

Research Article

The Residual Effect of Pre-Rice Green Manuring on a Succeeding Wheat Crop (*Triticum aestivum* L.) in the Rice-Wheat Cropping System in Banke, Nepal

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Rice-wheat is the most widely used cropping pattern in Nepal. This cereal-based cropping system is highly nutrient exhaustive and unsustainable from a soil management perspective. They contribute neither nitrogen nor biomass to the soil. The net effect is the export of nutrients from the soil. The unused period between wheat harvest and rice transplanting is the summer fallow, and the incorporation of green manure during this short period increases the yield of both crops and improves the soils chemical properties. Altogether, there were 9 treatments and 3 replications with the randomized complete block design (RCBD). Dhaincha, sun hemp, black gram, cowpea, mung bean, and rice bean were used as pre-rice green manure. No chemical fertilizers were used for the green manure, and in wheat, 150 : 50 : 50 NPK kg/ha was applied. Goat manure was applied at the rate of 10 t/ha. The main objective of the study is to ascertain the residual effect of pre-rice green manuring on the chemical properties of the soil and the yield attributes of the succeeding wheat crops. The chemical properties of the soil were analyzed before and after the harvesting of wheat, and the yield attributes parameters were analyzed. The result showed that the green manure-treated plots gave a significantly higher yield as compared to solely chemical fertilizers-treated plots. The maximum grain yield was obtained from black gram (5.870 t/ha). There was a 39.76% increase in the grain yield in the black gram-incorporated plots as compared to the only-chemical fertilizers-treated plots. There was a highly (<0.001) significant difference in the soil organic matter of the green manure-treated plots and the only-chemical fertilizers-treated plots. The sun hemp-incorporated plot increased the soil organic matter by 71% when compared to the only-chemical fertilizers-treated plot. There was no significant residual effect of pre-rice green manuring on the soil pH in a one-cropping season. However, there was a significantly higher residual effect of the green manure on the soil's total nitrogen content in all green manure-treated plots. It was found to be the highest (0.087%) in pre-rice dhaincha. The overall results indicate that the incorporation of pre-rice green manuring improved the soil's chemical properties and increased the grain yield of the succeeding wheat crops in a rice-wheat cropping system.

1. Introduction

Wheat (*Triticum aestivum* L.) is a major cereal crop cultivated globally. In the context of Nepal, it is regarded as the third most valuable cereal crop following rice and maize. Feeding the growing population with the production of wheat is a major global threat in most of the countries [1]. Kumar and

Sharma [2] reported that the growth of a leguminous crop in the previous season affects the yield and yield attributing parameters of wheat. Green manuring is the practice of using the undecomposed green plant material, grown in situ or cut and brought in for incorporation, to improve soil productivity. The incorporation of pre-rice green manuring significantly increased the nutrient status of the soil, and also, it

