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Potentiality of Organic Rice Production Fertilized with Different Agroforestry Tree Leaf Litter in Northern Bangladesh

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Authors' contributions

This work was carried out in collaboration between all authors. All the authors are involved in literature searching, designing the study, protocols and write up of the manuscript. All authors read and approved the final manuscript.

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ABSTRACT

This paper provides information on eco friendly rice production using tree leaf biomass as a source of organic fertilizer. The experiment was conducted in Agroforestry Research Farm, Hajee Mohammad Danesh Science and Technology University, Dinajpur, Bangladesh to evaluate the response of different leaf litter biomass of different agroforestry species on the yield of rice (BRRI DHAN 49). The experiment includes 10 different treatments i.e. T_0 (recommended doses of chemical fertilizer), T_1 (100 g of *Albizia*), T_2 (200 g of *Albizia*), T_3 (300 g of *Albizia*), T_4 (100 g of *Leucaena*), T_5 (200 g of *Leucaena*), T_6 (300 g of *Leucaena*), T_7 (100 g of *Melia*), T_8 (200 g of *Melia*) and T_9 (300 g of *Melia*). The experiment was conducted following Randomized Complete Block Design (RCBD) with three replications. The result of the experiment revealed that, highest yield (5.66 tha^{-1}) was recorded in T_0 (recommended doses of chemical fertilizer). Among the treatments with leaf biomass, maximum yield was recorded in T_3 (300 g of *Albizia*) 5.23 tha^{-1} followed by

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5.04 tha^{-1} in T_6 (300 g of *Leucaena*). Although, the yield was maximum with inorganic fertilizer but rice can be cultivated successfully with leaf biomass as a low cost environment friendly sustainable production system.

Keywords: Organic production; agroforestry; leaf litter; rice; Bangladesh.

1. INTRODUCTION

Agriculture is the basic livelihood of people in northern part of Bangladesh. Rice is the major staple food of the region. Rice is generally cultivated with chemical fertilizer is a very little use of organic and/or green manure. As a result soil acidification, emission of methane gas, nutritional imbalance including micronutrient deficiency and degradation of soil occurred due to low organic matter of soil. Presently organic matter in the soil of Bangladesh is very poor [1]; although organic matter acts as a reservoir of plant nutrients especially N, P, K and S and prevents leaching of the nutrients [2].The ever decreasing organic matter content in our soils causes' reduction in yield and environmental imbalance. It is believed that eco friendly organic farming can solve many of these problems as this system is believed to maintain soil productivity and pest control and environmental balance by enhancing natural processes and cycles in harmony with environment. Enhancement and maintenance of system productivity and resource quality is essential for sustainable eco friendly agriculture. Hence, agroforestry can play an effective role for combating with the existing problem. Agroforestry systems like alley cropping increase soil fertility by application of biomass to the soil through the input of nutrient and organic matter [3]. Plantations of multipurpose trees alone or combined with agricultural crops could be an effective land rehabilitation strategy [4-6]. One of the main tenets of agroforestry is that trees maintain soil fertility. This hypothesis is based partially on studies of the efficient transfer of nutrients from litter to trees in natural ecosystems. Decomposition and subsequent nutrient release from the leaves, twigs and roots may have an important influence on the organic matter and the nutrient budget of the soil [7]. Litter production, decomposition and nutrient release patterns determine the potential of tree species to improve soil fertility and productivity in degraded lands. Litter production from plants, particularly trees, is a major source of organic matter and energy to soil and is important for nutrient cycling. Leaf biomass that falls from the trees as litter considered as an important factor contributing to soil fertility. It is a very important organic source of soil fertility improvement.

