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Effect of forest litter on the important soil properties and performance of upland rice in Nagaland

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ABSTRACT

This research was conducted at the experimental plot in School of Agricultural Sciences and Rural Development (SASRD), Soil & Water Conservation Department, Nagaland University from 2019-2020, as a continuation of a field research carried out in the year 2018, with an objective of analysing the effect of forest litter on important soil properties and performance of upland rice. The research was based on a split plot design with two factors having four replications. The treatments adopted were incorporation of forest litter @ 0, 3, 6 and 9 t ha^{-1} at 45 and 30 days before sowing (DBS). The amount of applied forest litter significantly increased organic carbon, available NPK, soil pH, cation exchange capacity and bulk density. The maximum organic carbon, available NPK, soil pH, cation exchange capacity and bulk density was observed when forest litter was added @ 9 t ha^{-1} at 45 DBS. With respect to the growth and its attributes, a significant increase in the plant height, number of tiller, grain yield and straw yield was observed. The maximum plant height, number of tillers, grain yield and straw yield of rice was recorded when forest litter was applied at a rate of 9 t ha^{-1} at 45 DBS. The incorporation of forest litter at 45 days before sowing @ 9 t ha^{-1} provided a significant boosts to nutrient content, improves soil properties and provides better grain and straw yield.

1. Introduction

Rice (*Oryza sativa*) is a starchy cereal crop and is the staple food for a large portion of the world's human population, especially those of Asia, Latin America, parts of Africa and the Middle East (Muthayya *et al*., 2014). Upland rice is grown under rainfed conditions in well prepared fields. They are seeded under dry conditions, like those of maize or wheat. Almost two-thirds of the upland rice cultivated area is in Asia among which Cambodia, China and India are major producers. Upland rice farming areas are facing new challenges, as some of the world's poorest farmers try to earn their living from soils that are undergoing rapid degradation. The uplands are by default susceptible to drought, low fertility status, weed infestation and plant diseases.

The forest floor, also called as detritus or the O horizon is one of the most distinctive features of the forest ecosystem. It is principally composed of non-living organic material inhabiting millions of beneficial microbes aiding in decomposition of organic residues. In Nagaland, with respect to forest cover as percentage of total geographical area, 73.90% is under forest (Forest Survey, 2021). Forest litter consisting mainly of fallen leaves, branches, twigs, barks and stems existing in various stages of decomposition, plays a major role in maintaining the fertility status of the soil. Organic matter is one of the major factors that controls the soil aggregates stability, acts as a binding and cementing material and promotes the microbial activity in soil that is responsible for formation of stable soil aggregates. The stability of soil aggregates increases with increase in organic matter content. The high macro porosity and permeability of these aggregates reduces runoff and soil erosion rates.

It is a well-known fact that, rice has been in cultivation for long in the state of Nagaland. Yet, not much research has been conducted emphasizing on the study and analysis of the effects of locally available resources like forest litter. Therefore, a proper study on the influence of forest litter on important soil properties which can enhance the performance of rice was found crucial.

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2. Materials and methods

The experiment was conducted during the *kharif* season of 2019 and the upland rice variety used is Likhimo, on the experimental plot of the Department of Soil and Water Conservation, SASRD, Nagaland University. The research was laid on a split plot design with two factors having four replications. Out of the entire field, four main plots were created, which was further sub-divided into eight sub-plots, each measuring 2m x 3m. Treatments were given in a randomized manner into the sub-plots of each main plot. The treatments adopted were incorporation of forest litter @ 0, 3, 6 and 9 t ha^{-1} at 45 and 30 days before sowing (DBS). The treatment details were as follows, Factor-1: Time of application of forest litter and following are the treatments were D_1: 45 DBS and D_2: 30 DBS. In Factor-2: Dose of application of forest litter and the following are the treatments were F_0: 0 t ha^{-1}, F_1: 3 t ha^{-1}, F_2: 6 t ha^{-1} and F_3: 9 t ha^{-1}. This research was carried out on a patch of land which was earlier used for upland rice cultivation giving the same treatments.

