***Original Research Article***

**Evaluation of Nutrient Contribution by Sunn hemp at Different Growth Stages in Paddy Soil Study on Nutrient Provision of Sunn hemp at Various Ages on Paddy Soil**

**Abstract**

Green manuring contributes to nitrogen availability through biomass decomposition and also increases the soil carbon sequestration. The study aimed to estimate biomass contribution of sunn hemp at various growth stages and the mineralization of sunn hemp after incorporation into paddy soil under submerged condition, focusing on synchronizing nitrogen supply with rice crop demand. Sunn hemp was harvested at different growth stages (45, 60 and 75 days after sowing) to assess its biomass and nutrient contributions, particularly nitrogen and carbon. The harvested plants were incorporated into the soil, and rice seedlings were transplanted a week later. Nitrogen mineralization was monitored over eight weeks, alongside rice plant nitrogen uptake. The study was conducted at the Department of Agricultural Research, Nay Pyi Taw, with four treatments: control (no sunn hemp), SH45 (45 DAS), SH60 (60 DAS), and SH75 (75 DAS). Analytical results of sunn hemp at different growth stages showed minimal variation, however significant differences was observed in fresh and dry biomass weight. SH75 and SH60 contributed fresh biomass together with nitrogen and carbon three times higher than that of SH45. Nitrogen mineralization from different ages of sunn hemp reached maximum within first two weeks. Considering mineralization percentages, SH60 and SH75 showed continuous mineralization from 1st to 8th week, however mineralization in SH45 declined and approached to zero from 5th to the 8th week~~.~~Nitrogen demand of rice plants stared at 3rd week of SH incorporation into the soil, reached maximum at 6th week and continued to 8th week. Synchronization between nitrogen supply and demand was observed from the 3rd to the 8th week with the incorporation of SH60 and SH75, whereas in the case of SH45, it was limited to the period between the 3rd and 5th week.The research highlighted the nutrient provision potential of sunn hemp at different ages to rice plant under submerged paddy soil.

Key words; Sunn hemp, Biomass, Nitrogen, Carbon, Mineralization, Paddy soil

**1. Introduction**

Green manuring is one of the soil conservations practices as well as it can provide nitrogen (N) from decomposition process in the soil. Legume green manuring is alternative incorporation of organic matter into soil and it can enhance agricultural sustainability by improving nutrient retention [1] enhancing soil fertility [2]. It is the practice of incorporating undecomposed fresh/dry plant materials into soil and it can offer economically attractive and ecologically sound option of reducing external inputs and improving internal resources [3]. Incorporation of legume green manure into soil undergoes decomposition and mineralization process [4]. The dominant factors of decomposition and mineralization are the quantity and quality of green manure crops and it mainly depends upon the availability of N in soil [4]. Also, it is a kind of soil organic matter and can provide various benefits to soil physical, chemical and biological properties [5].

Sunn hemp is an excellent, rapid-growing green manure to be included in rotation with vegetable, ornamental, and other plants to add nitrogen and organic matter, to suppress weeds~~,~~and to reduce root-knot nematodes [6] It has ability to provide plant major nutrients as well as soil organic carbon. Sunn hemp incorporation significantly increased soil NO3-N fluxes and also enhanced extractable soil NO3-N concentration compared with the weedy fallow control during the first 3 weeks after incorporation [7]. Nitrogen content of the plant increased gradually up to 60 days of sowing and thereafter it declined. The percentage of ash in the dry matter was gradually increased in the same directions as that of nitrogen. Thus, mineral elements reached maximum amount at two months stage [8]. Schomberg (2007) [9] mentioned that date of planting and length of growing period influenced the biomass and N content of sunn hemp. Stallings *et.al*. (2017) [24] mentioned that harvesting of sunn hemp must be delayed until approximate planting of the following crop to increase the synchronization between N mineralization and crop demands. Moreover, other organic substances such as total carbohydrate and sucrose reaches its peak at 60-75 days and consideration of optimum harvesting days was reported that green manuring at 60 days after sowing was the best [10].~~]~~

In a study in 2019 and 2020, the nitrogen and acid detergent fiber yields of sunn hemp were significantly higher at 50 DAS compare to 60 DAS. These findings indicated that seeding and harvesting time should be considered as important factors to estimate decomposition [11Rice plant demands N maximum amount between the early to mid-tillering and panicle initiation stages [12]. Thus, quantifying the amount of mineral N supply at a particular period was essential for synchronization with crop demand. The study was undertaken to estimate potential provision of biomass & nutrients and to investigate mineralization rate after incorporation of sunn hemp regarding with different ages into paddy soil.

