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ORIGINAL RESEARCH ARTICLE

Weed control efficacy of combined application of grass pea and mustard crop residues in *T. aman* rice

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ABSTRACT

Among different methods of weed control, allelopathy could lead to reduced labor costs and increased efficiency, without any adverse effects on the environment. In this regard, an experiment was conducted at the Agronomy Field Laboratory, Bangladesh Agricultural University, Mymensingh to evaluate the allelopathic potential of grass pea and mustard crop residues on weed suppression and crop performance of transplanted *aman* rice. The experiment consisted of three cultivars of *T. aman* rice *viz.*, Binadhan-7, BRRI dhan49 and BR11 and five different level of crop residues such as no use of crop residues, grass pea crop residues @ 2.5 t ha^{-1}, mustard crop residues @ 2.5 t ha^{-1}, combined use of grass pea and mustard crop residues @ 1 t ha^{-1} of each and hand weeding. All crop residues applied in the experiment suppressed weed growth and inhibition at satisfactory level. The experiment was laid out in a randomized complete block design with three replications. Weed population, weed dry weight and percent inhibition of weed were not significantly influenced by the interaction effect of crop residues (grass pea and mustard) and cultivars. BR11 produced the highest grain and straw yield among the treatment combination. The highest numbers of tillers hill^{-1}, numbers of grains panicle^{-1}, 1000-grain weight, grain yield, straw yield were observed in hand weeding, followed by combined application of grass pea and mustard crop residues @ 1 t ha^{-1} of each treatment. The highest grain and straw yield (4.81 t ha^{-1} and 7.65 t ha^{-1}) was observed in hand weeding along with variety BR11 and the second highest (4.19 t ha^{-1} and 7.36 t ha^{-1}) was obtained from combined use of grass pea and mustard crop residues @ 1 t ha^{-1} of each. The results of this study indicate that hand weeding followed by combined application of grass pea and mustard crop residues @ 1 t ha^{-1} of each showed potential activity to suppress weed growth.

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INTRODUCTION

Rice is the staple food of about 135 million people of Bangladesh and contributes one-half of the agricultural GDP and one-sixth of the national income in Bangladesh. *Aman* is one of the second largest rice-crop in the country in respect to the volume of production while *Boro* remains the top. It is notable that the area coverage of *Aman* is the largest as a single crop and cultivation of *Aman* rice covers approximately 50.56% of the country's total cultivated land area for rice production (Sayeed and Yunus, 2018). Among the various factors reducing the rice yield, weeds are considered as the major constraint. There is no way to get maximum benefit from the rice field without keeping the land free from weed infestation. The subsistence farmers of Bangladesh spend more time and energy on weed control than any other aspects of rice cultivation. Hand weeding is generally practiced in major rice cultivation in Bangladesh. The availability of labors has decreased due to their job diversification. So, the hand weeding method for weed control has become costly and being more difficult day-by-day due to the scarcity of labor (Rahman, 2014). To reduce the cost of rice production, it has been urgently needed to adopt alternative method of weed control. Besides hand weeding there are different modern method of weed management such as, mechanical weed control, biological weed control, chemical or herbicidal weed control, allelopathic weed management etc. (Hossain *et al.*, 2017). Among these strategies, allelopathy is a natural and environment-friendly technique which may prove to be a unique tool for weed management and thereby increase crop yields (Uddin and Pyon, 2010).

Allelopathy is a phenomenon in which one organism release biochemical's that influences the growth, survival, development and reproduction of other organisms. Released biochemical is called as allelochemicals and which have good or lethal effects on targeted organisms (Cheng and Cheng, 2015). Decomposed crop residues releases allelochemicals that can suppress weed boom in farmlands, and decrease the prevalence of diseases and pests. Residue's mulch can increase the content of soil organic matter and improve soil fertility and also it shows negative effect by soil sickness. Foliar application of sorghum leaf extract significantly reduced the growth of weed (Won *et al.*, 2013). Allelopathy is a natural and environment-friendly technique which may prove to be a unique tool for weed management and thereby increase crop yields (Uddin and Pyon, 2010). The incidence of growth inhibition of certain weeds and the induction of phytotoxic symptoms by plants and their residues is well documented for many crops, including all major grain crops such as rice (*Oryza sativa* L.), rye (*Secale cereale* L.), barley, sorghum (*Sorghum bicolor* L.) Moench], wheat, mustard, marshpepper, hairy vetch, buckwheat and other crop residues (Belz, 2004; Uddin and Pyon, 2010; Uddin *et al.*, 2010; Won *et al.*, 2011; Uddin *et al.*, 2012; Won *et al.*, 2013; Uddin *et al.*, 2014; Ferdousi *et al.*, 2017; Hossain *et al.*, 2017; Sheikh *et al.*, 2017; Afroz *et al.*, 2018; Ahmed *et al.*, 2018; Pramanik *et al.*, 2019; Rahman *et al.*, 2000; Sarker *et al.*, 2020a; Sarker *et al.*, 2020b).

