Asian Journal of Soil Science and Plant Nutrition

Volume 10, Issue 3, Page 37-56, 2024; Article no.AJSSPN.117462
ISSN: 2456-9682

Evaluation of Nitrogen Uptake, Growth, and Yield of Rice Affected by Green Manure and Chemical Nitrogen Fertilizer

Thidar Hlaing [a++*], Kyi Moe [a#], Ei Han Kyaw [a†], Kyaw Ngwe [b‡], Myat Moe Hlaing [c†] and Htay Htay Oo [a‡]

[a] *Department of Agronomy, Yezin Agricultural University, Myanmar.*
[b] *Department of Soil and Water Science, Yezin Agricultural University, Myanmar.*
[c] *Department of Plant Breeding, Physiology and Ecology, Yezin Agricultural University, Myanmar.*

Authors' contributions

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

Article Information

DOI: https://doi.org/10.9734/ajsspn/2024/v10i3318

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://www.sdiarticle5.com/review-history/117462

Original Research Article

Received: 27/03/2024
Accepted: 03/06/2024
Published: 06/06/2024

ABSTRACT

To investigate the combined effect of green manures (GMs) and chemical nitrogen (N) fertilizer on N uptake, growth, and yield of rice, a pot experiment was conducted at the Department of Agronomy, Yezin Agricultural University (YAU). The experiment was conducted from December to June (the summer season) of 2023. The study used a split-plot design with three replications.

++ *PhD Candidate;*
# *Associate Professor;*
† *Member and Associate Professor;*
‡ *Professor and Head;*
**Corresponding author: Email: thidarhlaingagro@gmail.com;*

Cite as: *Hlaing, Thidar, Kyi Moe, Ei Han Kyaw, Kyaw Ngwe, Myat Moe Hlaing, and Htay Htay Oo. 2024. "Evaluation of Nitrogen Uptake, Growth, and Yield of Rice Affected by Green Manure and Chemical Nitrogen Fertilizer". Asian Journal of Soil Science and Plant Nutrition 10 (3):37-56. https://doi.org/10.9734/ajsspn/2024/v10i3318.*

Chemical N fertilizer was assigned as the main plot factor and different levels of N0%, N25%, N50%, N75%, and N100% were applied based on the N recommended rate (102 kg ha^{-1}) (1.55 g pot^{-1}) of the Sinn-thu-kha rice variety. GM crops were the subplot factor, including no GM (G0), rice bean (GRB), sunn hemp (GSH), and dahincha (GDC). According to the results, N75 and N100 produced the higher dry matter, N uptake, yield, and yield components of rice. The highest growth characters, N uptake, and yield were found in N100 for N levels, GSH for GM levels, and N100GSH as the combined effect. However, similar values were found in the treatment N75GSH. Statistically, the GSH + chemical N treatment produced higher N uptake and yields than those of GRB or GDC + chemical N treatment. When chemical N fertilizers were applied without the use of GMs, the rice yields were lower in comparison to the treatments GMs + N25 or N50 or N75 or N100. In conclusion, combining GSH with either 75% or 100% chemical N resulted in optimal performance for soil nutrient content, growth, N uptake, and rice yield. Additionally, it was observed that the use of chemical N fertilizers was reduced by 25%, which can help mitigate environmental pollution and improve soil health and rice production in the long run.

Keywords: Chemical N fertilizer; green manure; N uptake; plant growth; soil properties; and yield.

1. INTRODUCTION

Rice is a crucial crop for half of the world's population, providing around 35-60% of dietary calories for over three billion individuals worldwide [1]. As the global population continues to grow, farmers need to produce better-quality rice to meet the increasing demands of consumers [2]. However, the excessive use of nitrogen (N) fertilizers in modern rice farming practices can reduce yield and soil fertility [3]. The overuse of chemical fertilizers, particularly inorganic N fertilizers, can result in soil acidification and structural damage, water depletion, and changes in the soil microbe population and their activities [4]. In modern rice cropping systems, unbalanced N fertilizer usage leads to low productivity [5,6] and soil fertility.

Farmers need to maintain high productivity levels and find alternative methods such as animal manure, green manure (GM), compost, vermicompost, and biofertilizers. GM is an excellent option because it's easy to cultivate, and its biomass can be incorporated into the soil. It is a specific species of plant, typically a legume, which can be a tree, a bush, a vine, a crawling plant, or algae. Farmers grow them to maintain or improve soil fertility or control weeds [7]. The residues of GM are rich in N, which can be supplied to the succeeding crops. GM with nitrogen-fixing legume crops can provide a substantial portion of the N requirement for rice and also add organic matter to maintain soil fertility [8].

It is widely recognized that GM residues can improve the chemical and biological properties of soil. However, it is necessary to explore their effects on the soil properties and growth and yield of rice, as the N effect of GM varies depending on the legume species, agricultural management, and site. Leguminous crops such as pigeon peas, green gram, soybean, or groundnut can be used as GMs. Additionally, perennial woody multipurpose legume trees such as *Leucaena leucocephala* (Lam.) de Wit, *Gliricidia sepium* Kunth., *Cassia siamea* Lam., or non-grain legumes like sunn hemp (*Crotalaria* spp), dhaincha (*Sesbania* spp), Centosemia, Stylosanthes, and Desmodium can also be utilized [9]. In agriculture, legume crops are commonly used to increase the nitrogen content in the soil [10]. This is because legumes have the potential to fix atmospheric nitrogen [11] through a symbiotic relationship with Rhizobium bacteria [12], as well as associations with cyanobacteria [13] and non-symbiotic associations with free-living diazotrophic bacteria that interact with the plant roots [14]. The use of sunn hemp as green manure has been found to result in higher nitrogen use efficiency (NUE), as well as improved growth and yield of rice compared to using green manure with millet [15,16].

In our research, we examined three types of GM crops that have been shown to have a higher rate of N mineralization and a higher biomass in the previous study conducted by [17]. They are rice bean (GRB), sunn hemp (GSH), and dahincha (GDC). The fertility of soil in Myanmar has been decreasing, leading to a decline in rice production. GM crops can help restore soil properties, maintain organic matter, reclaim degraded soils, and provide plant nutrients [18]. They can also reduce the need for excessive chemical N fertilizer application [19] and improve rice production [20,21]. However, GM plants alone may not provide sufficient nutrients to rice crops. When GM is combined with chemical N fertilizer, the grain yield is equal to or higher than that of conventional cultivation with chemical fertilizer [22]. Incorporating GM has been shown to improve soil organic matter in rice fields by 0.1–0.9%, according to [23]. Using chemical N fertilizer and GM, rice plant growth and yield can be improved [24,25,26]. This study aims to investigate the impact of different GM crops, including rice bean, sunn hemp, and dhaincha, on soil properties, N uptake, growth, and rice yield. It also explores the optimal dosage of chemical N fertilizer when combined with suitable GM crops to achieve sustainable soil properties and rice yields.

2. MATERIALS AND METHODS

2.1 Experimental Site, Design and Treatments

A pot experiment was carried out at the Department of Agronomy, Yezin Agricultural University (YAU) in Nay Pyi Taw, Myanmar, from April to October 2023 during the summer season. The experiment used a split-plot design with three replications under natural conditions. The main plot factor involved four different percentages of the recommended chemical N fertilizer rate, while the subplot factor involved the cultivation of three GM varieties: rice bean (GRB), sunn hemp (GSH), and dhaincha (GDC). A control treatment was included for the two factors where no chemical N fertilizer was applied and no GM crops were grown. The recommended chemical N fertilizer rate for the tested rice variety (Sinn-thu-kha), a Myanmar rice variety, was 102 kg N ha^{-1}, 27 kg P_2O_5 ha^{-1}, and 117 kg K_2O ha^{-1} [27]. In this pot experiment, the application of N, P_2O_5, and K_2O (g pot^{-1}) and the weight of GMs (g pot^{-1}) were shown in Table 1.

2.2 Soil Sampling and Preparation of Pot

A composite surface soil sample (0-20 cm) was collected from 10 points in the rice field. The collected soil samples were processed by bulking, drying at room temperature, removing rocks and coarse organic materials, and grinding to pass through a 2-cm sieve. Approximately 17 kg of soil was then added to each plastic pot. The size of a pot was 1 foot in width and 1 foot in height (0.28 m^2). The soil in each pot was moistened with water for two days before planting the seeds.

