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OPTIMIZING NITROGEN AND WEED MANAGEMENT FOR TRANSPLANTED RICE: A YIELD AND WEED GROWTH ASSESSMENT

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Abstract

The most significant limiting nutrient in the production of rice is nitrogen, which has a beneficial impact on rice grain production. A high level of N supply may favor weeds over crop plants. This investigation examined the effect of integrated nitrogen management and weeding practices on weed growth and yield of *T. aman* rice (cv. BRRI dhan71). Beginning from June to October 2022, the experiment was executed at Agronomy Field Laboratory of Bangladesh Agricultural University (BAU), Mymensingh, Bangladesh. The experiment consisted of five nitrogen levels *viz*., control (no N), 100% N from prilled urea, 100% N from poultry manure (PM), 50% N from prilled urea + 50% N from PM and application of USG and five weeding practices *viz*., un-weeded control, weed-free condition, at 35 DAT a single hand weeding including herbicide (Superhit 500 EC (Pretilachlor) herbicide at 1 L ha^{-1}) as pre-emergence, at 35 DAT a one hand weeding herbicide of early post-emergence (Sarinda 18 WP (Acetachlor 14 WP + Bensulfuron methyl 14 WP) @ 500 g ha^{-1}), herbicide of both pre-emergence and early post-emergence. In the experimental fields, 14 species of weeds from 6 families were identified. With the help of USG and pre- and post-emergence herbicides, it was feasible to reduce the density and dry biomass of weeds reasonably. Numerically, the maximum yield (grain, straw (t ha^{-1}) (6.09, 6.50) was produced by using pre-emergence herbicide together with 50% N from urea + 50% N from PM. Pre-emergence and early post-emergence herbicide applications were included in USG, and the results were nearly identical (t ha^{-1}) 5.87 and 6.33. The study's findings may lead to the conclusion that USG combined with pre-emergence along with early post-emergence herbicides can be recommended for controlling weeds. On the other hand, it can be suggested that maximum production of the grain yield of *T. aman* rice can be achieved by applying pre-emergence herbicide afterward using early post-emergence herbicide combining 50% N from urea and 50% N from PM.

Key words: Weed growth; Yield; Transplanted *aman* rice; Integrated nitrogen management; Integrated weed management

Introduction

Bangladesh is the third-largest rice producer in the world. On rice (*Oryza sativa* L.) production, greater portion of the country's population depends on, which is the country's main crop (Anon., 2022). It is fed by almost half of the world's population, one of the major staple crops, essential to maintaining global food security (Javed *et al.*, 2021; Anwari *et al.*, 2019). One-third of the world's total cropped area is dedicated to its cultivation, and cultivation occurs in various countries under various agroclimatic conditions (Jahan *et al.*, 2022). Bangladesh's optimal agroclimatic conditions allow rice to be cultivated there year-round (Rahman *et al.,* 2020). Presently, on 11.70 million hectares of land, 38.14 million tons of rice are produced (Anon., 2022).

Bangladesh has three separate rice-growing seasons: *boro* (December to May), *aman* (July to November), and *aus* (March to July). According to the Anon., (2022) report, *aman* rice covers 5.72 million hectares which is the largest area covered as a single crop and 14.96 million metric tons of rice is being produced from that coverage. In contrast, *boro* rice remains the second in terms of area coverage. Around 72% of the net cultivable area is covered by the primary crop during the wet season, *aman* rice (Mainuddin *et al.,* 2014). According to the Anon., (2023) report, *aman* rice production increased to 3.059% from the previous economic year.

For cultivating rice, the most demanding macro-nutrient is nitrogen (N) and a huge amount of nitrogen fertilizer should be provided during the cultivation period of rice because of the insufficient amount of its presence in the soil of Bangladesh for getting a satisfactory harvest (Shrestha *et al*., 2022). Nitrogen, which is highly mobile throughout plants and soil, is essential for rice plant growth, development, and quality. It accelerates tillering, develops leaf area, forms grains, and synthesizes protein (Sandhu *et al*., 2021). The nutritional value along with the processing quality of rice can both be enhanced by increasing N fertilization; but, an excess of fertilizer can make rice chalkier and degrade its external appearance, cooking and consumption qualities (Bai, 2019; Li *et al.*, 2019). Solely using nitrogen from inorganic fertilizers causes heavy nutrient loss through volatilization, leaching runoff, immobilization and emission as well as degrades soil health which is not favorable for the environment and rice productivity (Mia *et al*., 2024; Tyagi *et al*., 2022). Therefore, integrated application of organic and inorganic fertilizing methods should be adopted for sustainable and higher productivity (Iqbal *et al*., 2019).

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For sustainable agricultural production, an effective fertilization plans that increases crop production and environmental quality while combining both chemical and organic fertilizers should be developed (Devkota *et al.*, 2019). Nutrients from integrated fertilizers produced higher yields than applying chemical fertilizers alone, even though chemical fertilizers contributed 59%–69% to rice yield and might increase grain yield and soil carbon storage (Iqbal *et al.*, 2020). There are various sources of organic (poultry manure, cowdung, farm yard manure, etc.) and inorganic nitrogen (prilled urea, urea super granules, ammonium nitrate, etc.). The most valuable manure produced by livestock is poultry litter (Maj, 2022). This is because the litter contains higher than average amounts of N (4.0%), P (1.6%), and K (2.3%) along with lower amounts of Ca, Mg, Mn, Cu, and Zn (Gollehon *et al.*, 2001; Bhuiyan *et al.*, 2015). So, it can be said that it has many nutrients for the utilization by crops and soil amendment quality which is better for crop production and soil health as well as the environment. Deep USG placement saves 30% nitrogen and increases absorption, soil health, and rice yield (Islam *et al.*, 2024), whereas 50% loss occurs through surface urea broadcast (Huda *et al.*, 2016). A suitable combination should be ensured to maximize the efficacy of manure and inorganic fertilizer mixture (Rouf *et al.*, 2017). Utilizing poultry manure and inorganic fertilizers together can boost rice's protein content and grain yield (Sarkar *et al.*, 2014).

During crop cultivation, the main constraint is created by weeds and that is a worldwide problem for growers (Khan *et al.*, 2013; Matloob *et al.*, 2015). Weeds are undesirable plants of a cultivated area. As a consequence of this, weed is regarded as one of the most significant pests in agriculture which causes low rice output (Parvez *et al.*, 2013). During rice cultivation, huge yield loss occurs due to weed infestation in Bangladesh. For instance, yield losses of 70–80% have been estimated in early summer *aus* rice, 22–36% in modern *boro* rice cultivars (winter), and 30–40% in transplanted *aman* rice (autumn) (Anon., 2009; Sarker *et al.*, 2021). Excessive use of nitrogen fertilizers favours weed growth over the crop. In Bangladesh, the use of herbicides is becoming famous as these are cheap and easily available (Bhuiyan *et al.*, 2020). Manual methods are becoming less acceptable because of high labor costs, labor intensiveness, and crisis as well as it is a time-consuming process (Hasan *et al.*, 2020). Weeds may become resistant to a herbicide if it is used frequently without understanding the proper dosage or if a fixed herbicide is applied without taking the weed's dynamics into account (Renton *et al.*, 2014). Therefore, IWM should be practiced to avoid herbicide resistance (Beckie & Harker, 2017). Furthermore, an effective weed management practice should be developed that is practical, acceptable, easily available, labour and cost-effective, less time-consuming, and most importantly effective in controlling weed infestation in rice fields (Matloob *et al.*, 2020; Khan *et al.*, 2022).

From the preceding discussion, an effective, sustainable, economically affordable, and acceptable management strategy should be developed by combining weed management and integrated nitrogen practices that result in the lowest weed dynamics and highest yield of *T. aman* rice. Therefore, the primary goals of this study were to determine how INM, weed control, and the combined effects of both on *T. aman* rice yield and weed growth.

Materials and Methods

Site of experimentation: The experimental site was roughly 18 m higher from sea level, in N latitude and E longitude successively at 24°75' and 90°50'. Situated in Agro-ecological Zone-9, the Old Brahmaputra Alluvial Floodplain, the experimental region is typified by a dark gray, noncalcareous floodplain soil called the Sonatola soil series. The creation and development of the Old Brahmaputra Floodplain have been greatly influenced by the alteration in the Brahmaputra River's course, which occurred approximately 200 years ago due to tectonic activity, erosion, or sedimentation. Fig. 1 represents the agroclimatic conditions throughout the research period. The soil in the area being studied was almost neutral in reaction, with a pH of 6.8 and adequate drainage features. The terrain was silty loam, with a modest height. Table 1 contains an explanation of the soil properties in the research field.

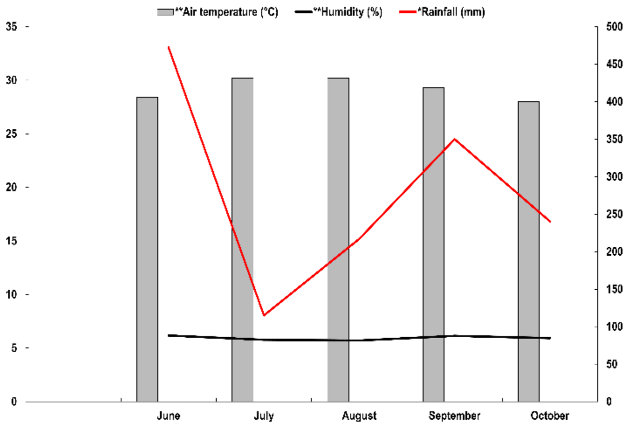

Fig. 1. Monthly average air temperature, relative humidity, rainfall, and sunlight hours' distribution at the experiment location from June to October, 2022.

Experimental treatments and set up: The nitrogen fertilizer was supplied from the BAU Agronomy Field Laboratory in Mymensingh. The experiment had two parts. The list follows. Factor A: 5 integrated nitrogen fertilizer management practices (ha^{-1}): Control (N_0), 150 kg 100% recommended dose prilled urea (N_1), 8 tons 100% recommended dose poultry manure (N_2), 75 kg 50% recommended dose prilled urea and 4 tons 50% recommended dose poultry manure (N_3), 1.8 g per 4 hills USG (N_4). Factor B: 5 Weed management practices (ha^{-1}): Control (W_0), Weed free throughout the growing period (W_1), 1 L Pretilachlor (pre-emergence herbicide) and at 35 DAT a hand-weeding (W_2), 750 g of both Acetachlor 14 WP and Bensulfuran methyle 4 WP (early post-emergence herbicide) and at 35 DAT 1 hand-weeding (W_3), 1 L Pretilachlor (pre-emergence herbicide), later 750 g of both Acetachlor 14 WP and Bensulfuran methyle 4 WP (early post-emergence herbicide) (W_4). Utilizing three replications, the experiment was set up using a randomized complete block design (RCBD). The three blocks that made up the experimental field each represented a replication. Each of the blocks comprised 25 units of plots which were assigned with the combination of five integrated nitrogen management and five weed management practices. Thus, there were 75 (5×5×3) plot units in total. Every plot measured 2.5 m ×2 m. Plots of the two units were kept apart by 0.5 m, and replications were maintained isolated by 1 m.