Control of weeds in *T. aman* rice with environmentally sound weed management practices will increase crop productivity along with economically suitable practice. However, in Bangladesh, a little attempt has been done to investigate the weed suppressing ability of grass pea and mustard crop residues and its optimum dose to establish an easy, economic and sustainable method for efficient weed management of *T. aman* rice. Therefore, the present study was conducted to evaluate the effectiveness of application of grass pea and mustard crop residues for suppressing weed growth and crop performance of *T. aman* rice.

MATERIALS AND METHODS

The experiment was carried out at the Agronomy Field Laboratory of Bangladesh Agricultural University, Bangladesh during *aman* season (July-November) of 2018 to investigate the combined effect of grass pea and mustard crop residues on weed management and crop performance of *T. aman* rice. The soil of the experimental site was more or less neutral in reaction with pH value 6.8, low in organic matter and fertility level. The experimental consisted of two factors, Factor A - Variety: (i) Binadhan-7 (V_1), (ii) BRRI dhan49 (V_2), (iii) BR11 (V_3) and Factor B- Application of grass pea and mustard crop residues (5): (i)No use of crop residues (T_1) (Control), (ii) Grass pea crop residues @ 2.5 t ha^{-1} (T_2), (iii) Mustard crop residues @ 2.5 t ha^{-1} (T_3), (iv) Combined use of grass pea and mustard crop residues @ 1 t ha^{-1} of each (T_4), (v) Hand weeding (T_5). The experiment was laid out in a randomized complete block design (RCBD) with three replications. The total number of plots was 45. Each plot size was (2.5 m× 2.0 m). The distance maintained between the individual unit plots was 0.5 m and distance between the replication was 1.0 m. The experimental plots were fertilized with urea, triple super phosphate, muriate of potash and gypsum @ 150, 52, 82, 60 kg ha^{-1}, respectively for the variety of BR11 & BRRI dhan49. On the other hand, 165 kg urea, 115 kg triple super phosphate, 65 kg muriate of potash, 55 kg gypsum and 6 kg zinc sulphate per hectare were applied to the field for Binadhan-7. Except urea, the whole amounts of other fertilizers were applied before final land preparation. Urea was top dressed in two installments at 20 and 40 DAT (Days after Transplanting). The prepared grass pea and mustard crop residues were applied one week before final land preparation as per treatment. Weeds were collected after 30 days of transplanting and counted accordingly. Then the weeds are oven dried for getting dry weight. Data of yield and yield contributing characters were recorded from five randomly selected sample plants from each plot. Data recorded for different parameters were compiled and tabulated in proper form and subjected to statistical analysis. The Analysis of variance was done with the help of computer package MSTAT-C program. The mean differences among the treatments were adjudged by Duncan's Multiple Range Test (DMRT) as laid out by Gomez and Gomez (1984).

RESULTS AND DISCUSSION

Infested weed species in the experimental field

Five weed species belonging to five families infested the experimental field. Local name, scientific name, family, morphological type and life cycle of the weed in the experimental plot have been presented in Table 1. The weeds of the experimental plots were *Echinochloa crusgalli*, *Nymphaea nouchali*, *Scirpus juncoides*, *Monochoria vaginalis*, *Marsilea quadrifolia L*. Among the weed species three were broadleaf, one sedge and one grass type morphology. There were three perennial and two annual weed species in the experimental plot.

Effect of variety and crop residues on weed growth and percent inhibition of different weed plants

Interaction effect of variety and different crop residues were found non-significant for different weed plants (Tables 2-4).

Table 1. Infesting weed species found in the experimental plots in rice

S. N.	Local name	Scientific name	Family	Morphological type	Life cycle
1	Shama	*Echinochloa crusgalli*	Gramineae	Grass	Annual
2	Pani Shapla	*Nymphaea nouchali* Wild.	Nymphaeacee	Broadleaf	Perennial
3	Chechra	*Scirpus juncoides*	Cyperaceae	Sedge	Perennial
4	Pani kachu	*Monochoria vaginalis*	Pontederiaceae	Broadleaf	Perennial
5	Susni Shak	*Marsilea quadrifolia* L.	Marsileaceae	Broadleaf	Annual

Table 2. Combined effect of variety and different crop residues on weed density of different weed plants.

