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Allelopathic Effects of Residues of *Fimbristylis dichotoma* Along with Manures and Fertilizers on the Weed Growth in Boro Rice

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Currently, the rice-growing system seeks a biological solution to reduce the negative impacts of chemical herbicides because it is heavily reliant on these for weed control. This is where allelopathy comes in; it's a potential substitute for conventional weed management strategies in rice cultivation by making use of allelopathic plant residues. In the study we used *Fimbristylis dichotoma* residues with several organic sources of nutrient to measure the integrated effect of manures, fertilizers, and *Fimbristylis dichotoma* residues on weed growth in *boro* rice field. Two rice varieties viz., BRRI dhan29 and BRRI dhan89; and six treatments total viz., Control (T_1), Residues @ 3 t ha^{-1} + Recommended doses of inorganic fertilizers (T_2), Residues @ 3 t ha^{-1} + Tricho-compost @5 t ha^{-1} (T_3), Residues @ 3 t ha^{-1} + Tricho-compost @1.5 t ha^{-1} + 25% less than recommended doses of inorganic fertilizers (T_4), Residues @ 3 t ha^{-1} + Tricho-compost @2.5 t ha^{-1} + 50% less than recommended doses of inorganic fertilizers (T_5) and Residues @ 3 t ha^{-1} + Tricho-compost @3.75 t ha^{-1} + 75% less than recommended doses of inorganic fertilizers (T_6) were taken. In the experiment, at 25 DAT (days after transplanting), BRRI dhan89 had the highest weed density (35.0) when no residue was applied, and BRRI dhan29 had the lowest (18.00) when 3 t ha^{-1} *F. dichotoma* residue with Tricho-compost @ 1.5 t ha^{-1} + 25% less than recommended doses of inorganic fertilizers were applied. At 55 DAT, BRRI dhan89 had the highest weed density (19.66) when no residue was administered, and the lowest (10.66) when 3 t ha^{-1} *F. dichotoma* residue was applied along with Tricho-compost @ 1.5 t ha^{-1} + 25% less than recommended doses of inorganic fertilizers. When it came to dry weight, at 25 DAT, BRRI dhan89 had the highest weed dry weight (3.76 g) when no residue was applied, and BRRI dhan29 had the lowest (1.72 g) when 3 t ha^{-1} *F. dichotoma* residue with Tricho-compost @1.5 t ha^{-1} + 25% less than recommended doses of inorganic fertilizers were applied. At 55 DAT, BRRI dhan89 had the highest weed dry weight (2.29 g) when no residue was sprayed, and the lowest (1.46 g) when 3 t ha^{-1} *F. dichotoma* residue with Tricho-compost @ 1.5 t ha^{-1} + 25% less than recommended doses of inorganic fertilizers were applied. The study's findings suggest that applying *F. dichotoma* residue and incorporating Tricho-compost @ 1.5 t ha^{-1} + 25% less than the recommended amounts of inorganic fertilizers may be able to suppress the growth of weeds and could a package in biological weed control strategy.

Keywords: Allelopathy; manures; fertilizer; Fimbristylis dichotoma; weed management.

1. INTRODUCTION

Mostly used as the primary food source for most people, rice (*Oryza sativa* L.) is the most significant grain crop in the world. Approximately 49% of all calories consumed by humans are derived from rice, wheat, and maize; 23%, 17%, and 9%, respectively, originate from these three sources. Bangladesh is an agriculture-based country, with agriculture contributing for around 13.47% of its GDP [1].

The World Bank estimates that Bangladesh's value added in fisheries, forestry, and agriculture in 2021 was 11.63% [2]. Bangladesh's gross domestic product in 2020 had agriculture as a 12.92 percent contributor [3]. Bangladesh's entire agricultural land was reported to be 70.69% in 2018, according to the World Bank. Over 80% of the irrigated land and 75% of the total cultivated area are planted with rice, according to BRRI. Agriculture remains the most important sector of Bangladesh's economy, employing 63% of the workforce and contributing 19.6% of the country's GDP. The total area of our nation is 14.86 million hectares, of which 8.52 million ha are cultivable and have a 191% cropping intensity [4]. After China, India, and Indonesia, Bangladesh is the world's fourth-largest producer and exporter of rice [5].