**2. Materials and Methods**

In this study, there were two experiments such as cultivation of sunn hemp with different dates for estimation of biomass production and cultivation of rice after incorporation of sunn hemp into the soil. N mineralization after was monitored incorporation of these sunn hemp with living rice plants. Nitrogen mineralization and rice plant nitrogen uptake were measured at weekly interval from 1st to 8th week.

**2.1 Experimental Site**

The tank-experiment (2 x 1 m2) was carried out in 15 Feb to 30 June 2024. The experiment was conducted at Water Utilization Research Section, Department of Agricultural Research, DAR (Yezin). It is situated at latitude 19.82415° or 19° 49' 27" north and longitude of 96.27597° or 96° 16' 34" east.

**2.2 Experimental Design**

There were four treatments such as control, sunn hemp at 45 days (SH45), 60 days (SH60) and 75 days (SH75). The experiment was designed as randomized completely block with 3 replications.

**2.3 Cultivation of Sunn hemp**

The soil in all tanks were mixed to be homogenous and samples were taken and analyzed at the laboratory of Land Use Division, Department of Agriculture (DOA). Seed rate of sunn hemp was 44.9 kg ha-1. Seed was broadcasted and other management such as irrigation were done based on requirement. Sunn hemp biomasses were separately collected at their different age by cutting plant near the soil surface. Fresh weights of biomass were recorded within 1 hour after harvest. ~~Terminated~~ Harvested sunn hemp were chopped into 5 cm long pieces of residue using chopper and then incorporated into the soil at a depth of 10-15 cm [7].

**2.4 Cultivation of Rice**

Sin Thu kha (*Oryza sativa*. L), life span of 135 days, was cultivated in the treated tanks. Before cultivation, seeds were soaked in water for 24 hours and then incubated for 48 hours. The sprouted seeds were sown on a well-prepared seed bed using wet bed method. Then, 25 days old seedlings were transplanted one seedling per hill with the spacing of 20 cm x 15 cm. Thus, there were 60 hills in a tank.

**2.5 Physicochemical properties of experimental soil**

Composite soil samples were collected prior to the experiments and analyzed for their physicochemical characteristics as shown in the table 1.

**Table 1. Physicochemical properties of experimental soil**

|  |  |  |  |
| --- | --- | --- | --- |
| **Parameter** | **Analytical results** | **Rating** | **Analytical methods** |
| pH | 7.53 | Slightly alkaline | 1:5 (soil:water) pH meter(4AI) [26] |
| EC (mS cm-1) | 0.1 | Very low | 1:5 (soil:water) EC meter (3AI) [27] |
| Total N% | 0.07 | Very low | Kjeldahl digestion method [28] |
| Available P2O5 (ppm) | 51 | Very high | Olsen method, Spectrophotometer [30] |
| Exchangeable K2 O (mg 100gm-1) | 7.23 | Low | 1N Ammonium acetate extraction (15AI) [31] |
| CEC (meq 100g-1) | 20.90 | Medium | 1N Ammonium acetate extraction method (6AI) [29] |
| Organic matter (%) | 1.96 | Low | Walkley and Black method (6AI) [28] |
| Bulk density (g cm-3) | 1.39 |  | Disturbed soil sample method [32] |
| Sand % | 85.90 |  |  |
| Silt% | 9.08 |  |  |
| Clay % | 5.02 |  |  |
| Soil texture |  | Loamy Sand | Pipette method [32] |

**2.6 Chemical Composition of Sunn hemp**

Subsamples consisting of 10-20 whole plants (depending on treatment) were randomly selected, weighted and placed in the oven at 66 °C for at least 72 hours to dry. Dry weights of subsamples were recorded to estimate the total sample dry weight. Total dry biomass contribution was calculated by multiplication of total fresh weight and remaining dry biomass percentages of the samples. Dried samples were ground to pass a 1.0 mm sieve and then analyzed at the Laboratory [9]. Nitrogen and carbon content of sunn hemp samples were calculated as multiplication of dry matter weight and N% and C% of samples respectively. The nutrient contents of each treatment were summarized in the table 2.