Treatment combination	Number of weeds (m^{-2})				
	E. crusgalli (Shama)	*N. nouchali* (Pani Shapla)	*S. juncoides* (Chesra)	*M. vaginalis* (Pani Kachu)	*M. quadrifolia* (Susni Shak)
V_1T_1	7.00	1.33	2.33	8.33	5.00
V_1T_2	3.33	1.00	2.33	5.33	1.33
V_1T_3	2.33	0.66	2.00	4.33	1.33
V_1T_4	1.66	0.33	1.33	4.33	1.33
V_1T_5	1.66	0.33	1.33	2.33	1.00
V_2T_1	7.00	1.33	2.33	7.66	4.00
V_2T_2	4.00	0.66	1.66	5.66	1.66
V_2T_3	3.33	0.66	1.66	4.00	1.33
V_2T_4	2.33	0.33	1.33	3.66	1.33
V_2T_5	1.66	0.33	1.00	1.66	1.33
V_3T_1	6.66	1.66	2.66	7.66	5.00
V_3T_2	3.33	1.00	2.00	6.33	2.00
V_3T_3	3.00	0.66	1.66	5.33	2.00
V_3T_4	2.00	0.33	1.33	3.00	1.33
V_3T_5	1.66	0.33	1.33	1.66	1.33
$LSD_{0.05}$	1.28	1.12	0.94	1.73	1.16
Level of significance	NS	NS	NS	NS	NS

In a column, figures with the same letters do not differ significantly as per DMRT, NS= Non-significant; V_1=Binadhan-7, V_2= BRRI dhan49, V_3= BR11; T_1=No use of crop residues, T_2 = Grass pea crop residues @ 2.5 t ha^{-1}, T_3= Mustard crop residues @ 2.5 t ha^{-1}, T_4 = Combined use of grass pea and mustard crop residues @ 1 t ha^{-1} of each, T_5 = Hand weeding.

Table 3. Combined effect of variety and different crop residues on dry weight of different weed plants.

Treatment combination	Dry weight of weed (g)				
	E. crusgalli (Shama)	*N. nouchali* (Pani Shapla)	*S. juncoides* (Chesra)	*M. vaginalis)* (Pani Kachu)	*M. quadrifolia* (Susni Shak)
V_1T_1	11.06	0.33	1.42	3.70	2.00
V_1T_2	5.28	0.25	0.89	2.36	0.70
V_1T_3	3.65	0.16	0.78	2.01	0.61
V_1T_4	2.61	0.07	0.54	1.85	0.50
V_1T_5	1.94	0.04	0.24	0.74	0.38
V_2T_1	10.98	0.40	1.14	3.26	1.77
V_2T_2	6.17	0.20	0.72	2.60	0.65
V_2T_3	5.16	0.15	0.55	2.08	0.58
V_2T_4	3.68	0.08	0.41	1.65	0.49
V_2T_5	2.08	0.04	0.20	0.61	0.34
V_3T_1	10.47	0.46	1.18	3.50	2.00
V_3T_2	5.16	0.24	0.69	2.75	0.83
V_3T_3	4.63	0.19	0.54	2.22	0.71
V_3T_4	3.09	0.11	0.43	1.33	0.52
V_3T_5	2.05	0.05	0.22	0.69	0.34
$LSD_{0.05}$	1.91	0.26	0.37	0.70	0.44
Level of significance	NS	NS	NS	NS	NS

NS= Non-significant; V_1=Binadhan-7, V_2= BRRI dhan49, V_3= BR11; T_1=No use of crop residues, T_2 = Grass pea crop residues @ 2.5 t ha^{-1}, T_3= Mustard crop residues @ 2.5 t ha^{-1}, T_4 = Combined use of grass pea and mustard crop residues @ 1 t ha^{-1} of each, T_5 = Hand weeding.

Table 4. Combined effect of variety and different crop residues on percent inhibition of different weed plants.

Treatment combination	% inhibition				
	E. crusgalli (Shama)	*N. nouchali* (Pani Shapla)	*S. juncoides* (Chesra)	*M. vaginalis* (Pani Kachu)	*M. quadrifolia* (Susni Shak)
V_1T_1	0.00	0.00	0.00	0.00	0.00
V_1T_2	52.29	35.63	37.17	35.37	64.13
V_1T_3	66.61	49.13	44.82	43.62	66.93
V_1T_4	75.37	73.56	62.82	48.34	74.65
V_1T_5	82.53	90.47	82.36	78.78	80.33
V_2T_1	0.00	0.00	0.00	0.00	0.00
V_2T_2	42.3	41.18	35.69	19.31	63.59
V_2T_3	51.66	64.61	51.15	36.64	63.32
V_2T_4	65.31	75.75	60.22	48.90	69.04
V_2T_5	80.61	91.66	80.96	81.08	79.12
V_3T_1	0.00	0.00	0.00	0.00	0.00
V_3T_2	49.32	53.00	36.08	21.32	55.19
V_3T_3	56.32	55.50	54.54	36.36	63.20
V_3T_4	69.95	68.57	63.01	62.42	73.85
V_3T_5	79.58	88.43	81.02	80.33	81.42
$LSD_{0.05}$	18.48	62.13	26.02	16.98	21.75
Level of significance	NS	NS	NS	NS	NS

In a column, figures with the same letters do not differ significantly as per DMRT, NS= Non-significant; V_1=Binadhan-7, V_2= BRRI dhan49, V_3= BR11;T_1=No use of crop residues, T_2 = Grass pea crop residues @ 2.5 t ha^{-1}, T_3= Mustard crop residues @ 2.5 t ha^{-1}, T_4 = Combined use of grass pea and mustard crop residues @ 1 t ha^{-1} of each, T_5 = Hand weeding.