Table 1. Treatments and application of chemical N fertilizer and green manures

Treatments	Recommended rate (g pot^{-1}) of chemical fertilizer			Applied green manure (g pot^{-1})	
	N	P_2O_5	K_2O	Fresh weight	Dry weight
N0G0	0.0	0.42	1.37	0.0	0.0
N0GRB	0.0	0.42	1.37	29.0	11.0
N0GSH	0.0	0.42	1.37	30.0	14.0
N0GDC	0.0	0.42	1.37	27.0	6.0
N25G0	0.39	0.42	1.37	0.0	0.0
N25GRB	0.39	0.42	1.37	29.0	11.0
N25GSH	0.39	0.42	1.37	30.0	14.0
N25GDC	0.39	0.42	1.37	27.0	6.0
N50G0	0.78	0.42	1.37	0.0	0.0
N50GRB	0.78	0.42	1.37	29.0	11.0
N50GSH	0.78	0.42	1.37	30.0	14.0
N50GDC	0.78	0.42	1.37	27.0	6.0
N75G0	1.16	0.42	1.37	0.0	0.0
N75GRB	1.16	0.42	1.37	29.0	11.0
N75GSH	1.16	0.42	1.37	30.0	14.0
N75GDC	1.16	0.42	1.37	27.0	6.0
N100G0	1.55	0.42	1.37	0.0	0.0
N100GRB	1.55	0.42	1.37	29.0	11.0
N100GSH	1.55	0.42	1.37	30.0	14.0
N100GDC	1.55	0.42	1.37	27.0	6.0

N0= N omission, N25 = 25% of chemical N rate, N50 = 50% of chemical N rate, N75 = 75% of chemical N rate, N100 = 100% of chemical N rate, G0= no GM, GRB = rice bean, GSH = sunn hemp, GDC = dhaincha

2.3 Analysis of Experimental Soil

Soil samples collected were sub-sampled, mixed, and filtered through a 2-mm sieve for analysis. The soil's physicochemical properties were measured before and after the experiment. Soil bulk density, porosity, and electrical conductivity were analyzed using core sampling and ECe method. Sand, silt, clay, and texture classes were analyzed using the international pipette method. Soil pH was analyzed using a glass electrode [28], and organic carbon by wet digestion [29]. Available N was analyzed by extraction and distillation [30], available P by Olsen bicarbonate method [31], available K by ammonium acetate extraction method [32], and cation exchange capacity (CEC) by leaching method [33].

2.4 Analysis and Application of Green Manures

Seeds of three GM plants (1 g pot^{-1}) were sown in the individual treatment pots, while the pot of G0 (control) was left unsown. No chemical fertilizers were used during cultivation to obtain the actual N content of the GM plants and their growth behavior. Necessary tasks such as watering, weeding, and earthing up were performed to ensure optimal plant growth.

During the flowering stage (50 days after planting), three GM crops (GRB, GSH, and GDC) were uprooted, and their plant parts were cut down to equal size (1 inch) using a knife. The fresh and dry weight of the plant parts was measured immediately and incorporated into the soil for rice cultivation. A small amount of plant parts (2 g) was used to measure the chemical composition of each GM. N was measured using the Kjeldahl distillation method, and carbon (C) by a CHN coder (MT-5, Yanaco). To measure the amount of P_2O_5 and K_2O, the samples were digested separately using the Molybivanado phosphoric acid and Wet digestion with HNO_3 methods, respectively [34].

2.5 Application of Chemical Fertilizers

In this study, a chemical N fertilizer with an equivalent rate of 102 kg ha^{-1} (1.55 g pot^{-1}) was applied to pots labeled as N100% in the form of urea. The control pots (N0) did not receive any N fertilizers, but all pots were given 27 kg P_2O_5 ha^{-1} (0.42 g pot^{-1}) (as triple superphosphate) and 117 kg K_2O ha^{-1} (1.37 g pot^{-1}) (as muriate of potash). The application of urea and muriate of potash was done in three doses: 60% was incorporated into the soil one day before transplanting, 20% during the active-tillering stage, and the remaining 20% during the panicle-initiation stage. All triple superphosphate was applied one day before transplanting.

2.6 Measurement of Growth Characters

After four weeks of incorporating GMs, 21-day-old seedlings of the Sinn-thu-kha rice variety (*Oryza sativa* L.), which is a high-yielding Myanmar variety of Indica type and matures in 140 days (medium duration variety), were transplanted into all pots. The plant height and the number of tillers per pot were measured weekly from 10 days after transplanting (DAT) until 50% flowering and then at 2-week intervals until the harvesting stages. Before panicle initiation, the Soil Plant Analysis Development SPAD value was measured using the uppermost fully expanded leaf by the SPAD-502 chlorophyll meter (Konica Minolta, Inc., Osaka, Japan), and afterward, the flag leaf was measured.

2.7 Determination of Dry Matter and N Uptake

The rice plants from each pot were cut 2 cm above the ground at harvest and were divided into sheaths, leaves, panicles, and seeds. They were then dried in an oven at 70℃ for 48 hours and weighed instantly. The total weight of all plant parts was added to calculate the dry matter (DM) accumulation, expressed in tons per hectare (t ha^{-1}). The dried samples were then ground into a fine powder using a Cyclotec 1093 Sample Mill (100–120 mesh; Tecator AB, Hoedanaes, Sweden). To measure the N accumulation, all plant parts were thoroughly mixed to get a homogeneous sample. It was then sub-sampled again to measure the N accumulation. The homogenized samples from each replication were pooled. The sample was then digested using the salicylic acid–H_2SO_4–hydrogen peroxide (H_2O_2) method. Total N was analyzed using the method mentioned in the soil analysis. The N uptake for each treatment was determined by multiplying the N content with the dry matter of the sample.

2.8 Determination of Yield and Yield Components of Rice

The number of panicles per pot, the number of spikelets per panicle, the percentage of filled grains, and the thousand-grain weight (in grams) were determined from the harvested plants. The rice yield was calculated based on the weight of the heavy seeds, which was adjusted to 14% moisture content. The harvest index (HI) was calculated as the ratio of economic yield (total seed weight) to biological yield (total dry matter weight) [35].

2.9 Statistical Analysis

The data were summarized, and an Analysis of Variance (ANOVA) was performed using the statistical software Statistix (Version 8.0). Treatment means were compared using the Least Significant Difference (LSD) test at a 5% level of significance.

3. RESULTS AND DISCUSSION

3.1 Physicochemical Properties of Experimental Soil

The soil used in the experiment was sandy loam, with a moderately acidic pH of 5.78. It had very low electrical conductivity (0.07 mS/cm), very low organic carbon content (0.76%), and very low total nitrogen (0.09%). The exchangeable cations were as follows: low Ca^{++} (9.62 meq/100 g), medium Mg^{++} (3.43 meq/100 g), high Na^{+} (1.25 meq/100 g), and low K^{+} (0.13 meq/100 g). The soil had a medium cation exchange capacity of 14.43 meq/100 g, low available phosphorus (2.8 ppm), low available potassium (6.25 ppm), and a bulk density of 1.19 (Table 2).

3.2 Chemical Composition of Green Manure

Based on the analysis data, GSH had the highest total N content (2.42%), the highest organic carbon (63.38%), and the lowest C:N ratio (22.06) among all GM varieties. GDC showed higher results in total P_2O_5 (0.21%) and total K_2O (2.26%) (Table 3). All tested GM crops had a higher N content and lower C:N ratio.