Collection of soil samples was done once before incorporation of forest litter and another after the crop was harvested to evaluate its physico-chemical properties. The soil pH was determined using Hanna® pocket meter in 1:2.5 ratio of soil water suspension. The soil samples were tested for their organic carbon content using wet digestion method of Walkey and Black as described by Jackson (1973). Following Ammonium Potassium Permanganate method with Kelplus Nitrogen Estimation system by Subbiah and Asija (1956), the available nitrogen content in the soil samples was determined. The available phosphorus in the soil was extracted using 0.03 NH_4F in 0.025 HCl solutions, which is the procedure applied to strongly acidic soil (Brays & Kurtz, 1945). Using neutral normal ammonium acetate (pH 7.0), the available potassium content in the soil was extracted. The extract was then fitted in a flame photometer to determine the potassium content (Jackson, 1973). Pycnometer method was followed to determine the bulk density of the soil (Majumdar & Singh, 2000). The statistical analysis of all the experimental data were carried out following standard procedure i.e., Analysis of variance (ANOVA) for two Split Plot Design as given by Gomez and Gomez (1984).

3. Results and Discussions

3.1 Effect of forest litter on soil fertility

3.1.1. Soil organic carbon: The organic carbon content of the soil samples was recorded to be within the range of 2.99 to 3.42%. Incorporation of forest litter @ 3, 6 and 9 t ha^{-1} showed a significant increase in organic carbon content of the soil at a rate of 4.35, 6.35 and 14.38%, respectively. Application of forest litter @ 9 t ha^{-1} (3.42%) i.e., D_1F_3 resulted in maximum organic carbon content while control i.e., D_1F_0 (2.99%) showed minimum organic carbon content. Also, over control, application of forest litter @ 3 and 6 t ha^{-1} showed a significant increase in organic carbon content. The increase in soil organic carbon is due to the application of organic matter which contains carbon and also the organic matter which later converts into soil organic matter. Such similar findings were reported by Rao *et al*. (2004), Singh *et al.* (2006) and Singh and Chandra (2011).

3.1.2. Available nitrogen: When the interaction among treatments were compared, a significant increase in nitrogen content (20.80%) was observed when forest litter was applied at 45 DBS as compared to that of 30 DBS. Incorporation of forest litter at 45 DBS, showed a higher level of available nitrogen (577.80 kg ha^{-1}) as compared to incorporation at 30 DBS (556.20 kg ha^{-1}), which is 3.60% higher. Application of forest litter at 3, 6 and 9 t ha^{-1} showed a significant increase in available nitrogen by 4.69, 11.44 and 29.69%, respectively as compared to the control plot. The highest level of nitrogen content was observed in D_1F_3 (669.53 kg ha^{-1}), where forest litter was applied at 45 DBS @ 9 t ha^{-1}, while the lowest value was obtained from control plot (490.60 kg ha^{-1}). The increase in available nitrogen in soils at 45 DBS could be due to the incorporation of the forest litter prior to the other treatments, which resulted in more microbial activity then the rest of the treatments, consequently it may have lead to improve the nitrification process. Bahadur *et al*. (2013) reported similar findings on incorporation of organic matter to the soil.

3.1.3. Available phosphorus: The level of phosphorus content in control was found to be 20.37 kg ha^{-1}, while it was 22.96 kg ha^{-1} in F_1 i.e., where forest litter was applied at 3 t ha^{-1}, 24.65 kg ha^{-1} in F_2 where forest litter was applied @ 6 t ha^{-1} and 25.40 kg ha^{-1} in F_3 i.e., where forest litter was applied @ 9 t ha^{-1}. In the interaction of the two factors, the maximum level of phosphorus was observed in D_1F_3 (25.31 kg ha^{-1}) i.e., where forest litter was applied @ 9 t ha^{-1} at 45 DBS, while the minimum level was seen in control (20.14 kg ha^{-1}). Irrespective of different amount of forest litter application there was significant increase in the available phosphorus whereas the interaction of time and dose of application treatments were found to be non-significant. Bahadur *et al.* (2013) reported similar improvement in the soil available phosphorus when higher level of crop residues was added.