Table 5. Effect of variety on yield contributing characters and yield of *T. aman* rice.

Variety	Plant height (cm)	Number of total tillers $hill^{-1}$	Number of effective tillers $hill^{-1}$	Number of non-effective tillers $hill^{-1}$	Panicle length (cm)	No. of grains $panicle^{-1}$	1000- grain weight (g)	Harvest index (%)
V_1	101.19c	11.54a	8.85a	2.69a	21.21a	87.36c	21.48c	38.69a
V_2	107.80a	10.81c	8.38b	2.42b	20.47b	91.34b	22.20b	37.70b
V_3	106.16b	11.06b	8.41b	2.64a	21.13a	97.45a	22.80a	37.30c
$LSD_{(0.05)}$	0.65	0.11	0.14	0.13	0.11	0.89	0.08	0.31
Level of significance	**	**	**	**	**	**	**	**

In a column, figures with same letter(s) or without letter do not differ significantly whereas figures with dissimilar letter differ significantly as per DMRT. **=Significant at 1% level of probability; V_1=Binadhan-7, V_2=BRRI dhan49, V_3=BR11.

Weed density of different weed plants had no significant difference among them. Numerically, the highest weed population of Shama (7.00), Pani Kachu (8.33) and Susni Shak (5.00) were found both in V_1T_1(Binadhan-7 × no crop residues) and V_2T_1 (BRRI dhan49 × no crop residues), and the lowest Shama population 1.66 was found in V_1T_4, V_1T_5, V_2T_5 and V_3T_5 treatment (Table 2). The maximum number of Pani Shapla weed (1.66) and Chesra (2.66) were found in V_3T_1 (BR11 × no crop residue). The lowest number of Pani Shapla (0.33) was found in V_1T_4, V_1T_5, V_2T_4, V_2T_5, V_3T_4 and V_3T_5 treatments. The lowest population of Chesra (1.00) and Pani Kachu (1.66) were observed fromV_2T_5 (BRRI dhan49 × hand weeding) treatment (Table 2). Ahmed *et al.* (2018) showed that variety have significant effect on number of weed population for biskatali, tit begun, shama and angta.

Combined effect of variety and different crop residues had no statistical significance on weed dry weight (Table 3). Numerically, the highest dry weight of Shama (11.06 g),Chesra(1.42 g), Pani Kachu (3.70 g) and Susni Shak (2.00 g) was found in V_1T_1 (Binadhan-7 × no crop residues) and the maximum dry weight of Pani Shapla (0.46 g) was found in V_3T_1(BR11 × no crop residue). The lowest weed dry weight of Shama (1.94 g), and Pani Shapla (0.04 g), were observed in V_1T_5 (Binadhan-7 × hand weeding). Treatment combination V_2T_5 showed the lowest result for Chesra(0.20 g), Pani Kachu (0.61 g) and Susni Shak (0.34g).

Apparently, percent inhibition of Shama (82.53%) and Chesra (82.36%) were the highest in V_1T_5(Binadhan-7 × hand weeding) treatment presented in Table 4. Treatment V_2T_5(BRRI dhan49 × hand weeding) showed the highest percent inhibition of Pani Shapla (91.66%),Pani Kachu (81.08%) and Susni Shak (81.42%). Ferdousi *et. al.* (2017) found that the highest percent inhibition of 75.32, 58.24, 72.60, 57.45 and 82.24 was in Shama, Panishapla, Pani chaise, Panikachu and Susnishak, respectively which was caused by the application of wheat crop residues @ 2 t ha^{-1}.

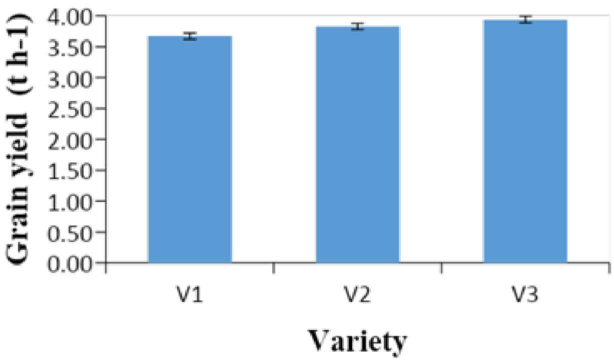

Figure 1. *Grain yield as influenced by variety (Bar represents standard error of mean); V_1=Binadhan-7, V_2= BRRI dhan49, V_3= BR11.*