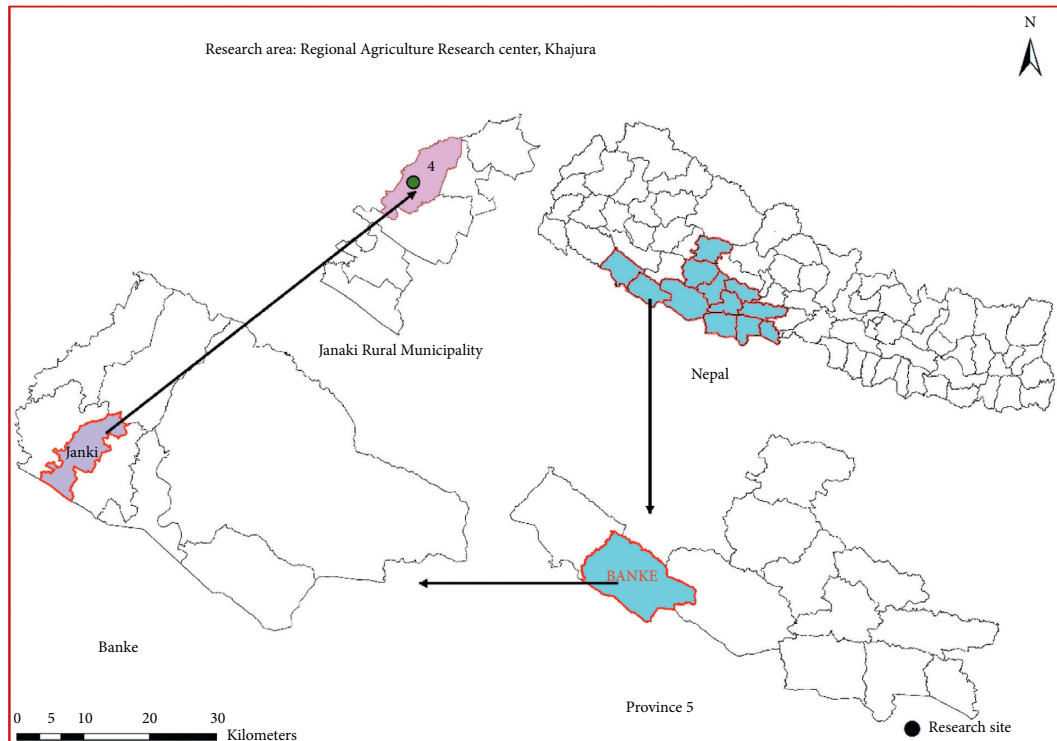


FIGURE 1: Location of experimental site at Regional Agriculture Research Station, Khajura.

contributed to the rice grain [3]. A continuous intensive cultivation led to the detachment and leaching of the nutrients from the root zone area and resulted in the reduction of the organic matter content of the soil. Hence, the incorporation of green manuring is the best option to restore soil fertility as it is ecofriendly, nutrient-rich, and easily biodegradable in nature [4]. After the harvest of winter crops, the period available until the next rainy season crops can be used for the plantation of rapidly growing green manuring. The incorporation of legumes green manure in a rice-based cropping system has been widely studied.

The unused remaining time after harvesting wheat and before transplanting the rice seedlings is sufficient for the growth of short-duration legume crops. Along with improving the soil fertility status, the incorporation of green manure reduces the demand for external chemical fertilizers. It improves soil fertility by the direct addition of nitrogen, and it improves soil structure by the addition of organic matter. The higher content of organic matter helps to bind the soil particles and form stable soil aggregates that ameliorate the chemical, physical, and biological characteristics of the cultivating soil.

2. Materials and Methods

2.1. Site Description. The experiment of field work was accomplished at Regional Agriculture Research Station (RARS), Khajura, Banke, Nepal. The research was conducted from November 2018 to April 2019. It is geographically situated at $80^{\circ}37''$ East longitude and $20^{\circ}06''$ North latitude at an elevation of approximately 181 meters above the sea level (masl). After harvesting rice, the soil samples were

taken from 27 plots using the soil auger before sowing the wheat. The soil was taken from 15 cm deep. The nature of the soil was clay loam. The soil of each plot was analyzed to determine the initial concentration of the total nitrogen content of the soil, soil organic matter, available phosphorus, available potassium, and soil pH. The location of the experimental site is shown in Figure 1.

2.2. Treatments. The treatment consists of green manuring, inorganic fertilizers, and organic manures (goat). The organic manure was applied in one plot treatment (T_3) at the rate of 10 tons/ha during wheat sowing. The experiment consists of three replications with nine treatments, and the layout was in a randomized complete block design (RCBD). The treatment details are shown in Table 1.

The wheat was sown in rows with a spacing of 25 centimeters (cm). The area of each plot was 20 m^2 . There were 19 rows of wheat in each plot with a 5 m length. A gap of 1 meter was maintained between the blocks and the plots. There was no application of chemical fertilizers in the green manures. The green manure was sown during the fallow period, and the in situ incorporation was done before rice transplanting. While sowing wheat, the recommended dose of phosphorus and potassium was applied to the soil. The application of nitrogen was done in three split doses, the first on the 21st day after sowing, the second just before flowering, and the last one just before heading. Before sowing and after harvesting wheat, the soil organic matter, soil total nitrogen, soil available phosphorus, potassium, and soil pH were determined. The soil analysis method is shown in Table 2.

TABLE 1: Treatments details.

Treatments	Treatment description
T_1	Rice-wheat-fallow (no nutrients application in rice and wheat)
T_2	Rice-wheat-fallow (chemical fertilizers application in rice NPK @100:30:30 kg/ha and wheat NPK @ 150:50:50 kg/ha)
T_3	Rice-wheat-fallow (organic manure in rice and wheat@10 ton/ha)
T_4	Rice-wheat-dhaincha (rice NPK @100:30:30 kg/ha, wheat NPK @ 150:50:50 kg/ha)
T_5	Rice-wheat-sun hemp (rice NPK @100:30:30 kg/ha, wheat NPK @ 150:50:50 kg/ha)
T_6	Rice-wheat-cowpea (rice NPK @100:30:30 kg/ha, wheat NPK @ 150:50:50 kg/ha)
T_7	Rice-wheat-black gram (rice NPK @100:30:30 kg/ha, wheat NPK @ 150:50:50 kg/ha)
T_8	Rice-wheat-mung bean (rice NPK @100:30:30 kg/ha, wheat NPK @ 150:50:50 kg/ha)
T_9	Rice-wheat-rice bean (rice NPK @100:30:30 kg/ha, wheat NPK @ 150:50:50 kg/ha)

TABLE 2: Soil analysis method.