**Table 2. Nutrient contents of Sunn hemp at different ages**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Treatments | Total N% | ~~Total P~~~~2~~~~O~~~~5~~~~%~~ P% | ~~Total K~~~~2~~~~O%~~ K% | Carbon % | C : N | Fiber content (%) |
| SH45 | 2.73 | 0.4 | 0.28 | 51.9 | 19.01 | 18.64 |
| SH60 | 2.76 | 0.75 | 0.25 | 52.9 | 19.17 | 20.13 |
| SH75 | 2.83 | 0.4 | 0.05 | 54.9 | 19.40 | 34.50 |

**2.7 Weather Condition**

Rainfall, minimum and maximum temperature at the research location during the study was mentioned in the figure 1.

**Fig. 1. Rainfall (mm) and Minimum & Maximum Temperature (°C) during the study**

**2.8 Analysis of Rice Plant Nitrogen Uptake and Soil Available Nitrogen**

**2.8.1 Analysis of Rice Plant Nitrogen Uptake**

Analysis of rice plant nitrogen uptake and soil available mineral nitrogen were undertaken at the laboratory under Water Utilization Research Section, Department of Agricultural Research. Rice plant samples were weekly collected to measure nitrogen uptake until the eighth week after the recovery period. Randomly selected rice plants were cut just above the soil surface, dried at 70°C, and analyzed for total nitrogen using the Kjeldahl method.

**2.8.2 Detection of Available N (Mineral N) from Experimental Soil**

Composite soil samples were separately collected for each treatment to determine mineral N. This was done weekly from the first to the eighth week after sunn hemp incorporation. Samples were taken from a 15 cm depth, air-dried, and sieved through a 2 mm sieve. Available nitrogen was determined using the Alkaline Permanganate Method. For the analysis, 20 grams of dried soil were weighed and placed into a 250 ml flat-bottom flask. Then, 20 ml of distilled water was added, and the mixture was left to stand for 30 minutes. Subsequently, 100 ml of KMnO4 and 100 ml of NaOH were added, and the flask was connected to a distillation apparatus. A 250 ml receiving conical flask containing 10 ml of 3% H3BO3 and three drops of a mixed indicator was simultaneously connected. The distillation process was carried out to obtain 100 ml of (NH4)3BO3 solution. Afterward, the apparatus was rinsed with a wash bottle and disconnected from the distillation setup. The conical flask was then cooled and titrated with normal H2SO4. Available nitrogen content (ppm) was calculated as following formula;

Nitrogen mineralization % was calculated as follows;

[7]

**2.8.3 Apparent Nitrogen recovery (ANR)**

There are several indicators to assess the nutrient performance on crop yield. Nutrient uptake efficiency that is the proportion of nutrient added to the soil and that taken up by the plant is used [13]. The proportion of nitrogen absorbed and derived from the applied fertilizer nitrogen cannot be precisely determined. Therefore, it is referred to as the "apparent" recovery of fertilizer nitrogen [14]. Apparent N recovery is commonly used and calculated as follow;

[15]

**3. Statistical Analysis**

Experimental data were analyzed with Analysis of Variance (ANOVA) by using Statistix 8.0. Treatment means were compared using least significant difference (LSD) test at P = 0.05 level [16].

**4.Results and Discussion**

**4.1 Estimation of Biomass and Nutrient Contributions**

Sunn hemp at three different growth stages (45, 60 and 75 days after sowing) showed the significant effects on plant growth parameters, biomass accumulation and nutrient contribution. A significant increase P=0.01 was observed in both plant height and root length with increasing plant age. The highest values were recorded at 75 days, with plant height reached 145.38 cm and root length 20.95 cm, compared to 103.27 cm and 15.95 cm, respectively, at 45 days. Fresh biomass weight increased from 2320 g tank-1 at SH45 to 5570 g tank-1 at SH60 which was nonsignificant with SH75. SH60 provided fresh biomass weight 140% greater than SH45 while it was 4.6% greater than SH75. SH75 did 129.6% greater than SH45. Although SH60 produced a higher fresh biomass than SH75, SH75 surpassed SH60 in dry biomass contribution. The reason of higher dry biomass in SH75 was related to its low moisture content (Table 3). Therefore, SH75 revealed superior dry biomass and nutrient contributions compared to SH60 and SH45. Moisture content declined with age from 74.7 % at SH45 to 64.33% at SH75.