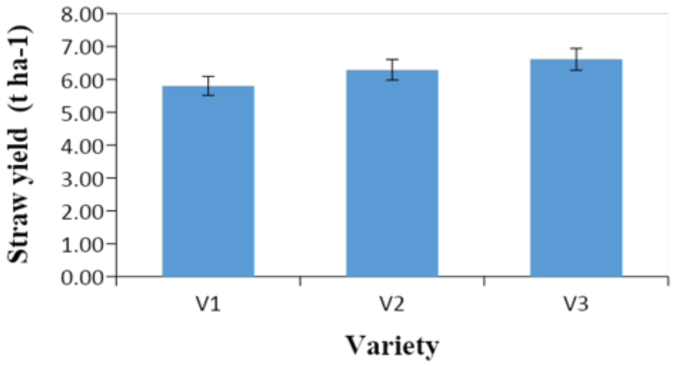

Figure 2. *Straw yield as influenced by variety (Bar represents standard error of mean); V_1=Binadhan-7, V_2= BRRI dhan49, V_3= BR11.*

Effect of variety on yield contributing characters and yield of crop

Variety had significant influenced on yield and yield contributing characters of *T. aman* rice (Table 5). The tallest plant (107.80 cm) was observed in BRRI dhan49 and the shortest plant (101.19 cm) was found in Binadhan-7. Plant height is a varietal character and the genetic constituent of the cultivar. Therefore, it was different among the three varieties. Similar findings were found by Rahman *et al.* (2020). The highest number of total tillers hill^{-1} (11.54) and number of effective tillers hill^{-1} (8.85) were found in Binadhan-7 and the lowest number of total tillers hill^{-1} (10.81) and effective tillers hill^{-1} (8.38) were found in BRRI dhan49 (Table 5). The probable reason of the differences in producing effective tillers hill^{-1} was the genetic make-up of the variety which was primarily influenced by heredity. These findings collaborated with those reported by BRRI (2018) who stated that effective tillers hill^{-1} was varied with variety. Sarker *et al.* (2020) reported similar trend of tillering habits with different varieties of rice. The longest panicle (21.21 cm) was recorded in Binadhan-7 and the shortest panicle (20.47 cm) was recorded in BRRI dhan49 (Table 5). This result was similar to Sheikh *et al.* (2017), who reported that panicle length has significant relationship with variety. The highest number of grains (97.45) was observed in BR11 and the lowest one (87.36) was found in Binadhan-7. Hasan (2015) reported variable number of grains among the varieties. The highest thousand grain weight (22.80 g) was found in BR11 and the lowest one (21.48) was found in Binadhan-7 (Table 5). Varietal differences regarding the number of grains and thousand grain weights might be due to differences in genetic constituents. This finding collaborates with the findings of Hasan (2015), Nomun *et al.* (2020), Sarker *et al.* (2020a) and Paul *et al.* (2021).

The studied varieties significantly affected the grain and straw yield (Figures 1 and 2). The highest grain yield (3.94 t ha^{-1}) was obtained in BR11, followed by (3.83 t ha^{-1}) in BRRI dhan49 and the lowest grain yield (3.67 t ha^{-1}) was obtained in Binadhan-7 (Figure 1). Different yield parameters (no. of tiller, no of grain panicle^{-1}, filled grain panicle^{-1}, 1000 grain weight etc.) influenced the grain and straw yields.

The highest straw yield (6.61 t ha^{-1}) was found in BR11 followed by BRRI dhan49 (6.29 t ha^{-1}) and the lowest straw yield (5.80 t ha^{-1}) was found in Binadhan-7 (Figure 2).

The highest biological yield (10.55 t ha^{-1}) was found in BR11 and the lowest biological yield (9.48 t ha^{-1}) was found in Binadhan-7. These results are in conformity with that obtained by Sheikh *et al.* (2017), who reported the differences in biological yield among the varieties. The highest harvest index (38.69%) was found in Binadhan-7 and the lowest harvest index (37.30%) was found in BR11 (Table 5). Similar findings were proposed by Rahman *et al.* (2020), who compared 10 varieties for yield components.

