* rice

Combining hot water ELG markedly affected yield and its contributing factors. The optimal results were observed when Hand weeding three times were used and the highest PH (101.67 cm), NET $hill^{-1}$ (11.25), PL (22.92 cm), NSP (82.25), TGW (22.91 g) and HI (44.31%) were recorded (Table 6). In contrast, the lowest outcomes were noted when no extract was used, resulting in the lowest PH (86.75 cm), NET $hill^{-1}$(4.33), PL (16.17 cm), NSP (68.92), TGW (19.53 g), and HI (36.00%) (Table 6). Effective weed management, by improving water, nutrient, and light availability, led to an increased grain count. Sarker *et al.* (2020) observed that the highest counts and TGW were achieved using the RDH, whereas the lowest were seen with hand weeding.

**Table 6.** Effect of hot water extract of lentil and 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 (%) |
|---|---|---|---|---|---|---|
| $T_1$ | 86.75d | 4.33d | 16.17d | 68.92d | 19.53d | 36.00d |
| $T_2$ | 92.33c | 6.83c | 18.92c | 75.58c | 20.59c | 42.49c |
| $T_3$ | 96.83b | 8.42b | 21.00b | 78.58b | 21.95b | 43.25b |
| $T_4$ | 101.67a | 11.25a | 22.92a | 82.25a | 22.91a | 44.31a |
| Level of Significance | ** | ** | ** | ** | ** | ** |
| CV% | 5.31 | 10.72 | 6.68 | 7.31 | 7.98 | 12.03 |

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 (control), $T_2$ - Combined hot water extract of lentil and grasspea as pre-emergence at 3 days after transplanting, $T_3$ - Combined hot water extract of lentil and grasspea as post-emergence at 10 days after transplanting, $T_4$ - Hand weeding three times.

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

| Interaction | PH (cm) | NET hill$^{-1}$ | PL (cm) | NSP | TGW (g) | HI (%) |
|---|---|---|---|---|---|---|
| $V_1T_1$ | 94.00ef | 5.00f | 17.33hi | 72.00h | 21.67d | 37.16ef |
| $V_1T_2$ | 104.00b | 7.67e | 20.00ef | 78.00ef | 22.75c | 44.98a |
| $V_1T_3$ | 106.00b | 9.33cd | 22.00b-d | 80.00cd | 23.70b | 45.20a |
| $V_1T_4$ | 110.00a | 12.00a | 24.00a | 84.00a | 24.30a | 46.19a |
| $V_2T_1$ | 86.00hi | 3.33g | 15.00j | 66.67j | 18.53i | 33.39g |
| $V_2T_2$ | 92.00f | 5.33f | 18.00gh | 77.00fg | 19.04h | 38.02de |
| $V_2T_3$ | 96.00de | 7.67e | 20.00ef | 78.00ef | 21.04e | 39.16d |
| $V_2T_4$ | 101.33c | 10.00bc | 22.00b-d | 82.00b | 22.66c | 41.72c |
| $V_3T_1$ | 85.00i | 4.33fg | 16.00ij | 67.00j | 19.33gh | 37.45e |
| $V_3T_2$ | 89.00g | 7.00e | 18.67f-h | 71.33hi | 21.02e | 42.07bc |
| $V_3T_3$ | 97.33d | 8.33de | 20.67de | 77.33fg | 22.89c | 42.70bc |
| $V_3T_4$ | 101.33c | 11.00ab | 22.67a-c | 81.00bc | 23.46b | 43.32b |
| $V_4T_1$ | 82.00j | 4.67fg | 16.33ij | 70.00i | 18.57i | 36.01f |
| $V_4T_2$ | 84.33i | 7.33e | 19.00fg | 76.00g | 19.57g | 44.88a |
| $V_4T_3$ | 88.00gh | 8.33de | 21.33c-e | 79.00de | 20.17f | 45.93a |
| $V_4T_4$ | 94.00ef | 12.00a | 23.00ab | 82.00b | 21.22e | 46.01a |
| Level of sig. | ** | * | * | ** | ** | ** |
| CV (%) | 5.31 | 10.72 | 6.68 | 7.31 | 7.98 | 12.03 |

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 (control), $T_2$ - Combined hot water extract of lentil and grasspea as pre-emergence at 3 days after transplanting, $T_3$ - Combined hot water extract of lentil and grasspea as post-emergence at 10 days after transplanting, $T_4$ - Hand weeding three times.

