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Research Article

Weed Dynamics, Productivity and Profitability of Transplanted *Aman* Rice as Influenced by Integrated Nutrient Management and Weeding Regime

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ABSTRACT

The excessive and improper application of fertilizers is the key factor contributing to nutrient losses to the environment and a decrease in the fertility of the soil. Also, using the wrong herbicide, applying higher than the recommended rate, or improper timing of application can cause crop damage. These factors adversely affect soil productivity and environmental stability. There is thus a need to expand an effective and inexpensive integrated nutrient management and weed control practice for acquiring better yields and profit from rice. The aim of the study was to find out the effect of six integrated nutrient management *i.e.*, BRRI Recommended Dose (RD) of chemical fertilizer, 50% RD + 5 t of cowdung ha^{-1}, 50% RD + 10 t of cowdung ha^{-1}, 50% RD + 2.5 t of poultry manure ha^{-1}, 50% RD + 5 t of poultry manure ha^{-1}, USG 1.8 g 4 $hills^{-1}$ + TSP, MoP, Gypsum and $ZnSO_4$ @RD along with four weeding regimes *i.e.*, control (no weeding), pre-emergence herbicide followed by one hand weeding at 30 DAT, early post-emergence herbicide followed by one hand weeding at 30 DAT, pre-emergence herbicide followed by early post-emergence herbicide on weed control, rice productiveness, and profitability. Our findings suggest that the application of 50% of the RD of chemical fertilizer + 5 t of poultry manure ha^{-1} with the application of pre-emergence herbicide followed by early post-emergence herbicide enhances weed suppression and provides higher rice productivity and profitability and can be practiced for the maximization of the yield and net return of transplanted *aman* rice.

Introduction

Rice *(Oryza sativa* L.) is the most widely grown cereal in the world and approximately 503 million metric tons of milled rice is produced annually (USDA, 2020). China and India alone account for ~ 50% of the rice grown and consumed worldwide (Muthayya *et al.*, 2014). Bangladesh is the third largest rice producer among the rice-producing countries (Childs, 2020). Here, annual production of rice is 38.14 million tons from 11.70 million ha of land. *Aman* rice comprises about 5.72 million ha of land with a production of 14.96 million tons (BBS, 2022). It is notable that, the area coverage of *aman* is the largest as a single crop and *boro* remains the second (BBS, 2022). In spite of the decline in the country's arable land since its independence in 1971, the rice cultivation area increased from almost 10 million ha in 2005 to nearly 11 million ha in 2022. Rice production also increased in the last 15 years from a low of 26 million tons in 2005 to nearly 38 million tons in 2020 (BBS, 2022).

One of the reasons for increased rice production is the extensive use of chemical fertilizers (Heffer, 2013). However, repeated use of chemical fertilizer and its use above threshold level impairs the physical condition and reduces the organic matter content of soils (Agbede, 2010; Naher *et al.,* 2019). Chemical fertilizer-dependent rice cultivation destroys soil health and it can be a threat to future rice production in our country. An integrated use of organic and inorganic fertilizers is proposed to be an effective approach to sustainable crop production (Kakar *et al.,* 2020).

Integrated nutrient management (INM) is the upkeep or adjustment of soil fertility; plant nutrients are delivered to the finest degree for sustaining the preferred productiveness via optimization of the benefits from all possible resources of plant nutrients in an integrated manner. This concept is crucial because it calls for the sustainable application of both inorganic fertilizers and natural resources to the soil to increase crop production

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and returns while minimizing negative environmental effects (Kumar *et al.,* 2021). INM has multifaceted potential for the improvement of plant performance and resource efficiency while also enabling the protection of the environment and resource quality (Wu and Ma, 2015). Organic manures like farmyard manure (FYM), green leaf manure (GLM), cowdung (CD), vermicompost (VC), and poultry manure (PM) are prioritized due to local availability with integration with inorganic fertilizers on growth and yield of rice (Hussainy and Arivukodi, 2020). Organic materials may be a boon to the poor marginal farmers who cannot afford to purchase fertilizer in the required quantities due to escalating prices.

Weeds are one of the major sources of yield loss in upland rice and its control is labor intensive. The climate as well as the edaphic condition of Bangladesh is favorable for the growth of weeds. So, the rice crops are usually infested heavily with weeds which results in the reduction of grain yield by 35-51% for direct seeded *aus* rice, 23-33% for *aman* rice, and 38-47% for modern *boro* rice (Chanda *et al.,* 2021). Weeds compete with crops for nutrients, space and water and thus reduce crop yield. Weed infestation in rice fields is always subjected to agroecological conditions and growing seasons (Zannat *et al*., 2014). Weeding in Bangladesh is commonly done manually; however, this is becoming difficult because of the non-availability of labor at the critical time of weeding and the high labor wage (Ghosh, 2014). Besides, the present weed management system which is done manually is laborious, time-consuming, expensive, and cannot be done on time due to various reasons (Ahmed *et al.*, 2005). For the last few decades, herbicides have been a tremendous contributor to agriculture. In large-scale rice farming, herbicide-based weed management has become the smartest and most viable option against the scarcity and high costs of labor (Singh *et al.*, 2006; Anwar *et al.*, 2012).

It is important to put an emphasis on increasing the yield of *aman* rice by the adoption of suitable management, particularly nutrient management and weed control that may be technically practicable, commercially viable, socially acceptable, and environmentally sound. In this context, INM which can incorporate locally accessible manures such as cowdung and poultry manure can be employed. To control weeds, herbicides, which provide independence from labor cost and crisis can be utilized. Therefore, the main objectives of the study were to determine the effect of INM including cowdung and poultry manure, and different weeding regimes including herbicides, and their interactions on the growth of weeds, rice productivity, and profitability.