Effect of crop residues on yield contributing characters and yield of crop

Grass pea and mustard crop residues had significant effect on yield and yield contributing characters of *T. aman* rice (Table 6). The tallest plant (114.99 cm) was found in T_5 (hand weeding) treatment followed by T_4 (combined use of grass pea and mustard crop residues @ 1 tha^{-1} of each) treatment and the shortest plant (99.57 cm) was found in T_1 (no crop residues) treatment. This might be due to the availability of more nutrients from a weed free environment. Similar findings were found by Hasan (2015), who reported that the highest plant height was produced due to weed free condition and the lowest plant height was in no weeding condition. The highest number of total tillers hill^{-1} (13.24) and the number of effective tillers hill^{-1} (10.91) were produced by T_5 (hand weeding) treatment, followed by T_4 (combined use of grass pea and mustard crop residues @ 1 t ha^{-1} of each) treatment and the lowest number of total tillers hill^{-1} (8.96) and number of effective tillers hill^{-1} (6.18) was produced by T_1 (no crop residue) treatment (Table 6). The longest panicle (21.87 cm) was observed in T_5 (hand weeding) treatment followed by T_4 (combined use of grass pea and mustard crop residues @ 1 t ha^{-1} of each) treatment and the shortest one (19.99 cm) was observed in T_1(no crop residue) treatment (Table 6). Similar findings were found by Hossain *et al.* (2017), who reported that weed free condition facilitates more favorable condition which improves the panicle length of crop plants. The highest number of grains panicle^{-1} (97.29) was produced by T_5 (hand weeding) treatment followed by T_4 (combined use of grass pea and mustard crop residues @ 1 t ha^{-1} of each) treatment while the lowest number of grains panicle^{-1} (87.01) was produced by T_1(no crop residue) treatment. It indicates that the highest crop residues encourage the number of grains.

Table 6. Effect of crop residues on yield contributing characters and yield of *T. aman* rice.

Treatment	Plant height (cm)	Number of total tillers hill^{-1}	Number of effective tillers hill^{-1}	Panicle length (cm)	No. of grains panicle^{-1}	1000- grain weight (g)	Harvest index (%)
T_1	99.57e	8.96e	6.18e	19.99e	87.01e	21.34e	36.02c
T_2	100.85d	10.02d	7.32d	20.48d	89.38d	21.56d	37.88b
T_3	102.97c	10.80c	8.12c	20.93c	91.60c	22.10c	38.08b
T_4	106.88b	12.65b	10.21b	21.41b	94.97b	22.51b	38.03b
T_5	114.99a	13.24a	10.91a	21.87a	97.29a	23.31a	39.48a
$LSD_{(0.05)}$	0.84	0.14	0.18	0.14	1.16	0.09	0.40
Level of significance	**	**	**	**	**	**	**

In a column, figures with same letter(s) or without letter do not differ significantly whereas figures with dissimilar letter differ significantly as per DMRT; ** = Significant at 1% level of probability; T_1=No use of crop residues, T_2= Grass pea crop residues @ 2.5 t ha^{-1}, T_3= Mustard crop residues @ 2.5 t ha^{-1}, T_4= Combined use of grass pea and mustard crop residues @ 1 t ha^{-1} of each, T_5= Hand weeding.

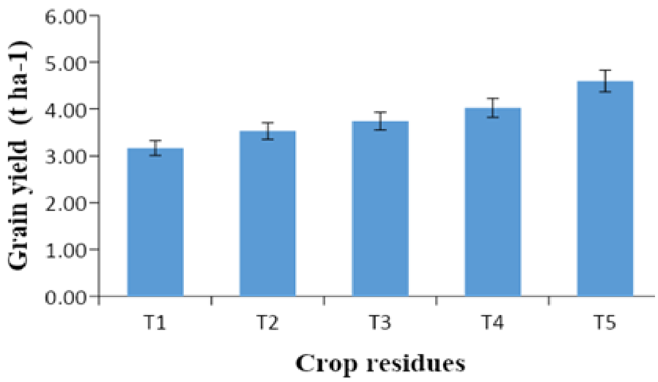

Figure 3. *Grain yield as influenced by grass pea and mustard crop residues (Bar represents standard error of mean); T_1=No use of crop residues, T_2= Grass pea crop residues @ 2.5 t ha^{-1}, T_3= Mustard crop residues @ 2.5 t ha^{-1}, T_4= Combined use of grass pea and mustard crop residues @ 1 t ha^{-1} of each, T_5= Hand weeding.*

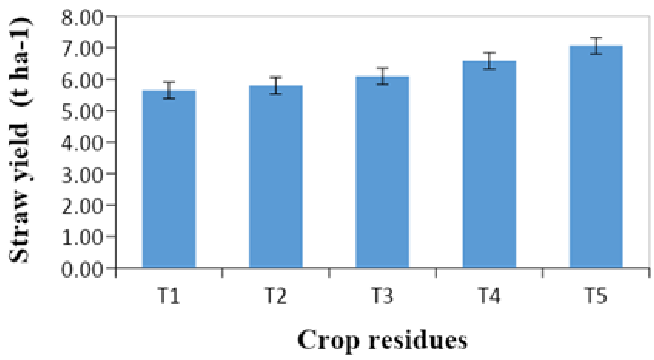

Figure 4. *Straw yield as influenced by grass pea and mustard crop residues (Bar represents standard error of mean); T_1=No use of crop residues, T_2= Grass pea crop residues @ 2.5 t ha^{-1}, T_3= Mustard crop residues @ 2.5 t ha^{-1}, T_4= Combined use of grass pea and mustard crop residues @ 1 t ha^{-1} of each, T_5= Hand weeding.*

Rahman *et al.* (2020) observed that effective weed management increased number of grains due to more availability of water, nutrients and light. The highest weight of 1000 grains (23.31 g) were recorded in T_5 (hand weeding) treatment, followed by T_4 (combined use of grass pea and mustard crop residues @ 1 t ha^{-1} of each) treatment and the lowest one (21.34) was produced by T_1 (no crop residue) treatment (Table 6). Similar findings were found by Hossain (2017), who reported that weed free condition facilitates more favorable condition for crop plants which ultimately improve 1000-grain weight.