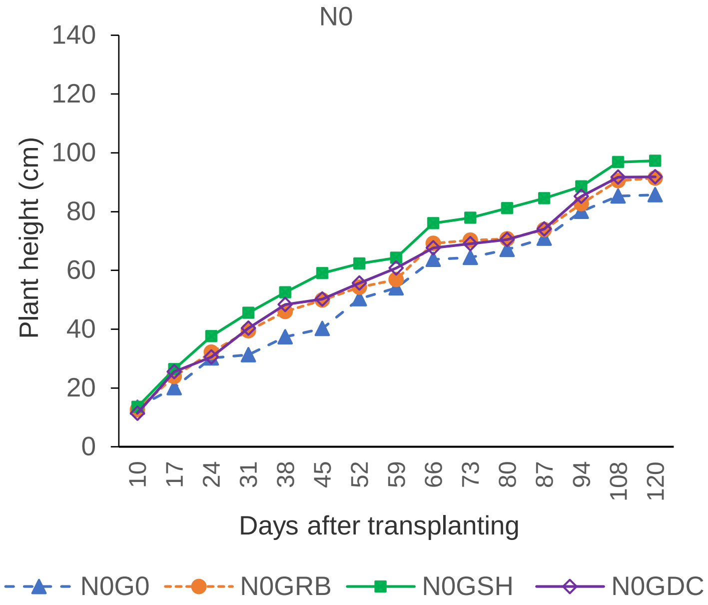
3.3 Plant Growth Characters

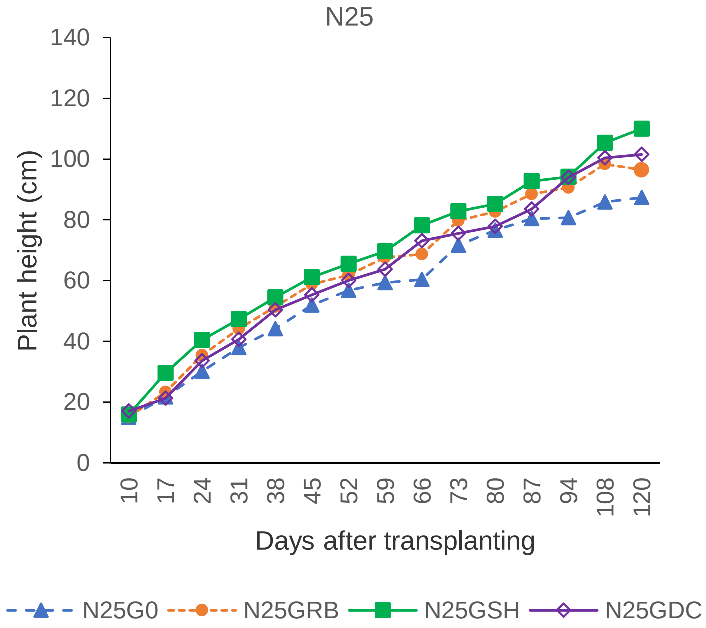
3.3.1 Plant height (cm)

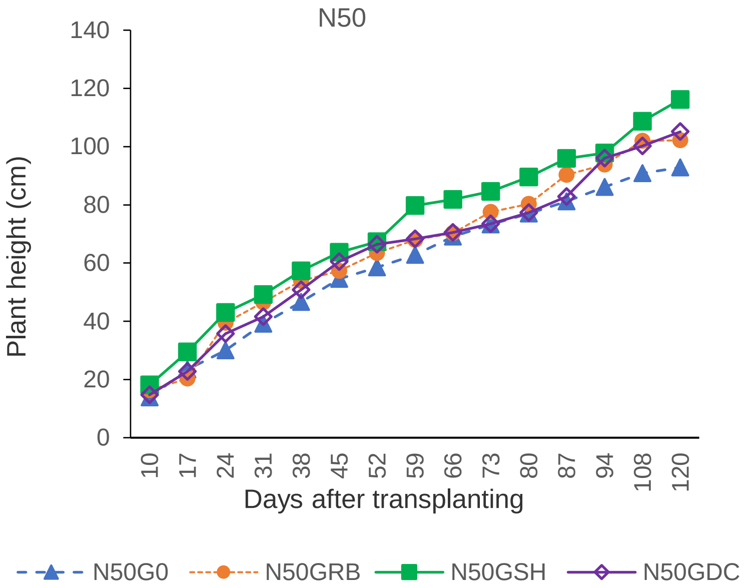
In this study, the plant heights were increased along with the increment of N level from 0 to 100% (Fig. 1). The treatment N100 among chemical N levels produced the maximum plant height during the crop period. Regarding GM crops, GSH produced higher plant height than other GMs throughout the crop period. For the combined effect, the treatments N100GSH (120 cm) and N75GSH (118 cm) provided the maximum plant height among all treatments, but their values were almost similar (Fig. 1). GSH + chemical N fertilizer can provide higher plant height due to their N supplement to the soil, resulting in higher nitrogen use efficiency (NUE), growth, and yield of rice compared to other GMs [36,37].

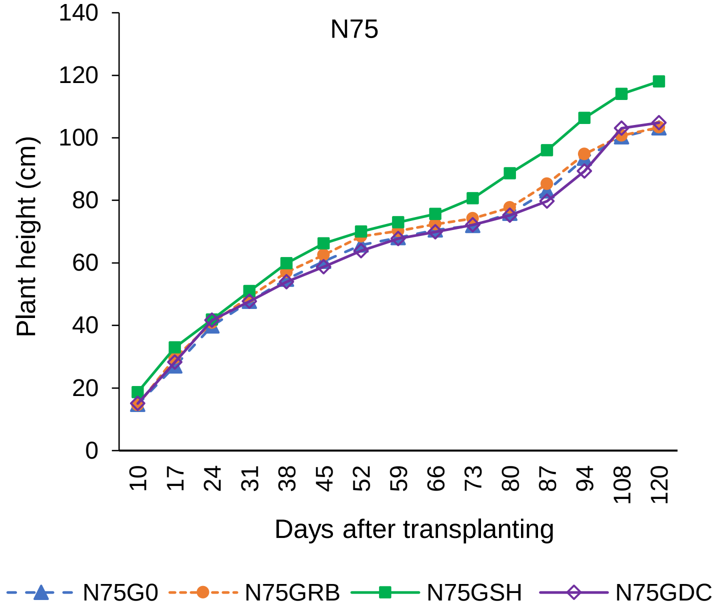
Table 2. Physicochemical properties of experimental soil before experiment

No.	Parameter	Value	Rating
1	pH (1:2.5)	5.78	Moderately acid
2	EC (mS/cm)	0.07	Very Low
3	Organic carbon (%)	0.76	Very Low
4	Total N (%)	0.09	Very Low
5	Exchangeable Cations (meq/100g)		
	Ca^{++}	9.62	Low
	Mg^{++}	3.43	Medium
	Na^{+}	1.25	High
	K^{+}	0.13	Low
6	CEC (meq/100g)	14.43	Medium
7	Available P (ppm)	2.8	Low
8	Available K_2O (ppm)	6.25	Low
9	Bulk density	1.19	-
10	Texture		Sandy Loam
	Sand (%)	**63.28**	
	Silt (%)	**20.89**	
	Clay (%)	**15.83**	


N0
Plant height (cm)
0
20
40
60
80
100
120
140
10
17
24
31
38
45
52
59
66
73
80
87
94
108
120
Days after transplanting
N0G0
N0GRB
N0GSH
N0GDC


N25
Plant height (cm)
0
20
40
60
80
100
120
140
10
17
24
31
38
45
52
59
66
73
80
87
94
108
120
Days after transplanting
N25G0
N25GRB
N25GSH
N25GDC


N50
Plant height (cm)
0
20
40
60
80
100
120
140
10
17
24
31
38
45
52
59
66
73
80
87
94
108
120
Days after transplanting
N50G0
N50GRB
N50GSH
N50GDC


N75
Plant height (cm)
0
20
40
60
80
100
120
140
10
17
24
31
38
45
52
59
66
73
80
87
94
108
120
Days after transplanting
N75G0
N75GRB
N75GSH
N75GDC