The biological process known as allelopathy occurs when a single organism (plant or animal) emits certain secondary metabolites that are detrimental to the survival, germination, growth, and reproduction of other plants or species. There are secondary metabolites (allelopathic substances) in a variety of plant components, including roots, leaves, stems, flowers, and fruits. The physiological and chemical processes of nearby plants and organisms are impacted in various ways by these allelopathic substances [6].

While a number of variables contribute to reduced rice yields, weeds have been highlighted as a significant biological barrier to Bangladesh's pursuit of optimal rice output. Weeds are thought to be the main factor limiting rice yield among the other elements. Without keeping the soil free of weed infestation, it is impossible to get the full benefits of the rice field [7]. The current climatic and edaphic conditions in Bangladesh are particularly conducive to the rapid growth of several weed species that fiercely compete with rice plants [8]. Weeds are severe competitors with rice plants for space, nutrients, air, water, and light because they adversely affect plant height, shading capacity, leaf architecture, growth pattern, tillering behavior, and crop length [9]. Weeds in farmers' fields in Bangladesh are believed to have caused a 43–51% reduction in rice grain output [10].

One of the main weeds of paddy rice, *Fimbristylis dichotoma*, is widely dispersed throughout Asia, Africa, and other tropical regions. Although *F. dichotoma* can thrive on aerated soil, it prefers damp soils [11]. The present research was undertaken to explore the allelopathic potentiality of *F. dichotoma* as there are no available information on allelopathy of these weed in field conditions. Organic manures are environment friendly than inorganic fertilizers. It has been found that adding fertilizer to the soil modifies it in a variety of ways, including chemical changes that may or may not affect how productive the soil is. *F. dichotoma* residues was included in this research to measure the combined effect residues along weed manures and fertilizers. Sustainable agriculture requires a suitable mix of inorganic and organic sources of nutrients because soil fertility is the primary resource for raising rice yield and because improper application of inorganic fertilizers and minimal or nonexistent use of organic manures diminish soil fertility.

2. MATERIALS AND METHODS

2.1 Experimental Site and Soil

Geographically, the area of study is set in the southwest of the Old Brahmaputra River at an elevation of 18 meters above sea level, at latitude 24° 75′ N and longitude 90° 50′ E. This location is part of the Old Brahmaputra Floodplain AEZ-9, which is covered by non-calcareous dark gray floodplain soil [12]. Table 1 shows the research period's physical and chemical properties of the experiment field and soil.

2.2 Climate and Weather

The main meteorological variables that dominated the experimental period—temperature, humidity, rainfall, and daily sunlight hours are displayed in Fig. 1. November through May saw relatively low air temperatures, whereas the remaining months saw high air temperatures. Between 16.46°C to 24.24°C was the average air temperature during the experiment. From November to May, the total sunlight hours ranged from 132.9 to 203.9 hours each month, while the average relative humidity was between 74.18% and 83.71%.

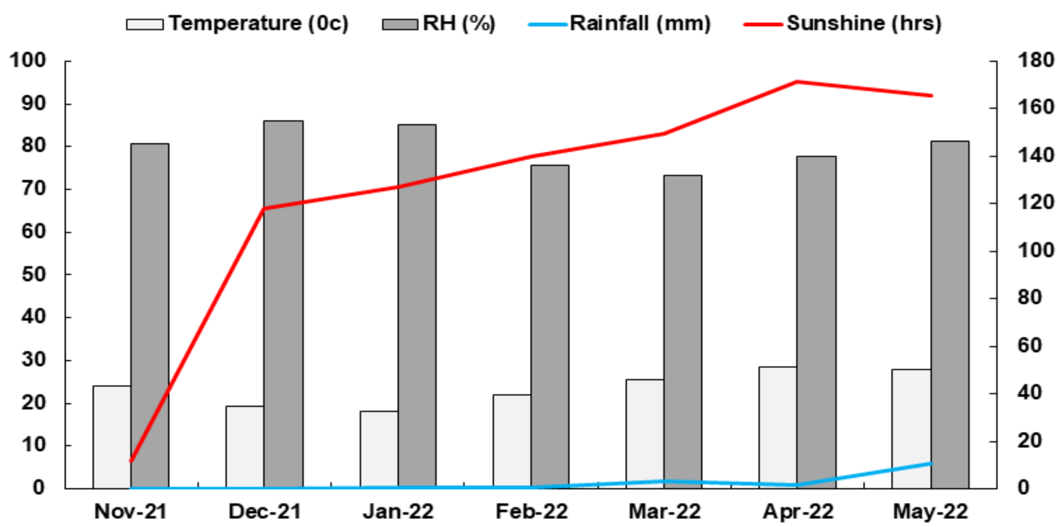

Fig. 1. Monthly distribution of the experiment site's average air temperature, relative humidity, rainfall, and sunlight hours from November 2021 to May 2022