Materials and Methods

The experiment was conducted during July to November 2019.

Experimental site

The experimental site was located at 24°75´ N latitude and 90°50´ E longitude at an elevation of 18 m above the mean sea level. The experimental area is characterized by non-calcareous dark grey floodplain soil belonging to the *sonatola* soil series under the Old Brahmaputra Floodplain, Agro-ecological Zone 9 (FAO and UNDP, 1988). The soil of the experimental field was more or less neutral in reaction with pH value 6.8, low in organic matter content and fertility level. The land type was medium-high with silty loam in texture.

Experimental treatments

The experiment included six INM treatments *i.e*., BRRI Recommended Dose (RD) of chemical fertilizer (*i.e*., 171-83-100-100-10 kg ha^{-1} of urea-TSP-MoP-gypsum-$ZnSO_4$, respectively) (I_1), 50% of the RD of chemical fertilizer + 5 t of cowdung ha^{-1} (I_2), 50% of the RD of chemical fertilizer + 10 t of cowdung ha^{-1} (I_3), 50% of the RD of chemical fertilizer + 2.5 t of poultry manure ha^{-1} (I_4), 50% of the RD of chemical fertilizer + 5 t of poultry manure ha^{-1} (I_5) and application of urea super granule (USG) 1.8 g 4 $hills^{-1}$ + TSP, MOP, Gypsum and $ZnSO_4$ @RD (I_6); and four weeding regimes *i.e*., control (no weeding) (W_0), application of pre-emergence herbicide followed by one hand weeding at 30 days after transplanting (DAT) (W_1), application of early post-emergence herbicide followed by one hand weeding at 30 DAT (W_2), application of pre-emergence herbicide followed by early post-emergence herbicide (W_3). Here, Pretilachlor @1 L ha^{-1} was used as pre-emergence herbicide, and Acetachlor 14% + Bensulfuron methyl 4% @500 g ha^{-1} was used as early post-emergence herbicide.

Experimental design and layout

The experiment was laid out in a randomized complete block design with three replications. The total number of unit plots was 6 × 4 × 3 = 72. Each plot size was 2.5 m × 2 m.

Cultivar (BRRI dhan49)

BRRI dhan49, a cultivar of T. *aman* rice was developed by Bangladesh Rice Research Institute (BRRI). It was released in 2007. It is a popular T. *aman* rice variety with *Nizershail* type grain quality and one-week earliness than BR11. It is a high-yielding and highly photosynthetic cultivar. The average plant height is 100 cm and medium slender. It takes almost 135 days to complete its life cycle. The average yield is 5.5 t ha^{-1}.

Organic source of nutrients

Cowdung and poultry manure were used as organic sources of nutrients. Cowdung contained 0.50% N, 0.43% P, 0.58% K, 0.23% S and other nutrients in small quantities while the poultry manure contained a high amount of secondary and micronutrients in addition to 0.95% N, 0.89% P, 0.81% K and 0.45% S.

Applied herbicides

A short description of herbicides that were used in the experiment is given in Table 1.

Table 1. Description of herbicides that were used in the experiment

Trade name	Common name	Mode of Action	Selectivity	Time of application
Superhit 500 EC	Pretilachlor	Systemic	Rice	Pre-emergence
Sarinda 18 WP	Acetachlor 14% + Bensulfuron methyl 4%	Systemic	Rice	Early post-emergence

Crop husbandry

Healthy seedlings were raised in the nursery bed with proper care. The field was prepared by using a power tiller. After final land preparation cowdung and poultry manure (as per treatment) were applied to the plots. 25 days-old Seedlings were transplanted in the well-prepared puddle field on 30 July 2019 at the rate of two to three seedlings hill^{-1}, maintaining row and hill distances of 25 cm and 15 cm, respectively. Seedlings were transplanted after seven days of cowdung and poultry manure application. Chemical fertilizers were applied according to the experimental treatments. Irrigation was provided as and when necessary. Excess water was drained out from the plot after the hard dough stage.

Data collection

Data on weed growth, crop growth, and yield were collected. Data on weed population were collected from each plot at 25 and 50 DATs of the rice plants by using 0.25 m × 0.25 m quadrate as per the method described by Cruz *et al.* (1986). The quadrate was placed in three randomly selected spots outside the 1 m² central area, which was reserved for yield data collection. The weeds within the quadrate were counted species-wise and converted to number m^{-2} multiplying by sixteen. After counting the weed density, the weeds inside each quadrate were uprooted, cleaned, numbering plot-wise, and dried in an electrical oven for 72 hours at a temperature of 60^{0} C. Weed dry weight of each plot was taken by an electrical balance and expressed in g m^{-2}. The height of the rice plant was recorded at 25 and 50 DAT from the base of the plant to the tip of the leaf. Tillers, that had at least one visible leaf, were counted at 25 and 50 DATs. After recording the fresh weight of plants hill^{-1}, the plant samples were dried in an electric oven for 72 hours at a temperature of 80°C. Then the dry weight of the plants was taken by an electric balance and expressed in g hill^{-1}. To determine the leaf area index, three leaf samples were collected from the plot. Leaf blades were separated and leaf area was measured by using a leaf area meter (model LI-3100 area meter). Finally, LAI was calculated according to the formula used by Hunt (1978).