### Effects of interaction between variety and hot water ELG on the yield contributing characters and yield of *boro* rice

Variety has significant effect on total number of branches 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 ELG. The highest PH (110.00 cm) NET hill$^{-1}$ (12.00), PL (24.00), NSP (84.00), TGW (24.30) and HI (46.19 %) were recorded for BAU dhan3 treated with Hand weeding three times. The minimum values for PH (86.00 cm) NET hill$^{-1}$ (3.33), PL (15.00 cm), NSP (66.67), TGW (18.53 g) and HI (33.39 %) 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.

### Effect of variety on GY, SY and BY

The study revealed that different varieties significantly influenced both GY, SY and BY. The highest GY (5.97 t ha$^{-1}$) for BAUdhan3. Lowest number of sterile spikelet panicle$^{-1}$ is the main reason for highest yield. The lowest GY (3.87 t ha$^{-1}$) was observed in BRRI dhan28 (Figure 1). Similarly, the highest SY and BY (7.69 t ha$^{-1}$, 13.64 t ha$^{-1}$) was found in BAUdhan3 and the lowest SY and BY (5.68 t ha$^{-1}$, 10.10 t 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 crop performance.

### Effect of hot water ELG on GY, SY and BY

The application of the hot water ELG had a significant impact on GY, SY and BY. The highest GY (6.08 t ha$^{-1}$) was observed in three times hand weeding and lowest GY (3.56 t ha$^{-1}$), was observed in no extract treatment (Figure 2). Similarly, SY, BY were significantly affected, with the highest SY and BY (7.67 t ha$^{-1}$,13.67 t ha$^{-1}$) recorded in three times hand weeding treatment. The lowest SY and BY (5.99 t ha$^{-1}$, 9.86 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 crop performance. Ahmed *et al.* (2018) also confirmed that the aqueous extract of sorghum crop residues significantly impacts yield and yield-contributing traits.

### Effect of interaction between variety and hot water ELG on GY, SY and BY

The interaction between varieties and hot water ELG significantly influenced GY, SY and BY. The highest GY (7.07 t ha$^{-1}$) was produced by BAUdhan3 and three times hand weeding treatment, and the lowest GY (2.96 t ha$^{-1}$) was produced by

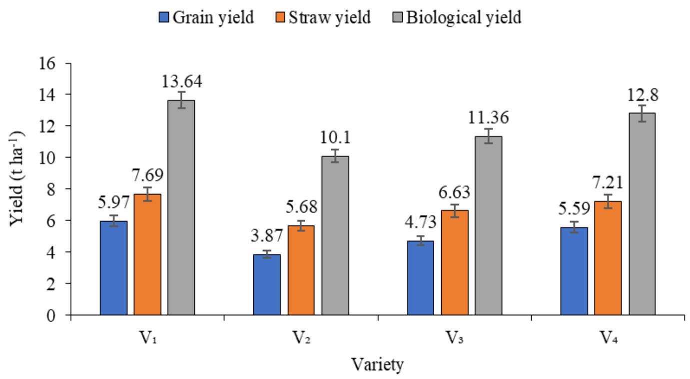



**Figure 1.** *Effect of variety on grain, straw and biological yield of boro rice $V_1$ - BAU dhan3, $V_2$ - BRRI dhan28, $V_3$ - BRRI dhan81, $V_4$ - BRRI dhan96.*