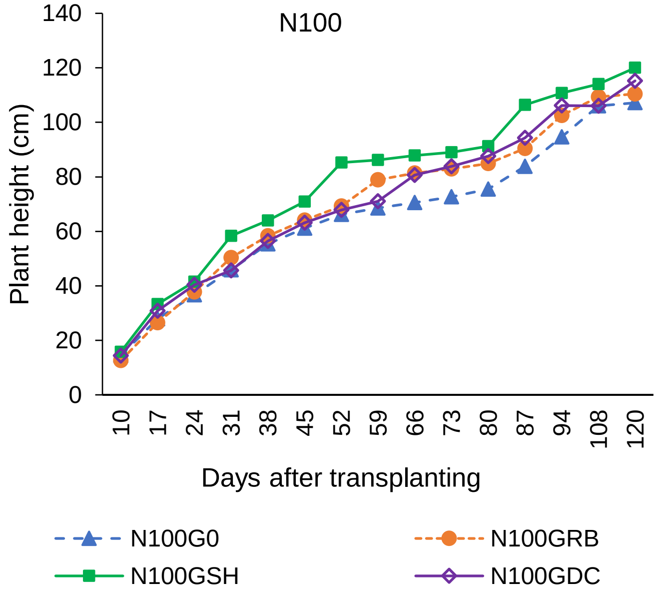
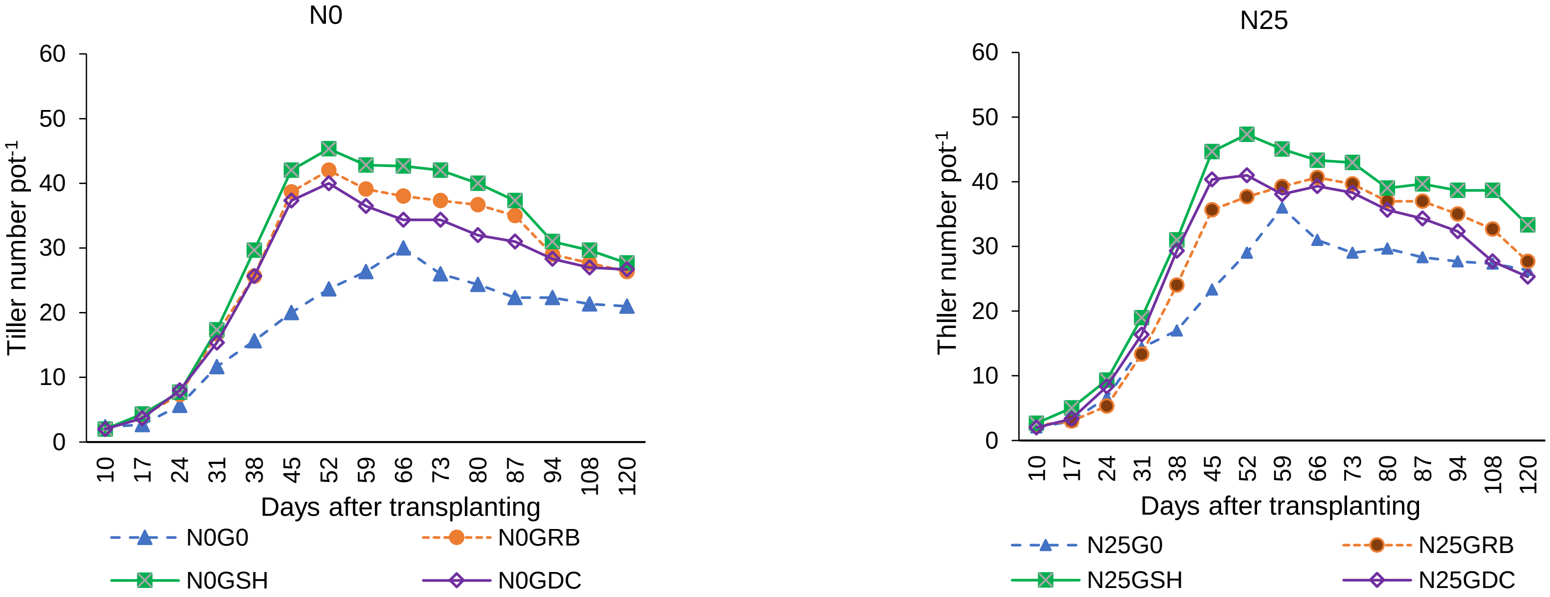
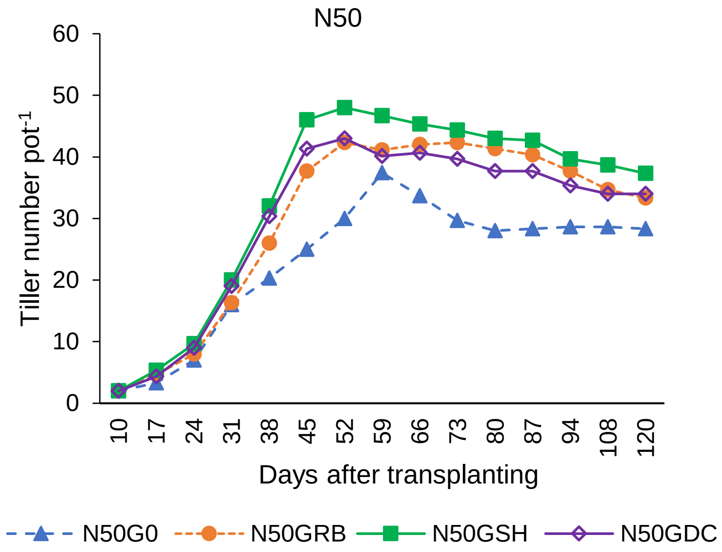
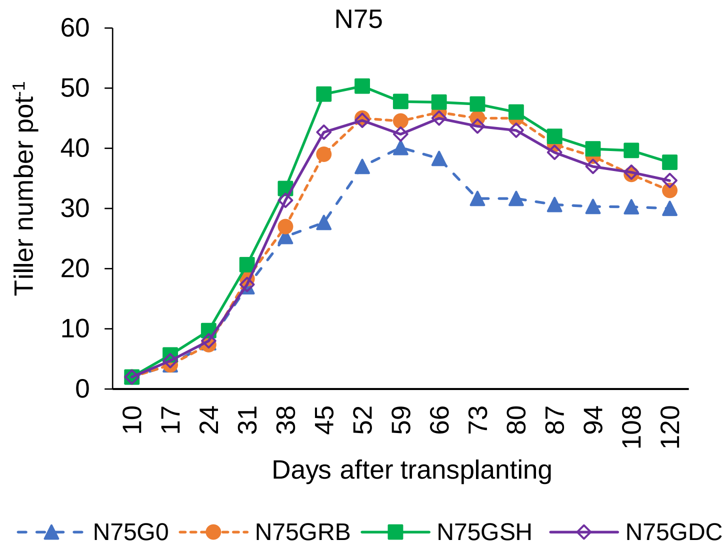


Fig. 1. Plant height (cm) of Sinn-thu-kha rice variety as affected by GMs and levels of chemical N fertilizer, 2023

N_0 = N omission G0 = No green manure
N_{25} = 25% N GRB = Rice bean
N_{50} = 50% N GSH = Sunn hemp
N_{75} = 75% N GDC = Dhaincha
N_{100} = 100%


N0
Tiller number pot-1
0
10
20
30
40
50
60
10
17
24
31
38
45
52
59
66
73
80
87
94
108
120
Days after transplanting
N0G0
N0GRB
N0GSH
N0GDC
N25
Thller number pot-1
Days after transplanting
N25G0
N25GRB
N25GSH
N25GDC