Significant differences were also found in nutrient contributions. Nitrogen contribution of SH75 was 53.78 g tank-1, representing 236% increase over SH45 and 9.3% higher than SH60’s contribution. The N contributions of SH45, SH60 and SH75 were equivalent to the 80 kg ha-1, 245.9 kg ha-1 and 268.9 kg ha-1 respectively. Similarly, carbon contribution of SH75 was 243% higher than SH45 and 10.7% higher than SH60. The C contribution data from SH45, SH60 and SH75 were equivalent to 1520 kg ha-1, 4710 kg ha-1, 5215.5 kg ha-1 respectively. The results were similar to the research results that sunn hemp biomass and N content increased with days after plantation (DAP) at two research location [9]. Pereira (2018) [17] mentioned that carbon stock was positively changed at almost all of the evaluation times and he concluded that fertilization with sunn hemp increased the C stock in labile and recalcitrant fractions of soil organic matter. The research finding indicated that all treatments provided the nitrogen and carbon to the soil, but in comparison, plant height, fresh weight, dry weight provisions of SH60 and SH75 were not significantly different to each other whereas SH45 consistently recorded the lowest values across all parameters.

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| --- | --- | --- | --- | --- | --- | --- | --- |
| **Table 3. Contributions Biomass and Nutrients at Different Ages of Sunn hemp** | | | | | | | |
| **Treat-ments** | **Plant height (cm)** | **Root Length (cm)** | **Fresh Weigh**  **(g tank-1)** | **Dry Weight**  **(g tank-1)** | **Mois- ture**  **(%)** | **N contri-bution**  **(g tank-1)** | **C contri-bution**  **(g tank-1)** |
| SH45 | 103.27b | 15.95c | 2320.0b | 586.0b | 74.7 a | 16.00b | 304.1b |
| SH60 | 139.17a | 18.40b | 5570.0a | 1782.1a | 68.0 b | 49.18a | 942.7a |
| SH75 | 145.38a | 20.95a | 5326.7a | 1900.0a | 64.3 c | 53.78a | 1043.1a |
| LSD | 14.32 | 2.23 | 588.15 | 170.0 | 1.51 | 4.69 | 89.62 |
| *P* value | *P* =0.01 | *P* =0.01 | *P* =0.01 | *P* =0.01 | *P* =0.01 | *P* =0.01 | *P* =0.01 |
| CV% | 8.61 | 9.75 | 10.38 | 10.81 | 3.85 | 10.75 | 10.66 |

**4.2 Physicochemical Properties of the Soil Before and After the Experiment**

Following the incorporation of sunn hemp with respect to the treatments, the physicochemical properties of the experimental soil were analyzed and results were presented in Table 4. Compared to the pre-experiment soil test, slight increases were observed in soil pH, electrical conductivity (EC), organic matter percentage, and cation exchange capacity. Available P2O5 was originally very high and it was slightly reduced after experiment except for control. Notably, available K₂O levels increased rating from low to medium in treatment SH45, from low to high rate in SH60, and from low to medium rate in SH75.

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| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Table 4. Physicochemical Properties of the Soil Before and After the Experiment** | | | | | | | | | | | | | | | |
| Sr. | Treat-ments | pH | | EC | | Organic Matter % | | Total N% | | Available P2O5(ppm) | | K2O  (mg/100gm) | | CEC meq/100gm | |
| Before | After | Before | After | Before | After | Before | After | Before | After | Before | After | Before | After | |
| 1 | Control | 7.53 | 8.26 | 0.1 | 0.11 | 1.96 | 1.98 | 0.07 | 0.05 | 51 | 55.41 | 7.23 | 10.31 | 20.9 | 20.9 | |
| 2 | SH45 | 7.53 | 8.09 | 0.1 | 0.13 | 1.96 | 2.15 | 0.07 | 0.07 | 51 | 43.95 | 7.23 | 16.48 | 20.9 | 21.4 | |
| 3 | SH60 | 7.53 | 8.01 | 0.1 | 0.20 | 1.96 | 2.75 | 0.07 | 0.07 | 51 | 44.31 | 7.23 | 29.61 | 20.9 | 24.9 | |
| 4 | SH75 | 7.53 | 8.18 | 0.1 | 0.14 | 1.96 | 2.70 | 0.07 | 0.07 | 51 | 45.21 | 7.23 | 18.33 | 20.9 | 22.1 | |