Table 1. Properties of the soil.

Physical							Chemical					
Sand (%)	**Silt (%)**	**Clay (%)**	**Textured**	**Porosity (%)**	**Bulk density (g/cc)**	**Particle density (g/cc)**	**OM (%)**	**N (%)**	**S (ppm)**	**Po (meq%)**	**Ph (ppm)**	**pH**
25.2	72.0	2.8	Silt loam	46.67	1.35	2.60	0.93	0.13	13.90	0.28	16.3	6.8

Source: Findings from the initial soil sample's mechanical examination performed at Bangladesh Agricultural University in Mymensingh's Department of Soil Science

Table 2. Infesting species of weed in the experimental plots of short duration drought tolerant *T. aman* rice cv. BRRI dhan71.

Sl. No.	Local name	Scientific name	Family	Morphology type
1.	Boro shama	*Echinochloa crussgalli* (L.) P. Beaauv.	Poaceae	Grass
2.	Khude shama	*Echinochloa colonum* (L.) Link.	Poaceae	Grass
3.	Kodo millet	*Paspalum scrobiculatum* (L.) Var.	Poaceae	Grass
4.	Anguli ghash	*Digitaria sanguinalis* (L.) Scop.	Poaceae	Grass
5.	Khude anguli ghash	*Digitaria ischaemum* (Schreb.) Schreb. ex Muhl.	Poaceae	Grass
6.	Chaise	*Fimbristylis dichotoma* (L.) Vahl	Cyperaceae	Sedge
7.	Joina	*Fimbristylis miliacea* (Retz.) Vahl	Cyperaceae	Sedge
8.	Sabuj Nakphul	*Cyperus difformis* (L.)	Cyperaceae	Sedge
9.	Pani chaise	*Eleocharisatro purpurea* (Retz.) J. Presl & C. Presl	Cyperaceae	Sedge
10.	Panikachu	*Monochoria vaginalis* (Burm. f.) C. Presl.	Pontederiaceae	Broad leaved
11.	Kachuripana	*Eichhornia crassipes* (Burm. f.) C. Presl.	Pontederiaceae	Broad leaved
12.	Pani shapla	*Nymphaea nouchali* (L.) Burm. f.	Nymphaeaceae	Broad leaved
13.	Shusni shak	*Marsilea quadrifolia* C. Presl.	Marsileaceae	Broad leaved
14.	Amrul shak	*Oxalis corniculata* (L.) Scop.	Oxalidaceae	Broad leaved

Crop husbandry: A piece of land was chosen at the Agronomy Field Laboratory, BAU to raise seedlings. The soil was extensively puddled with a country plough, and then by a ladder, the area was cleaned and leveled. Full doses of zinc sulphate, gypsum, muriate of potash (MOP), and triple super phosphate (TSP) by (kg ha^{-1}) 10, 60, 85, and 60 respectively were applied at final land preparation. For allowing proper decomposition poultry manure was collected from the poultry farm, later it was mixed into the soil during the last stages of land preparation. Fifteen plots were treated with 8 tons of manure per hectare, while the remaining 15 plots were treated with 4 tons of manure per hectare. After being soaked in water for 24 hours on 14 June 2022, gunny bags were used to store grains, then after 48 hours' grains started to germinate and within 72 hours almost all the grains completed sprouting. On June 18, 2022, grains were sprouted and sown in the wet nursery bed. The seedlings in the nursery bed were raised with due attention. The nursery bed was irrigated when needed and weeds were pulled. The nursery bed was moistened with water to make it soft the day before uprooting the seedlings.

A careful uprooting of 35-day-old seedlings was carried out early in the morning, on 23 July 2022. Prior to their transplantation into the main field, the uprooted seedlings were maintained on soft mud in the shade. About 10 days before transplanting the experimental land was prepared by a power tiller. After 4 sessions of ploughing and cross-ploughing, the ground was laddered to get the proper tilth and prepare it for transplanting. The invasive plants, crop residues, and debris were removed, and the site was cleaned. Carefully, the uprooted seedlings were replanted on July 23, 2022, by 3 seedlings together in a hill maintaining 20 cm x 15 cm space between row and hill. Three hills were randomly chosen from each plot (outside the area allotted for the very last harvest) for the purpose of collecting data. Ninety percent of the grains had to turn a golden yellow color when the crops were ready to be considered fully mature. For the purpose of gathering the yields of the grain and straw, a one square meter patch was manually cut from the ground level in the middle of each plot. Around October 26, 2022, BRRI dhan71 matured. Therefore, it was harvested on 26 October 2022. Accurately labeled, the harvested crop was brought in separate bundles to the concrete threshing floor. Using a pedal thresher, the crops were harvested, and the fresh weights of the grain and straw were calculated and adjusted to t ha^{-1}. The grains were cleaned and then dried to 14% moisture content. To determine the straw yield per square meter, straws were sun dried. Finally, the yield of grain and straw was converted from one square meter to t ha^{-1}.

Harvest index (%): It was calculated by the formula given below denoting the proportion of biological to economical yield.

$$\text{Harvest index (\%)} = \frac{\text{Economical yield}}{\text{Biological yield}} \times 100$$

Statistical analysis: In order to prepare the data for statistical analysis, the recorded data for weed parameters, growth parameters, yield, and yield contributing characters were collected and formatted appropriately. With the use of the computer application MSTAT-C, the gathered data were statistically examined using the "Analysis of Variance" technique. To assess the significance of the mean difference among the treatments, Duncan's Multiple Range Test (DMRT) (Gomez and Gomez, 1984) was used.

Results

Weed dynamics: In the experimental plots 14 species of weeds belonging to six distinct families were recorded (Table 2). The families of weeds included Poaceae (5), Cyperaceae (4), Pontederiaceae (2), Marsileaceae (1), Nymphaeaceae (1), and Oxalidaceae (1). In the experimental fields, Panikachu (*Monochoria vaginalis* (Burm. f.) C. Presl.) and Shama (*Echinochloa crussgalli* (L.) P. Beaauv.) were the most prevalent weed species. Other infesting species of weeds were Kodo millet (*Paspalum scrobiculatum* L.), Shushni shak (*Marsilea quadrifolia* C. Presl.), Khude shama *(Echinochloa colonum* L.), Kachuripana (*Eichhornia crassipes* (Burm. f.) C. Presl.), Pani chaise (*Eleocharisatro purpurea* (Retz) J. Presl & C. Pres), Anguli ghash (*Digitaria sanguinalis* L. Scop.), Khude anguli (*Digitaria ischaemum* (Schreb.) Schreb. ex Muhl.), Sabuj nakphul (*Cyperus difformis* L.), Pani Shapla *(Nymphaea nouchali* L.), Amrul shak (*Oxalis corniculata* L.), *and* Joina (*Fimbristylis miliacea* (Retz) Vahl) (Table 2).

Effect of integrated nitrogen management on density (m^{-2}) and dry biomass (g m^{-2}) of weeds: The outcome showed that dry biomass and weed density at 15 and 35 DATs were significantly influenced by integrative nitrogen management. The maximum weed density (11.87 m^{-2} at 15 DAT, 27.54 m^{-2} at 35 DAT) and dry biomass (7.25 g m^{-2} at 15 DAT, 18.20 g m^{-2} at 35 DAT) were recorded in the experimental plots treated with N_1. The minimum weed density at 15 DAT (6.94 m^{-2}), 35 DAT (20.14 m^{-2}), and dry biomass at 35 DAT (15.44 g m^{-2}) were recorded by applying N_4, whereas the dry biomass of weed at 15 DAT (5.99 g m^{-2}) was recorded lowest from the application of N_2 (Fig. 2a).

Effect of weed management on density (m^{-2}) and dry biomass (g m^{-2}) of weeds: Weed density and dry biomass were significantly affected by weed management at 15 and 35 DATs at 1% level of probability. Weed density (17.87 m^{-2} at 15 DAT and 32.93 m^{-2} at 35 DAT) and dry biomass (9.03 g m^{-2} at 15 DAT and 22.20 g m^{-2} at 35 DAT) were observed maximum in the plots where no weed management was practiced. The density of weed (0.00 m^{-2} at 15 DAT and 0.00 m^{-2} at 35 DAT) and dry biomass (0.00 g m^{-2} at 15 DAT and 0.00 g m^{-2} at 35 DAT) were observed to be the lowest in W_1 (weed-free). However, this was a costly, time-consuming, and labour-intensive practice. After the result achieved from practicing W_1(weed-free), weed density (8.93 m^{-2} at 15 DAT and 27.93 m^{-2} at 35 DAT) and dry biomass (19.49 g m^{-2}) at 35 DAT was found to be minimum by treating the plots with W_4) but, weed dry biomass was recorded lowest (7.76 g m^{-2} at 15 DAT) when the experimental plots were treated with W_2 (Fig. 2b).

Interaction effect of integrated nitrogen and weed management on density (m^{-2}) and dry biomass (g m^{-2}) of weeds: The interaction of integrated nitrogen and weed management had significant influence on weed density at 15 DAT and dry biomass at both 15 DAT and 35 DAT at a 5% level of probability except weed density at 35 DAT which showed non-significance. The highest weed density (22.00) at 15 DAT and weed dry biomass (11.67 g m^{-2}) at 15 DAT and (26.67 g m^{-2}) at 35 DAT was found from the interaction, N_1W_0. The lowest weed density and dry biomass was found in N_0W_1. As hand weeding was laborious and costly, another effective treatment, applying which the lowest weed density (6.33 m^{-2}) at 15 DAT and weed dry biomass (16.67 g m^{-2}) at 35 DAT was achieved in N_4W_4, whereas weed dry biomass (6.427 g m^{-2}) at 15 DAT was found to be the lowest in N_0W_2. However, weed density at 35 DAT showed non-significance to weed management treatments. Numerically, the highest weed density at 35 DAT was 38.00 m^{-2} which was recorded in the plots where N_1W_0 was applied and the lowest weed density was observed in every interaction where W_1 was combined with one of the 5 nitrogen management treatments followed by N_4W_4 by 22.33 m^{-2} (Table 3).