N50
Tiller number pot-1
Days after transplanting
N50G0
N50GRB
N50GSH
N50GDC


N75
Tiller number pot-1
Days after transplanting
N75G0
N75GRB
N75GSH
N75GDC

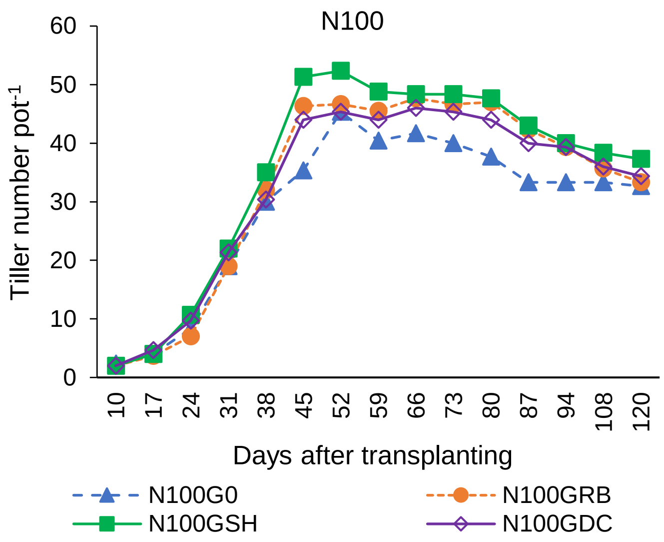
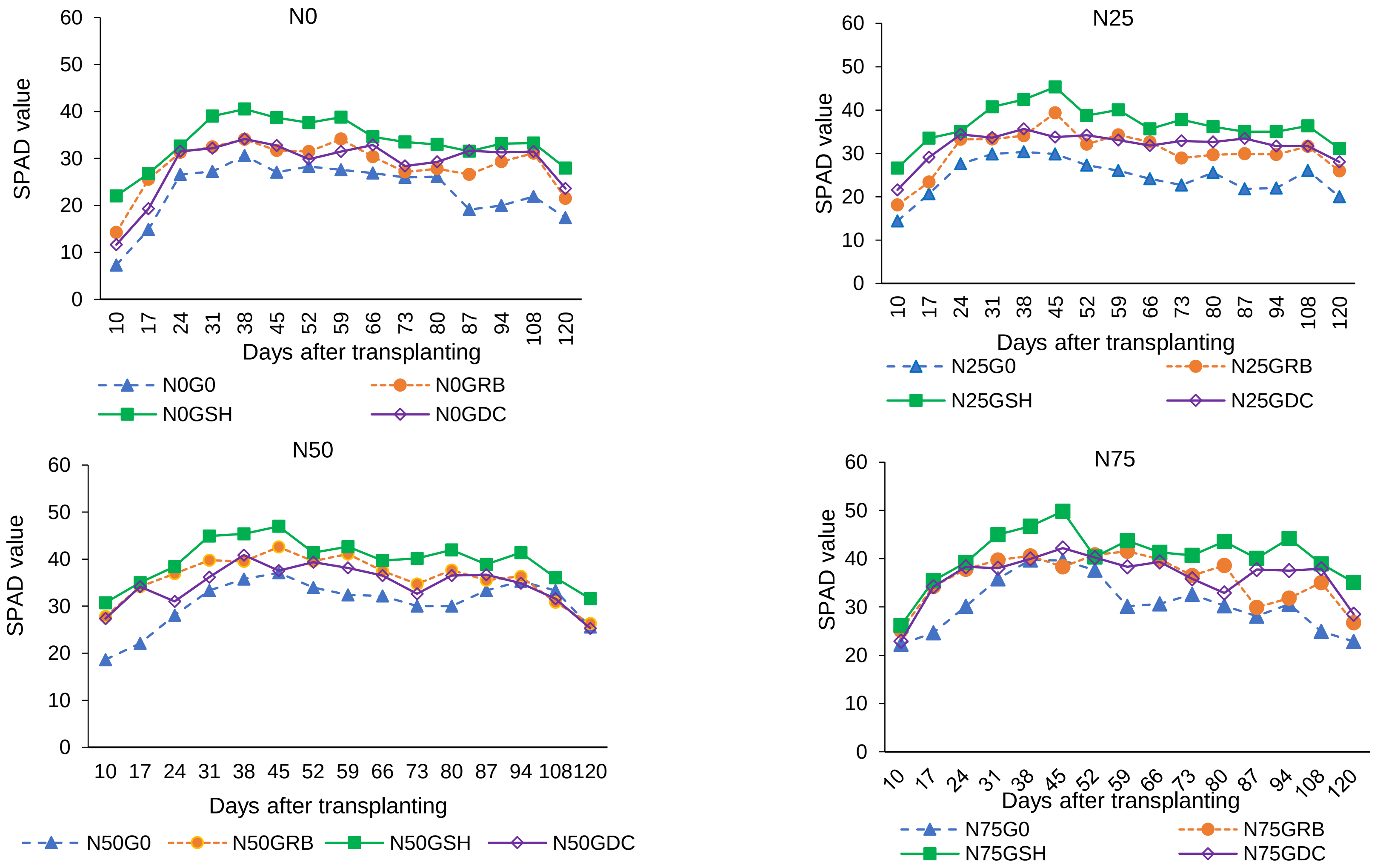


Fig. 2. Tiller number pot^{-1} of Sinn-thu-kha rice variety as affected by GMs and levels of chemical N fertilizer, 2023

N_0 = N omission G0 = No green manure
N_{25} = 25% N GRB = Rice bean
N_{50} = 50% N GSH = Sunn hemp
N_{75} = 75% N GDC = Dhaincha
N_{100} = 100%


N0
SPAD value
60
50
40
30
20
10
0
10
17
24
31
38
45
52
59
66
73
80
87
94
108
120
Days after transplanting
N0G0
N0GRB
N0GSH
N0GDC
N25
N25G0
N25GRB
N25GSH
N25GDC
N50
N50G0
N50GRB
N50GSH
N50GDC
N75
N75G0
N75GRB
N75GSH
N75GDC

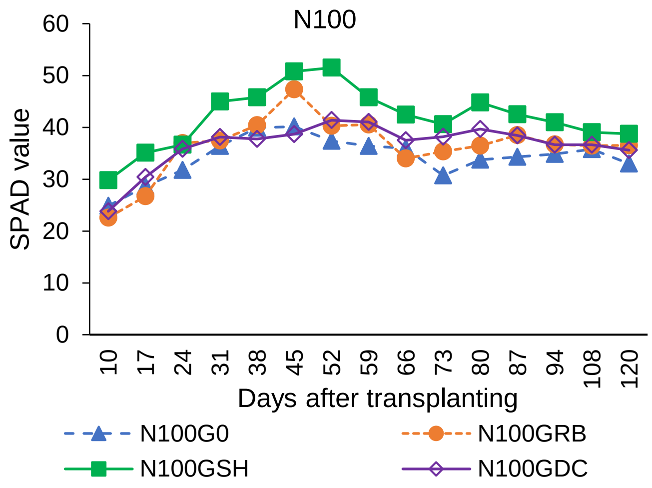


Fig. 3. SPAD value of Sinn-thu-kha rice variety as affected by GMs and levels of chemical N fertilizer, 2023

N_0 = N omission G0 = No green manure
N_{25} = 25% N GRB = Rice bean
N_{50} = 50% N GSH = Sunn hemp
N_{75} = 75% N GDC = Dhaincha
N_{100} = 100%

Table 3. Chemical composition of green manure crops

No.	Green manure	Percentage					C:N
		Moisture	Total N	Total P_2O_5	Total K_2O	Organic carbon	
1.	Rice Bean	60.67	2.02	0.13	1.89	50.71	25.10
2.	Sunn hemp	65.51	2.42	0.14	1.37	63.38	22.06
3.	Dhaincha	57.64	2.52	0.21	2.26	51.09	25.10

3.3.2 Tiller number per pot

The resulting pattern of tiller number was similar to that of plant height. As the N level increased from 0 to 100%, the tiller number also increased. The maximum number of tillers was found at 52 DAT, after which the number of tillers decreased. The highest value was found in N100, which was similar to that of N75. The treatment GSH showed the highest number of tillers compared to GDC and GRB at all growth stages. At the harvesting stage, the maximum tiller numbers were observed in N100GSH (37.3), N75GSH (37.7), and N50GSH (37.3), but the values were not significantly different (Figure 2). According to [38], GSH can provide rice plants with a higher tiller number due to their increased nitrogen supply. On the other hand, the tiller numbers in treatment N100G0 were lower when GMs were not incorporated, compared to the treatment combined with GMs.

3.3.3 SPAD value

The SPAD values varied depending on the chemical N level and GMs (Fig. 3). The higher application of N resulted in an increase in SPAD values for the sinn-thu-kha rice variety. The maximum values were observed in treatment N100. The peak point for SPAD values was observed between 38 and 45 DAT in all treatments, after which the values gradually decreased. All GM crops improved SPAD values, especially GSH, which maintained the highest value throughout the crop period, followed by GDC and GRB. Treatment N100GSH maintained higher SPAD values (38.8) until the harvesting stage, which is similar to N75GSH (35.1) (Fig. 3). GSH contains a higher nitrogen percentage and provides greater biomass to the soil. These higher N doses from GSH significantly increased SPAD values at different growth stages of rice [39]. However, lower SPAD values were observed at all N levels without GMs, in contrast to the treatments that included GMs.