Soil parameters	Analysis method (0–15 cm depth)
Soil pH	Glass-electrode pH meter method [5]
Soil texture	Bouyoucos hydrometer method [6]
Soil organic matter	[7]
Soil total nitrogen	Kjeldahl distillation [8]
Available phosphorus in soil	Modified Olsen's bicarbonate method [9]
Available potassium in soil	Ammonium acetate method [10]

TABLE 3: Initial chemical properties of soil (0–15 cm) at RARS, Khajura.

Treatments	Av. P_2O_5	SD P_2O_5	Av. K_2O	SD K_2O	Av. SOM (%)	SD SOM (%)	Av. pH	SD pH	Av. N (%)	SD N (%)
T_1	0.026	0.004	6.497	0.269	1.410	0.429	6.833	0.058	0.050	0.010
T_2	0.041	0.001	8.140	0.333	2.320	0.478	6.867	0.115	0.060	0.010
T_3	0.053	0.003	8.967	0.472	2.609	0.344	6.800	0.000	0.065	0.022
T_4	0.056	0.005	11.867	0.757	3.780	0.220	6.800	0.000	0.080	0.010
T_5	0.045	0.003	8.737	0.594	3.967	0.365	6.900	0.173	0.080	0.000
T_6	0.043	0.001	8.733	0.562	3.436	0.340	6.833	0.058	0.073	0.006
T_7	0.038	0.003	8.423	0.447	3.150	0.046	6.800	0.000	0.067	0.012
T_8	0.054	0.005	9.020	0.079	3.064	0.519	6.867	0.115	0.073	0.006
T_9	0.058	0.003	9.200	0.452	3.610	0.040	6.833	0.058	0.073	0.006
Total	0.045	0.010	8.840	1.396	3.030	0.832	6.830	0.079	0.060	0.013

2.3. *Chemical Properties of Soil before Wheat Sowing.* The initial chemical properties of soil are shown in the Table 3.

2.4. *Statistical Analysis.* The kobo collect tool was used from the beginning of the experiment to record the data on plant height, tillers number, and the length of panicle on the successive interval of 21, 42, 63, 84, and 105 days, respectively. The data were directly extracted from the kobo collect. Other data, such as plant height, panicle length, grain yield, filled grain, and unfilled grain at the time of harvesting, were recorded manually, and the data were subjected to the analysis of variance (ANOVA) using the Gen-stat software. Duncan's multiple range test at a 5% level of significance was used for the mean separation.

3. Results and Discussion

3.1. Effect on Yield and Yield Attributing Parameters

3.1.1. *Plant Height.* There was no significant difference in the plant height between the green manure-with-chemical fertilizers-treated plots and the only-chemical fertilizers-treated plots. The maximum plant height (102.65) cm was

obtained from the black gram-treated plot, which was statistically at par with all green manure-incorporated plots and chemical fertilizers-treated plots. It has been well-established that the application of green manure with the combined use of chemical fertilizers promotes the wheat plant's height as it increases the availability of major nutrients, especially N, which has a positive effect on the plant's height. These findings are in accordance with the result of [11] who had observed an increased plant height in both crops by the incorporation of green manure along with chemical fertilizers. A similar result was obtained by Nawaz et al. [12]. Indeed, the incorporation of legumes green manuring increased the uptake of nitrogen (N), phosphorus (P), potassium (K), zinc (Zn), iron (Fe), manganese (Mn), and copper (Cu). It might be the possible reason for an increase in the plant's height. Black gram as a preceding crop had a relatively higher residual effect than the mung bean on the succeeding wheat crop [13]. The incorporation of dhaincha and cowpea green manure increased the yield of the first (rice) and second succeeding crops (maize) by 21% and 4% in the first year and by 38% and 13% in the second year of the experiment done at Selangor, Malaysia [14]. A similar result

TABLE 4: Effect of chemical fertilizers and green manure treatments on the plant height, spike length, number of grains/spike, and 1000-grain weight.