Effect on yield contributing attributes of *T. Aman* rice

Effect of integrated nitrogen management: The effect of integrated nitrogen management on plant height showed a significant influence on plant height at 1% level of probability. The highest plant height (108.91 cm) was observed in N_2, and the lowest (101.90 cm) was observed in N_0 (Fig. 3a). At a 1% probability level, integrated nitrogen management showed a significant difference in total tillers hill^{-1} (9.24) was the highest value for total tillers hill^{-1} and was obtained from N_3, and the lowest one (7.20) was found in N_0 (Fig. 3b). Effective tillers hill^{-1} was significantly influenced by integrated nitrogen management at 1% level of probability. The highest effective tillers hill^{-1} (7.84) was observed in N_3, and the lowest (6.51) was found in N_0 (Fig. 3c). The effect of integrated nitrogen management on panicle length was statistically insignificant. In terms of panicle length, the N_4 produced the longest panicle (23.70 cm), while the N_0 produced the shortest (22.83 cm) (Table 4). Grains panicle^{-1} was significantly influenced by integrated nitrogen management at 1% level of probability. The highest number of grains panicle^{-1} (96.32) was observed in N_2, and the lowest (82.09) was found in N_0 (Fig. 3d). Integrated nitrogen management's effect on sterile spikelets panicle^{-1} was statistically significant at 5% level of probability. The highest number of sterile spikelets panicle^{-1} (13.30) was observed in N_1, and the lowest (10.96) was found in N_4 (Table 4).

At a 5% probability level, integrated nitrogen management exhibited significant effect on 1000-grain weight. The heaviest 1000-grain weight (26.12 g) was observed in N_2, while lowest (25.70) was found in the N_0 (Fig. 4a). Integrated nitrogen management had a significant effect on grain yield at 1% level of probability. The highest grain yield (5.66 t ha^{-1}) was obtained from N_3, and the lowest (4.02 t ha^{-1}) was found in N_0 (Fig. 4b). Integrated nitrogen management exerted significant influence on straw yield at 1% level of probability. The result showed that the highest straw yield (6.18 t ha^{-1}) was in N_3, and the minimum (4.86 t ha^{-1}) was found in N_0 (Fig. 4c). The biological yield was influenced significantly by integrated nitrogen management at harvest at 1% level of probability. In N_3 11.84 t ha^{-1}, the highest biological yield was found, while the lowest (8.88 t ha^{-1}) was recorded in N_0 (Table 4). On the harvest index, integrated nitrogen management had an insignificant effect. Numerically, N_4 had the highest HI (47.80%), whereas N_0 had the lowest HI (45.27%) (Table 4).

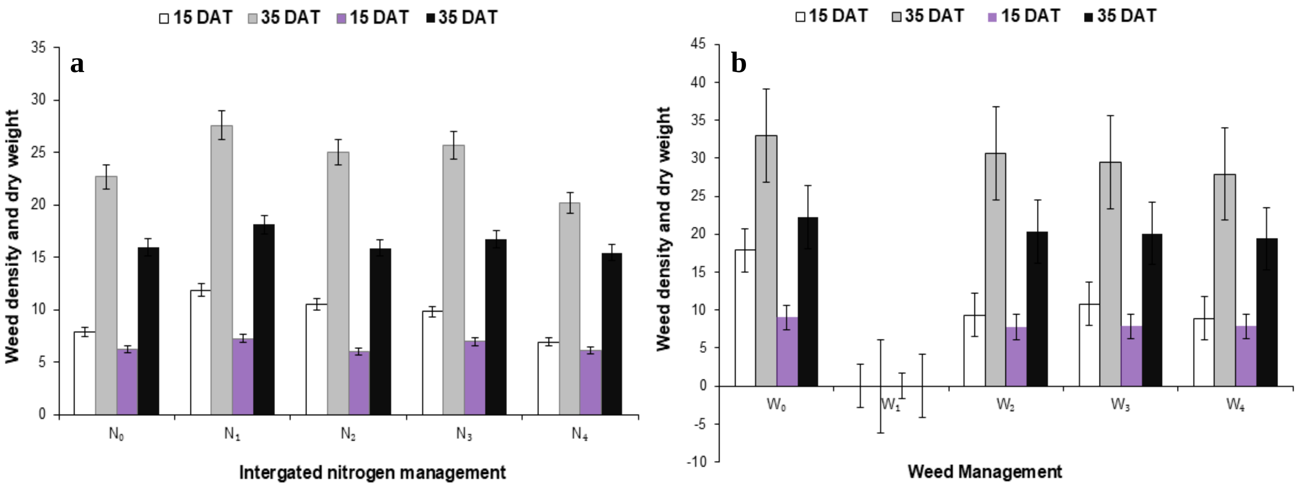

Fig. 2. Effect of integrated nitrogen management and weed management on weed growth in *T. aman* rice field. N_0 = Control, N_1= 150 kg ha^{-1} 100% recommended dose prilled urea, N_2 = 8 tons ha^{-1} 100% recommended dose poultry manure, N_3 = 75 kg ha^{-1} 50% recommended dose prilled urea and 4 tons ha^{-1} 50% recommended dose poultry manure, N_4 = 1.8 g per 4 hills USG, W_0 = Control, W_1 = weed free throughout the growing period, W_2 = 1 L Pretilachlor and at 35 DAT a hand-weeding, W_3 = 750 g of both Acetachlor and Bensulfuran methyle and at 35 DAT a hand-weeding, W_4= 1 L Pretilachlor and 750 g Acetachlor and Bensulfuran methyle.

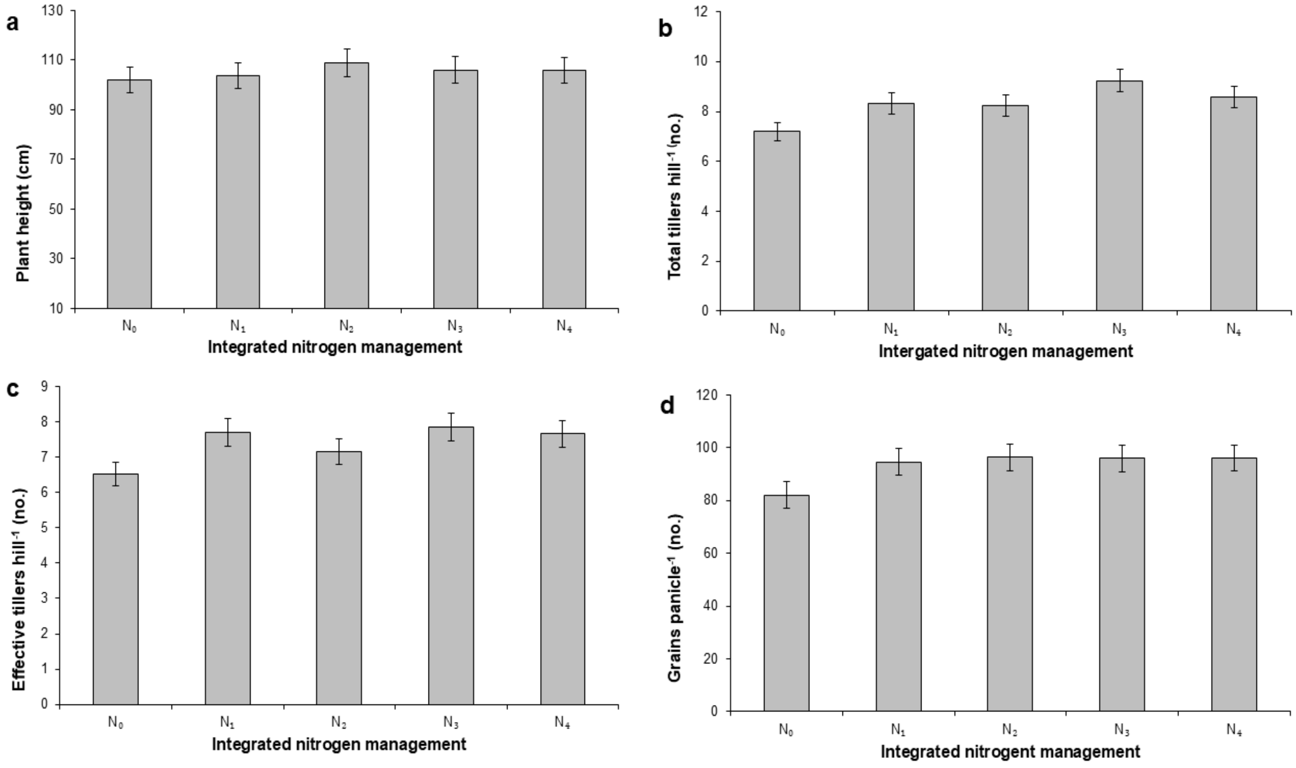

Fig. 3. Influence of combined nitrogen management on *T. aman* rice yield-contributing parameters. Others details are same as shown in Fig. 2.

Effect of weed management: The result indicates that the effect of weed management on plant height was statistically significant at 5% level of probability. The highest plant height (107.10 cm) was observed in the W_1, this treatment exerted the highest plant height because there was no weed interference allowing the rice to grow without any below and above-ground competition of resources. The lowest plant height (103.30 cm) was found in the W_0 (Fig. 6a) due to crop-weed competition and weed absorbed more nutrients than rice hence shortest plant was observed in this treatment. The result of the study indicates that, at the 5% probability level, the impact of weed management on the total tillers $hill^{-1}$ was statistically significant. W_3 produced the maximum total tillers $hill^{-1}$ (8.69), whereas W_0 exhibited the lowest number (7.63) (Fig. 6b). At the 5% probability level, results exhibited that the impact of weed control on effective tillers $hill^{-1}$ was statistically significant. W_0 had the lowest total tillers $hill^{-1}$ (6.63), while W_3 had the greatest total tillers $hill^{-1}$ (7.75) (Fig. 6c). The effect of weed management on panicle length was statistically insignificant. Numerically, the longest panicle (23.70 cm) was recorded in W_1 and the shortest panicle (22.85 cm) was found in (Table 5). The effect of weed management on grains $panicle^{-1}$ was statistically significant at 1% level of probability. The highest number of grains $panicle^{-1}$ (99.25) was observed in W_2 and the lowest grains panicle^{-1} (84.39) was found in W_1 (Fig. 6d). Sterile spikelets panicle^{-1} showed no significant variation in response to weed treatment. Numerically, the W_0 had the greatest number of sterile spikelets panicle^{-1} (12.18), whereas the W_3 had the lowest number of sterile spikelets panicle^{-1} (17.51) (Table 5).