Table 1. Physical and chemical properties of the experiment field and soil

Chemical								Physical					
OM (%)	**pH**	**N (%)**	**S (ppm)**	**P (ppm)**	**Po (me%)**	**Zn**	**CEC**	**BD (g/cc)**	**PD (g/cc)**	**Porosity (%)**	**Sand (1%)**	**Silt (%)**	**Clay (%)**
1.30	6.5	0.10	22.7	27	0.12	0.52	42.27	1.42	2.60	44.7	21.75	66.60	11.65

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

Here, OM= Organic matter, N= Nitrogen, S= Sulphur, P= Phosphorous, Po= Potassium, Zn= Zinc, CEC= Cation Exchange Capacity, BD= Bulk density, PD= Particle density

2.3 Experimental Treatments

The experimental treatment consisted of two factors. They are as follows. Factor A: Rice cultivar (2): BRRI dhan29 (V_1), BRRI dhan89 (V_2). Factor B: Combination of manures and fertilizers with residues of *F. dichotoma*: Control (T_1), Residues @ 3 t ha^{-1} + Recommended doses of inorganic fertilizers (T_2), Residues @ 3 t ha^{-1} + Tricho-compost @5 t ha^{-1} (T_3), Residues @ 3 t ha^{-1} + Tricho-compost @1.5 t ha^{-1} + 25% less than recommended doses of inorganic fertilizers (T_4), Residues @ 3 t ha^{-1} + Tricho-compost @2.5 t ha^{-1} + 50% less than recommended doses of inorganic fertilizers (T_5), Residues @ 3 t ha^{-1} + Tricho-compost @3.75 t ha^{-1} + 75% less than recommended doses of inorganic fertilizers (T_6)

2.4 Experimental Design

Three replications were included in the Randomized Complete Block Design (RCBD) used to set up the experiment. The experiment consisted of 36 plots in all. The unit plot measured 2.5 meters by two meters. There was a 0.5 m gap between each plot and a 1 m gap between each replication. Within a row, the spacing were 15 cm for plants and 30 cm for rows.

2.5 Description of the Rice Cultivar

2.5.1 BRRI dhan29

A high-yielding cultivar of boro rice called BRRI dhan29 was developed by Bangladesh's Rice Research Institute (BRRI) in Gazipur. The 1994 release of the cultivar resulted from the crossing of BG 90-2 and BR 51-45-5. In 155–160 days, the cultivar BRRI dhan29 reaches maturity. BRRI dhan29 is a medium-slim, white plant that grows to a height of 95 cm. Medium in size, the grain has a golden yellow hue. Mid-April to the beginning of May is when BRRI dhan29 is harvested. For BRRI dhan29, 7.5 tons/ha is the ideal yield. BRRI dhan29 is moderately tolerant to leaf blight and sheath blight.

2.5.2 BRRI dhan89

The Bangladesh Rice Research Institute (BRRI) produced the high-yielding boro rice variety BRRI dhan89. 2018 saw the emergence of the cultivar, which was created by crossing Oryza rufipogon with BRRI dhan29. High yielding BRRI dhan89 is a transplanted boro cultivar with a 28.5% amylose content and a 154–158-day crop period. There is 9.8% protein. Weight in 1000-grains is 24.4 grams. Plant height is 106 cm. The harvesting period of BRRI dhan89 is June-August. The optimum yield of BRRI dhan89 is 8-9.7 t ha^{-1}.

2.6 Collection and Preparation of Crop Residues

In this study, *F. dichotoma* residues were employed. These were gathered from Bangladesh Agricultural University's Agronomy Field Laboratory. Following collecting, the residues were sickled into small pieces and allowed to dry under shade on the covered threshing floor.