3.1.4 Available potassium: On application of forest litter at 45 DBS, the available potassium content in the soil was comparatively higher by 0.65% (D_1 @ 163.73 kg ha^{-1}) than when forest litter was applied at 30 DBS (D_2 @ 162.67 kg ha^{-1}). The highest level of available potassium content was found in D_1F_3 (193.09 kg ha^{-1} while, the minimum value was recorded from control (137.88 kg ha^{-1}). Addition of forest litter showed a significant increase in available potassium over control. Also, the available potassium was found to be higher than F_0 by 11.36, 20.80 and 37.65% in F_1, F_2 and F_3, respectively. The increase in available potassium was because the organic sources usually tend to have a large cation exchange capacity which enables them to retain K^+ effectively. Therefore, when higher dose of organic materials was added to the soil, higher levels of available potassium were observed over control which is support of the findings of Surekha *et al.* (2004).

3.2 Effect of forest litter on physico-chemical properties of soil

3.2.1. Soil pH: The pH of the soil increased with the increase in the dose of application of forest litter, and was recorded in the range of 4.98 to 5.28. However, no significant variation was observed between D_1 and D_2. The plot where forest litter was incorporated @ 9 t ha $^{-1}$ showed a significant increase in pH by 4.59% as compared with the control plot. Also, an increase in pH at a rate of 1.8 and 2.99% was observed where forest litter was incorporated @ 3 and 6 t ha^{-1}, respectively. The highest pH was observed in D_1F_3, where forest litter was incorporated at 45 DBS at the rate of 9 t ha^{-1}, while the lowest pH was recorded from controlled plot, however in the treatment combinations there was no significant increase or decrease in soil pH. Noble *et al.* (1996) also stated that addition of leaf litter increased the soil pH in acidic soil. Significant increase in soil pH on addition of forest litter burned and FYM was also reported by Humtsoe and Chauhan (2005). More (1994) and Dutta *et al*. (2013) reported similar improvements in the pH with the incorporation of organic residues.

3.2.2. Cation exchange capacity (CEC): D_1 i.e., where forest litter was applied at 45 DBS was observed to have slightly higher CEC [(17.98 c mol (p$^+$) kg^{-1})] as compared to that of D_2, where the forest litter was applied just 30 DBS [(17.63 c mol (p$^+$) kg^{-1})]. In comparison to control plot, higher value of CEC was observed when forest litter was applied @ 3, 6 and 9 t ha^{-1}, and the increase was found to be by 8.19, 15.86 and 27.79%, respectively. Also, the maximum CEC was observed when forest litter was applied @ 9 t ha^{-1} at 45 days before sowing [(20.48 c mol (p$^+$) kg^{-1})], while it was minimum in control [(15.55 c mol (p$^+$) kg^{-1})]. Though, there was significant increase in different doses of application of forest litter, CEC did not show any significant difference in the Factor-1 and treatment combinations. The increase in CEC of the soil maybe due to the rise in humus content which is caused by the decomposition of organic matter i.e. forest litter, that leads to increase in the negative charge on the organic colloid of the soil, which in turn contribute to the rise in cation exchange capacity of the soil. Similar findings were reported by Babhulkar *et al*. (2000) and Selvi *et al*. (2003) who stated that application of NPK fertilizers along with organic residues cause increase in CEC of soil.

3.2.3. Bulk density (g cm^{-3}): D_1 showed slightly lower bulk density (1.05 g cm^{-3}) than D_2 (1.06 g cm^{-3}). The bulk density of the soil was found to be 1.10 g cm^{-3} (F_0) in control plot, followed by 1.07, 1.04 and 0.99 gcm^{-3} in F_1, F_2 and F_3, respectively. It was observed that, with the increase in the addition of forest litter, the bulk density decreased rapidly at the rate of 2.73, 5.45 and 10.00% when forest litter was incorporated @ 3, 6 and 9 t ha^{-1}, respectively. It was observed that with the addition of forest litter, the bulk density of the soil decreased significantly. The decrease in bulk density could be due to the increase in organic C content of the soil. Similar records were also indicated by Bajpai *et al*. (2006), who reported that application of crop residue as a substitute of N significantly reduced the bulk density of the soil. Celik (2005), reported similar decline in bulk density with the addition of organic matter into the soil.

