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RESPONSE OF UPLAND RICE LANDRACES TO FERTILIZERS IN SHIFTING CULTIVATION: RATE AND APPLICATION METHODS

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ABSTRACT

Shifting cultivation, popularly known as jhum farming is the dominant crop production system that the resource-poor upland farmers have been practicing in the Chattogram Hill Tracts (CHT) of Bangladesh and mountainous areas in Southeast Asia over centuries. Upland rice is the major component of shifting cultivation. Farmers plant landraces of upland rice usually applying no or low rates fertilizers resulting in poor yield. In view of shifting cultivators' dependence on rice production for household food security the increase in grain yield of upland rice under shifting cultivation is imperative. We evaluated the yield response of two upland rice landraces – Gunda and Maemonsing in shifting cultivation conducting on-farm participatory trials applying medium (40:10:20 kg NPK ha^{-1}) and high (80:20:40 kg NPK ha^{-1}) fertilizer rates along with fertilizer placements. We also estimated greenhouse gas emissions based on Cool Farm Tool Beta-3. Grain yield varied between 193 to 420 kg ha^{-1} in Gunda, and between 366 and 3,877 kg ha^{-1} in Maemonsing across farmers' plots and fertilizer rates. Rice grain yield increased progressively with fertilizer application in both the landraces, though the two landraces Gunda and Maemonsing differed a little in grain yields across fertilizer rates. Variation in yield due to fertilizer application was statistically significant but the interaction between fertilizer rates and landraces on rice yield was not statistically significant. In the second experiment using the landrace Gunda with high rate of fertilizers, basal application of whole amounts of P & K and 50% at planting and topdressing of the remaining 50% N 45 days after planting gave the highest yield (2,928.8 kg ha^{-1}) compared with other fertilizer placement techniques. Landraces differed a little in GHG emission, but fertilizer application accelerated GHG emission. Averaged over landraces, GHG emission was 4.22 times higher with high rates of fertilizer application compared with rice grown without applied fertilizers. More studies are needed for crop yield improvement and GHG measurement in hilly regions of Bangladesh.

Keywords: Shifting cultivation, upland rice, landraces, fertilizer rate and methods, grain yield, GHG emission.

Introduction

Rice is an important crop globally covering an area of 162.90 million ha producing 156.5 million tons of processed rice in tropical and temperate regions (USDA 2021). Over half of the world population depends on rice. Rice constitutes the major staple in Bangladesh and covers over 80% of the country's total cropped land (11.42 million ha) producing 36.60 million tons annually (BBS 2021). Rice provides nearly two-thirds of daily calorie intake of Bangladesh population. Rice is grown in three seasons a year - aus, aman and boro. Grown with irrigation boro rice enjoys most favored weather while aman is grown in monsoon mostly under rainfed condition. All the three rice ecotypes are grown in lowland ecosystem (Garrity *et al*. 1978) in floodplains of Bangladesh. In the Chattogram Hill Tracts (CHT), located in southeastern corner of Bangladesh comprising Bandarban, Khagrachari and Rangamati districts, upland rice is grown in shifting cultivation.

In this rugged mountainous region farmers grow upland rice in the sloping uplands without irrigation depending on natural rainfall. Unlike lowland ecosystems in the plains and hills, farmers grow indigenous rice varieties in shifting cultivation, popularly known as *jhum*, in the mountainous terrain (Hamid *et al.* 2021). Upland rice is also the major component in shifting cultivation in northeast states of India (Kithan 2014) and Southeast Asian countries (Roder 2001; Pandey and Minh 1998). Shifting cultivation is a

traditional farming practice that tribal farmers have been following for centuries. The practice is practically a form of rotational crop growing where farmers clear secondary forest and bushes (Choudhury *et al*. 2021) by slashing and burning before dibbling seeds of several crops without land tillage. Gafur (2001) and Chakma and Ando (2008) provide details of shifting cultivation in the CHT. Practices of shifting cultivation vary across tribes and communities and geographical regions (Thrupp *et al*. 1997).