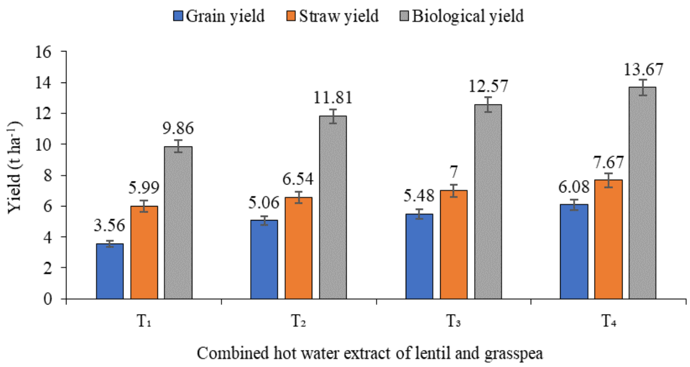



**Figure 2.** *Effect of combined hot water extract of lentil and grasspea on grain, straw and biological yield of boro rice; $T_1$ - No extract (control), $T_2$ - Combined hot water extract of lentil and grasspea as pre-emergence at 3 days after transplanting, $T_3$ - Combined hot water extract of lentil and grasspea as post-emergence at 10 days after transplanting, $T_4$ - Hand weeding three times.*

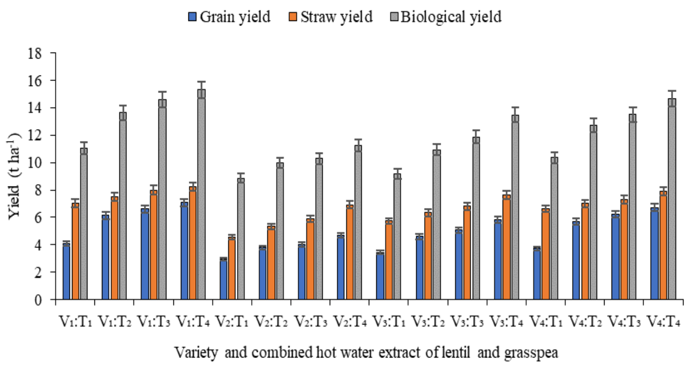



**Figure 3.** *Interaction effect of variety and combined hot water extract of lentil and grasspea on grain, straw and biological yield of boro rice; $V_1$ - BAU dhan3, $V_2$ - BRRI dhan28, $V_3$ - BRRI dhan81, $V_4$ - BRRI dhan96, $T_1$ - No extract (control), $T_2$ - Combined hot water extract of lentil and grasspea as pre-emergence at 3 days after transplanting, $T_3$ - Combined hot water extract of lentil and grasspea as post-emergence at 10 days after transplanting, $T_4$ - Hand weeding three time.*

BRRI dhan28 and no extract treatment (Figure 3). The highest SY and BY (8.23 t ha$^{-1}$, 15.30 t ha$^{-1}$) was observed in BAUdhan3 and three times hand weeding treatment. The lowest SY and BY (4.57 t ha$^{-1}$, 8.87 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 Hossain *et al.* (2017) 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.

## Conclusion

In conclusion, the findings from this study indicate that the three times hand weeding was particularly effective in controlling weeds, thereby minimizing crop loss and inhibiting weed proliferation. Additionally, the treatment that Combined hot water extract of lentil and grasspea as post-emergence at 10 days after transplanting that were closely aligned with those achieved using the three times hand weeding. This indicates that the Combined hot water extract of lentil and grasspea as post-emergence at 10 days after transplanting, nearly matched the weed control effectiveness of the three times hand weeding. The research clearly demonstrates that the Combined hot water extract of lentil and grasspea crop residue not only enhances yield but also serves as an effective herbicidal agent, contributing to the suppression of weed growth.

## DECLARATIONS

### Author contribution statement

Conceptualization: M.R., U.K.S. and M.R.U.; Methodology: M.R.; Software and validation: M.T.A.; Formal analysis and investigation: M.R.; Resources: M.R.; Data curation: M.R.; Writing—original draft preparation: M.R. and M.T.A.; Writing—review and editing: U.K.S. and M.R.U; Visualization: M.R.; Supervision: M.R.U.; Project administration: M.R.U.; Funding acquisition: M.R.U. All authors have read and agreed to the published version of the manuscript.