2.7 Seed Sprouting

By using gravity, healthy seeds were chosen. A bucket of water was used to soak the seeds for a full day. Once out of the water, these were packed densely in a gunny sack. After 72 hours, the seeds were placed in the nursery bed and began to sprout after 48 hours.

2.8 Preparation of Seedling Nursery and Seed Sowing

In Bangladesh Agricultural University, Mymensingh, a high area of land was chosen for the purpose of producing seedlings in the Agronomy Field Laboratory. Cleaning and leveling using a ladder, the soil was thoroughly puddled with a country plough. November 20, 2021, saw the sowing of pre-germinated seeds in the wet nursery bed. The seedling was raised in the bed with the necessary attention. The nursery bed received irrigation when needed and weeds were pulled.

2.9 Land Preparation

Using a powered tiller, the area was plowed on December 25, 2021. Then, in order to level the soil, the ground was completely puddled by plowing and cross-plowing four times with a country plough and two laddering. A country plough was then used to puddle the land. The land was cleared of weeds and stubble. On January 1, 2022, the experimental field's layout was completed in compliance with the experimental design.

2.10 Application of Crop Residues

At the time of the last land preparation, *F. dichotoma* residues were applied seven days prior to rice transplanting. Following that, a shovel was used to thoroughly mix the remains into the corresponding plots.

2.11 Application of Chemical Fertilizers

Applied at 248, 124, 112, 62, and 10 kg ha^{-1}, respectively, were urea, triple super phosphate, muriate of potash, gypsum, and zinc sulphate. In addition to urea applied in three equal splits at 15, 30, and 45 days after transplanting in response to experimental treatments, the full amount of triple super phosphate, muriate of potash, gypsum, and zinc sulphate were applied at the time of final soil preparation.

2.12 Uprooting of Seedlings

The seedlings that were 40 days old were carefully uprooted. To prevent mechanical harm, water was applied to the nursery beds both in the morning and evening of the days before the seedlings were uprooted. The seedlings were then stored in soft dirt in the shade.

2.13 Transplanting of Seedlings

On January 5, 2022, seedlings were moved, resulting in three seedlings per hill at a spacing of 25 cm by 15 cm.

2.14 Procedure of Recording Data

2.14.1 Weed Density (WD)

At 25 and 55 days after transplanting (DAT), data on the WD was gathered from every rice experimental plot. The number and information on the weeds in the experimental plots were recorded.

2.14.2 Weed dry weight (WDW)

The weeds within each quadrate were counted, then they were pulled up, cleaned, divided into species, and dried for 96 hours at 80°C in an electric oven before being placed back in the sun. Using an electric balance, the dry weight of each species was determined.

2.15 Statistical Analysis

In order to facilitate statistical analysis, the data were correctly collected and tabulated. We used statistical analysis to determine the relevance of variance resulting from the experimental treatments on the recorded data on different plant features. The Duncan's Multiple Range Test was utilized to compare the variations in treatment means [13].

3. RESULTS AND DISCUSSION

3.1 Infested Weed Species in the Experimental Field

Infesting the experimental field were six weed species from four families. Table 2 lists the weeds in the experimental plots along with their local name, scientific name, morphological type, family, and life cycle. *Echinochloa crusgalli*, *Paspalum scrobiculatum*, *Monochoria Vaginalis, Cyperus difformis*, *Eleocharis atropurpurea*, and *Eclipta prostrata* were the weeds in the experimental plots. One species of weed was broadleaf, two were sedges, one was herbaceous, and two had morphologies similar to grass. The experimental plot contained two perennial and four annual weed species. Three significant weeds of rice fields were identified by Bari et al. [14] in an experiment conducted at Bangladesh Agricultural University: *Scirpus juncoides*, *Cyperus difformis*, and *Echinochloa crusgalli*.

3.2 Effect of Variety on Different Parameters

It was discovered that there was no substantial difference in the impact of cultivars on WD. BRRI dhan89 (V_2) had the highest WD (29.66) at 25 DAT, while BRRI dhan29 (V_1) had the lowest WD (26.94). According to Table 3, at 55 DAT, BRRI dhan89 (V_2) had the highest WD (15.50) and BRRI dhan29 (V_1) had the lowest WD (14.27). Varietal variations in the leaf area index may result from variations in the genetic components [15].