3.4 Dry Matter

The supply of N level positively affected the DM as its concentration increased from 0% to 100%, resulting in an increase in DM (Fig. 4). The highest value for chemical N level was recorded in N100. In the case of GM crops, GSH resulted in the maximum DM at each N level. All GM crops showed higher DM production than the control treatment (N0G0). When the combined effect of different factors was analyzed, N100GSH exhibited the highest DM (112.90 g pot^{-1}), which was also observed in N75GSH (106.12). However, the treatment N100G0 resulted in lower DM, even though N100% was applied to the rice plants, but no GM cultivation was carried out in that treatment. On the other hand, using only GM incorporation wasn't enough to provide the optimum DM for rice plants. This was evident in the treatments N0GRB, N0GSH, and N0GDC. The GSH had a better N supply than GRB and GDC, resulting in similar DM among treatments: N75GSH, N100GRB, and N100GDC, even though the chemical N levels were differently combined**.** Under sunn hemp incorporation, both rice grain and straw biomass yields exceeded those of millet or no green manure application [40].

3.5 N uptake

In this study, we analyzed the N content of the pooled samples from each replication. Due to this, we could not calculate the mean comparison among the treatments. However, we observed that rice plants responded differently in terms of N uptake based on the chemical N levels and GM crops. As shown in Fig. 5, N uptake increased with an increase in chemical N application. Among GMs, GSH provided higher N uptake than GRB and GDC. At harvest time, N100GSH showed the highest N uptake of 1.04 g pot^{-1}, while N75GSH achieved a similar N uptake of 0.96 g pot^{-1}. However, treatments with GRB and GDC resulted in lower values. Without GMs, treatments N25G0, N50G0, and N100G0 did not accumulate optimum N uptake. The plots N0G0 achieved the lowest N uptake. According to the chemical composition of GMs (Table 3), the GSH contains a higher total amount of nitrogen than the GRB and GDC. In the other studies, the greater N content in both shoot and root was obtained from sunn hemp than millet, possibly due to biological N fixation by sunn hemp [41,42,43]. Additionally, the GSH has achieved higher biomass and applied more nitrogen than GRB and GDC (Table 1). Therefore, it can be inferred that the total nitrogen supply from GSH is possibly higher than those of GRB and GDC. As a result, the total nitrogen uptake of rice is high in the treatments that are incorporated with GSH. This result proves that GSH possesses higher biomass, higher N content, and higher decomposition rate than other GMs and can release N faster than others. Studies with three legumes, Odhiambo [44], showed that sunn hemp tends to release N at a faster rate, followed by lablab and velvet bean.

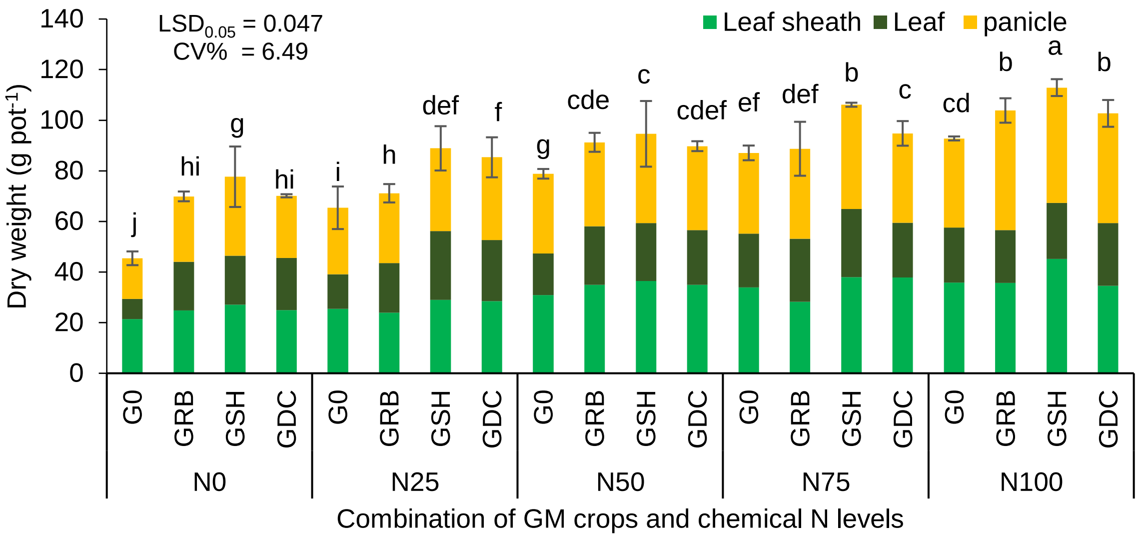


Fig. 4. Dry matter (g pot⁻¹) of Sinn-thu-kha rice variety affected by GMs and levels of chemical N fertilizer at harvesting stage, 2023

The bar graph with the same letter is significantly different by the LSD test ($p < 0.05$). The error bar represents the standard error

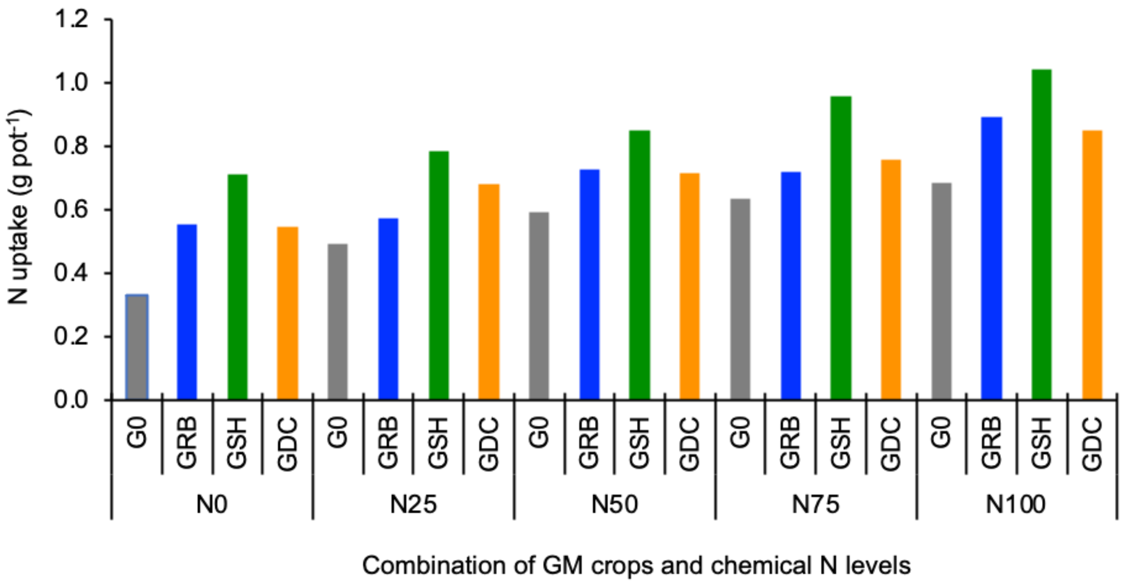


Fig. 5. N uptake (g pot^{-1}) of Sinn-thu-kha rice variety affected by GMs and levels of chemical N fertilizer at harvesting stage, 2023

Table 4. Harvest index, yield, and yield components of Sinn-thu-kha rice variety affected by GMs and levels of chemical N fertilizer, 2023

Treatments	Harvest Index	No. of panicles pot^{-1}	No. of spikelet panicle^{-1}	Filled grain (%)	1000 grain weight (g)	Yield (g pot^{-1})
Nitrogen (N)						
N0	0.47 a	25.42 c	146.67 d	58.48 d	18.45 ab	30.67 c
N25	0.43 b	28.00 bc	160.17 c	71.53 c	17.98 b	33.03 c
N50	0.42 b	33.25 ab	173.75 b	75.80 b	18.57 a	37.28 b
N75	0.41 b	33.92 a	183.42 ab	79.93 a	18.37 ab	39.13 ab
N100	0.40 b	34.33 a	192.83 a	82.83 a	18.40 ab	41.48 a
$LSD_{0.05}$	0.03	5.60	11.66	3.90	0.54	4.08
Green manure (GM)						
G0	0.38 b	27.87 c	157.07 c	68.07 c	17.85 b	27.50 c
GRB	0.45 a	30.53 b	171.00 b	75.76 b	18.21 b	37.21 b
GSH	0.45 a	34.47 a	183.60 a	80.70 a	19.07 a	42.39 a
GDC	0.43 a	31.07 b	173.80 ab	70.33 c	18.29 b	38.18 b
$LSD_{0.05}$	0.03	2.51	10.2	3.04	0.50	1.72
Pr>F						
Nitrogen	**	*	**	**	ns	**
Green manure	**	**	**	**	**	**
N × GM	**	ns	ns	**	ns	**
CV% (a)	**7.89**	**19.21**	**7.23**	**5.62**	**3.10**	**11.92**
CV% (b)	**9.74**	**10.84**	**7.98**	**5.52**	**3.68**	**6.36**