LAI = LA/P

Where,
LAI = Leaf area index
LA = Total leaf area of the leaves of all the sampled plants (cm^2)
P = Area of the ground surface covered by the plant (cm^2)

At harvest, five hills (excluding border hills) were selected randomly from each experimental plot to record data on yield contributing characters. An area of 1 m^2 was selected in the middle portion of each plot to record the yields of grain and straw. Finally, the grain weight was adjusted to 14% moisture content. The straw was sun-dried and the yields of grain and straw were recorded and converted to t ha^{-1} basis.

Statistical analysis

The recorded data were compiled and tabulated for statistical analysis. Analysis of variance was done with the help of a computer package program, MSTAT-C. Duncan's Multiple Range Test adjudged the mean differences among the treatments (Gomez and Gomez, 1984).

Economic analysis

The cost of individual head of expenditure was recorded and a partial budget analysis was done. All non-material and material costs constituted the variable cost. Eight working hours of labor and a pair of bullocks were considered as a man-day and an animal-day, respectively. Gross return was computed by adding market values of grain yields @20000 Tk. t^{-1} and straw yields @6500 Tk. t^{-1}. Net income and Benefit Cost Ratio (BCR) were calculated by using the following formula:

Net income = Gross return - Variable cost

$$\text{Benefit Cost Ratio (BCR)} = \frac{\text{Gross return (Tk.)}}{\text{Total cost of production (Tk.)}}$$

Results and Discussion

Infested weed species in the experimental plots

Aman rice is grown in Bangladesh during *kharif* season when soil moisture content remains high which provides favorable conditions for the extensive growth of some weeds. The experimental plots were infested with eleven weed species belonging to five families. Four weed species were of the family Poaceae, four of the family Cyperaceae, and one each of the family Pontederiaceae, Oxalidaceae, and Marsileaceae. The most abundant weed species in our experimental fields were *Echinochloa crusgalli* (25.09%), *Leersia hexandra* (13.7%), *Paspalum scrobiculatum* (10.05%), *Cyperus difformis* (10.27%) and *Monochoria vaginalis* (20.23%) (Table 2). *Echinochloa crusgalli* was found to be the most dominating species in the *aman* rice field at the same location by many other researchers (Islam *et al.*, 2018; Afroz *et al*., 2019; Monira *et al*., 2020).

Effect on weed density and weed dry weight

Due to weeds' competition with rice for nutrients, space, water, and light, weeds significantly reduce rice yields (Khanh *et al.,* 2007; Vincent, 2016). As weeds typically absorb nutrients more quickly and efficiently than crop plants, their flora is more competitive with applied plant nutrients than that of crops (Kaur *et al.,* 2017). Thus, plant nutrient management may play a significant role in regulating weed interference in crops. We found that the sources of nutrients as organic or inorganic did not have any significant impact on total weed density at both 25 and 50 DATs (Table 3). This may be due to the short duration of the experiment. Ghosh *et al*. (2020) also reported that, during the initial year, INM had no impact on the weed population. However, the application of poultry manure with chemical fertilizers showed some positive influence in controlling weed dry weight at 50 DATs (Table 3). Nitrogen supplied through the organic source suppressed weed growth which was also reported by Davis and Liebman (2001). Additionally, poultry manure can increase soil temperature and reduce weed growth (Cimen *et al*., 2012).

Table 2. Infesting species of weed in the experimental plots of transplanted *aman* rice

Sl. No.	Local name	Scientific name	Family	Morphological type	Importance Value (IV) %
1.	Shama	*Echinochloa crusgalli* (L.) P. Beauv.	Poaceae	Grass	25.09
2.	Arail	*Leersia hexandra* Swartz	Poaceae	Grass	13.7
3.	Angta	*Paspalum scrobiculatum* L.	Poaceae	Grass	10.05
4.	Anguli ghash	*Digitaria sanguinalis* (L.) Scop.	Poaceae	Grass	6.7
5.	Sabuj nakphul	*Cyperus difformis* L.	Cyperaceae	Sedge	10.27
6.	Mutha	*Cyperus rotundus* L.	Cyperaceae	Sedge	4.08
7.	Pani Chechra	*Scirpus juncoides* Roxb.	Cyperaceae	Sedge	2.7
8.	Pani chaise	*Eleocharis atropurpurea* (Retz.) J. Presl & C. Pres	Cyperaceae	Sedge	5.96
9.	Pani kachu	*Monochoria vaginalis* (Burm. F.) C. Presl	Pontederiaceae	Broad leaved	20.23
10.	Amrul shak	*Oxalis corniculata* L.	Oxalidaceae	Broad leaved	0.57
11.	Shusni shak	*Marsilea crenata* C. Presl	Marsileaceae	Broad leaved	0.56

Table 3. Weed density and weed dry weight as influenced by integrated nutrient management and weeding regime in transplanted *aman* rice

Treatment	Weed density (no. m^{-2})		Weed dry weight (g m^{-2})	
	25 DAT	50 DAT	25 DAT	50 DAT
Integrated Nutrient Management (INM)				
I_1-RD	79.50*	55.67	54.76	133.5
I_2-50% RD + 5 t CD	63.67	55.17	50.83	133.6
I_3-50% RD + 10 t CD	62.25	55.42	55.33	138.9
I_4-50% RD + 2.5 t PM	68.08	57.17	56.45	123.8
I_5-50% RD + 5 t PM	68.17	53.92	53.40	125.5
I_6-USG + RD	66.00	53.50	53.07	131.8
Weeding Regime (WR)				
W_0-Control (No weeding)	135.3a*	99.56a	97.74a	233.8a
W_1-Pre-emergence herbicide fb 1 HW at 30 DAT	48.44b	41.94b	39.05b	97.90b
W_2-Early post-emergence herbicide fb 1 HW at 30 DAT	46.11b	41.44b	39.93b	94.52b
W_3-Pre-emergence herbicide fb early post-emergence herbicide	41.94b	37.61b	39.17b	98.48b
Level of significance				
INM	NS	NS	NS	NS
WR	0.01	0.01	0.01	0.01
INM× WR	0.01	NS	NS	NS
CV (%)	22.71	20.25	29.29	19.92

*In a column figures with the same letters or without letters do not differ significantly whereas figures with dissimilar letters differ significantly as per DMRT. 0.01 = Significant at 1% level of probability, NS = Not -significant.