The effect of weed management on 1000-grain weight was statistically significant at 5% level of probability. The W_0 exhibited the lowest 1000-grain weight (25.72 g), whereas the W_1 produced the highest 1000-grain weight (26.24 g) (Fig. 5a). Grain yield was significantly influenced by weed management at 1% level of probability. Maximum grain yield (5.39 t ha^{-1}) was estimated from W_4 and the lowest grain yield (4.26 t ha^{-1}) was noticed in W_0 (Fig. 5b). Straw yield was significantly influenced by weed management practices at 5% level of probability. The treatment having the highest straw yield (5.96 t ha^{-1}) was W_4 (pre-emergence herbicide followed by early post-emergence herbicide), while the treatment with the lowest straw yield (5.08 t ha^{-1}) was W_0 (Fig. 5c). Weed management had significant effect on biological yield at harvest at 1% level of probability. W_4 had the highest biological yield (11.35 t ha^{-1}), whereas W_0 had the lowest biological yield (9.34 t ha^{-1}) (Table 5). The effect of weed management on weed was statistically insignificant. Numerically, the highest HI (47.59%) was observed in W_4 and the lowest HI (45.61%) was achieved from W_0 (Table 5).

Interaction effect of integrated nitrogen and weed management: We did not find any significant interaction effect between integrated nitrogen management and weed management (Supplementary Tables 1 and 2).

Table 3. Interaction effect of integrated nitrogen and weed management on weed growth.

Interaction (Integrated nitrogen management × weed management)	Weed density (No. m^{-2})		Weed dry biomass (g m^{-2})	
	15 DAT	35 DAT	15 DAT	35 DAT
N_0W_0	13.00bcd*	32.67abc	9.33b	20.67bc
N_0W_1	0.00g	0.00d	0.00e	0.00d
N_0W_2	9.33c-f	27.67abc	6.43d	19.33bc
N_0W_3	9.00c-e	27.00abc	7.81bcd	19.00bc
N_0W_4	7.66ef	26.00bc	7.69bcd	20.76bc
N_1W_0	22.00a	38.00a	11.67a	26.67a
N_1W_1	0.00g	0.00d	0.00e	0.00d
N_1W_2	12.67bcd	34.67ab	8.77bc	21.17b
N_1W_3	12.33b-e	34.00abc	7.93bcd	21.00bc
N_1W_4	12.33b-e	31.00abc	7.85bcd	21.67b
N_2W_0	20.33a	30.00abc	7.00cd	20.00bc
N_2W_1	0.00g	0.00d	0.00e	0.00d
N_2W_2	8.33def	34.67ab	7.56bcd	20.67bc
N_2W_3	15.33b	29.33abc	7.73bcd	19.36bc
N_2W_4	8.66c-f	31.00abc	7.63bcd	19.33bc
N_3W_0	20.67a	37.00ab	9.30b	22.67b
N_3W_1	0.00g	0.00d	0.00e	0.00d
N_3W_2	8.66c-f	30.67abc	8.63bc	20.84bc
N_3W_3	10.00c-f	31.33abc	8.27bcd	21.41b
N_3W_4	9.66c-f	29.33abc	8.53bcd	18.57bc
N_4W_0	13.33bc	27.00abc	7.87bcd	21.00bc
N_4W_1	0.00g	0.00d	0.00e	0.00d
N_4W_2	7.66ef	25.67bc	7.40bcd	19.83bc
N_4W_3	7.33f	25.67bc	7.50bcd	19.67bc
N_4W_4	6.33f	22.33c	7.70bcd	16.67c
Level of significance	*	NS	*	*
CV (%)	16.35	14.76	16.49	13.74

*Table in a column that have the same letter or letters and those that do not differ substantially from one another (DMRT) are distinguished from one another. * = Significant by probability of 5%; NS= No Significance. N_0 = Control, N_1= 150 kg ha^{-1} 100% recommended dose prilled urea, N_2 = 8 tons ha^{-1} 100% recommended dose poultry manure, N_3 = 75 kg ha^{-1} 50% recommended dose prilled urea and 4 tons ha^{-1} 50% recommended dose poultry manure, N_4 = 1.8 g per 4 hills USG, W_0 = Control, W_1 = weed free throughout the growing period, W_2 = 1 L Pretilachlor and at 35 DAT a hand-weeding, W_3 = 750 g of both Acetachlor and Bensulfuran methyle and at 35 DAT a hand-weeding, W_4= 1 L Pretilachlor and 750 g Acetachlor and Bensulfuran methyle

Table 4. Effect of integrated nitrogen management on yield attributes and yield of *T. aman* rice cv. BRRI dhan71.

Integrated nitrogen management	Panicle length (cm)	Sterile spikelets panicle^{-1} (no.)	Biological yield (t ha^{-1})	Harvest index (%)
N_0	22.83	11.58b	8.88c	45.27
N_1	23.02	13.30a	10.67b	45.83
N_2	23.16	11.75b	10.87ab	46.92
N_3	23.00	11.83b	11.84a	47.80
N_4	23.70	10.96b	10.91b	46.84
Level of significance	NS	*	**	NS
CV (%)	5.55	15.66	12.43	8.09

** = Significant at 1% level of probability, others details are same as shown in Table 3

Table 5. Effect of weed management on yield attributes and yield of *T. aman* rice cv. BRRI dhan71.

Weed management	Panicle length (cm)	Sterile spikelets panicle^{-1} (no.)	Biological yield (t ha^{-1})	Harvest index (%)
W_0	22.96	12.18	9.34b	45.61
W_1	23.70	11.88	10.90a	47.06
W_2	23.26	11.87	10.75a	45.77
W_3	22.95	11.51	10.88a	47.24
W_4	22.85	11.99	11.35a	47.49
Level of significance	NS	NS	**	NS
CV (%)	5.55	15.66	12.43	8.09

**= Significant by 1% level of probability, others details are same as shown in Table 3

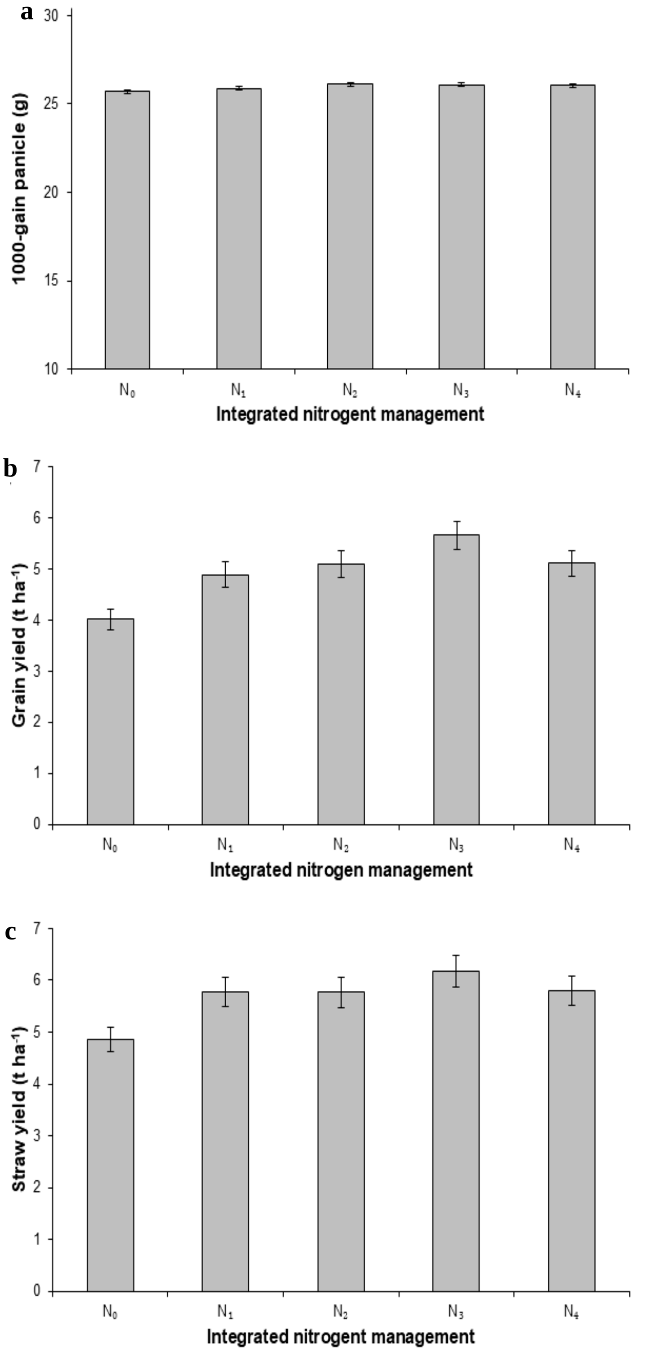

Fig. 4. Influence of combined nitrogen management on *T. aman* rice yield-contributing parameters. Others details are same as shown in Fig. 2.