Decomposition of tree leaf litter is an integral and significant part of biochemical nutrient cycling and food webs of floodplain agroforestry system. Nutrients may be released from leaf litter by leaching or mineralization [8]. Leaf litter plays a fundamental role in the nutrient turnover and in the transfer of energy between plants and soil, the source of the nutrient being accumulated in the upper most layers of the soil [9]. Plant litter produced during senescence processes and plant residues left on site after harvest operations are the primary substrate for heterotrophic respiration in plant-soil ecosystems. Substrate quality, together with the physico-chemical environment and the decomposer community, is one of the three interacting factors regulating the rate of decomposition. The decomposition of leaf litters influence the amount of N availability for plant uptake. Leaf litter supplies the carbon, nitrogen, phosphorus, potassium and other nutrients in soil that are further considered as important indicators of soil productivity and the ecosystem health. Moreover, this leaf litter has been wastage by several ways. So, if we can utilize these materials as a source of organic matter for rice cultivation, then we can reduce the considerable amount of chemical fertilizer like urea. Moreover, Rice (*Oryza sativa, L.)* is the principle food of Bangladesh and it is the world's second important food grain. In Bangladesh it is cultivated throughout the year as Aush, Aman and Boro. In 2011-12, the total rice cultivation area was 28.48 million acre and the production was 33.89 million metric ton. So, the integration of agroforestry in organic rice production is uncommon, creating a significant opportunity for research to assist farmers in this underdeveloped strategy.

2. MATERIALS AND METHODS

2.1 Experimental Site

The experiment was conducted in the Agro-forestry Research Farm, Hajee Mohammad Danesh Science and Technology University (HSTU), Dinajpur, Bangladesh during July-

November, 2013. The experimental plot was in a medium high land belonging to the old Himalayan Piedmont Plain Area [10]. The site was between 25º 13´ latitude and 88º 23´ longitude, and about 37.5 m above the sea level. The soil was sandy loam having pH 5.5 to 6.0. Organic matter content of the soil was 1.06 per cent. The soil content 0.10% total nitogen, 24.0 µg/g phosphorus and 0.26 meq/100 g potassium.

2.2 Experimental Materials

Rice variety BRRI DHAN 49 was used as a test crop. It is a high yielding variety of rice cultivated throughout the country. The variety was released by Bangladesh Rice Research Institute (BRRI) in 2008. Consequently, leaf biomass of *Albizia lebbeck*, *Leucaena leucocephala* and *Melia azedarach* are uses as a source of organic fertilizer. The *Albizia* leaves are bippinate in nature, slightly hairy on the axis. Leaves content 2-4 pairs of pinnae having oblong leaflets. Again, the *Leucaena* leaves are also bipinnate in nature having 4-9 pairs of pinnae. Leaves are linear oblong to weakly elliptic and leaflets fold up with head. While the *Melia* leaves are *bipinnate* or *tripinnate*, 3-7 leaflets in each pinnae. Therefore, the experiment was designed following Randomized Complete Block Design (RCBD) with three replications. These three tree species are widely planted as a woody component in all over Bangladesh. The experiment includes 10 different treatments i.e. T_0 (recommended doses of chemical fertilizer), T_1 (100 g of *Albizia* leaf biomass), T_2 (200 g of *Albizia* leaf biomass), T_3 (300 g of *Albizia* leaf biomass), T_4 (100 g of *Leucaena* leaf biomass), T_5 (200 g of *Leucaena* leaf biomass), T_6 (300 g of *Leucaena* leaf biomass), T_7 (100 g of *Melia* leaf biomass), T_8 (200 g of *Melia* leaf biomass) and T_9 (300 g of *Melia* leaf biomass). Again, the leaf biomass of the trees was collected from the trees of HSTU campus and the litter of the trees was collected from the alley cropping model in Agroforestry Research Farm. These leaf biomass and litter of each trees was mixed thoroughly and chopped by hand. These chopped materials were then mixed uniformly with soil during final land preparation and then left to decompose for ten days. In T_0 treatment, recommended doses of chemical fertilizer were applied. The doses of NPKS was 30, 5, 20, 4 kgha^{-1} [11]. The unit plot size was 1 m x 1 m. The spacing between blocks was 100 cm and the plots were separated from each other by 50 cm space. Thirty days old seedlings were planted in 20 July, 2013 with a spacing of 15 cm × 20 cm. In each plot, 2-3 healthy seedlings per hill were planted. Intercultural operation was performed as and when needed. Among the two rice growing season (Rabi and Kharif) in Bangladesh, one season depend on the natural rainfall and another season depend on the irrigation. In this experiment, BRRI DHAN 49 was cultivated under rainfall condition. Perching was given in each plot to control insects biologically. The rice plants were harvested on 29 November, 2013.