Here, RD = Recommended dose, CD = Cowdung, PM = Poultry Manure, USG = Urea Super Granule, fb = followed by, HW = Hand Weeding. Weed density (no. m^{-2}) = (Weed density 0.0625 m^{-2} × 16), Weed dry weight (g m^{-2}) = (Weed dry weight 0.0625 m^{-2} × 16).

In Bangladesh, mechanical and manual methods of weed control are mainly practiced by the farmers which are labor-intensive and time-consuming. Furthermore, the labor shortage during the busy season is getting worse. Herbicides, on the other hand, have proven to be the most effective weed control method ever created. They are manageable in terms of persistence if used at the right dose, manner, and time. They are also cost-effective, very simple to apply, and selective (Yaduraju and Mishra, 2002). Beltran *et al*. (2012) suggested that herbicide applications are more effective for weed control in rice than other methods, especially when weed density is high. In our experiment, we used pre or early post-emergence herbicides + hand weeding and pre + early post-emergence herbicides for comparison. We found significant variation in weed density and dry weight due to weeding regimes at all sampling dates (Table 3). Unweeded plots produced the highest weed population at all sampling dates because they allowed the weeds to grow without any control measures. Parvez *et al*. (2013) and Salam *et al.* (2020) also found the highest weed density in the weedy check treatments. All the weed control combinations performed similarly in reducing weed density and dry weight. However, the lowest weed density was found at all sampling dates when pre-emergence herbicide was applied followed by early post-emergence herbicide (Table 3). This might be due to the effective weed control at earlier stages of weed growth. Pre-emergence herbicides target the weeds that have not emerged yet and early post-emergence herbicides kill the weeds that have just come out of the ground. Zahan *et al.* (2017) reported that, the application of pre and post-emergence herbicides provided control on weed density and biomass by 49-98% and 56-95%, respectively.

The effect of the interaction between INM and weeding regime on weed density and dry weight was not significant at all sampling dates except weed density at 25 DAT (Table 3). The highest weed density and dry weight were observed in the treatment combination where no weeding was combined with different INM treatments (Table 3). Unweeded plots caused heavy crop weed competition and provided a competitive advantage to the weeds to grow in number which was previously confirmed by Paul *et al.* (2019).

Effect on vegetative growth of rice

Crop growth parameters, plant height at 25 DAT, and LAI at 50 DAT were significantly influenced by INM. The tallest plants and the highest LAIs were observed when, USG 1.8 g 4 hills^{-1} were applied with TSP, MoP, Gypsum and $ZnSO_4$ @RD at all sampling dates (Table 4). The growth is mainly influenced by nitrogen fertilization and prilled urea provides readily available nitrogen. The highest plant height and LAI with the application of USG would most likely be associated with a better effect of USG on vegetative growth that eventually contributed to more ground cover with USG than other N fertilizer sources. This might be due to the fact that the applied N as USG was steadily available to the growing rice plants, which resulted in more vegetative growth than conventional urea and organic manures. Islam *et al*. (2013) and Ali *et al*. (2017) also found the highest plant height and LAI with the application of USG with other chemical fertilizers. Integrated nutrient management had no significant effect on the number of total tillers hill^{-1} and dry matter accumulation (Table 4). The shortest plants and the minimum number of total tillers hill^{-1} at all sampling dates, the lowest LAI and dry matter accumulation at 25 DAT were found when 50% of the RD of chemical fertilizer was applied with 10 t of cowdung ha^{-1} (Table 4.) Farid *et al.* (2011) also found lowest growth characteristics with cowdung application compared to poultry manure with chemical fertilizer or sole inorganic fertilizer application. As cowdung has lower nutrient contents than poultry manure and chemical fertilizers, this might be the reason for the poor growth performance of rice.

The effect of weeding regime was statistically significant on the number of total tillers hill^{-1} and dry matter accumulation and non-significant on plant height and LAI at all sampling dates (Table 4). The highest number of total tillers hill^{-1} and LAI at both DATs and dry matter accumulation at 25 DAT were observed where pre-emergence herbicide was applied followed by early post-emergence herbicide. Weed density was the lowest in this treatment which provided a competitive advantage to the crop which contributed to the increased number of tillers and dry matter accumulation by the rice plants. Ahmed and Chauhan (2014) also found the lowest weed density with pre and post-emergence herbicide application. Other weed management treatments performed similarly. No weeding treatment showed inferior performance in the case of all the studied growth parameters except plant height (Table 4). Weed competition was severe in no weeding condition and thus crop growth was reduced. On the other hand, in different weed management treatments through the crop growth period, competition at weeds with crop plants was less therefore crop growth was vigorous. Similar research findings were also reported by Parvez *et al*. (2013), Mou *et al*. (2017) and Afroz *et al*. (2019) where inferior performance was observed in the case of no weeding treatment. No significant variation was found on crop growth parameters due to the interaction of INM and weeding regime (Table 4). Ghosh *et al.* (2020) also found a non-significant variation in crop growth characters in the case of interaction between INM and weed management.