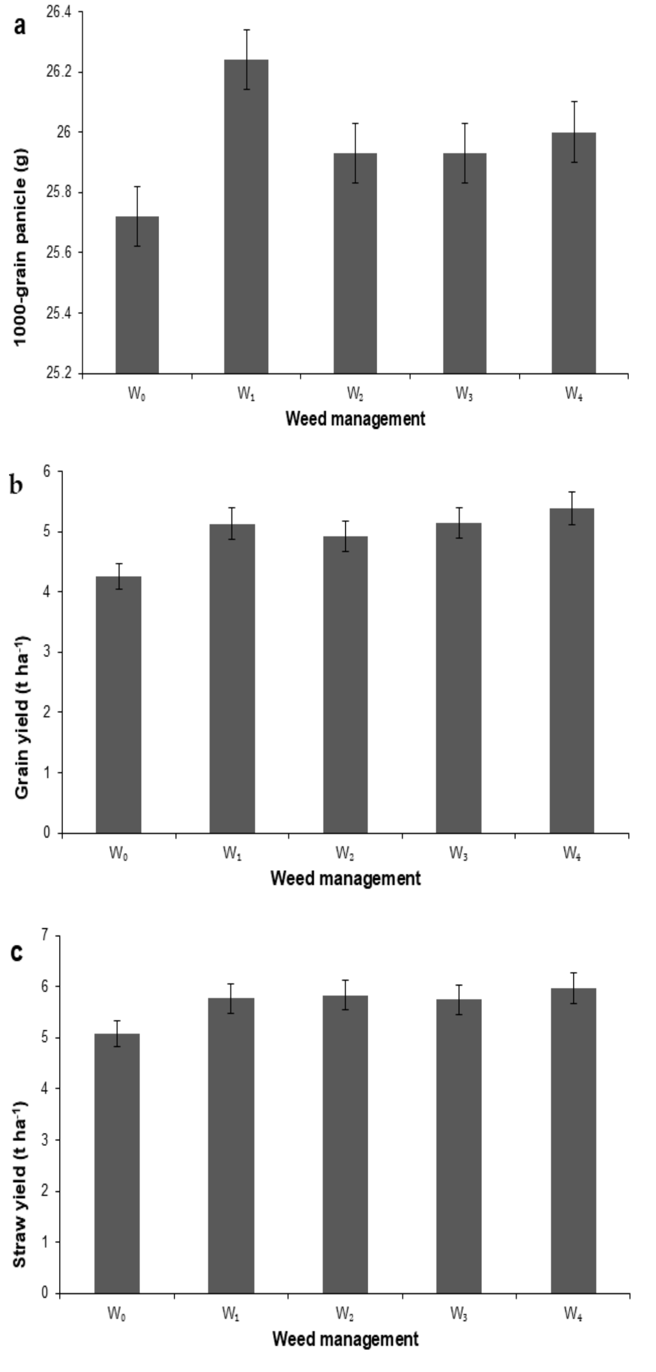

Fig. 5. Impact of weed management on several *T. aman* rice yield-contributing parameters. Others details are same as shown in Fig. 2.

Supplementary Table 1. Interaction effect of integrated nitrogen and weed management on yield attributes and yield of *T. aman* rice cv. BRRI dhan71.

Interaction (Integrated nitrogen management × Weed management)	Plant height (cm)	Total tillers hill^{-1} (no.)	Effective tillers hill^{-1} (no.)	Panicle length (cm)	Grains panicle^{-1} (no.)	Sterile spikelets panicle^{-1} (no.)
N_0W_0	101.33	6.89	5.78	22.93	76.47	10.88
N_0W_1	101.78	6.55	6.12	23.46	85.80	12.51
N_0W_2	103.55	7.22	6.22	22.88	84.72	12.68
N_0W_3	101.56	8.22	7.15	22.23	81.69	10.95
N_0W_4	101.33	7.11	7.27	22.63	81.74	10.89
N_1W_0	103.00	7.56	7.55	22.90	87.70	12.14
N_1W_1	108.00	8.89	7.89	22.90	92.91	14.43
N_1W_2	103.33	8.45	7.56	23.45	103.42	13.04
N_1W_3	102.78	8.11	7.56	23.19	95.91	12.27
N_1W_4	102.55	8.67	7.89	22.67	92.99	14.62
N_2W_0	106.44	7.44	6.34	23.22	91.06	11.27
N_2W_1	109.78	7.89	7.11	23.08	100.40	10.79
N_2W_2	107.22	9.00	7.55	23.44	101.68	12.85
N_2W_3	112.00	9.00	7.78	23.13	94.70	11.05
N_2W_4	109.11	7.90	7.00	22.95	93.74	12.79
N_3W_0	101.56	8.78	7.00	23.06	81.77	13.22
N_3W_1	109.33	9.55	8.33	23.33	97.16	11.47
N_3W_2	109.22	9.89	8.44	22.63	100.88	10.83
N_3W_3	102.78	9.55	8.22	22.74	98.20	12.60
N_3W_4	107.33	8.45	7.22	23.28	102.20	11.02
N_4W_0	104.22	7.47	6.47	22.69	84.94	13.37
N_4W_1	106.78	9.22	8.44	25.74	89.52	10.18
N_4W_2	109.67	8.44	7.56	23.91	105.56	9.94
N_4W_3	103.11	8.55	8.06	23.46	100.40	10.69
N_4W_4	105.67	9.22	7.78	22.73	100.10	10.62
Level of significance	NS	NS	NS	NS	NS	NS
CV (%)	3.90	14.75	13.18	5.55	9.13	15.66

Others details are same as shown in Table 3

Supplementary Table 2. Interaction effect of integrated nitrogen and weed management on yield attributes and yield of *T. aman* rice cv. BRRI dhan71.

Interaction (Integrated nitrogen management × Weed management)	1000-grain weight (g)	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
N_0W_0	25.56	3.41	3.92	7.33	46.52
N_0W_1	26.05	3.97	4.88	8.85	44.86
N_0W_2	25.49	3.70	4.88	8.58	43.12
N_0W_3	25.59	3.97	4.72	8.69	45.68
N_0W_4	25.78	5.06	5.88	10.94	46.25
N_1W_0	25.36	4.63	5.57	10.20	45.39
N_1W_1	25.96	5.51	5.93	11.44	48.16
N_1W_2	26.06	4.95	5.93	10.88	45.50
N_1W_3	25.77	4.82	5.66	10.48	45.99
N_1W_4	26.23	4.55	5.79	10.34	44.00
N_2W_0	26.15	3.87	4.99	8.86	43.68
N_2W_1	26.44	5.53	6.23	11.76	47.02
N_2W_2	25.84	5.37	6.04	11.41	47.06
N_2W_3	26.13	5.60	6.32	11.92	46.98
N_2W_4	26.06	5.27	5.36	10.63	49.58
N_3W_0	25.74	5.03	5.44	10.47	48.04
N_3W_1	26.38	5.68	6.19	11.87	47.85
N_3W_2	26.03	5.74	6.67	12.41	46.25
N_3W_3	26.29	5.76	6.11	11.87	48.53
N_3W_4	25.89	6.09	6.50	12.59	48.37
N_4W_0	25.79	4.38	5.49	9.87	44.38
N_4W_1	26.41	4.94	5.62	10.56	46.78
N_4W_2	26.22	4.83	5.63	10.46	46.18
N_4W_3	25.85	5.53	5.92	11.45	48.30
N_4W_4	26.04	5.87	6.33	12.20	48.11
Level of significance	NS	NS	NS	NS	NS
CV (%)	1.57	14.80	14.19	12.43	8.09

Others details are same as shown in Table 3

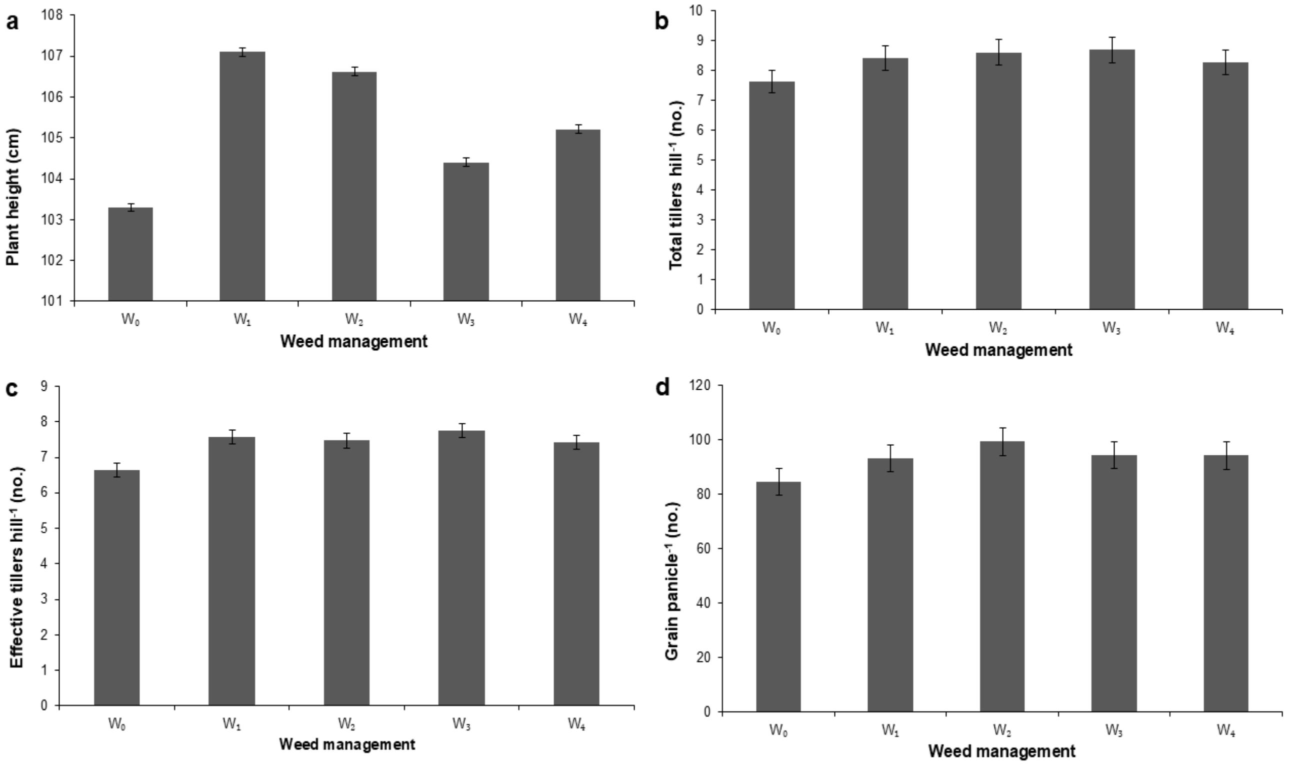

Fig. 6. Impact of weed management on several *T. aman* rice yield-contributing parameters. Others details are same as shown in Fig. 2.