Treatments	Plant height (cm)	Spike length (cm)	No of grains/spike	1000-grain weight (g)
T_1	74.23 ^c	7.47 ^b	26 ^b	40.37 ^d
T_2	100.26 ^a	9.70 ^a	37 ^a	43.10 ^b
T_3	83.54 ^b	8.01 ^b	32.87 ^{ab}	42.10 ^c
T_4	98.75 ^a	9.79 ^a	40.53 ^a	44.01 ^a
T_5	100.67 ^a	9.67 ^a	41.87 ^a	44.70 ^a
T_6	100.70 ^a	9.53 ^a	36.8 ^a	44.60 ^a
T_7	102.65 ^a	9.38 ^a	39.27 ^a	44.48 ^a
T_8	97.77 ^a	9.40 ^a	34.87 ^{ab}	44.72 ^a
T_9	101.38 ^a	9.65 ^a	40.4 ^a	43.27 ^a
Grand mean	95.55	9.18	37	43.48
<i>F</i> -probability	<0.001	0.002	0.034	<0.001
SEM (\pm)	2.267	0.360	2.9	0.244
LSD _{0.05}	6.798	1.078	8.6	0.732
CV (%)	4.1	6.8	13.5	1

SEM = standard error of mean; CV = coefficient of variation. Means followed by difference letters are significantly different among each other on DMRT at 5% level of significance.

was obtained by Yang et al. [15] because of the incorporation of green manure along with a recommended dose of chemical fertilizers.

3.1.2. Spike Length and Number of Grains/Spike. The spike length ranged from 7.47 cm to 9.79 cm. There was no significant difference in the spike length between the solely chemical fertilizers-treated plots and the green manure-with chemical fertilizers-treated plots. The number of grains per spike ranged from 26 to 40. There was also no significant difference in the number of grains per spike between the green manure-with chemical fertilizer-treated plots and the only-chemical fertilizers-treated plots. However, the highest number of grains per spike (41) was recorded from T_5 (the plot with sun hemp incorporation), which was statistically at par with T_2 (recommended dose of fertilizers), T_4 (dhaincha), T_6 (cowpea), and T_7 (black gram).

3.1.3. 1000-Grain Weight. The 1000-grain weight of wheat was statistically affected by pre-rice green manuring treatments. All green manuring treated plots significantly improved the test weight of wheat compared to summer fallow with only chemical fertilizers treated plot. The highest test weight (44.72 g) was obtained from mung bean (T_8) with a recommended dose of fertilizers and the lowest (40.37 g) was from the fallow plots without nutrients application (T_1). The 1000-grain weights significantly improved by 3.75%, 3.71%, and 3.48% because of the incorporation of pre-rice mung bean, sun hemp, and cowpea along with a recommended dose of fertilizers as compared to a summer fallow plot with chemical fertilizers (T_2). The effect of chemical fertilizers and green manure treatments on the plant height, spike length, number of grains/spike, and 1000-grain weight is shown in Table 4.

3.1.4. Grain Yield. Compared with the only-chemical fertilizers-treated plots, the application of chemical fertilizers with green manure surged the wheat yield. The maximum

grain yield (5.870 t/ha) was obtained from black gram with a recommended dose of fertilizers 150:50:50 kg/ha (T_7), which was statistically at par with all other green manure-treated plots. The increment in the grain yield with the incorporation of black gram (T_7) was 39.76% compared to summer fallow with only chemical fertilizers-treated plot (T_2). The sun hemp (T_5) and mung bean (T_8)-treated plots with a recommended dose of fertilizers increased the grain yield by 31.30% and 30.42%, respectively, as compared to the only-chemical fertilizers-treated plot (T_2). A similar result was found in [16]. Between the legumes as well, the black gram-treated plot with the recommended doses of fertilizers (T_7) increased the yield by 22.3% compared to the rice bean-treated plot with a recommended dose of fertilizers (T_9). This may be because of the rapid decomposition of green manures. It quickly released the nutrient and increased the nutrients availability to the plants, which increased the growth parameters. A similar result was obtained by [12]. Indeed, the incorporation of legumes green manuring increased the uptake of the essential plant nutrients, including micronutrients, such as zinc (Zn), iron (Fe), manganese (Mn), and copper (Cu), which might be the possible reason for a higher grain yield. The incorporation of dhaincha and cowpea green manures increased the yield of the first (rice) and second (maize) succeeding crops by 21% and 4% in the first year and by 38% and 13% in the second year of the experiment done at Selangor, Malaysia [14]. A similar result was obtained by [15] because of the incorporation of green manure along with the recommended dose of chemical fertilizers. The results were also in line with Pandey and Bista [17], where they observed that the incorporation of mung bean before rice significantly increased the rice yield while sowing rice after wheat. Similarly, research conducted at Indian Agriculture Research Institute [18] suggested that the incorporation of pre-rice green manuring sun hemp, dhaincha, cowpea along with 120, 26, 33, and 5 kg/ha of nitrogen, phosphorus, potassium, and zinc fertilization (5 kg/ha) had a significant residual influence on the wheat yield as compared to summer fallow. The pre-rice

TABLE 5: Effect of chemical fertilizers and green manure treatments on grain yield and straw yield.