3.3 Effect of forest litter on growth, yield and yield attributes of upland rice

3.3.1. Plant height: At 30 days after sowing, D_1 showed a higher plant height (37.25 cm) than D_2 (37.07 cm), a difference of 0.49%. Also, a significant increase in plant height was observed when higher dose of forest litter was applied. Plant height was highest when forest litter was applied at a rate of 9 t ha^{-1} at 45 days before sowing (41.91 cm) while it was lowest when application of forest litter was fully avoided i.e., control (32.46 cm). The rate of increase in plant height with respect to the controlled plot was found to be 9.56, 19.10 and 28.35% when forest litter was added @ 3, 6 and 9 t ha^{-1}.

At 60 days after sowing, application of forest litter @ 3, 6 and 9 t ha^{-1} showed a significant increase in plant height by 10.33, 18.84 and 26.12%, when compared with the controlled plot. At 90 days after sowing, it was observed that D_1 was at a plant height of 101.42 cm while D_2 was observed to have a plant height of 101.40 cm. With respect to the controlled plot (95.99 cm), the plant height was seen to be at 98.41, 102.44 and 108.79 cm when forest litter was applied at 3, 6 and 9 t ha^{-1}, showing a significant increase rate of 2.52, 6.72 and 13.33% respectively.

Maximum plant height was observed in D_1F_3 i.e., when forest litter was applied at a rate of 9 t ha^{-1} at 45 days before sowing (109.83 cm) while it was minimum when application of forest litter was fully avoided i.e., controlled (95.78 cm). It was observed that, with the increase in the addition of forest litter, the plant height increased proportionately i.e., $F_0<F_1<F_2<F_3$. This increase in plant

height could be due to the higher dose of application of forest litter. Adekiya *et al.* (2019) reported that the incorporation of organic matter in the soil increases the plant height. Dass *et al*. (2009) also opined that application of 50.00% of recommended dose of fertilizer along with organic matter showed the highest plant height of upland rice.

3.3.2. Number of tillers plant^{-1}: The number of tillers was recorded to be in the range of 3.13 - 4.75 in the treatment combinations. Maximum number of tillers was observed in D_1F_3 (4.75 tillers) while it was minimum in control (3.13 tillers plant^{-1}). The number of tillers borne by the plants in F_1, F_2 and F_3 where forest litter was applied @ 3, 6 and 9 t ha $^{-1}$ was recorded to be 3.63, 4.19 and 4.56 on an average while it was 3.19 in control. The rate of number of tillers with respect to the controlled plot was recorded to be higher by 13.79, 31.35 and 42.95%, respectively. Lubis *et al.* (2020) also corroborated that provision of organic material increased the number of tillers in upland rice in Cengkeh Turi Binjai. The above study was also supported by Ginting *et al.* (2014) as they concluded that soil tillage 2 times with 5 t ha^{-1} of organic matter gave the highest effect on the number of tillers per hill.

3.3.3. Grain yield (t ha^{-1}): It was observed that D_1 i.e., when forest litter was applied at 45 DBS gave a higher grain yield (2.57 t ha^{-1}) than D_2 i.e., forest litter was applied just 30 days before sowing (2.50 t ha^{-1}). Maximum grain yield was obtained when forest litter was applied @ 9 t ha^{-1} at 45 DBS (2.86 t ha^{-1}) while the lowest grain yield was obtained from control (2.23 t ha^{-1}). The present findings are in agreement with Sarwad *et al.* (2005) who cited that the increase in the grain yield could be due to the amalgamate effect of improvement in biological and physical properties of soil and nutrient supply. This was also supported by Eliartati *et al.* (2021) as they concluded that use of different kinds of compost to the soil enhances the growth and yield of upland rice. Similarly, Dass *et al.* (2009) also documented that the application of *Gliricidia, Azotobactor,* phosphate solubilising bacteria and 50.00% of recommended dose of fertilizer resulted in the highest grain and straw yield of upland rice.