**4.3 Rice Plant Nitrogen Uptake and Apparent Nitrogen Recovery (ANR)**

**4.3.1 Rice Plant Nitrogen Uptake**

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| --- |
| Rice plant nitrogen uptake (g tank-1) |

**Fig. 2. Plant Nitrogen Uptake (g tank-1)** **by Rice plant** **during incorporation period of 8 weeks. SH45= incorporation of sunn hemp at the age of 45 days, SH60= incorporation of sunn hemp at the age of 60 days, SH75= incorporation of sunn hemp at the age of 75. Rice plant were transplanted at 1st week after incorporation and recover at the second week, afterwards, uptake was measured after the incorporation of 3rd week until 8th week**

Statistically significant differences in plant nitrogen uptake were observed among all treatments (P = 0.01). Rice plants exhibited the highest nitrogen uptake from soils incorporated with sunn hemp at 75 days of growth (SH75), followed by SH60, SH45, and the control. Across all weeks, the control consistently demonstrated the lowest nitrogen uptake. The uptake patterns for SH75 and SH60 showed a steady increase beginning from the 3rd week, reaching a peak at the 6th week, and subsequently declining during the 7th and 8th weeks. The SH45 treatment resulted in significantly higher nitrogen uptake than the control, though it remained consistently lower than SH60 and SH75. These trends were in agreement with the apparent nitrogen recovery (ANR) values presented in Figure 3, where maximum nitrogen recovery was also observed at the 6th week.

**4.3.2 Apparent Nitrogen Recovery (ANR)**

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| --- |
| Apparent Nitrogen Recovery % |

**Fig. 3. Apparent Nitrogen Recovery % (ANR) by Rice Plant during incorporation period of 8 weeks.**

ANR is the indicator for efficient N release and uptake by plant, leading to better Nitrogen Use Efficiency (NUE). Aulakh (2000) [18] and Morris *et al.*, (1986) [19] discussed that the value of ANR decreased by greater application of green manure to the rice field and NUE was reduced. ANR % was calculated based on rice plant uptake and N contribution from different ages of sunn hemp within the period of incorporation of 60 days as shown in the figure 3. It was found that apparent N recovery from SH45 was 18.94%, the highest at the 7th week throughout the incorporation period whereas SH60 and SH75 were the highest at the 6th week and the values were 33.79 and 32.06. Then, ANR values of them were decreasing to the 8th week as 26.31 and 26.85. Hu *et al*., (2023) [20] and Ladha *et al.,* (2020) [21] mentioned that rice taken up 30 -50% of N inputs and improving NUE was remaining as a challenge in the rice production. In this study, ANR value were less than 50% for all treatments. It can be assumed that more than 50% of nitrogen inputs from different growth stages were lost to the environment. Pathway of N losses from rice system were NH3 volatilization and nitrification- denitrification [25]. Fageria and Baligar, (2005) [22] explained that synchrony of N supply with crop demand could ensure adequate quantity of uptake.

(Table 4).

**4.3.3 Nitrogen mineralization after Sunn hemp incorporation into soil (g tank-1)**

Except at 8th week, mineral Nitrogen at 1st to 7th week were statistically significant at p<0.05 and p<0.01 respectively (table 4). Control showed the minimum amount of mineral N at every week and SH45 placed at the second. Comparing the amount of available N including (NH4-N and NO3-N), SH60 was the highest at 1st ,3rd ,4th ,6th ,7th and 8th week, followed by SH75 which was highest at the week of 2nd, 4th, 5th, 8th. According to the results, the net mineral N remained the highest in the first two week; the highest mineral N amount were produced by SH45 and SH75 at the 2nd week and that of SH60 was produced at the 1st week. The research findings were consistent with the research of Aulakh (2000) [18] and Brar & Sidhu (1995) [13]. In their finding, the incorporation of fresh green manure accumulated mineral N in soil during 1-2 weeks, followed by a slow decline during 2 to 3 weeks period.