Treatments	Grain yield (t/ha)	Straw yield (t/ha)
T_1	1.447 ^d	1.77 ^d
T_2	4.2 ^b	7.547 ^{ab}
T_3	2.762 ^c	3.567 ^c
T_4	5.183 ^{ab}	7.843 ^{ab}
T_5	5.515 ^a	8.160 ^a
T_6	5.003 ^{ab}	6.510 ^b
T_7	5.870 ^a	7.510 ^{ab}
T_8	5.478 ^a	7.563 ^{ab}
T_9	4.796 ^{ab}	7.033 ^{ab}
Grand mean	4.38	6.39
F-probability	<0.001	<0.001
SEM (\pm)	0.339	0.485
LSD _{0.05}	1.017	1.455
CV %	13.1	13.2

SEM = standard error of mean; CV = coefficient of variation. Means followed by difference letters are significantly different among each other on DMRT at a 5% level of significance.

amalgamation of legumes may increase the availability of nitrogen and required essential nutrients. It might improve the soil's physicochemical and biological characteristics that lead to an increase in the grain yield [19, 20].

The incorporation of dhaincha green manure after 50 and 70 days of sowing along with 75% of the recommended dose of the nitrogen chemical fertilizers results in a higher BRRI dhan28 yield [21]. Similarly, using dhaincha and mung bean as pre-rice green manuring along with the application of 75% of the nitrogen fertilizers was found effective to increase the yield of BINA dhan7 [16].

3.1.5. Straw Yield. The straw yield ranges from 1.77 to 8.16 t/ha. There was no significant residual effect of green manuring with the chemical fertilizers-treated plots and only-chemical fertilizers-treated plot on the straw yield in the rice-wheat cropping system. The sun hemp-treated plot with the recommended dose of fertilizers results in a maximum straw yield of 8.160 t/ha (T_7) followed by dhaincha (T_4). The increment in straw yield with a recommended dose of fertilizers and sun hemp (T_5) was 8.12% as compared to summer fallow with only chemical fertilizers applied plot (T_2). The effect of chemical fertilizers and green manure treatments on the grain and straw yield of wheat is shown in Table 5.

3.2. Effect on Soil Chemical Properties

3.2.1. Effect on Soil Available Phosphorus (P) before and after Harvest. The soil available phosphorus before and after the experiment was significantly affected by the incorporation of green manures. The highest available phosphorus was observed from the incorporation of rice bean (0.05807 ppm) before wheat sowing. There was an increase in soil available phosphorus by 41%, 30.9%, and 37.39% in rice bean, mung bean, and dhaincha-treated plots with the recommended dose of chemical fertilizers as compared to the traditional

rice-wheat cropping system (T_2). The same trend was found even after the harvest of wheat. The plots with the incorporation of rice bean and mung bean green manuring significantly increased the soil available phosphorus by 28.88% and 18.31% than the summer fallow with only-chemical fertilizers-treated plot (T_2). Dhaincha, sun hemp, mung bean, and rice bean residues contributed to improving the concentration of soil available phosphorus. The secretion of organic acids, breakdown of organophosphatic compounds, and the conversion of the organic phosphate to an inorganic form results in the release of more phosphorus that would be available to the soil [22]. The rapid decomposition of biomass residues produced organic acids which is the major source of available soil phosphorus for plant uptake and directly linked to the productivity of crops. The green manure consists of adequate nutrients, such as phosphorus, which is immediately released into the soil after the decomposition process may be the attributing factor for more available phosphorus in soil. The same results of an increase in the soil available phosphorus were found by Adekiya et al. [4] in green manuring-incorporated plots relative to the only-chemical fertilizer-applied plots. The application of chemical fertilizers releases the phosphorus nutrients that are absorbed by the wheat crop and thus have a better performance than the control. A similar result was observed by Kumar and Prasad [23]. Sometimes, the phosphorus availability may not increase because of the incorporation of green manuring as the microbial population competes for the available phosphorus in the soil. The experiment in rice showed that the application of rock phosphate in green manuring-treated plots significantly increased the soil available phosphorus [24]. Bah et al. [25] reported that the green manure markedly increased the efficiency of the phosphorus fertilizer by (3–39) % in combination with the chemical fertilizers, and it could increase the concentration of phosphorus in the soil. According to the findings of Prasad and Misra, [26] the three-year experiment with the application of mung bean, organic residues, cowpea, dhaincha, and farmyard manure had a significant influence on the soil sodium bicarbonate extractable phosphorus in both years' rice harvest. Ahlawat et al. [27] reported that incorporating mung bean as green manuring or its residues into the soil after harvesting the pods increases the organic matter content and concentration of phosphorus availability in the soil. Mann et al. [28] also suggested that the incorporation of dhaincha green manure increased the organic matter content and phosphorus content of the soil.