Grain yield and straw yield were significantly influenced by grass pea and mustard crop residues (Figure 3 and Figure 4). The highest grain yield (4.60 t ha^{-1}) was produced by T_5 (hand weeding) treatment, followed by T_4 (combined use of grass pea and mustard crop residues @ 1 t ha^{-1} of each) (4.02 t ha^{-1}) and lowest one (3.17 t ha^{-1}) was produced by T_1 (no crop residue) treatment (Figure 3). Incorporation of grass pea and mustard crop residues @ 1 t ha^{-1} of each, decrease weed emergence in the rice field and produced second maximum grain yield. On the other hand, control plot (no crop residue) showed maximum weed population and highest dry weight of weed. The weeds compete with the crop for nutrient, water, air, sunlight and space and so grain yield decreased. Uddin and Pyon (2010) reported that crop residues influence crop performance.

The highest straw yield (7.06 t ha^{-1}) was observed in T_5 (hand weeding) treatment and the lowest straw yield (5.64 t ha^{-1}) was observed in T_1 (no crop residues) treatment (Figure 4). It might be due to application of crop residues added organic matter to the soil and enhance straw yield.

The highest biological yield (11.66 t ha^{-1}) was obtained in T_5 (hand weeding) treatment and the lowest biological yield (8.81 t ha^{-1}) was obtained in T_1 (no crop residue) treatment (Table 6). Variations in biological yield among the weed control treatment were dependent upon the severity of weed infestation and climatic condition. The highest harvest index (39.48%) was observed in T_5 (hand weeding) treatment, and the lowest harvest index (36.02%) was observed in T_1 (no crop residue) treatment (Table 6). Higher weed infestation not only reduced grain yield and finally influenced straw yield as well as biological yield.

Table 7. Combined effect of variety and different crop residues on yield contributing characters and yield of *T. aman* rice.

Interaction	Plant height (cm)	Number of total tillers hill^{-1}	Number of effective tillers hill^{-1}	Panicle length (cm)	No. of grains panicle^{-1}	No. of sterile spikelets panicle^{-1}	1000- grain weight (g)	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Harvest index (%)
V_1T_1	97.17j	9.33h	6.36i	20.14fg	83.67k	17.36	20.58j	3.07l	5.32j	36.56g
V_1T_2	98.70i	10.16f	7.43g	20.67e	86.00ij	16.53	20.85i	3.43j	5.52i	38.35cde
V_1T_3	101.14gh	11.64d	8.72e	21.23d	87.57hi	15.78	21.64h	3.66gh	5.78h	38.81bc
V_1T_4	102.82f	12.99b	10.53c	21.82b	89.13gh	15.16	21.90g	3.91ef	6.02f	39.36b
V_1T_5	106.12e	13.57a	11.20a	22.19a	90.45g	14.48	22.45de	4.31c	6.36d	40.38a
V_2T_1	100.73h	8.75i	6.22ij	19.69h	84.87jk	18.18	21.59h	3.22k	5.84gh	35.52h
V_2T_2	102.46fg	9.66g	7.06h	20.07g	87.53hi	17.58	21.87g	3.54i	5.93fg	37.41f
V_2T_3	105.00e	10.03f	7.56g	20.32f	90.24g	16.82	22.12f	3.73g	6.18e	37.66ef
V_2T_4	109.96c	12.54c	10.17d	20.85e	95.44de	15.98	22.31e	3.97e	6.36d	38.46cd
V_2T_5	120.86a	13.08b	10.90ab	21.44cd	98.65bc	15.43	23.11c	4.67b	7.16c	39.47b
V_3T_1	100.80h	8.81i	5.96j	20.14fg	92.52f	18.34	21.84g	3.23k	5.75h	35.98gh
V_3T_2	101.39fgh	10.24f	7.47g	20.71e	94.63e	17.35	21.95g	3.63hi	5.95fg	37.87def
V_3T_3	102.75f	10.75e	8.08f	21.24d	97.01cd	16.54	22.54d	3.83f	6.32d	37.76ef
V_3T_4	107.86d	12.44c	9.94d	21.56c	100.34b	16.00	23.32b	4.59b	7.36b	36.27g
V_3T_5	118.01b	13.08b	10.63bc	21.99ab	102.78a	15.23	24.37a	4.81a	7.65a	38.61c
$LSD_{(0.05)}$	1.46	0.24	0.31	0.24	2.00	0.41	0.17	0.09	0.12	0.69
Level of significance	**	**	**	*	**	NS	**	**	**	**

In a column, figures with same letter(s) or without letter do not differ significantly where figures with dissimilar letter differ significantly as per DMRT, ** = Significant at 1% level of probability, * = Significant at 5% level of probability, NS = non-significant, V_1=Binadhan-7, V_2= BRRI dhan49, V_3= BR11, T_1=No use of crop residues, T_2= Grass pea crop residues @ 2.5 t ha^{-1}, T_3= Mustard crop residues @ 2.5 t ha^{-1}, T_4= Combined use of grass pea and mustard crop residues @ 1 t ha^{-1} of each, T_5 = Hand weeding.