In the CHT, shifting cultivation is practiced by resource-poor tribal farmers primarily for household food security (Nath *et al*. 2005, Chakma and Ando 2008, Grogan *et al*. 2012, Bos *et al.* 2020, Nahar *et al.* 2020). Farmers grow a wide range of crops including food crops, vegetables, spices and condiments, and cash crops are grown in the shifting cultivation although rice dominates in the system. In absence of suitable high yielding varieties, farmers use upland rice landraces with low and variable yield potentials (Zonayet and Paul 2020, Hamid *et al.* 2021). Increased demand for food and other agricultural produces in the CHT due to rising population, demographic changes and improved livelihood strategies requires to be met through increasing production either through crop intensification or by raising yield, or both. In the sloping uplands, expansion of cropped area is not possible, nor can crop intensification be introduced to the extent that lowland farmers practice. Hence, raising the crop yields, particularly of rice could be a viable option. Throughout the humid tropics shifting cultivation is in transition (Van Noordwijk *et al.* 2008, Chaudhury *et al*. 2021). Fallow period between two cycles of shifting cropping has decreased from 10 or more years to 2-3 years during recent years resulting in yield decline (Borggaard *et al.* 2003, Wapongnungsang *et al.* 2021) and raising environmental concern (Chakma and Nahar 2012). Experiencing yield decline due to shortening of the fallow period between crop cycles in the shifting cultivation, some farmers are reported to have been using of fertilizers at low and disproportionate rates. Adverse effects of applying disproportionate or inappropriate rate of fertilizers on crop yield and soil are well documented (Mutert and Fairhurst 2002).

Agronomic technologies that triggered quantum jump in lowland rice production (Tionco and Hossain 2015) in the plains are not suitable for upland farming in shifting cultivation. Research on yield improvement evolving upland rice varieties or management practices have not been reported. Nor there any standard fertilizer recommendations for rice cultivation in shifting cultivation are available (BARC 2018). Yield variability in upland rice (Hamid *et al.* 2021) indicates scope of raising yields through improved management practices. Recent studies suggest positive response of indigenous rice varieties to fertilizer application both in lowland (Hamid *et al*. 2016, Mamun *et al*. 2018) and upland (Saito *et al*. 2006) ecosystems. Mahmud *et al.* (2018) reported rice yield improvement through agronomic management in shifting cultivation using moderate to high rates of fertilizers. In Nagaland (India) Chankija and Gohain (2020) demonstrated that grain yields differed from 1,421 to 2,638 kg per ha among indigenous varieties and from 1,441 to 2,259 kg per ha across fertilizer rates applied. A fertilizer dose of 60:30:30 NPK kg ha^{-1} resulted in yield increase by 34%. Similar information on varietal response to fertilizers and methods of application on upland rice yields have not been reported in Bangladesh. Apart from fertilizer application farmers are now increasingly using herbicides and pesticides. Use of these chemicals not only increases cost of production, but also enhances GHG emission from the crop fields (Haque *et al.* 2015). However, not much information is available on GHG emission from crop fields in hilly regions of the country.

In this study we explored the possibility of raising grain yields of two upland rice landraces conducting participatory on-farm experiments evaluating the response of rice landraces to variable rates and methods of fertilizer application in shifting cultivation. We also estimated GHG emission in relation to fertilizer rates and rice landraces.

Materials and Methods

The on-farm experiment was conducted in three mid-range hills in three villages (locally known *para)* – Hanshama para, Rajakhamar and Ramjadi para in Rowangchari subdistrict (upazila) of Bandarban district. 16 farmers belonging to Marma community, the dominating tribe in Bandarban, conducted the experiments on their land parcels distributed in mid-range hills. The villages are located between 22°19’ and 22°21’ N latitude and 92°25 and 92°27’ E longitude. Elevation of the hills ranged between 136 m and 209 m above mean sea level, msl.

Climate in Bandarban is characterized by humid sub-tropical with distinct wet and dry seasons. Bandarban receives an average of 2,085 mm rainfall annually with significant inter-annual variability. Soils in the hills are largely silty clay loam with low water holding capacity (Broggaard *et al*. 2003, Osman *et al.* 2013). The

experiments were planted in the upper segment of the hill down to mid-hill. Apparently, the soil in the upper segment of the hills were light textured compared with mid-hill or at the base.