*Means followed by the same letter in each factor in each column are not significantly different in LSD tests ($p < 0.05$). * Significant at 5% level, ** significant at 1% level*

Numbers in N treatments show the amount of N applied as a percentage based on 1.55 g pot^{-1}

G0 = no GM, GRB = rice bean, GSH = sunn hemp, GDC = dhaincha

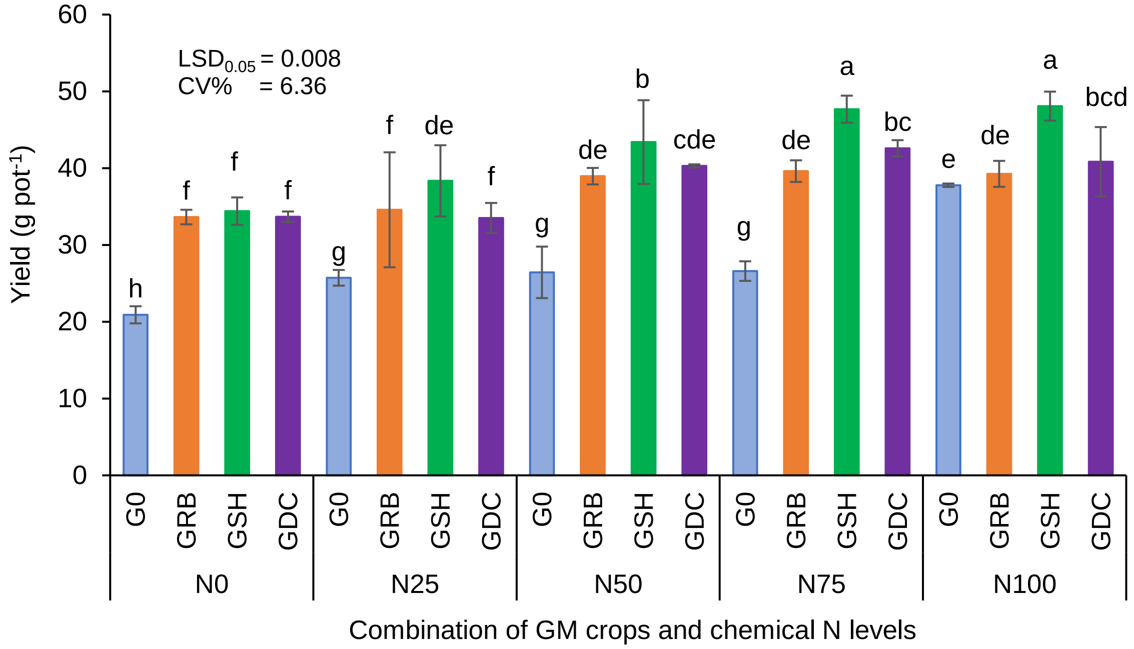


Fig. 6. Yield (g pot^{-1}) of Sinn-thu-kha rice variety by the combined effect of GMs and levels of chemical N fertilizer, 2023

The bar graph with the same letter is significantly different by the LSD test ($p < 0.05$). The error bar represents the standard error

Image 1. GMs cultivation as treatments in the pot experiment

Image 2. Rice cultivation after the incorporation of GMs in the pot experiment

3.6 Yield and Yield Components

Yield and yield components were significantly different among different N levels and GMs, except for the 1000 grain weight (*P*≤0.01) (Table 4). An interaction effect of N and GMs was also observed on the yield of the sinn-thu-kha rice variety (*P*≤0.01). For the chemical N level, the maximum yield (g pot^{-1}) was obtained by the treatment N100 (41.48) due to higher yield components. However, similar yields were also achieved from treatments: N75 (39.13) and N50 (37.28).

Regarding GM crops, it was found that GSH produced the highest yield (42.39 g pot^{-1}) due to having a higher number of panicles and filled grain percentage. GDC (38.18) and GRB (37.21) yielded less than GSH but more than G0. When chemical N level and GMs were combined, N100+GSH resulted in the highest yield (48.07 g pot^{-1}), which was similar to that (47.68) of N75GSH (Fig. 6). This means that using 25% less chemical N fertilizer would not decrease rice yield.

In this study, rice yields were significantly lower when chemical N levels were applied without incorporating GMs. The recommended chemical nitrogen fertilizer N100% + no GM provided a lower yield than the yields obtained by treatments N100GRB, N100GSH, and N100GDC. Therefore, incorporating GMs effectively improves the yield components and yield of rice. Among GMs, GSH was more effective in supplying N to rice plants, resulting in higher grain yield when 75% and 100% of the recommended chemical N rate were applied. Our findings prove that GMs, when combined with chemical N fertilizer, can lead to higher rice yield. Several researchers also reported that biological N fixation by leguminous GMs can reduce the need for inorganic N fertilizers for the succeeding crop [45,46].

4. CONCLUSION

Our study showed that combining GMs with chemical N fertilizer effectively promotes N uptake, growth, yield components, and yield of the Sinn-thu-kha rice variety, especially when GSH (sunn hemp) is used. This is because sunn hemp provides the necessary N demands for rice, but it needs to combine with 75% of the recommended chemical N fertilizer rate, 1.55 g pot^{-1} (102 kg N ha^{-1}). When a 100% chemical N fertilizer rate is used, GRB (rice beans) and GDC (dahincha) can also provide satisfactory rice yields. By using GSH, it is possible to reduce the chemical N fertilizer rate by 25% without decreasing the rice yield. Therefore, incorporating GMs, particularly GSH, not only increases rice yield but also helps alleviate the pollution caused by chemical fertilizers, leading to sustainable agriculture.

ACKNOWLEDGEMENT

This study received advice and guidance from my supervisory committee and financial support from the Yuntianhua scholarship of Yuntianhua Co., Ltd, Yunnan Province, China. I gratefully acknowledge all the supporters of my research.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Fageria NK. Plant tissue test for determination of optimum concentration and uptake of nitrogen at different growth stages in low-land rice. Communications in Soil Science and Plant Analysis. 2003;34(1–2):259–270. DOI: 10.1081/CSS-120017430
2. Peng SB, Yang JC. Current status of the research on high yielding and high efficiency in resource use and improving grain quality in rice. Chinese Journal of Rice Science. 2003;17:275–280.
3. Yadav DS. Long-term effect of nutrient management on soil health and productivity of rice (*Oryza sativa*) wheat (*Triticum aestivum*) system. National Symposium on New Paradigms in Agronomic Research, Navsari, Gujarat; 2008;19–21 November.
4. Liu X, Zhang Y, Han W, Tang A, Shen J. Enhanced nitrogen deposition over China. Nature. 2013;494:459–462. DOI: 10.1038/nature11917
5. Biswas PP, Sharma PD. A new approach for estimating fertilizer response ratio-the Indian. Ind J Fert. 2008;4(7):59–62.
6. Patil VC. Declining factor productivity and improving nutrient use efficiency. In: National symposium on new paradigms in agronomic research. Navsari, Gujarat; 2008;19–21 November.
7. Florentín MA, Peñalva M, Calegari A, Translated RD, Mcdonald M J. Green

manure/cover crops and crop rotation in conservation agriculture on small farms. 2010;12.