3.3.4. Straw yield (t ha^{-1}): The straw yield ranged from 3.87-3.93 t ha^{-1} and 3.61- 4.32 t ha^{-1} in Factor-1 and Factor-2 respectively. In the interaction of the above factors, the highest straw yield was obtained when forest litter was applied @ 9 t ha^{-1} at 45 DBS (4.43 t ha^{-1}) while the lowest straw yield was obtained from control (3.59 t ha^{-1}). Application of forest litter at a rate of 3, 6 and 9 t ha^{-1} gave a significantly higher straw yield than control, and this rate of increase was found to be by 3.32, 9.70 and 19.67%. This increased in the straw yield could be attributed to the higher dose of application of organic matter which helped in increasing the plant biomass production. It was also observed that application of forest litter at a rate of 3, 6 and 9 t ha^{-1} gave a higher grain yield than control, and this rate of increase was found to be by 6.09, 12.17 and 22.17%, respectively. This increased in the straw yield could be attributed to the higher dose of application of organic matter which helped in increasing the straw yield. Biswal *et al.* (2021) also opined that application of organic matter (FYM and poultry manure) showed the highest straw yield.

4. Conclusion

The early incorporation of forest litter aids in increasing the soil fertility status, improves the physico-chemical properties and provides good condition for plant growth resulting is better yield. Early addition of forest litter before sowing provides enough time for the organic matter to decompose which serves as the source of nutrients. Addition of forest litter year after year shows a promising effect in maintaining the soil fertility and providing residual nutrient benefits to the crops. Therefore, early and higher dose of application of forest litter along with proper management practices holds a promising future for upland rice cultivation.

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Table 1. Effect of time and dose of application of forest litter on organic carbon, available nitrogen, available phosphorus, available potassium, soil pH, cation exchange capacity and bulk density

Treatments	*Organic carbon (%)*	*Available Nitrogen (kg ha^{-1})*	*Available Phosphorus (kg ha^{-1})*	*Available Potassium (kg ha^{-1})*	*Soil pH*	*Cation exchange capacity [c mol (p^{+}) kg^{-1}]*	*Bulk density (g cm^{-3})*
Days before sowing							
D_1: 45 DBS	3.16	577.80	23.17	163.73	5.11	17.98	1.05
D_2: 30 DBS	3.19	556.20	23.52	162.67	5.14	17.63	1.06
SEm±	*0.03*	*2.51*	*0.06*	*1.05*	*0.02*	*0.11*	*0.01*
CD (P=0.05)	*NS*	*11.31*	*NS*	*NS*	*NS*	*NS*	*0.02*
Dose of application							
F_0 (Control)	2.99	502.45	20.37	138.95	5.01	15.76	1.10
F_1: (3 tha^{-1})	3.12	534.68	22.96	154.73	5.10	17.05	1.07
F_2: (6 tha^{-1})	3.18	565.26	24.65	167.85	5.16	18.26	1.04
F_3: (9 tha^{-1})	3.41	665.61	25.40	191.27	5.24	20.14	0.99
SEm±	*0.04*	*3.64*	*0.12*	*1.06*	*0.04*	*0.19*	*0.00*
CD (P=0.05)	*0.12*	*10.80*	*0.35*	*3.16*	*0.11*	*0.56*	*0.01*

Table 2. Interaction effects of time and dose of application of forest litter on organic carbon, available nitrogen, available phosphorus, available potassium, soil pH, cation exchange capacity and bulk density