3.2.2. Effect on Soil Available Potassium (K) before and after Harvest. The soil available potassium content was significantly ($P < 0.001$) affected with the green manure treatment. Before the harvest of wheat, the maximum available soil potassium was recorded (11.867 ppm) in the dhaincha-treated plot (T_4), which was significantly different from the only-chemical fertilizers-treated plot. There was a 45.78% and 13% increase in the soil available potassium in dhaincha (T_4) and rice bean (T_9) plots with a recommended dose of

TABLE 6: Effect on soil potassium content before and after the wheat harvest.

Treatments	Before P (ppm)	After P (ppm)	Before K (ppm)	After K (ppm)
T_1	0.025 ^d	0.0173 ^e	6.49 ^d	6.23 ^d
T_2	0.04 ^{bc}	0.04733 ^{cd}	8.14 ^c	8.04 ^c
T_3	0.05 ^a	0.04133 ^d	8.96 ^{bc}	8.20 ^c
T_4	0.06 ^a	0.05233 ^{bc}	11.86 ^a	8.76 ^{ab}
T_5	0.05 ^a	0.044 ^d	8.73 ^{bc}	9.21 ^a
T_6	0.04 ^{bc}	0.05067 ^{bc}	8.73 ^{bc}	8.79 ^{ab}
T_7	0.04 ^c	0.04267 ^d	8.42 ^{bc}	8.40 ^{bc}
T_8	0.05 ^a	0.056 ^{ab}	9.02 ^{bc}	8.48 ^{bc}
T_9	0.06 ^a	0.061 ^a	9.20 ^b	9.02 ^a
Grand mean	0.05	0.05	8.84	8.35
F-probability	<0.001	<0.001	<0.001	<0.001
SEM (\pm)	0.002	0.002	0.28	0.15
LSD _{0.05}	0.006	0.006	0.83	0.45
CV %	7.5	7	5.4	3.1

SEM = standard error of mean; CV = coefficient of variation. Means followed by difference letters are significantly different among each other on DMRT at a 5% level of significance.

fertilizers as compared to the only-chemical fertilizers' application (T_2). However, after the harvest of wheat, the maximum soil available potassium was recorded (9.217 ppm) on the sun hemp (T_5)-treated plot, which was significantly different from the only-chemical fertilizers-treated plot. Along with the organic matter, green manuring provides mineral nutrients, such as potassium, required for the growth of crops. A similar result was found by [4]. Green manuring decomposition releases potassium by the recycling process as per Singh et al. [29]. There could be better root growth because of the addition of organic matter with the incorporation of dhaincha, which further helps in the uptake of potassium by the plants as per Schumann et al. [30]. In the same way, green manuring enhances the microbial action which speed up the decomposition process and increases the availability of potassium to plants as per Eriksen [31]. There was also an increase in the available potassium because of the application of chemical fertilizers in combination with green manuring by Kumar and Prasad [23]. The effect on the available soil phosphorus and potassium before and after the harvest of wheat is shown in Table 6.

3.2.3. Effect on Soil Organic Matter (SOM). There was a significant difference in the organic matter content of soil because of the incorporation of different green manure in the pre-rice crop. The sun hemp-incorporated plot with a recommended dose of fertilizers had (3.97%) an organic matter content that was significantly different from that of the only-chemical fertilizers-treated plot (T_2), whose value is only 2.32% but is statistically at par with (T_4), (T_6), and (T_9) treatments. The introduction of sun hemp, dhaincha, rice bean, and black gram increased the organic matter content of the soil by 71%, 62.93%, 55.6%, and 35.77%, respectively as compared to summer fallow with chemical fertilizers applied plot (T_2). A similar trend was found even after the wheat harvest. The decomposition of green manure adds a significant concentration of organic acids, amino acids, sugars, vitamins, organic carbon, and energy