Principal component analysis (PCA), correlation and heatmap analysis

Principal component analysis (PCA): By identifying the key factors that explain the pattern of correlations within the treatment of the detected manures, fertilizers, and plant residues, Principal Component Analysis was applied to figure out how the integrated nitrogen affected the growth of weeds and the yield of transplanted *aman* rice. In Fig. 7, the loadings of variables and the bi-plot of the first two main components are presented. The first principal component, or PC1 represented by the x-axis accounted for 53.5% of the total variance. The second main component, or PC2, represented by the y-axis and accounted for 20.58% of the total variance. The biplot displayed several data points (labeled as 1 to 5) representing treatments. Variables such as the weed density at the both 15 and 35 DAT, and the weed dry biomass at both 15 and 35 DAT had a strong positive correlation with PC1 and a moderate correlation with PC2 while variables such as effective tillers hill^{-1}, straw yield, biological yield, grain's panicle^{-1}, total tillers hill^{-1}, grain yield, harvest index and 1000-grains weight had a positive correlation with PC1 but a weaker influence. Panicle length was negatively correlated with PC1 but had a minor influence on PC2. Treatment 2 was highly influenced by the sterile spikelets panicle^{-1}, weed dry biomass at 35 DAT etc. While treatments 1 and 3 were more average or had mixed characteristics relative to the entire dataset. The harvest index, 1000-grains weight, and plant height had a strong positive correlation with each other and negative with the weed density at both 15 and 35 DAT, the weed dry biomass at both 15 and 35 DAT, and sterile spikelets panicle^{-1}. The straw yield total tillers hill^{-1}, grains panicle^{-1}, biological yield, and grain yield were positively associated with each other and had a negative correlation with the weed density at both 15 and 35 DAT, the weed dry biomass at the both 15 and 35 DAT and sterile spikelets panicle^{-1}. Panicle length had a strong negative correlation with the weed's parameters.

Using principal component analysis, it was possible to determine how weed control affected the growth of weeds and the yield of transplanted *aman* rice by pinpointing the vital variables that accounted for the patterns of correlations found in the treatments of the found manures, fertilizers, and plant residues. In Fig. 8, the loadings of variables and the bi-plot of the first two main components are presented. The first principal component, or PC1 represented by the x-axis accounted for 53.5% of the total variance. The second main component, or PC2, represented by the y-axis accounted for 20.8% of the total variance. The biplot displayed several data points (labeled 1 to 7) representing treatments. Variables such as the weed density at both 15 and 35 DAT and the weed dry biomass at both 15 and 35 DAT vectors were clustered closely together and point in a similar direction, suggesting they were strongly positively correlated with each other and contribute significantly to the variance explained by PC1 while1000-grains weight and panicle length had different effects on the variance captured by PC1 and PC2. The straw yield, total tillers hill^{-1}, grains panicle^{-1}, biological yield, grain yield, effective tillers hill^{-1}, harvest index, were strongly correlated with each other and there was a negative correlation between the weed density at 15 DAT, weed density at 35 DAT, weed dry biomass at 15 DAT and weed dry biomass at 35 DAT. Plant height, 1000-grain weight and panicle length were very negatively correlated with the weed density at 15 DAT and at 35 DAT, weed dry biomass at 15 DAT and at 35 DAT. Treatment 3 positioned in a region of the biplot where many important variables were clustered (like straw yield, grain yield, effective tillers hill^{-1}, etc.) indicating that Point 3 was strongly influenced by these positively correlated variables. So, it could be considered the "best" observation in this context.

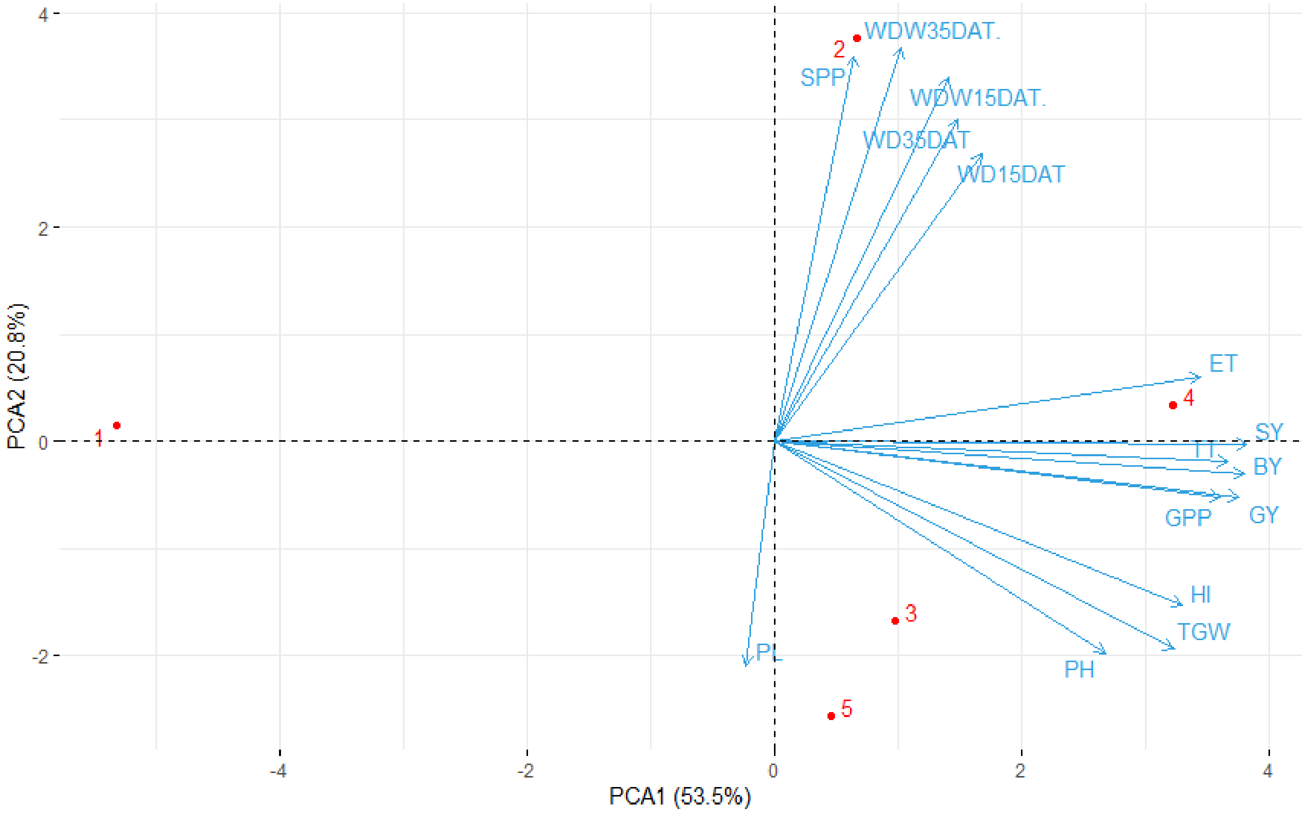

Fig. 7. Bi-plot of principal component analysis (PCA) showing the first two principal components (PC 1 and PC 2). For PCA, data on weed growth and yield and yield contributing attributes under the integrated nitrogen management. Where PH= Plant height (cm), TT= Total tillers hill^{-1}, ET= Effective tillers hill^{-1}, PL= Panicle length (cm), GPP= Grain panicle^{-1}, SPP= Sterile spikelets panicle^{-1}, TGW= 1000-grain weight (g), GY= Grain yield (t ha^{-1}), SY= Straw yield (t ha^{-1}), BY= Biological yield (t ha^{-1}), HI= Harvest index (%), WD15DAT= Weed density at 15 days after transplanting, WD35DAT= Weed density at 35 days after transplanting, WDW15DAT= Weed dry biomass at 15 days after transplanting and WDW35DAT= Weed dry biomass at 35 days after transplanting. ∗∗∗, ∗∗, ∗ and NS (Not Significant) represent probability of ≤0.001, ≤0.01, ≤0.05 and >0.05, respectively.

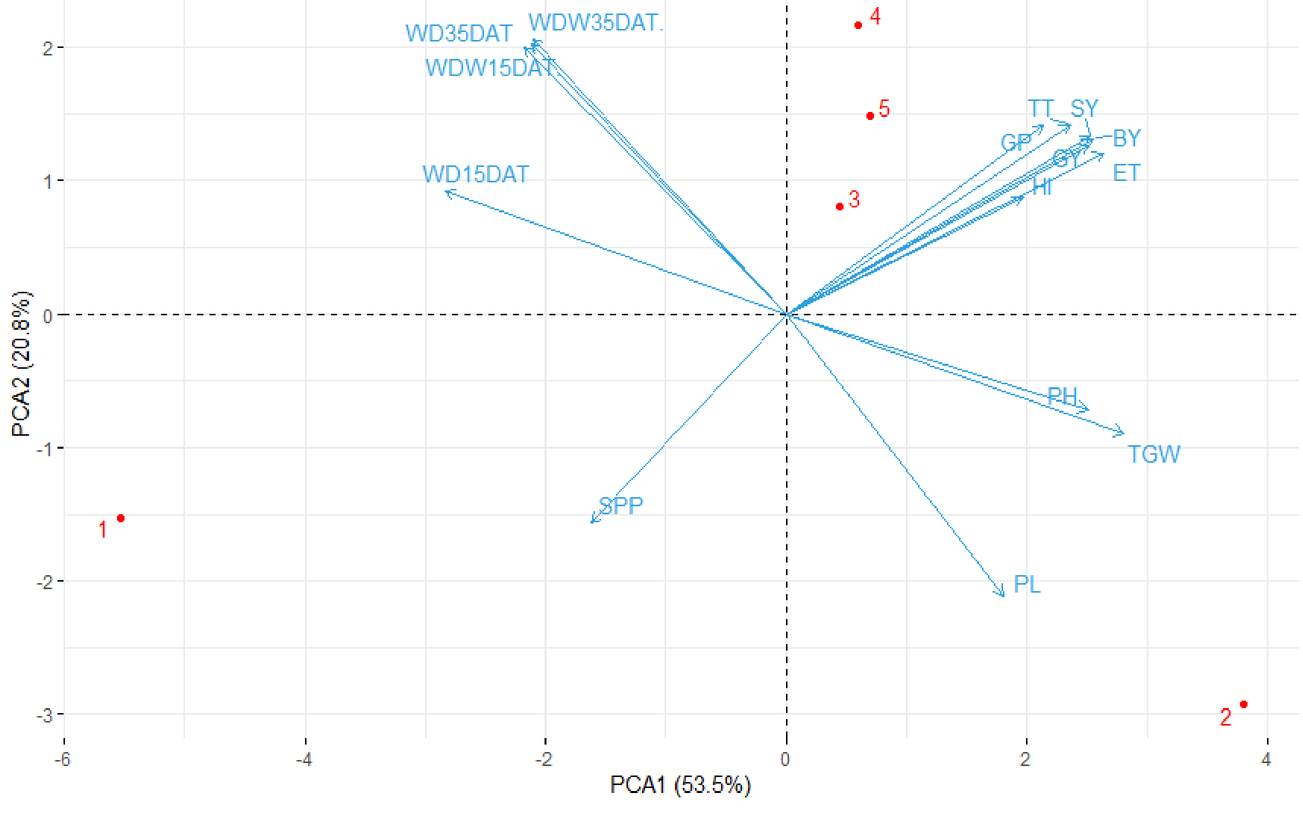

Fig. 8. Bi-plot of principal component analysis (PCA) showing the first two principal components (PC 1 and PC 2). Others details are same as shown in Fig. 7.