Table 4. Effect of integrated nutrient management and weeding regime on growth parameters of transplanted *aman* rice

Treatment	Plant height (cm)		Total tillers hill^{-1} (no.)		Leaf Area Index (LAI)		Dry matter (g m^{-2})	
	25 DAT	50 DAT	25 DAT	50 DAT	25 DAT	50 DAT	25 DAT	50 DAT
Integrated Nutrient Management (INM)								
I_1-RD	50.75b*	80.63	13.33	14.42	1.06	2.61b	196.4	475.41
I_2-50%RD + 5 t CD	50.67b	79.06	13.58	14.33	0.94	2.56b	180.7	450.04
I_3-50% RD + 10 t CD	50.17b	77.60	11.92	13.25	0.83	2.68b	169.7	494.07
I_4-50% RD + 2.5 t PM	51.25b	78.63	13.42	13.67	0.83	2.58b	180.7	485.26
I_5-50% RD + 5 t PM	51.08b	79.45	15.50	16.08	1.15	3.22ab	208.7	491.83
I_6-USG + RD	55.08a	84.00	14.58	15.50	1.42	3.52a	203.3	511.92
Weeding Regime (WR)								
W_0-Control (No weeding)	51.72	79.96	11.50b*	11.61b	0.799	2.73	132.7b	377.1c
W_1-Pre-emergence herbicide fb 1 HW at 30 DAT	51.06	78.82	13.33ab	14.56a	1.09	2.60	205.0a	471.1b
W_2-Early post-emergence herbicide fb 1 HW at 30 DAT	51.61	79.34	14.89a	15.78a	1.02	3.21	195.4a	578.3a
W_3-Pre-emergence herbicide fb early post-emergence herbicide	51.61	81.46	15.17a	16.22a	1.25	2.91	226.6a	512.5ab
Level of significance								
INM	0.01	NS	NS	NS	NS	0.05	NS	NS
WR	NS	NS	0.01	0.01	NS	NS	0.01	0.01
INM × WR	NS	NS	NS	NS	NS	NS	NS	NS
CV (%)	6.67	6.64	26.07	18.53	51.65	32.36	34.90	25.62

*In a column figures with the same letters or without letters do not differ significantly whereas figures with dissimilar letters differ significantly as per DMRT. 0.01 = Significant at 1% level of probability; 0.05 = Significant at 5% level of probability; NS = Not -significant.
Here, RD = Recommended dose, CD = Cowdung, PM = Poultry Manure, USG = Urea Super Granule, fb = followed by, HW = Hand Weeding.

Effect on growth at harvest, yield contributing characters, and yield of rice

The effect of INM on different growth parameters, yield contributing characters and yield of rice at harvest was not significant except for plant height. Application of USG @1.8 g 4 hills^{-1} + TSP, MoP, Gypsum and $ZnSO_4$ @RD resulted in the tallest plants as this treatment favored increasing height during the growing period. However, the application of 50% of the RD of chemical fertilizer + 5 t of poultry manure resulted positive increase in the number of total tillers hill^{-1}, grains panicle^{-1}, grain yield, straw yield, and biological yield compared to other treatments. The lowest number of total tillers hill^{-1}, effective tillers hill^{-1}, grain yield and harvest index were found when 50% of the RD of chemical fertilizer was applied with 5 t of cowdung ha^{-1}. The minimum plant height, grains panicle^{-1}, sterile spikelets panicle^{-1} and straw yield were obtained from 50% of the RD of chemical fertilizer + 10 t of cowdung ha^{-1} treatment (Table 5). Poultry manure with chemical fertilizers performed better compared to cowdung with chemical fertilizers. This may be due to the higher nutrient content of poultry manure compared to cowdung.

Table 5. Effect of integrated nutrient management on the performance of transplanted *aman* rice

Integrated nutrient management	Plant height (cm)	Total tillers hill^{-1} (no.)	Effective tillers hill^{-1} (no.)	Length of panicle (cm)	Grains panicle^{-1} (no.)	Sterile spikelets panicle^{-1} (no.)	1000-grain weight (g)	Grain yield (t ha^{-1})	Straw yield (t ha^{1})	Biological yield (t ha^{-1})	Harvest Index (%)
I_1-RD	105.5ab*	9.88	8.78	22.09	109.7	13.48	20.46	3.99	5.28	9.26	42.81
I_2-50% RD + 5 t CD	104.1bc	9.18	8.09	22.31	109.0	13.81	20.20	3.62	5.40	9.02	40.02
I_3-50% RD + 10 t CD	101.9c	9.48	8.51	21.93	110.8	13.11	20.40	4.00	5.26	9.27	42.53
I_4-50% RD + 2.5 t PM	105.1a-c	9.50	8.95	22.13	112.9	13.79	20.26	4.08	5.51	9.59	42.20
I_5-50% RD + 5 t PM	104.9a-c	10.03	8.85	21.65	116.3	14.33	20.24	4.31	5.86	10.18	42.15
I_6-USG + RD	107.6a	9.96	8.92	22.11	111.0	13.52	20.18	4.20	5.80	10.00	41.85
Level of sig.	0.05	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
CV (%)	3.62	10.49	10.71	2.64	5.64	11.50	3.26	15.87	12.19	12.77	6.67