2.3 Data Collection and Analysis

The data were collected on plant height, number of effective tiller, panicle length, number of grains per panicle, 1000 grain weight and yield. The collected data were then subjected to analysis with computer package MSTAT-C and the mean differentiation was performed following Duncan's Multiple Range Test (DMRT) and ranking was indicated by letters [12].

3. RESULTS AND DISCUSSION

Leaf litter biomass of different trees significantly influences the growth and yield contributing characters of rice (BRRI DHAN 49). Among the different treatment, plant height varies significantly. Maximum plant height of rice (106.0 cm) was recorded in the treatment T_0 (recommended doses of chemical fertilizer) followed by in the treatment T_3 (103.7 cm) i.e. fertilized with 300 g of *Albizia* leaf biomass, T_1 and T_2 (102.5 cm and 102.4 cm). However, the minimum plant height (98.17 cm) was recorded in the treatment T_8 (200 g of *Melia* leaf biomass) which is statistically identical with the treatment T_7 (98.92 cm). Again, in case of number of effective tiller hill^{-1}, significantly highest number of tiller (12.64) was found in the treatment fertilized with recommended doses of chemical fertilizer i.e. T_0, followed by in the treatment T_3, T_1 and T_2 (12.29, 12.07 and 12.05). While, the lowest number of effective tiller hill^{-1} (9.91) of rice was recorded in the treatment T_7 (100 g of *Melia* leaf biomass). Abdullah, et al. [13] found highest number of effective tiller with the application of *Leucaena* leaf litter along with chemical fertilizer . Moreover, panicle length of rice varies significantly with respect of different treatments. Maximum length of panicle (24.91 cm) was observed in the treatment where rice was fertilized with chemical fertilizer i.e. T_0, which was statistically identical with the treatment T_3 (24.70 cm) followed by in T_1 and T_2 (23.19 cm and 23.15 cm) whereas the minimum length of panicle was recorded in T_8 i.e. fertilized with

200 g of *Melia* leaf biomass. The growth and yield contributing characters were highest when balanced inorganic fertilizers were applied. Rahman et al. [14] found similar result in case of boro rice with teak leaf biomass.

Significantly, maximum number of grains panicle^{-1} was (120.0) in T_0 followed by in T_3 (117.3) and minimum was recorded in T_8 (99.0) which was statistically identical with the treatment T_9. However, in case of 1000 grain weight highest grain weight (23.82 gm) was recorded in T_0 and the lowest grain weight was recorded in T_9 (300 g of *Melia* leaf biomass). Among the different treatment, the grain weight was found non significant.

The yield of rice (BRRI DHAN 49) varied significantly with different fertilizer treatment. Application of recommended doses of chemical fertilizer gave the highest yield (5.66 t ha^{-1}) i.e. in T_0 followed by in T_3, T_6 and T_1 (5.23 t ha^{-1}, 5.04 t ha^{-1} and 4.94 t ha^{-1}). The lowest yield was recorded in T_7 (3.62 t ha^{-1}). This result may be due to the leguminous character of the species which helps to fix atmospheric nitrogen to the soil and the leaf litter biomass added to the soil decomposed quickly and add organic matter to the soil, which ensures maximum production.