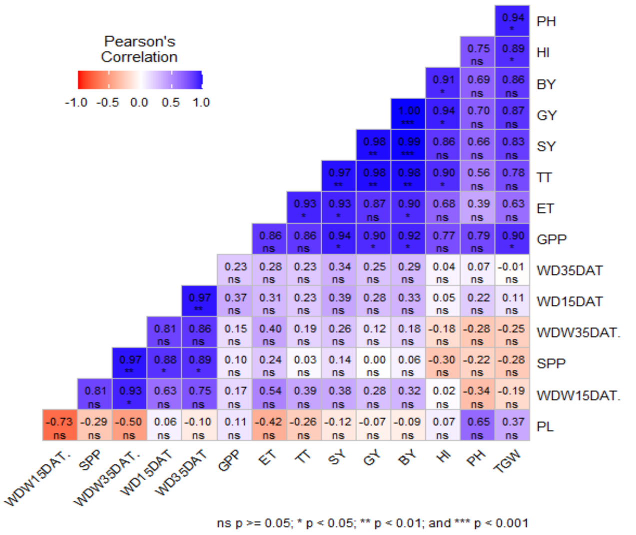

Fig. 9. Pearson correlation analysis the growth of weed and yield of transplanted *aman* rice as influenced by the integrated nitrogen management. Others details are same as shown in Fig. 7.

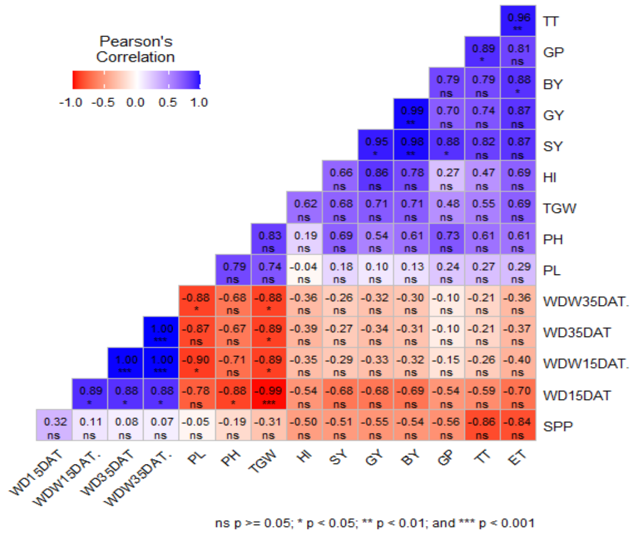

Fig. 10. Pearson correlation analysis the growth of weed and yield of transplanted *aman* rice as influenced by the weed management. Others details are same as shown in Fig. 7.

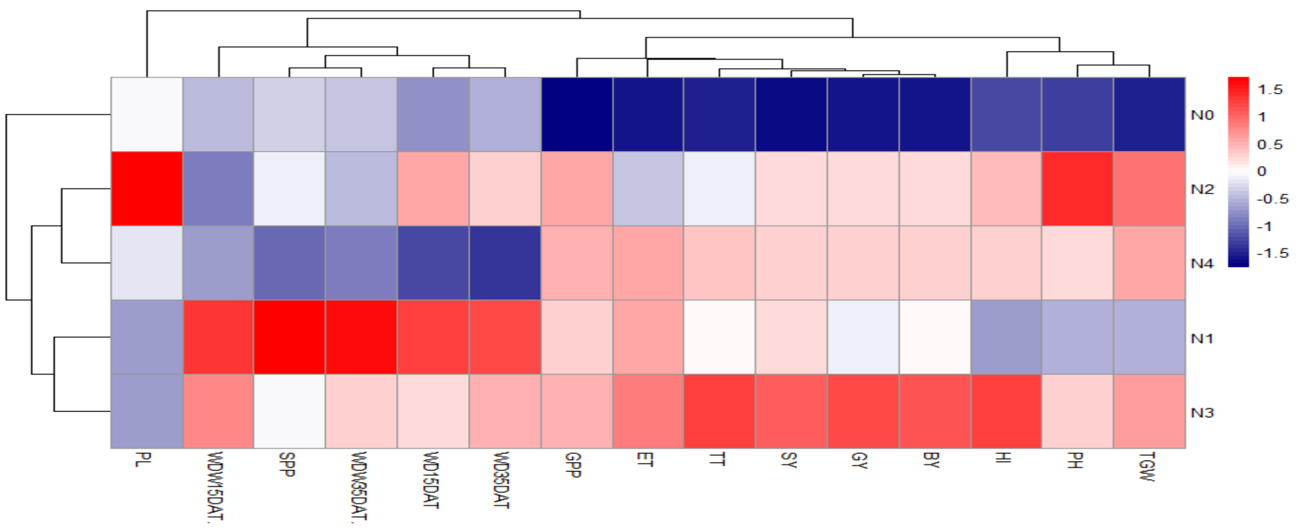

Fig. 11. Heat map analysis of the growth of weed and yield of transplanted *aman* rice as influenced by the integrated nitrogen management. Others details are same as shown in Fig. 7.

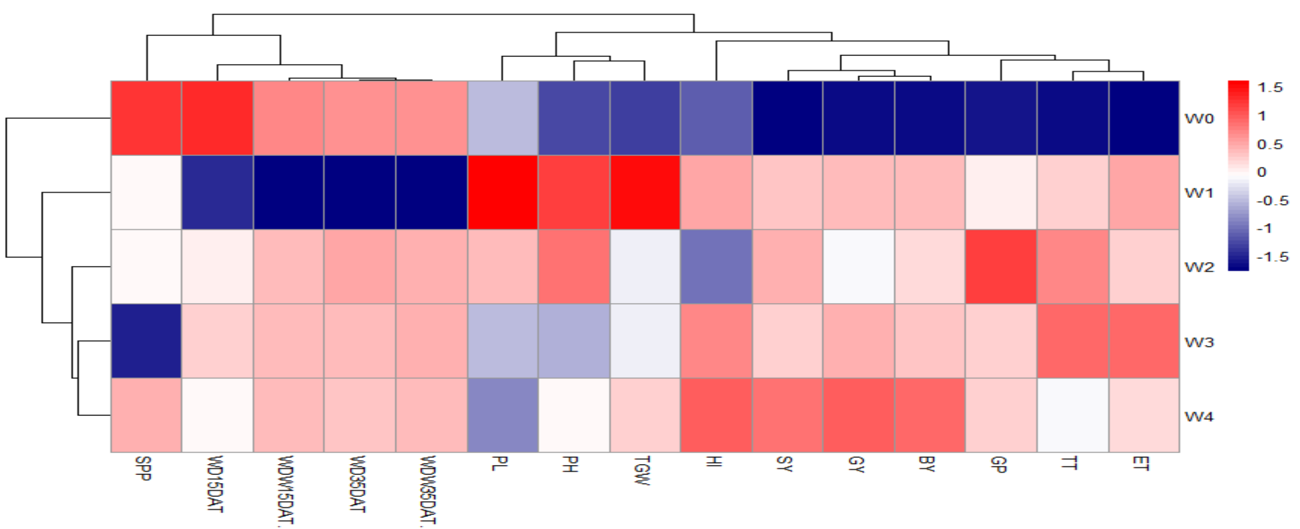

Fig. 12. Heat map analysis of the growth of weed and yield of transplanted *aman* rice as influenced by the weed management. Others details are same as shown in Fig. 7.

Correlation analysis: Interrelationship between different growth of weed and yield of transplanted *aman* rice was identified by a correlation which was influenced by the integrated nitrogen management (Fig. 9). In addition to having a positive correlation at (<0.05) with the number of grains panicle^{-1} and a non-significant positive correlation with the effective tillers hill^{-1}, the analysis showed that the grain yield had a strong positive correlation (<0.01) with the straw yield and total tillers hill^{-1}. The biological yield demonstrated a highly positive significance with the straw and grain yield and moderately with total tillers hill^{-}1, besides with the effective tillers hill^{-1}, grains panicle^{-1} had a positive correlation. The harvest index showed a positive mutualism with the biological yield, grain yield, and total tillers hill^{-1}. On the contrary, it showed a non-significant negative correlation with the weed dry biomass at 35 DAT and sterile spikelets panicle^{-1}. A non-significant positive correlation between plant height and most of the yield contributing parameters, besides had a negative correlation with the weed dry biomass at both 35 and 15 DAT and sterile spikelets panicle^{-1}. The 1000 grain weight had a significant positive correlation with plant height, harvest index, and grains panicle^{-1} while a non-significant negative correlation with the weed dry biomass at both 35 and 15 DAT and sterile spikelets panicle^{-1}. The total tillers hill^{-1} and effective tillers hill^{-1} exhibited a positive mutualism, besides sterile spikelets panicle^{-1} and weed dry biomass at 35 DAT showed a strong positive correlation.

To identify the interrelationship between different the growth of weed and yield of transplanted *aman* rice as influenced by weed management, a correlation was performed (Fig. 10). The result of the investigation showed that the grain yield and the biological yield had a strong positive correlation (<0.01) and with the straw yield at (<0.05). The biological yield demonstrated a highly positive significant mutualism with the straw yield and non-significant with the harvest index, plant height, and 1000-grains weight. Grains panicle^{-1} had a significant positive correlation with the total tillers hill^{-1} and the straw yield again the effective tillers hill^{-1} showed a strong positive relationship with total tillers hill^{-1} and biological yield. 1000-grains weight had a highly negative correlation with the weed density at 15 DAT and a negative correlation at 0.05 with the weed density at 35 DAT and the weed dry biomass at both 15 and 35 DAT. Panicle length showed a significant negative relationship with the weed dry biomass at both 15 and 35 DAT while the plant biomass showed negative relationship with the weed density at 15 DAT. Besides other yield contributing parameters marked a non-significant negative correlation with the weed density at the both 15 and 35 DAT, the weed dry biomass at the both 15 and 35 DAT.