A total of 16 farmers of three villages participated in running the experiments. Twelve farmers planted the experiment on fertilizer response to two landraces of rice, and four farmers conducted the fertilizer application management experiment.

Experiment 1: Response of two upland rice landraces to applied fertilizers.

Treatments:

A. Two locally selected, farmers' adopted landraces of upland rice – (i) Gunda, and (ii) Maemonsing were used in the experiment. Landraces were used because neither high yielding varieties (HYVs) of upland rice are available, nor any farmer is reported to have adopted HYVs (Hamid *et al.* 2021).
B. Each of landraces was administered three levels of fertilizers – (O): no fertilizers applied; (M): medium 40:10:20, and (H): high- 80:20:40 kg NPK ha^{-1} in the form of urea, triple super phosphate (TSP), and muriate of potash (MoP), respectively. In absence of standard fertilizer recommendation for growing upland rice as sole crop or a component crop in shifting cultivation, we used a blanket rate of 80:20:40 kg NPK ha^{-1} as optimal or high dose (H).

Since the crops are grown without irrigation and given the incidence of rainfall uncertain, the whole amount of fertilizers was basally applied in both the treatments involving fertilizer application. Twelve farmers of Rajakhamar and Ramjadi para each having 0.22 ha parcel of land participated in running the experiment. Each land parcel was vertically split into two, and into three horizontally. Each of the vertically split parcel was taken as main plot and each of the three horizontal segments was considered sub-plot. The experiment was thus set up in a factorial split-plot design accommodating two rice landraces in the main plots, and three fertilizers treatments distributed randomly in the sub-plots. Each farmer's land parcel represented a replication.

Experiment 2: Effect of fertilizer application methods on rice yield in shifting cultivation.

Treatments: A blanket of fertilizers 80:20:40 kg NPK ha^{-1} was used differing in the methods of fertilizer application. The experiment comprised of four treatments:

M1: No fertilize application,

M2: No fertilizer application at planting; but band placement and incorporated 10 cm away from rows 9 days after planting following rain,

M3: Basal application of the whole amount of P&K, and 50% N and the remaining 50% N 45 days after planting, and

M4: basal application of the whole amount of fertilizers at planting.

The single factor experiment comprising four treatments was set up in a randomized block design. Four farmers in Ramjadi para and Rajakhamar participated in running the experiment. Each treatment was replicated four times considering each participating farmer's land parcel a replication.

Crop production methods: In both the experiments farmers followed similar practice in growing crops including rice in traditional shifting cultivation Agronomic management practices included land selection, land clearing, planting seeds, fertilizer and pesticide applications, and harvesting and hauling of crops. Almost all of the operations were done manually since mechanization in the sloping uplands has not been introduced yet. Crops were grown without irrigation depending on rainfall. Farmers started slashing the forest regrowth and bushes in the month of February 2019. Slashed bushes were left in the land parcel for sun-drying. In April prior to the onset of rain farmers started burning the slashed plants and bushes in the field and the ashes were manually spread in the field. Farmers started dibbling seeds when the topsoil was wet in middle of May 2019. This allowed seed germination and seedling establishment before the monsoon set in. Farmers had different sets of crops planted of their choice but upland rice dominated. Dry seeds of locally selected and adopted rice landraces specific to experiments were planted at 60 kg per ha in all the five land parcels following traditional shifting cultivation practices. Gunda is a relatively high yielding genotype while Maemonsing a moderately drought tolerant. In the traditional practice of shifting cultivation farmers maintain no row or definite planting configuration. Agronomic management for weed control was done manually. Invariably in all the land parcels, upland rice formed the dominant component of the system in terms of seeds planted and space occupied.