Varieties did not significantly affect the dry weight of weeds. According to DAT data, BRRI dhan89 (V_2) had the greatest WDW (2.79 g) and BRRI dhan29 (V_1) had the lowest (2.55 g) at 25 days. BRRI dhan89 (V_2) had the highest WDW (1.92 g) at 55 DAT, while BRRI dhan29 (V_1) had the lowest WDW (1.9 g) (Table 3). Jabber [16] and Hossain et al. [17], who discovered a considerable range in WDW, reported similar results.

Table 2. Infesting weed species found growing in the experimental plots of rice

Local Name	**Panichaise**	**Shama**	**Angta**	**Panikachu**	**Sabuj Nakful**	**Keshuti**
Scientific Name	*Eleocharis atropurpurea*	*Echinochloa crusgalli*	*Paspalum scrobiculatum*	*Monochoria Vaginalis*	*Cyperus difformis*	*Eclipta prostrata*
Family	Cyperaceae	Gramineae	Gramineae	Pontederiaceae	Cyperaceae	Asteraceae
Morphological Type	Sedge	Grass	Grass	Broadleaf	Sedge	Herb
Life Cycle	Annual	Annual	Annual	Perennial	Annual	Annual/perennial

Table 3. Effect of varieties on WD and WDW **at the experimental plots of rice field**

Variety	WD		WDW (g)	
	25 DAT	**55 DAT**	**25 DAT**	**55 DAT**
V_1	26.94	14.27	2.55	1.90
V_2	29.66	15.50	2.79	1.92
LSD $_{(0.05)}$	6.17	3.39	0.92	0.53
Level of Significance	NS	NS	NS	NS
CV%	21.54	13.03	19.89	20.17

In a column, figures with the same letter do not differ significantly as per DMRT. NS = Not significant, V_1 = BRRI dhan29, V_2= BRRI dhan89

3.3 Effect of *Fimbristylis dichotoma* Residues with Manures and Fertilizers

F. dichotoma (L.) residues in several concentrations of manures and inorganic fertilizers were shown to have no noticeable effect on WD. When all factors were taken into account, T_4 (Residues @ 3 t ha^{-1} + Tricho-compost @ 1.5 t ha^{-1} + 25% less than recommended doses of inorganic fertilizers) had the lowest WD (25.5) and T_1 (Control) had the greatest WD (32). T_1 (Control) had the highest WD (16.66) at 55 DAT, while T_4 (Residues @ 3 t ha^{-1} + Tricho-compost @ 1.5 t ha^{-1} + 25% less than recommended doses of inorganic fertilizers) had the lowest WD (13.5) (Table 4). Similar outcomes have been presented by Rahman et al. [18].

It was discovered that there was no significant difference in the impact of varying dosages of *F. dichotoma* (L.) residues on WDW. The results showed that at 25 days after treatment, T_4 (Residues @ 3 t ha^{-1} + Tricho-compost @ 1.5 t ha^{-1} + 25% less than recommended doses of inorganic fertilizers) had the lowest WDW (1.99 g) and Control (T_1) had the highest WDW (3.29 g). At 55 DAT, T_4 (Residues @ 3 t ha^{-1} + Tricho-compost @ 1.5 t ha^{-1} + 25% less than recommended doses of inorganic fertilizers) had the lowest WDW (1.69 g) and the greatest WDW (2.17 g) (Table 4). This outcome concurs with the research conducted by Akshay et al. [19].

In a column, figures with the same letter do not differ significantly as per DMRT. NS = Not significant, $T_{1\,=}$ Control, $T_{2\,=}$ Residues @ 3 t ha^{-1} + Recommended doses of inorganic fertilizers, $T_{3\,=}$ Residues @ 3 t ha^{-1} + Tricho-compost @5 t ha^{-1}, $T_{4\,=}$Residues @ 3 t ha^{-1} + Tricho-compost @1.5 t ha^{-1} + 25% less than recommended doses of inorganic fertilizers, $T_{5\,=}$ Residues @ 3 t ha^{-1} + Tricho-compost @2.5 t ha^{-1} + 50% less than recommended doses of inorganic fertilizers, $T_{6\,=}$ Residues @ 3 t ha^{-1} + Tricho-compost @3.75 t ha^{-1} + 75% less than recommended doses of inorganic fertilizers.