to the soil microorganisms, which enhances the decomposition process and adds organic matter after they die. They are the possible factors for an increase in the organic matter content in the soil. The nutrient accumulation in dhaincha was primarily a function of the growing period available for the biomass production [32]. The NPK fertilizers provide the soluble nutrients immediately to the plant and lack the decomposing materials for further decomposition, which results in no addition of organic matter for forming a better soil structure [4]. The findings agree with [33]. Salahin et al., [14] suggested that the incorporation of sesbania green manuring in the maize-rice cropping system increased the organic matter content as compared to the control plots. The possible reason for the increase in the organic matter content is the addition of more biomass. The soil microbial biomass, nitrogen, and carbon significantly increased because of the legume crop residue incorporation, which could directly enhance the organic matter content [34]. The soil organic carbon plays a vital role in the formation of stable soil aggregates, and it increases the water holding capacity of the soil. It acts as a nutrient pool that contributes to sustainable agriculture [35]. In general, the legume crop residue incorporation increases the soil labile organic carbon, which is an important form of soil organic matter [36].

Several authors reported that the integration of various green manures increased the soil organic matter [37, 38]. Dhaincha incorporation enhances the concentration of organic matter and soluble phosphorus in the soil as per the study of Mann [39]. The organic matter is increased because of the application of more biomass and its rapid decomposition [40]. The increase in the levels of the organic matter is associated with treating the soils with crop residues. This observation agrees with those made by Ogbodo [33], Demir, and Gülser [41]. A similar result was found by Rixon [42], where mung bean had a significant effect on the organic carbon of soil. The decomposition of mung bean residue formed a product that acts as a binding agent. It supported the formation of stable soil aggregates and increased carbon storage.

TABLE 7: Soil nitrogen and organic matter content before and after wheat harvest.

Treatments	Before SOM (%)	After SOM (%)	Before N (%)	After N (%)
T_1	1.41 ^c	0.84 ^c	0.05 ^d	0.04 ^c
T_2	2.32 ^d	0.897 ^c	0.067 ^c	0.05 ^{bc}
T_3	2.61 ^{cd}	1.877 ^{ab}	0.08 ^a	0.05 ^c
T_4	3.78 ^a	2.149 ^a	0.09 ^a	0.08 ^a
T_5	3.97 ^a	1.286 ^d	0.08 ^{abc}	0.08 ^a
T_6	3.44 ^{ab}	1.649 ^{bc}	0.07 ^{bc}	0.08 ^a
T_7	3.15 ^{bc}	1.411 ^{cd}	0.07 ^{bc}	0.07 ^a
T_8	3.06 ^{bc}	1.953 ^a	0.07 ^{abc}	0.07 ^a
T_9	3.61 ^a	1.467 ^{cd}	0.08 ^{ab}	0.07 ^a
Grand mean	3.04	1.50	0.073	0.066
<i>F</i> -probability	<0.001	<0.001	0.001	<0.001
SEM (\pm)	0.191	0.087	0.005	0.005
LSD _{0.05}	0.573	0.26	0.014	0.014
CV %	10.9	10	11.4	12.5

SEM = standard error of mean; CV = coefficient of variation. Means followed by difference letters are significantly different among each other on DMRT at a 5% level of significance.

3.2.4. Effect on Total Soil Nitrogen (N). The data revealed that there was a significant difference in the soil total nitrogen content with the practice of different types of green manuring. The maximum nitrogen (0.087%) content was observed in dhaincha (T_4)-treated plot, which was at par with T_3 , T_9 , T_8 , and T_5 , respectively, and significantly different than the only-chemical fertilizers-treated plot (T_2). There was an increase in the nitrogen content of the soil with the incorporation of green manure before the preceding crops (rice) and its residual effect on the succeeding wheat crops. The plots treated with green manure showed high nitrogen content. The lowest nitrogen content was 0.047% in the fallow (T_1). After the harvest, the plots treated with green manure had more nitrogen content as compared to summer fallow with chemical fertilizer application plot. The increase in the soil total nitrogen might be the decomposition of organic residues left after the harvest of crops [43]. There was a 29.85% and 23.88% increase in the soil total nitrogen content by the dhaincha and mung bean-treated plots as compared to the only-chemical fertilizer-treated plots. This may be because of an increase in nitrogen mineralization from green manuring, which adds the available nitrogen in the soil [44, 45]. The combination of green manure and reduced dose of fertilizers significantly increased the soil total nitrogen content as compared to a recommended dose of chemical fertilizer-treated plot in the finding of [15]. The possible reason may be the supplement of green manure nitrogen that significantly contributed to the soil total nitrogen. It might be attributed to the enhanced nitrogen mineralization of the residual organic matter by the green manure having a greater soil microbial biomass nitrogen relative to only chemical fertilizers treated plot. Even after the wheat harvest, a similar trend was observed. The result is in accordance with [4]. Generally, legumes decompose rapidly than non-legumes because of the high content of nitrogen. It results in the addition of nitrogen to the soil after decomposition [46]. The incorporation of crop residues increases microbial immobilization and prevents the loss of nitrogen through leaching. Furthermore, it improves the physical, chemical, and biological features of the soil [47]. The addition of legume crop residues enhances the rapid