Heatmap analysis: A heatmap is a visual representation of data where the values are depicted by color. The labels on the rows (left side) are various treatments and on the columns (bottom) are various yield contribution parameters. The yield-contributing parameters had no significant correlation with the N_0 treatment. Most of the parameters performed well at N_3 treatment. The weed density at both 15 and 35 DAT, weed dry biomass at both 15 and 35 DAT and SPP showed higher abundance under N_1. N_4 performed the best regarding weed management among the treatments. Grain yield and biological yield showed almost similar results, regarding the treatments same scenario had happened to weed density at 15 DAT and 35 DAT, sterile spikelets panicle^{-1}, weed dry biomass at 35 DAT, plant height, and 1000-grains weight. N_2 and N_4 performed similarly regarding the yield contributing parameters (Fig.11).

W_1 performed better for weed management and other yield-contributing parameters among other treatments while W_0 performed the least. Regarding the treatments weed density at 35 DAT, and weed dry biomass at both 15 and 35 DAT parameters exhibited almost identical results. The corresponding result was also found between grain yield, effective tillers hill$^{-1,}$ biological yield, and total tillers hill^{-1}. Regarding the yield contribution parameters statistically similar result was found between W_3 and W_4 treatments (Fig. 12).

Discussion

The experimental field's diversified weed flora, reflects ideal ecological circumstances for widespread weed growth, is indicated by the presence of 14 weed species from 6 families. Strong competitive potential is shown by the dominance of *Echinochloa crusgalli* L. and *Monochoria vaginalis* (Burm. F.) C. Presl., underscoring the necessity of early and comprehensive weed management techniques. Research on the same experimental location was done by Ali *et al*., (2022), who found that the two most common weeds in *T. aman* rice cultivation were *Monochoria hastata* L. and *Echinochloa crusgalli* L. Research on the same experimental location was done by Kheya *et al.*, (2024), who found that the most common weeds in *T. aman* rice production were Topapana (*Pistia stratiotes* L.), Shama (*Echinochola crusgalli* L.), Kodo millet (*Paspalum scrobiculatum* L.) and Anguli ghash (*Digitaria sanguinalis* L. Scop.). Similar to this experiment, Ashraf *et al.*, (2021) found that *Nymphaea nouchali* L., *Echinochloa crusgalli*, *Monochoria vaginalis* (Burm. F.) C. Presl., *Scirpus juncoides* L., and *Marsilea quadrifolia* C. Presl. were the common weeds infesting the experimental plots of *T. aman* rice at the Agronomy Field Laboratory of BAU, Mymensingh. Moreover, the N_1 treatment, consisting of 100% recommended nitrogen applied as prilled urea, recorded the highest dry biomass and weed density. At both 15 and 35 DAT, the weed density was 11.87 m^{-2} and 27.54 m^{-2}, respectively, and the dry biomass was 7.25 g m^{-2} and 18.20 g m^{-2}.

The use of nitrogen fertilizer was found to boost weed growth, according to the research conducted by Little *et al.*, (2021). The probable cause might be due to the fact that in a nitrogen applied plots weeds uptake more N than rice hence weed density and dry biomass are increased (Maimunah *et al*., 2021). Moreover, when prilled urea is broadcast, the entire weed community is fertilized along with the crops which enhances weed seed germination. Additionally, the lowest weed dry biomass at 15 DAT (5.99 g m^{-2}) was recorded in the plots treated with N_2, where 100% of the RD of nitrogen was supplied through poultry manure. Differences in nitrogen management were also noted by Nandan (2017) to cause variance in weed density and dry biomass. The use of prilled urea (N_1) resulted in the highest weed density and biomass, possibly due to the quick release and availability of nitrogen, which may also promote weed growth (Nelson *et al*., 2013). On the other hand, the application of USG (N_4) and poultry manure (N_2) resulted in lower weed density and biomass, indicating a potential advantage in reducing weed pressure (Sajjad *et al*., 2024). The slower release of nitrogen from USG and poultry manure may provide a more balanced nutrient availability to the rice plants while limiting the nutrient availability to weeds (Kheya *et al*., 2023). Weed density and dry biomass were the highest in the experimental plots where no weed management was practiced. Weed density and dry biomass were lowest in the W_1 treatment, which maintained a weed-free condition. In these plots, both the weed density and dry biomass were 0.00 m^{-2} at 15 DAT and 0.00 m^{-2} at 35 DAT. The absence of weed management led to significantly higher weed proliferation, which could challenge rice plants for nutrients, moisture, and light, ultimately lowering crop productivity and quality. Maintaining a weed-free environment can significantly enhance rice plant growth and productivity by minimizing competition from weeds. These findings emphasize the need for adopting effective weed management strategies to achieve optimal crop performance and sustainable agricultural practices. Salam (2020) and Parvez *et al.,* (2013) similarly reported that the weedy control treatments had the highest weed density. These results indicate the positive effect of nitrogen application on plant growth, with the use of poultry manure in the N_2 treatment leading to the tallest plants. Poultry manure likely provided a steady release of nutrients, enhancing nitrogen availability and supporting better vegetative growth. Conversely, the absence of nitrogenous fertilizer in the N_0 treatment resulted in the shortest plants, highlighting the importance of nitrogen for optimal plant development. The conformity of this result was also observed by Kheya *et al.,* (2024). Additionally, they observed that plant height was positively influenced by nitrogen levels. These results highlight the beneficial effect of combining organic and inorganic nitrogen sources on tiller production in rice cultivation. The N_3 treatment, with its balanced nutrient supply from both prilled urea and poultry manure, likely provided a more comprehensive nutrient profile, promoting better vegetative growth and tiller formation. These findings suggest that integrating organic and inorganic nitrogen sources can be an effective strategy for enhancing tiller production and overall crop performance. This approach can provide a steady supply of nutrients, improve soil health, and support sustainable agricultural practices. The conformity of this finding was also noticed by Salem *et al.,* (2011), who noted, there was a positive impact between nitrogen management and total tillers hill^{-1}. The N_3 treatment, which provided a balanced supply of nutrients from both prilled urea and poultry manure, likely enhanced nutrient availability and uptake, leading to better tiller formation and development. Ahmed *et al.,* (2005) and Salam *et al.,* (2022) demonstrated that effective tillers hill^{-1} increased with the improved reaction to nitrogen. The highest grains per panicle, 96.32, was observed in the N_2 treatment, which involved the application of 100% of the recommended dose (RD) of nitrogen from poultry manure. In contrast, the lowest grains per panicle, 82.09, was found by N_0, where there was no nitrogenous fertilizer. These findings emphasize the importance of adequate nitrogen nutrition for maximizing grain yield in rice cultivation. Using fertilizers made of organic materials, like poultry manure, can effectively support grain production while also contributing to soil health and sustainability in agricultural systems. These results highlight the beneficial effect of integrating organic and inorganic nitrogen sources on grain yield, straw yield and biological yield. The N_3 treatment, which combined prilled urea and poultry manure, provided a balanced nutrient supply, enhancing overall plant growth and grain production. The synergy between the quick-release prilled urea and the slow-release poultry manure likely resulted in better nutrient availability throughout the growing season, leading to higher grain yield. Conversely, the absence of nitrogenous fertilizer in the N_0 treatment resulted in lower grain yield, emphasizing the critical role of nitrogen in achieving optimal crop performance. These findings underscore the importance of integrated nutrient management strategies that combine both organic and inorganic sources to maximize grain yield. Such approaches not only improve crop productivity but also contribute to sustainable agricultural practices by enhancing soil fertility and reducing dependence on chemical fertilizers alone. Lower nitrogen levels decreased biological yield as well as grain and straw yields (Mia and Salam, 2024; Alam, 2006). Dutta *et al*., (2002) obtained identical results as well. They reported that when the level of nitrogen increased biological yield gradually increased too. These results indicate that effective weed management, as demonstrated in the W_1 treatment, positively impacts plant growth and height. The weed-free condition likely minimized competition for essential resources such as light, nutrients, and water, allowing the rice plants to achieve their full growth potential. On the other hand, the presence of weeds in the W_0 treatment led to competition for these resources, resulting in shorter plants. Kaur *et al*., (2018) discovered a comparable outcome. These results demonstrate the effectiveness of combining chemical and manual weed management methods in promoting tiller production. The W_3 treatment represents early post-emergence herbicide followed by a hand weeding, likely providing comprehensive control of weeds throughout the critical stages of rice growth, reducing competition for resources, and enabling the rice plants to produce more tillers. Sultana *et al*., (2021) also found a strong correlation between total tillers hill^{-1} and weed management, by applying early post-emergence herbicide and a hand weeding at 30 DAT, which ensured maximum total tillers hill^{-1} counts. The comprehensive weed control provided by the W_3 treatment likely minimized competition for essential resources such as light, nutrients, and water, allowing the rice plants to produce more effective tillers. Conversely, the presence of weeds in the W_0 treatment led to resource competition, resulting in fewer effective tillers. This underscores the importance of integrated weed management strategies in enhancing crop performance and maximizing yield potential (Alhammad *et al*., 2023). The results suggest that a carefully timed combination of chemical and manual weed control, as seen in W_2, can enhance grain filling and yield potential compared to a strictly weed-free regimen. This emphasizes the importance of selecting appropriate weed management practices to optimize grain production in rice (Kolo *et al*., 2021). The presence of weeds in W_0 likely led to competition for essential resources such as nutrients, water, and light, which could have adversely affected grain development. These results underscore the importance of effective weed management in achieving higher 1000-grain weights. By preventing weed competition, the W_1 treatment supported better grain filling and overall grain quality, demonstrating that maintaining a weed-free environment can significantly enhance crop performance (Jha *et al*., 2017). The W_4, involving an early post-emergence herbicide and a pre-emergence herbicide, produced the maximum straw yield, grain yield, and biological yield. This dual-approach likely provided effective and sustained weed control throughout the growing season, reducing competition for resources and allowing the rice plants to achieve their maximum yield potential. These findings highlight the critical role of integrated weed control strategies in optimizing grain production. The W_4 treatment's success underscores the benefit of combining pre- and post-emergence herbicides to enhance crop yield and overall productivity. Sharma *et al*., (2021), Chauhan *et al*., (2020), Dass *et al*., (2017), Manalil *et al*., (2017), and Peerzada *et al*., (2017) reported findings that are in conformity with the present study.

Conclusion

According the result, it may be suggested that BRRI dhan71 treated with USG and pre-emergence herbicide and later by early post-emergence herbicide in order to effectively control weeds. On the other hand, the interaction of BRRI dhan71 and 50% recommended of prilled urea + 50% recommended of poultry manure with pre-emergence herbicide followed by early post-emergence herbicide might be recommended for obtaining the maximum grain yield in transplanted *aman* rice cultivation. However, further investigations may be required to guarantee the current performance in Bangladesh's agro-ecological zones (AEZs).

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