*In a column figures with the same letters or without letters do not differ significantly whereas figures with dissimilar letters differ significantly as per DMRT. NS = Not-significant, 0.05 = Significant at 5% level of probability

Here, RD = Recommended dose, CD = Cowdung, PM = Poultry Manure, USG = Urea Super Granule

The effect of different weeding regimes on all the studied growth parameters at harvest, yield contributing characters and yield of rice was statistically significant except for plant height, length of panicle and 1000-grain weight (Table 6). Application of early post-emergence herbicide followed by one hand weeding at 30 DAT treatment showed superior performance in the case of all the studied yield contributing characters and yield except 1000-grain weight. Pre-emergence herbicide followed by one hand weeding at 30 DAT and pre-emergence herbicide followed by early post-emergence herbicide treatments also performed similarly. No weeding treatment showed inferior performance in case of most of the studied yield contributing characters and yield of BRRI dhan49 (Table 6). Weeding reduced crop-weed competition and provided scope to the rice plants for efficient utilization of sunlight and nutrients. This might help to obtain a better performance of the yield contributing parameters and yield of rice. Similar results were reported elsewhere by Sarkar *et al.* (2016); Hia *et al.* (2017); Popy *et al.* (2017); Islam *et al.* (2018); Afroz *et al.* (2019) and Salam *et al.* (2020).

Table 6. Effect of weeding regime on the performance of transplanted *aman* rice

Weeding regime	Plant height (cm)	Total tillers hill^{-1} (no.)	Effective tillers hill^{-1} (no.)	Length of panicle (cm)	Grains panicle^{-1} (no.)	Sterile spikelets panicle^{-1} (no.)	1000-grain weight (g)	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest Index (%)
W_0-Control (No weeding)	103.6	8.41b*	6.99b	22.04	102.8b	14.22a	20.21	2.94b	4.65b	7.59b	38.81b
W_1-Pre-emergence herbicide fb 1 HW at 30 DAT	104.8	9.82a	9.17a	21.88	112.8a	13.51a	20.16	4.18a	5.56a	9.73a	42.86a
W_2-Early post-emergence herbicide fb 1 HW at 30 DAT	106.4	10.30a	9.29a	22.17	115.1a	14.36a	20.35	4.59a	5.95a	10.53a	43.52a
W_3-Pre-emergence herbicide fb early post-emergence herbicide	104.6	10.17a	9.28a	22.06	115.8a	12.59b	20.44	4.43a	5.93a	10.35a	42.54a
Level of sig.	NS	0.01	0.01	NS	0.01	0.01	NS	0.01	0.01	0.01	0.01
CV (%)	3.62	10.49	10.71	2.64	5.64	11.50	3.26	15.87	12.19	12.77	6.67

*In a column figures with the same letters or without letters do not differ significantly whereas figures with dissimilar letters differ significantly as per DMRT. NS = Not-significant, 0.01 = Significant at 1% level of probability

Here, fb = followed by, HW = Hand Weeding

The interaction effect of INM and weeding regime showed non-significant variation in all the studied growth parameters at harvest, yield contributing characters and yield of BRRI dhan49 except the number of total tillers hill^{-1} (Table 7). Aktar *et al.* (2020) and Adhikari *et al.* (2018) also found that the interaction effect of nutrient management and weed management did not illustrate a significant effect on final plant height. However, numerically the highest number of grains panicle^{-1}, grain yield, straw yield, and biological yield were obtained from the application of 50% of the RD of chemical fertilizer + 5 t of poultry manure ha^{-1} with the application of pre-emergence herbicide followed by early post-emergence herbicide (Table 7). Roy *et al.* (2017) also reported the highest grain yield with the application of chemical fertilizer with poultry manure followed by the application of pre and post-emergence herbicide. Inferior performance was observed in the case of yield contributing characters and yield when no weeding was combined with other INM treatments. Numerically, the lowest grain yield was found when 50% of the RD of chemical fertilizer + 10 t of cowdung ha^{-1} were combined with no weeding (Table 7). Islam *et al.* (2015) also found the lowest grain yield in no weeding with cowdung @10 t ha^{-1} combination. The lowest grain yield (2.92 t ha^{-1}), straw yield (4.15 t ha^{-1}), and biological yield (7.0 t ha^{-1}) were found when RD of chemical fertilizer and no weeding treatment were applied in combination (Table 7). Aktar *et al.* (2020) also found the lowest straw yield in RD of chemical fertilizer + no weeding combination.

Economics of integrated nutrient management and weeding regime

From the economic analysis, it was observed that, the highest net income Tk. 62194 and benefit-cost ratio 1.72 were obtained when 50% of the RD of chemical fertilizer + 5 t of poultry manure ha^{-1} were applied with pre-emergence herbicide followed by early post-emergence herbicide (Table 8). This treatment performed better individually and in combination in reducing weed pressure and thereby increasing crop growth performance and ultimately yield which might contribute to the net profit and benefit-cost ratio. The additional cost of cultivation for using poultry manure and herbicides was compensated by producing additional yield. Roy *et al.* (2017) also found the highest BCR with chemical fertilizer + poultry manure with pre and post-emergence herbicide application. On the other hand, RD of chemical fertilizers with 10 t of cowdung ha^{-1} with no weeding combination resulted in the highest loss of capital and the lowest BCR (0.76) as the yield on this combination was lowest which might be due to the highest weed pressure in this combination. Islam *et al.*, (2015) also found the lowest BCR with no weeding + cowdung @10 t ha^{-1}.