Treatments	*Organic carbon (%)*	*Available Nitrogen (kg ha^{-1})*	*Available Phosphorus (kg ha^{-1})*	*Available Potassium (kg ha^{-1})*	*Soil pH*	*Cation exchange capacity [c mol (p^{+}) kg^{-1}]*	*Bulk density (g cm^{-3})*
D_1F_0	2.99	514.30	20.14	140.01	4.98	15.96	1.09
D_1F_1	3.07	542.52	22.68	154.73	5.08	16.99	1.07
D_1F_2	3.16	584.86	24.57	167.07	5.13	18.48	1.04
D_1F_3	3.42	669.53	25.31	193.09	5.28	20.48	0.99
D_2F_0	3.00	490.60	20.61	137.88	5.05	15.55	1.11
D_2F_1	3.17	526.84	23.25	154.72	5.13	17.12	1.08
D_2F_2	3.21	545.66	24.73	168.63	5.20	18.05	1.05
D_2F_3	3.40	661.69	25.27	189.45	5.20	19.80	1.00
SEm±	*0.06*	*5.14*	*0.17*	*1.50*	*0.05*	*0.27*	*0.01*
CD (P=0.05)	*0.17*	*15.27*	*NS*	*4.47*	*NS*	*NS*	*0.02*

Table 3. Effect of time and dose of application of forest litter on plant height of rice and number of tillers per plant

Treatments	*Plant height (cm)*			*Number of tillers plant^{-1}*
	30 DAS	*60 DAS*	*90 DAS*	
Days before sowing				
D_1: 45 DBS	37.25	72.57	101.42	3.97

D_2: 30 DBS	37.07	72.44	101.40	3.81
SEm±	*0.10*	*0.30*	*0.69*	*0.08*
CD (P=0.05)	*0.46*	*1.35*	*3.11*	*0.34*
Dose of application				
F_0 (Control)	32.52	63.70	95.99	3.19
F_1: (3 tha^{-1})	35.63	70.28	98.41	3.63
F_2: (6 tha^{-1})	38.73	75.70	102.44	4.19
F_3: (9 tha^{-1})	41.74	80.34	108.79	4.56
SEm±	*0.14*	*0.25*	*0.36*	*0.10*
CD (P=0.05)	*0.41*	*0.75*	*1.07*	*0.29*

Table 4. Interaction effect of time and dose of application of forest litter on plant height of rice and number of tillers per plant

Treatments	***Plant height (cm)***			***Number of tillers plant^{-1}***
	30 DAS	***60 DAS***	***90 DAS***	
D_1F_0	32.46	64.14	96.20	3.13
D_1F_1	35.84	69.55	98.64	3.50
D_1F_2	38.78	75.91	101.00	4.25
D_1F_3	41.91	80.68	109.83	4.75
D_2F_0	32.57	63.25	95.78	3.25
D_2F_1	35.42	71.00	98.19	3.25
D_2F_2	38.69	75.50	103.88	4.13
D_2F_3	41.58	80.00	107.75	4.38
SEm±	*0.20*	*0.36*	*0.51*	*0.13*
CD (P=0.05)	*0.59*	*1.06*	*1.51*	*0.37*

Table 5. Effect of time and dose of application of forest litter on grain and straw yield of upland rice

Treatments	***Grain yield (t ha^{-1})***	***Straw yield (t ha^{-1})***
Days before sowing		
D_1: 45 DBS	2.57	3.93
D_2: 30 DBS	2.50	3.87
SEm±	*0.02*	*0.04*
CD (P=0.05)	*0.07*	*0.20*
Dose of application		
F_0 (Control)	2.30	3.61
F_1: (3 tha^{-1})	2.44	3.73
F_2: (6 tha^{-1})	2.58	3.96
F_3: (9 tha^{-1})	2.81	4.32
SEm±	*0.02*	*0.03*
CD (P=0.05)	*0.05*	*0.10*

Table 6. Interaction effects of time and dose of application of forest litter on grain and straw yield of upland rice

Treatments	*Grain yield (t ha^{-1})*	*Straw yield (t ha^{-1})*
D_1F_0	2.36	3.64
D_1F_1	2.46	3.75
D_1F_2	2.60	3.92
D_1F_3	2.86	4.43
D_2F_0	2.23	3.59
D_2F_1	2.42	3.70
D_2F_2	2.57	4.01
D_2F_3	2.77	4.21
SEm±	*0.02*	*0.05*
CD (P=0.05)	*0.07*	*0.14*