Interaction effect of variety and crop residues on yield contributing characters and yield of crop

The effect of interaction between variety and crop residues had significant impact on yield and yield contributing characters of *T. aman* rice (Table 7). The tallest plant (120.86 cm) was obtained from BRRI dhan49 in T_5 (hand weeding) treatment and Binadhan-7 produced the shortest plant in T_1 (no crop residue) treatment. This might be due to the availability of more nutrients from a weed free environment. The highest number of total tillers hill^{-1} (13.57) and number of effective tillers hill^{-1} (11.20) were produced by Binadhan-7 in T_5 (hand weeding) treatment, while the lowest number of total tillers hill^{-1} (8.75) and number of effective tillers hill^{-1} were found from BRRI dhan49 in T_1 (no crop residue) treatment. Sarkar *et al.* (2020) reported that interaction between variety and crop residues facilitate tillering by suppressing weed population. The longest panicle (22.19 cm) was observed in Binadhan-7 in T_5 (hand weeding) treatment and the shortest one (19.69) was found in BRRI dhan49 in T_1 (no crop residue) treatment (Table 6). Similar findings were found by Sheikh *et al.* (2017), who reported that interaction between variety and crop residues suppress the weed population which facilitate the panicle length of crop plants. The highest number of grains panicle^{-1} (102.78) was produced by BR11 in T_5 (hand weeding) treatment and the lowest number of grains panicle^{-1} (83.67) was produced by Binadhan-7 in T_1 (no crop residue) treatment (Table 7). The interaction between variety and crop residues plays an important role in effective weed management which increased number of grains due to more favorable environment (Hossain *et al.*, 2017). Weight of 1000-grains was significantly affected by the interaction between variety and crop residues. The highest weight of 1000 grains (24.37) were recorded in BR11 in T_5 (hand weeding) treatment (Table 7). This finding was similar with the findings of Sarker *et al.* (2020b), who reported that interaction between variety and crop residues plays an important role in case of increased 1000-grain weight.

Grain yield and straw yield were significantly influenced by the interaction between varieties and crop residues. The highest grain yield (4.81 t ha^{-1}) and straw yield (7.65 t ha^{-1}) were produced by BR11 in T_5 (hand weeding) treatment and the lowest grain yield (3.07 t ha^{-1}) and straw yield (5.32 t ha^{-1}) were produced by Binadhan-7 in T_1 (no crop residue) treatment (Table 7). The lowest yield ha^{-1} in the control plot might be due to the poor performance of yield contributing characters like number of tillers hill^{-1} and grain panicle^{-1}. Severe weed infestation occurred in the plots due to competition for moisture, nutrients between weed and rice plants. Similar results were also observed by Sarker *et al.* (2020). The highest biological yield (12.47 t ha^{-1}) and harvest index (40.38%) were produced by BR11 in T_5 (hand weeding) treatment and the lowest biological yield (8.39 t ha^{-1}) and harvest index (35.52%) were produced by Binadhan-7 in T_1 (no crop residue) treatment (Table 7). Similar findings were found by Sarker et al. (2020a), who reported that interaction between variety and crop residues plays an important role in increasing biological yield.

Conclusion

Interaction of combined use of grass pea and mustard crop residues and varieties had significant effect on yield and yield contributing characters of transplant *aman rice*. Among the interactions, (V_3T_5) BR11 with hand weeding showed the best performance, followed by (V_3T_4) BR11 from combined use of grass pea and mustard crop residues @ 1 t ha^{-1} of each, in reducing weed infestation and highest yield of *T. aman* rice. The highest grain and straw yield (4.81 t ha^{-1} and 7.65 t ha^{-1}) was observed in hand weeding along with variety BR11, whereas the second highest (4.59 t ha^{-1} and 7.36 t ha^{-1}) was obtained from combined use of grass pea and mustard crop residues @ 1 t ha^{-1} of each along with BR11 and the lowest dry weight of weed produced in that combination. From the results of this study, it may be concluded that both of grass pea and mustard crop residues have weed suppressing ability, whereas their combined application showed better performance than that of their single application in weed control. Therefore, grass pea and mustard crop residues could be a prospective source of weed control tool for crop production in modern agricultural science.

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