**Conflicts of interest:** The authors declare that there are no conflicts of interest regarding the publication of this manuscript.

**Ethics approval:** Not applicable.

**Consent for publication:** All co-authors gave their consent to publish this paper in AAES.

**Data availability:** Data will be made available on request.

**Supplementary data:** There is no supplementary data was used.

**Funding statement:** The authors extend their appreciation to University Grants Commission of Bangladesh for financial support.

**Additional information:** No additional information is available for this paper.

## REFERENCES


Afroz, F., Uddin, M. R., Hasan, A. K., Sarker, U. K., Hoque, M. M. I., & Islam, M. A. (2018). Combined allelopathic effect of buckwheat and marsh pepper residues on weed management and crop performance of transplant *aman* rice. *Archive of Agriculture and Environmental Science, 3*(3), 289-296.

Akondo, S., Ahmed, M. T., Uddin, M. R., & Sarker, U. K. (2024). Combined application of herbicide and aqueous extract of sorghum and mustard crop residue enhance weed management and yield of wheat. *Journal of Agroforestry and Environment, 17*(2), 1-11. https://doi.org/10.55706/jae1710

Ahmed, F., Uddin, M. R., Hossain, M. D., Sarker, U. K., Sarkar, D., & Chadny, D. N. (2018). Effect of aqueous extract of sorghum crop residues on weed management and crop performance of wheat. *Bangladesh Agronomy Journal*, *21*(2), 87-95.

Ashraf, S., Sarker, U. K., Perveen, S., Shah, M. S. I., Azam, G., & Uddin, M. R. (2021). Weed control efficacy of combined application of grass pea and mustard crop residues in *T. aman* rice. *Archives of Agriculture and Environmental Science*, *6*(2), 134-141.

BBS. (2023). Yearbook of agricultural statistics, Bangladesh Bureau of Statistics Division, Government people's Republic. Bangladesh, Dhaka.

Cruz, E.D., Moody, K., & Ramos, M.B. (1986). Reducing variability sampling weeds in upland rice (*Oryza sativa*). *Philippine Journal of Weed Science*, *13*, 56-9.

Delye, C., Jasieniuk, M., & Le, C. V. (2013). Deciphering the evolution of herbicide resistance in weeds. *Trends in Genetics*, *29*(11), 649–658.

Dola, N. A., Sarker, U. K., Ahmed, M. T., Upama, S. A., Rashid, M. H. O., & Uddin, M. R. (2024). Comparative advantages of aqueous extract of mustard crop residues with herbicide to weed control and crop performance of wheat. *Archives of Agriculture and Environmental Science*, *9*(2), 294-301.

FAO. & UNDP. (1988). Land resources Appraisal of Bangladesh for Agricultural Development, Report. 2. Agro-Ecological Regions of Bangladesh. BARC/ UNDP, New Airport Road, Farmgate, Dhaka, 1207. pp. 212-221.

Ferdousi, S., Uddin, M. R., Begum, M., Sarker, U.K., Hossain, M. N., & Hoque, M. M. I. (2017). Herbicidal activities of wheat residues in transplant aman rice. *Progressive Agriculture, 28*(4), 253-261.

Gomez, K. A., & Gomez, A. A. (1984). Duncan's, Multiple Range Test. Statistical Procedures for Agricultural Research. 2nd Edition. A Wiley Inter-Science publication, John Wiley and Sons, New York. pp.202-215.

Hossain, M. N., Uddin, M. R., Salam, M. A., Sarker, U. K., Ferdousi, S., & Uddin, M. J. (2017). Allelopathic potential of mustard crop residues on weed management and performance of transplant aman rice. *Journal of Bangladesh Agricultural University*, *15*(2), 133–139.

Khan, M. I., Khan, I., Khan, R., Ahmad, I., & Hashmatullah. (2015). Allelopathic effect of aqueous extract of four weed species on germination of some crops. *The Philippine Journal of Agricultural Scientist, 98*(3), 328–332.

Khan, N., O'Donnell, C., George, D., & Adkins, S.W. (2013). Suppressive ability of selected fodder plants on the growth of Parthenium hysterophorus. *Weed Research*, *53*, 61–68.