3.4 Effect of Interaction of Variety and Residues of *F. dichotoma* with Manures and Fertilizers

At the 5% level of probability, it was discovered that the interaction impact on WD between the variety and various doses of manures and inorganic fertilizers with *F. dichotoma* residue was significant. V_2T_1 (BRRI dhan89 x control) had the highest WD (35.00) at 25 DAT, while V_1T_4 (BRRI dhan29 x Residues @ 3 t ha^{-1} + Tricho-compost @ 1.5 t ha^{-1} + 25% less than authorized doses of inorganic fertilizers) had the lowest WD (18.00). V_2T_1 (BRRI dhan89 x control) had the highest WD (19.66) at 55 DAT, while V_2T_4 (BRRI dhan89 x Residues @ 3 t ha^{-1} + Tricho-compost @ 1.5 t ha^{-1} + 25% less than recommended doses of inorganic fertilizers) had the lowest WD (10.66) (Table 5). Xu et al. [20] reported a similar outcome.

At the 5% level of probability, the interaction impact between variety and *F. dichotoma* residue on WDW was determined to be non-significant. At 25 DAT, V_2T_1 (BRRI dhan89 x control) had the highest WDW (3.76 g), while V_1T_4 (BRRI dhan29 x Residues @ 3 t ha^{-1} + Tricho-compost @ 1.5 t ha^{-1} + 25% less than recommended doses of inorganic fertilizers) had the lowest WDW (1.72 g). At 55 DAT, V_2T_1 (BRRI dhan89 x control) had the highest WDW (2.29 g), while V_2T_4 (BRRI dhan89 x Residues @ 3 t ha^{-1} + Tricho-compost @ 1.5 t ha^{-1} + 25% less than recommended doses of inorganic fertilizers) had the lowest WD (1.46 g) (Table 5). Similar phenomenon was also reported by Shultana et al. [21].

Table 4. Effect of *Fimbristylis dichotoma* residues along with manures and fertilizers

Treatment	WD		WDW (g)	
	25 DAT	55 DAT	25 DAT	55 DAT
T_1	32.00	16.66	3.29	2.17
T_2	28.66	15.83	2.84	2.06
T_3	25.66	14.50	2.50	1.77
T_4	25.50	13.50	1.99	1.69
T_5	27.00	14.50	2.50	1.96
T_6	31.00	14.33	2.90	1.82
LSD $_{(0.05)}$	10.68	5.88	1.59	0.92
Level of Significance	NS	NS	NS	NS
CV%	21.54	13.03	19.89	20.17

Table 5. Effect of interaction of variety and residues of *Fimbristylis dichotoma* along with manures and fertilizers

Interaction	WD		WDW (g)	
	25 DAT	55 DAT	25 DAT	55 DAT
V_1T_1	27.00ab	12.00ab	2.96	1.97
V_1T_2	28.66ab	13.66ab	3.65	2.16
V_1T_3	27.00ab	18.33ab	2.27	1.57
V_1T_4	18.00b	11.66ab	1.72	2.01
V_1T_5	28.66ab	14.00ab	1.91	1.62
V_1T_6	32.33ab	16.00ab	3.15	2.19
V_2T_1	35.00a	19.66a	3.76	2.29
V_2T_2	28.66ab	16.66ab	2.02	2.06
V_2T_3	33.00ab	17.33ab	2.05	1.97
V_2T_4	24.33ab	10.66b	2.82	1.46
V_2T_5	25.33ab	13.00ab	3.10	1.76
V_2T_6	31.66ab	15.66ab	2.66	1.91
LSD $_{(0.05)}$	15.11	8.32	2.26	1.30
Level of Significance	*	*	NS	NS
CV%	21.54	13.03	19.89	20.17

** = Significant at 5% level of probability, others details are same as shown in Table 3 &Table 4*

4. CONCLUSION

The variety BRRIdhan29 and T_4 (residues 3 t ha^{-1} + trichocompost @ 1.5 t ha^{-1} + 25% less than prescribed fertilizers treatment) treatment showed the best effect, according to the data above. The current study's findings indicate that the combined action of *Fimbristylis dichotoma* residues exhibited herbicidal activity, which inhibited the growth of weeds. Therefore, *F. dichotoma* residue, in addition to manures and inorganic fertilizers, may provide an ecologically friendly package for sustainable crop production and a source of weed management tools.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Authors hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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