Moreover, nitrogen mineralization % from sunn hemp contribution was showen in the figure 3. N mineralization % from SH45 was very low at the week of 5th, 6th, 7th and 8th whereas, SH60 and SH75 showed that increased mineralization % at the 6th and 7th week. According to the findings, SH45 amendment mineralized 54.99% after 14 days whereas SH60 and SH70 did 15.16% and 27.86%, respectively. These results were likely explained by the greater moisture content of SH45 (74.7%) which decompose rapidly than SH60 (68%) and SH75 (64.3%) (Table 3). On the other hand, fiber content of SH45 was the lowest (18.64%) and SH60 & SH75 contain 20.13% and 34.5% (Table 2). The fleshy portions of sunn hemp were decomposed at first, leaving behind recalcitrant high fiber tissues that were resistant to decomposition and high level of carbon content which decomposed gradually at the later weeks [23].

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Table 5. N mineralization after sunn hemp incorporation into soil (g tank-1)** | | | | | | | | |
| **Treatments** | **1st**  **Week** | **2nd**  **Week** | **3rd**  **Week** | **4th Week** | **5th Week** | **6th Week** | **7th Week** | **8th Week** |
| Control | 14.77c | 8.80 c | 7.64 c | 5.31 b | 6.64 b | 6.64 c | 8.13 b | 7.64 a |
| SH45 | 17.16 bc | 17.59 b | 16.27 ab | 7.64 ab | 7.14 b | 6.73 c | 8.38 b | 7.96 a |
| SH60 | 24.17 a | 16.60 b | 19.75 a | 10.62 a | 7.30 b | 18.26 a | 16.10 a | 8.30 a |
| SH75 | 18.82 b | 23.41 a | 12.78 b | 9.46 a | 10.79 a | 16.38 b | 9.63 b | 8.47 a |
| LSD | 1.17 | 0.46 | 1.71 | 1.31 | 0.53 | 0.71 | 0.65 | 0.71 |
| CV% | 7.66 | 3.36 | 14.91 | 19.37 | 8.16 | 7.21 | 8.34 | 10.70 |
| P value | P =0.01 | P =0.01 | P =0.01 | P =0.05 | P =0.01 | P =0.01 | P =0.01 | NS |

Nitrogen mineralization (%)

**Fig. 4. Nitrogen Mineralization % by sunn hemp during incorporation period of 8 weeks SH45= incorporation of sunn hemp at the age of 45 days, SH60= incorporation of sunn hemp at the age of 60 days, SH75= incorporation of sunn hemp at the age of 75, mineral N was measured after a week incorporation of sunn hemp until 8th week**

**5. Conclusion**

This study estimated nutrient provision of sunn hemp at different ages to rice plant under submerged paddy soil. For fresh biomass provision, SH60 contributed the maximum amount to paddy soil while SH75 provided the maximum amount of dry weight. Chemical composition analysis of sunn hemp at different growth stages showed minimal variation. As fresh and dry weight production differed significantly, it leads to variations in nutrient inputs, particularly nitrogen and carbon. Under 2-month study of mineralization in submerged paddy soil, nitrogen mineralization of all treatments was the highest at the 1st and 2nd week, afterwards, it declined. The nitrogen mineralization percentage in SH45 remained markedly low between the 5th and 8th weeks, whereas SH60 and SH75 exhibited sustained mineralization with comparatively higher nitrogen release throughout this period. Regrading ~~to~~ the nitrogen input, SH60 and SH75 covered until 8th week while SH 45 as low as control from 5th week to 8th week. Plant nitrogen uptake initiated in the third week of sunn hemp incorporation and reached its peak by the sixth week and continued to 8th week at all treatments. Apparent nitrogen recovery percentages indicated that rice plants achieved the highest nitrogen recovery from soils incorporated with sunn hemp at 60 and 75 days of growth, while significantly lower recovery was observed in the SH45 treatment. Additionally, the incorporation of sunn hemp into paddy soil occurred rapid decomposition and resulted in a high rate of nitrogen release during the initial two weeks. Consequently, the synchronization between nitrogen supply and crop demand was minimal during the first two weeks across all treatments. Thereafter, consistent synchronization was observed only in the SH60 and SH75 treatments. In conclusion, incorporation of Sunn hemp at different ages into paddy soil provided carbon and nitrogen with different proportions. By maximizing the synchronization of N supply and demand, it benefits ~~to~~ rice crop production. It can be suggested that many studies focused on better synchronization of N supply and crop demands are still required.

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