Khan, R., Khan, M. A., Shah, S., Uddin, S., Ali, S., & Ilyas, M. (2016). Bio herbicidal potential of plant extracts against weeds of wheat crop under agroclimatic conditions of Peshawar-Pakistan. *Pakistan Journal of Weed Science Research*, *22*(2), 285–294.

Oad, F. C., Siddique, M. H., & Buriro, U. A. (2007). Growth and yield losses in Wheat due to different weed densities. *Asian Journal of Plant Spices, 6*, 173-176.

Pramanik, S. K., Uddin, M. R., Sarkar, U. K., Sarker, D., Ahmed, F., & Alam, M. J. (2019). Allelopathic potential of marsh pepper residues for weed management and yield of transplant aman rice. *Progressing Agriculture*, *30*(4), 379-386.

Sarkar, D., Uddin, M. R., Paul, S. K., Sarker, U. K., Ahmed, F., Pramanik, S., & Chadny, D. N. (2020). Aqueous extract of mustard crop residues on weed management and crop performance of wheat. *SAARC Journal of Agriculture*, *18*(2), 17-26.

Sarker, U. K., Kaysar, Md. S., Nahar, J., & Uddin, M. R. (2022). Reduction in use of herbicides by combining aqueous extract of grass pea for weed management and yield of wheat. *Archives of Agriculture and Environmental Science*, *7*(1), 97–103.

Sarker, U. K., Uddin, M. R., & Faruk, G. M. (2020). Weed suppressing ability and performance of common crop residues for sustainable weed management. *Journal of Research in Weed Science, 3*(3), 310-327.

Sheikh, M. A. H., Uddin, M. R., Salam, M. A., Sarker, U. K., & Haque, M. A. (2017). Weed suppression and crop performance of rice (cv. BRRI dhan29) as influenced by application of different crop residues. *Fundamental and Applied Agriculture*, *2*(1), 207-211.

Soltys, D., Krasuska, U., Bogatek, R., & Gniazdowsk, A. (2013). Allelochemicals as bioherbicides- present and perspectives. *Herbicides- Current Research and Case Studies in Use*, 517–542.

Uddin, M. R., Kim, Y. K., Park, S. U., & Pyon, J. Y. (2009). Herbicidal activity of sorgoleone from grain sorghum root exudates and its contents among sorghum cultivars. *Korean Journal of Weed Science*, *29*(3), 229-236.

Uddin, M. R., Park, K. W., Han, S. M., Pyon, J. Y., & Park, S. U. (2012). Effects of sorgoleone allelochemical on chlorophyll fluorescence and growth inhibition in weeds. *Allelopathy Journal*, *30*(1), 61-70.

Uddin, M. R., & Pyon, J. Y. (2010). Herbicidal activity of rotation crop residues on weeds and selectivity to crops. *Journal of Agricultural Science*, *37*(1), 1-6.

Uddin, M. R., Park, S. U., Dayan, F. E., & Pyon, J. Y. (2014). Herbicidal activity of formulated sorgoleone, a natural product of sorghum root exudate. *Pest Management Science, 70*, 252-257.

Ullah, H., Khan, N., & Khan, I. A. (2023). Complementing cultural weed control with plant allelopathy: Implications for improved weed management in wheat crop. *Acta Ecological Sinica*, *43*(1), 27-33.

Weir, T. L., Park, S. W., & Vivanco, J. M. (2004.) Biochemical and physiological mechanisms mediated by allelochemicals. *Current Opinion in Plant Biology*, *7*, 472-479.

Won, O. J., Uddin, M.R., Park, K. W., Pyon, J. Y., & Park, S. U. (2013). Phenolic compounds in sorghum leaf extracts and their effects on weed control. *Allelopathy Journal*, *31*(1), 147-156.

Yunus, M., Rashid, S., & Chowdhury, S. (2019). Per capita rice consumption in Bangladesh: available estimates and IFPRI's validation survey results. *Washington DC: International Food Policy Research Institute*, 15738.