Plant residue with low C: N ratio, lignin and polyphenol content, decomposed and released nutrient faster. Woody species with high nitrogen content, ash and acid detergent cell wall decomposes rapidly [15]. The deciduous nature of the tree also ensures maximum penetration of sunlight to the soil. As a result maximum photosynthesis occurred which also ensures maximum production. *A. lebbek*, *A. nepalensis*, *D. sissoo* and *F. glomerata* considered as suitable species for rapid recovery of degraded lands as their litter decomposed faster than *B. rugulosa* and *F. roxburghii* [16]. *Albizia* leaves decomposing rapidly than from *Cordia* leaves, suggesting that a high polyphenol content does not necessarily retard decomposition [17]. *Azadirachta* biomass of 300 gm gave maximum yield in case of rice variety BR11 [18]. Out of the nine agroforestry species studied in India, litters of *Leucaena* decomposed quickly and completely. They also found that, initial litter N concentration was highest (3.33%) in *Leucaena* [19]. *L. leucocephala* when it was incorporated into soil as a green manure and mulch decomposed rapidly and shows greater N recovery [20]. Similar results have been obtained with a large number of species with both high and low quality biomass [21]. Overall the greatest challenge is to develop ways of managing the decomposition rates of organic matter to optimize rates of short- and long-term nutrient release, and to maintain soil organic matter.

Manipulation of residue quality by mixing resources from different tree species is one way in which this might be achieved. The highest yield obtained with recommended doses of chemical fertilizer was only 8, 12 and 14% higher than those fertilized with Albizia and Leucaena biomass.

Table 1. Effect of tree leaf litter biomass on plant height and yield contributing characters of BRRI DHAN 49

Treatment	Plant height (cm)	No. of effective tillers hill^{-1}	Panicle length (cm)	Numbers of grains panicle^{-1}	1000 grain weight (gm)
T_0	106.0 a	12.64 a	24.91 a	120.0 a	23.82
T_1	102.5 c	12.07 c	23.15 b	112.0 cd	23.78
T_2	102.4 c	12.06 c	23.19 b	110.7 d	23.71
T_3	103.7 b	12.29 b	24.70 a	117.3 b	23.80
T_4	100.4 d	11.52 e	21.64 c	108.7 e	23.70
T_5	100.1 de	11.64 de	21.79 c	108.3 e	23.72
T_6	101.9 c	11.75 d	21.87 c	112.7 c	23.79
T_7	98.92 ef	9.91 h	21.08 d	103.7 f	23.69
T_8	99.17 f	10.30 g	20.53 e	99.00 g	23.72
T_9	99.97 de	10.80 f	21.69 c	105.0 f	23.67
Level of Significance	**	**	**	**	NS

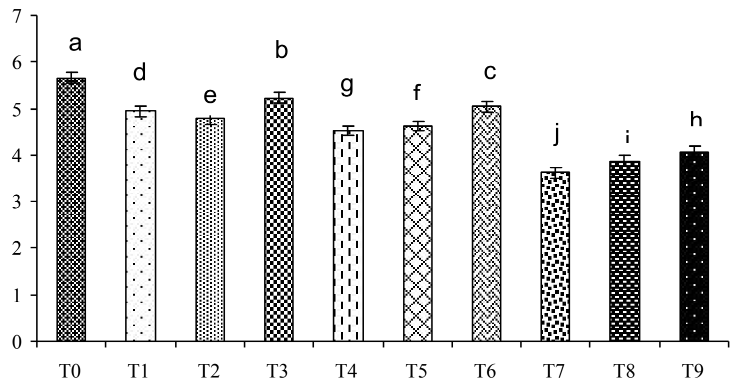

Fig. 1. Showing yield (t ha^{-1}) of BRRI DHAN 49 influenced by different leaf litter biomass and chemical fertilizer

Though the recommended fertilizers treatment gave the best performance but residual effect in soil is negative and also decreases the future productivity of soil. Our observation is similar with the findings of [22]. They reported 5,9,11 and 14% higher yield when fertilized with teak leaf biomass compared to recommended doses of fertilizer.

4. CONCLUSION

Agroforestry tree species used in this study are capable of contributing substantial quantities of organic matter as litter. Since fertilizer - an essential input for rice production in Bangladesh - is very expensive and out of reach of the small-scale farmers, available low-cost organic fertilizer (leaf biomass of *Albizia* and *Leucaena*) is recommended to increase food production and to ensure the food sufficiency of the country. This valuable resource must be sourced locally to minimize the needs for expensive inorganic fertilizer. So, organic production of rice (BRRI DHAN 49) with different leaf litter biomass would be viable, sustainable and eco friendly production system.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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