Table 7. Interaction effect of integrated nutrient management and weeding regime on the performance of transplanted *aman* rice

INM × Weeding regime	Plant height (cm)	Total tillers hill^{-1} (no.)	Effective tillers hill^{-1} (no.)	Length of panicle (cm)	Grains panicle^{-1} (no.)	Sterile spikelets panicle^{-1} (no.)	1000-grain weight (g)	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest Index (%)
I_1W_0	103.18	8.06e*	6.50	21.70	107.7	14.9	20.75	2.92	4.15	7.0	41.11
I_1W_1	107.63	10.27a-c	9.33	22.26	106.5	13.41	19.71	4.37	5.86	10.23	42.73
I_1W_2	104.25	10.47ab	9.53	22.53	112.4	13.52	20.77	4.54	5.59	10.14	44.74
I_1W_3	107.04	10.73ab	9.77	21.85	112.1	12.06	20.59	4.11	5.50	9.61	42.68
I_2W_0	105.95	9.27a-e	7.40	22.15	97.33	13.58	20.38	2.78	5.17	7.95	35.21
I_2W_1	103.72	9.60a-e	8.70	22.13	113.3	12.62	20.17	3.55	4.83	8.38	42.24
I_2W_2	102.02	8.40c-e	7.47	22.39	113.0	15.64	20.30	4.07	5.67	9.74	41.90
I_2W_3	104.67	9.47a-e	8.80	22.57	112.4	13.39	19.97	4.09	5.94	10.04	40.74
I_3W_0	101.07	8.87b-e	7.27	22.13	100.5	13.12	20.17	2.72	4.26	6.98	38.47
I_3W_1	97.54	8.13e	7.83	21.68	114.4	12.37	20.50	4.38	5.59	9.97	44.02
I_3W_2	106.04	10.60ab	9.50	22.26	114.6	13.52	20.67	4.54	5.63	10.17	44.40
I_3W_3	102.89	10.33a-c	9.43	21.66	113.6	13.42	20.27	4.39	5.57	9.95	43.24
I_4W_0	106.36	8.27de	7.60	22.50	102.9	15.34	19.89	3.02	4.63	7.66	39.23
I_4W_1	104.47	10.27a-c	9.97	21.74	115.4	13.61	20.33	4.20	5.55	9.75	42.98
I_4W_2	106.63	10.40ab	9.50	21.81	116.2	15.26	19.99	4.74	6.16	10.90	43.51
I_4W_3	103.13	9.07a-e	8.73	22.48	117.2	10.97	20.83	4.34	5.72	10.05	43.09
I_5W_0	101.54	8.00e	6.53	21.37	103.4	14.39	19.84	3.17	5.08	8.25	38.64
I_5W_1	107.31	10.50ab	9.57	21.67	114.3	15.40	20.04	4.03	5.41	9.44	42.62
I_5W_2	107.71	10.87ab	9.83	21.80	122.6	14.00	20.29	4.83	6.26	11.10	43.54
I_5W_3	103.15	10.77ab	9.47	21.77	125.2	13.53	20.79	5.23	6.69	11.92	43.79
I_6W_0	103.45	8.00e	6.67	22.41	104.9	14.00	20.26	3.08	4.60	7.68	40.18
I_6W_1	108.25	10.13a-d	9.60	21.78	112.7	13.67	20.20	4.54	6.11	10.65	42.55
I_6W_2	111.69	11.07a	9.93	22.22	112.1	14.26	20.09	4.81	6.35	11.16	43.02
I_6W_3	106.87	10.63ab	9.50	22.03	114.1	12.19	20.18	4.39	6.14	10.54	41.66
Level of sig.	NS	0.05	NS	NS	NS	NS	NS	NS	NS	NS	NS
CV (%)	3.62	10.49	10.71	2.64	5.64	11.50	3.26	15.87	12.19	12.77	6.67

*In a column figures with the same letters or without letters do not differ significantly whereas figures with dissimilar letters differ significantly as per DMRT. NS = Not-significant, 0.05 = Significant at 5% level of probability; I_1 = Control (RD of chemical fertilizer), I_2 = 50% of the RD of chemical fertilizer + 5 t of cowdung ha^{-1}, I_3 = 50% of the RD of chemical fertilizer + 10 t of cowdung ha^{-1}, , I_4 = 50% of the RD of chemical fertilizer + 2.5 t of poultry manure ha^{-1}, I_5 = 50% of the RD of chemical fertilizer + 5 t of poultry manure ha^{-1}, I_6 = Application of USG 1.8 g 4 hills^{-1} + TSP, MoP, Gypsum and ZnSO4 @RD; W_0 = Control (No weeding), W_1 = Application of pre-emergence herbicide followed by one hand weeding at 30 DAT, W_2 = Application of early post-emergence herbicide followed by one hand weeding at 30 DAT, W_3 = Application of pre-emergence herbicide followed by early post-emergence herbicide