degradation of residues by the microorganism and increases the easily decomposable organic carbon and nitrogen concentration in the soil [36]. As per [48], the soil microorganisms decompose the legume residues and contribute to the soil total nitrogen.

This result was similar to [49], who found that the nitrogen level in the soil increased especially in the legumes-based cropping system. Instead of a decline, there was a slight increase in the N level. The possible reason may be the addition of N through the roots, stubbles, and leaf fall of the legumes, as well as because of the better recycling of nitrogen in the residues. The dhaincha-incorporated plot had a significantly higher nitrogen content than the only-chemical fertilizers-treated plot. It might be the rapid decaying of the incorporated residues and prolific stem nodules. The green manure prevents the loss of nitrogen from urea by maintaining the pH of flood water and helps to rehabilitate the balance of the nitrogen fertilizer in the soil [50]. A study done at Faizabad, Uttar Pradesh showed that mung bean and black gram shown in the monsoon along with the application of nitrogen have significant residual effects on wheat grown, sequentially. The residual effect of black gram was greater as compared to mung bean [13]. The effect on the soil organic matter content and nitrogen content before and after wheat harvest is shown in Table 7.

3.2.5. Effect on Soil pH. The green manure treatments have a less significant effect on the soil pH before and after the harvest of wheat. The effect of all treatments was statistically at par. After the harvest of rice, the soil pH was low, especially in the rice-wheat-organic manure (T_3), rice-wheat-dhaincha (T_4), and rice-wheat-mung bean (T_7)-treated plots as compared to other plots. However, after the harvest of wheat, there was an increase in the soil pH in all treatments. A similar result was found by Raju [51] who agree on no change in the soil pH after the incorporation of green manuring in a short period of time. Regmi et al. [52] also revealed the same results in the multiple-year soil fertility research done at the National Wheat Research Program, Nepal.

4. Conclusion

The green manure has many advantages over the chemical fertilizers as it is easily grown and incorporated into the desired field during the field preparation period. It plays a major role in the improvement of physicochemical and biological features of the soil and has a subsequent contribution to the yield of the following crops. The research done at Regional Agriculture Research Station (RARS), Khajura, revealed that the incorporation of green manures before rice planting has a substantial influence on the chemical properties of the soil, such as its organic matter content, NPK content, grain yield, and yield attributing wheat parameter in the rice-wheat cropping pattern. More specifically, incorporating green manure along with the NPK fertilizers and summer fallow with chemical fertilizers increased the yield of the succeeding wheat crops. However, there was a better improvement in the soil chemical properties (soil organic matter and nitrogen) because of the inclusion of green manure as compared to summer fallow with only chemical fertilizer. The unused summer fallow periods between wheat harvesting and rice transplanting is fruitful for cultivating different legumes and green manures that have a subsequent residual impact on the soil chemical properties and the grain yield of the following wheat crop in the rice-wheat cropping system. As compared to the regular intensive monocropping system, the adoption of green manures in the rice-wheat cropping system creates an enabling environment and increase the soil organic matter content. There was no significant change in the soil pH because of the incorporation of green manure in a short cropping period. Thus, maintaining the soil health and productivity can be furnished by the incorporation of the green manure and the recommended doses of inorganic chemical fertilizers, utilizing the uncultivated period between wheat harvesting and rice transplanting. However, the finding was from a one-year experiment that needs multiyear verifications. In the context of Nepal, a majority of the farmers are poor, and the adoption of green manure at the farm level will make a substantial contribution in increasing the wheat productivity. Also, it contributes to a sustainable rice-wheat production system. Thus, the green manure can be the best alternative for Nepalese farmers to improve the chemical properties and yield at present.

Data Availability

The original data of the research will be available from the corresponding authors through mail upon request for further information in the future.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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