8. Latt YK, Myint AK, Yamakawa T. The effects of green manure (*Sesbania rostrata*) on the growth and yield of rice. J Fac Agric Kyushu Univ. 2009;54(2):313–319.
9. Fageria NK. Green manuring in crop production. J. Plant Nutr. 2007; 30(October):691–719.
10. Mäder P. et al. Soil fertility and biodiversity in organic farming soil fertility and biodiversity in organic farming. Atlantic. 2002;296(5573):1694–1697.
11. Fageria NK, Baligar VC, Bailey BA. Role of cover crops in improving soil and row crop productivity. Commun. Soil Sci. Plant Anal. 2005;36(19–20):2733–2757.
12. Subedi P, Shrestha, J. Improving soil fertility through Azolla application in low land rice: A review. 2015;2(2):35–39.
13. Yadav RK, Abraham G, Singh YV, Singh PK. Advancements in the utilization of Azolla-Anabaena system in relation to sustainable agricultural practices. Proc. Indian Natl. Sci. Acad. 2014;80(2):301–316.
14. Santi C. et al. Biological nitrogen fixation in non-legume plants. 2013;743–767.
15. Meng X, Li Y, Zhang Y, Yao H. Green manure application improves rice growth and urea nitrogen use efficiency assessed using 15N labeling. Soil Science and Plant Nutrition. 2019;65:511-518.
16. Supsuan P. Effects of type and timing of organic fertilizer application on rice growth and nitrogen availability in paddy soil. (Master Thesis). King Mongkut's Institute of Technology Ladkrabang, Thailand; 2019.
17. Hlaing T, Moe K, Kyaw EH, Ngwe K, Hlaing MM, Oo HH. Assessment of green manure crops and their impacts on mineralizable nitrogen and changes of nutrient contents in the soil. Asian Soil Research Journal. 2024;8(2):29–38. Available:https://doi.org/10.9734/asrj/2024/v8i2149
18. Scotti R, Bonanomi G, Scelza R, Zoina A, Rao MA. Organic amendments as sustainable tool to recovery fertility in intensive agricultural systems, J. Soil Sci. Plant Nutr. 2015;15(2)333–352.
19. Zhang DB, Yao PW, Zhao N, Yu CW, Cao WD, Gao YJ. Contribution of green manure legumes to nitrogen dynamics in traditional winter wheat cropping system in the loess plateau of China. European Journal of Agronomy. 2016;72:47–55. DOI:10.1016/j. eja.2015.09.012
20. Lee CH, Park KD, Jung KY, Ali MA, Lee D, Gutierrez J, Kim PJ. Effect of Chinese milk vetch (*astragalus Sinicus* L.) as a green manure on rice productivity and methane emission in paddy soil. Agriculture, Ecosystems & Environment. 2010;138: 343–347. DOI: 10.1016/j. agee.05.011
21. Zhu B, Yi LX, Guo LM, Chen G, Hu YG, Tang HM, Xiao CF. Performance of two winter cover crops and their impacts on soil properties and two subsequent rice crops in donating lake plain, Hunan, China. Soil & Tillage Research. 2012;124:95–101. DOI: 10.1016/j. still.2012.05.007
22. Azuma H, Saito T, Koike J. Management of nitrogen supply using Hairy Vetch as basal application of paddy rice. Jpn. J. Soil Sci. Plant Nutr. 2017;88:458-464.
23. Chen L. Green manure cultivation and use for rice in China. In Proceedings of a Symposium on Sustainable Agriculture: Green Manure in Rice Farming, Manila. 1988;63-109.
24. Fageria NK, Baligar VC, Clark RB. Physiology of crop production. New York: Haworth Press; 2006.
25. Ahmad RM, Naveed M, Aslam ZA, Arshad M. Economizing the use of nitrogen fertilizer in wheat production through enriched compost. Rev Agric Food Sys. 2008;23:243–249.
26. Masarirambi MT, Mandisodza FC, Mashingaidze AB, Bhebhe E. Influence of plant population and seed tuber size on growth and yield components of potato (*Solanum tuberosum*). Int J Agric Biol. 2012;14:545–549.
27. Department of Agriculture (DOA). Recommended fertilizer application rates from national government agricultural agencies. Recommended Fertilizer Application Rates from Land Use Division, Myanmar; 2020.
28. Jason ML. Soil chemical analysis. Prentic-Hall, Inc., Englewood Cliffs, NJ; 1958.
29. Walkley A, Black IA. An examination of the degtjareff method for determining soil organic matter and a proposed modification of the chromic Acid titration method. Soil Science.1934;37:29-38. Available: doi.org/10.1097/00010694-193401000-00003.

30. Bremner JM. Total nitrogen. In: Black CA et al. (ed.). Methods of soil analysis, Part 2. Agronomy 9 Am. Soc of Agron., Inc., Madison, Wis. 1965;1149-1178.
31. Olsen SR, Sommers LE. Phosphorus. Methods of soil analysis, Part 2. In: Page AL et al. (ed.)., Chemical and microbial properties. 2nd ed. Agro. Monogr, 9. ASA and SSSA, Madison, WI. 1982;403-430.
32. Kudsen D, Peterson GA, Pratt PF. Lithium sodium and potassium. In: Page, A. L(Ed.), Method of soil analysis, Part 2. Chemical and microbiological properties, 2nd ed. Agronomy No. 9. ASA, SSAA, Madison, WI. 1982;225-246.
33. Lu HJ, Ye ZQ, Zhang X, Lin XY, Ni WZ. Growth and yield responses of crops and macronutrient balance influenced by commercial organic manure used as a partial substitute for chemical fertilizers in an intensive vegetable cropping system. Phys Chem Earth Parts A/b/c. 2011;36(9–11):387–394.
34. Zheljazkov V D, Nielson N E. Effect of heavy metals on peppermint and corn mint. Plant Soil.1996;178:59-66.
35. Yoshida S. Fundamental of Rice Crop Science. 1st (ed), International Rice Research Institute, Los Baños, Laguna, Philippines. 1981;269.
36. Meng X, Li Y, Zhang Y, Yao H. Green manure application improves rice growth and urea nitrogen use efficiency assessed using 15N labeling. Soil Science and Plant Nutrition. 2019;65:511-518.
37. Supsuan P. Effects of type and timing of organic fertilizer application on rice growth and nitrogen availability in paddy soil. (Master Thesis). King Mongkut's Institute of Technology Ladkrabang, Thailand; 2019.
38. Espinal FSC, Silva EC da, Muraoka T, Franzini VI, Trivelin PCO, Teixeira MB, Sakadevan K. Utilization of nitrogen (15N) from urea and green manures by rice as affected by nitrogen fertilizer rate. African Journal of Agricultural Research. 2016; 11:1171-1180.
39. Gholizadeh A, Saberioon M, Boruvka L, Wayayok A, Soom MAM. Leaf chlorophyll and nitrogen dynamics and their relationship to lowland rice yield for site-specific paddy management. Inf Process Agric. 2017;4: 259–268.
40. Espinal FSC, Silva ECda, Muraoka T, Franzini VI, Trivelin PCO, Teixeira MB, Sakadevan K. Utilization of nitrogen (15N) from urea and green manures by rice as affected by nitrogen fertilizer rate. African Journal of Agricultural Research. 2016;11: 1171-1180.
41. Muraoka T, Ambrosano EJ, Zapata F, Bortoletto N, Martins ALM, Trivelin PCO, Boaretto AE, Scivittaro WB. Eficiencia de abonos verdes (Crotalaria y mucuna) y urea, aplicadas solos ojuntamente, como fuentes de N para el cultivo de arroz. Terra. 2002;20(1):17-23.
42. Scivittaro WB, Muraoka T, Boaretto AE, Trivelin PCO. Transformações do nitrogênio proveniente de mucuna-preta e uréia utilizados como adubo na cultura do milho. Pesqui. Agropecu. Bras. 2003; 38(12):1427-1433.
43. Singh Y, Singh B, Ladha JK, Khind CS, Gupta RK, Meelu OP, Pasuquin E. Long-term effects of organic inputs on yield and soil fertility in the rice-wheat rotation. Soil Sci. Soc. Am. J. 2004; 68:845-853.
44. Odhiambo JJO. Decomposition and nitrogen release by green manure legume residues in different soil types. Afr. J. Agric. Res. 2010;5(1):90-96.
45. Bordin L, Farinelli R, Penariol FG, Fornasieri Filho D. Sucessãode cultivo de feijão-arroz com doses de adubação nitrogenada apósadubação verde, em semeadura direta. Bragantia. 2003; 62(3): 417-428.
46. Fageria NK, Santos AB. Resposta do arroz irrigado à adubaçãoverde e química no Estado de Tocantins. Rev. Bras. Eng. Agríc. Ambient. 2007;11(4):387-392.

Peer-review history:
The peer review history for this paper can be accessed here:
https://www.sdiarticle5.com/review-history/117462