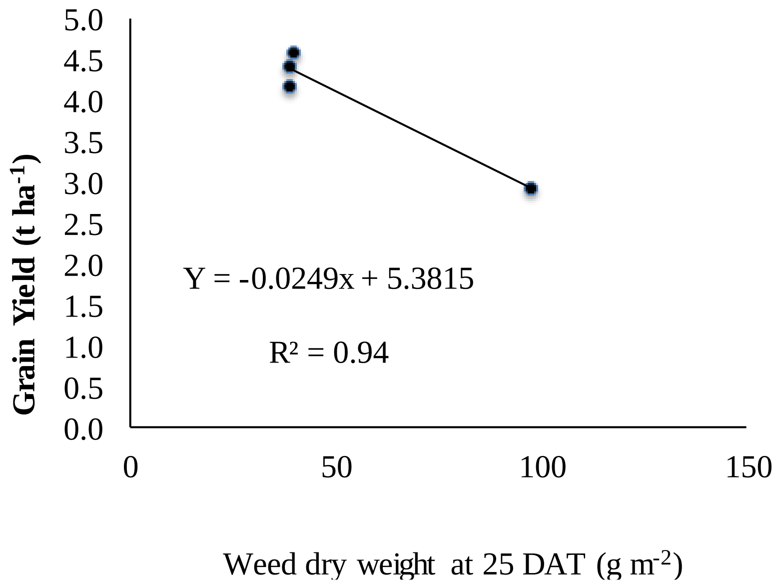
Table 8. Cost-effectiveness of integrated nutrient management and weeding regime (BDT ha^{-1})

Treatments	No weeding (W_0)		Pre-emergence herbicide followed by one hand weeding at 30 DAT (W_1)		Early post-emergence herbicide followed by one hand weeding at 30 DAT (W_2)		Pre-emergence herbicide followed by early post-emergence herbicide (W_3)	
	Net income (TK.)	BCR (%)	Net income (TK.)	BCR (%)	Net income (TK.)	BCR (%)	Net income (TK.)	BCR (%)
I_1 -RD	3456	1.04	33868	1.37	35813	1.39	32928	1.39
I_2 -50% RD + 5 t CD	-3586	0.96	-96	0.99	16064	1.16	24519	1.25
I_3 -50% RD +10 t CD	-25701	0.76	15444	1.13	10204	1.09	13114	1.12
I_4 -50% RD +2.5 t PM	10204	1.13	30084	1.33	45149	1.50	40589	1.49
I_5 -50% RD + 5 t PM	13629	1.16	25274	1.27	45099	1.49	62194	1.72
I_6 -USG+ RD	6954	1.08	36269	1.38	43529	1.46	40064	1.46

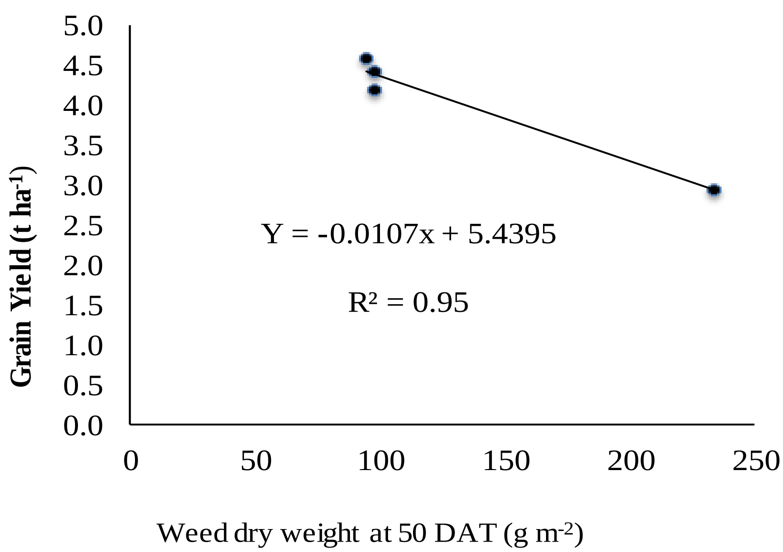
Here, RD = Recommended dose, CD = Cowdung, PM = Poultry Manure, USG = Urea Super Granule

Correlation and regression analysis

Regression analysis was done to find out the relationship between weed dry matter production and grain yield of rice at both growth stages (Figure 1). We found a significant ($p<5\%$) negative correlation between weed dry matter production and grain yield. The regression equation was $Y=-0.0249x+5.3815$ ($R^2=0.94$) for the dry matter at 25 DAT and $Y=-0.0107x+5.4395$ ($R^2=0.95$) for the dry matter at 50 DAT (Figure 1a and 1b). It implies that the grain yield of rice decreased with a proportional increase in weed dry matter. On average grain yield could be decreased at the rate of 0.02 t ha^{-1} and 0.01 t ha^{-1} with an increase of weed dry matter production at 25 and 50 DAT, respectively. A similar negative correlation between weeds and crops was reported by Mondal *et al*. (2019), who stated that increased weed biomass led to notable reductions in yield attributes, which in turn greatly decreased crop production.



1(a)



1(b)

Figure 1 (a) & (b): Relationship between weed dry matter production and grain yield at 25 and 50 DATs

Conclusion

From the present study, it is observed that; the highest weed density and weed dry weight were found in the RD of chemical fertilizer with no weeding combination which also exhibited inferior performance on most of the yield and yield attributes of rice. 50% of the RD of chemical fertilizer + 5 t of poultry manure ha^{-1} with the application of pre-emergence herbicide followed by early post-emergence herbicide showed better performance in respect of yield and yield contributing characters, net income, and benefit-cost ratio and reducing weed population as compared to the other interactions. Therefore, application of 50% of the RD of chemical fertilizer + 5 t of poultry manure ha^{-1} with the application of pre-emergence herbicide (Pretilachlor @1 L ha^{-1}) followed by early post-emergence (Acetachlor 14% + Bensulfuron methyl 4% @500 g ha^{-1}) herbicide may be used to boost the performance of transplanted *aman* rice (cv. BRRI dhan49). Further study may be needed to check the consistency of the present performance in different seasons and Agro-ecological Zones (AEZs) of Bangladesh.

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