Color change of peduncle or panicle base from green to yellowing is indicative of rice maturity. But the tribal farmers traditionally harvest rice when the panicles and most leaves turn dry. Both the genotypes used in the experiments were tolerant to shattering and yield loss due to over-maturity was not apprehended. Delay in harvesting allows the farmers dry the grains in the standing crop and thus reduces post-harvest labor cost. Maemonsing was an early maturing genotype compared with Gunda. Maemonsing started maturity by early September, while Gunda matured by third week of September. Farmers harvested the crop cutting the panicles as their usual practice. Harvesting of rice completed by the first week of October.

Data collection: Immediately prior to harvest three samples, each measuring 15 m^2 from each land parcel. Plant density, and the number of panicles per sample area were counted at harvest. 10 panicles per sample were selected and data on the number of spikelets and filled spikelets were separated and counted. Each of the sample areas was harvested separately, panicles were threshed, grain weight and grain moisture content were recorded for individual treatment per treatment and replication (farmer). Sub-plots were harvested separately for recording grain yield and moisture content. Yields of sample areas (15 m^2) were added to the plot yields. Yields were adjusted at 13% moisture content and converted to kg ha^{-1}.

Cool Farm Tool version 2-beta-3 was used to determine total greenhouse gas (GHG) emission from two upland rice landraces grown in shifting cultivation with different fertilizer. GHG was estimated considering upland rice culture and residue incorporation/mulch at 3.0 t ha^{-1}. Growth durations for Gunda and Maemonsing were 120 and 110 days, respectively. As rice was grown in upland conditions, carbon dioxide and nitrous oxide emissions were the main GHG.

Data analysis: Grain yield and yield components of rice harvested from individual farmer's land parcel were collected and collated for statistical analysis. For data analysis and presenting data on the variation in grain yields across farmers' land parcels, and in relation to rates of fertilizers and method of application we used Box-Whisker plotting method. Analysis of variance (ANOVA) was, however, employed in analyzing data on yield components and means compared using LSD test in Experiment 2.

Results and Discussion

Experiments were conducted in three closely located hills that share similar soils and environmental conditions. Rainfall data were obtained from SCWMC, SRDI, Meghla, Bandarban, about 8 km west-southwest of the experimental locations. Bandarban district experienced unusually low rainfall in 2019 (Figure 1) receiving a total of 948 mm rainfall during January through October. The first rain (mm) occurred on 24 February with substantial rainfall in April and crop seeds were dibbled in May. Rainfall was low in the beginning of the season, peaked in July and progressively decreased thereafter. The accumulated rainfall in February through May (100

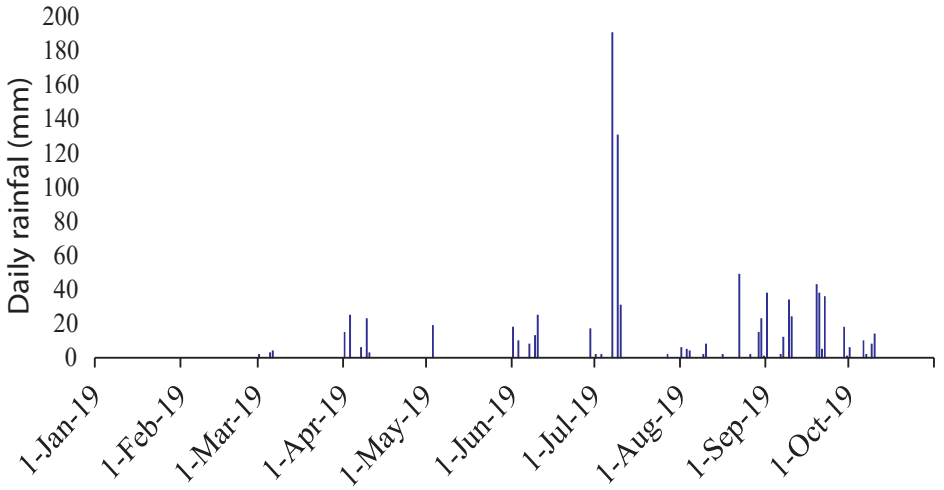


Figure 1. Rainfall (mm) in Bandarban, January -October 2019.

mm) might have supported seed germination but crop establishment suffered due to low rainfall in May-June when all the crops including rice were in vegetative phase. Most rain in the season came in July (359 mm) when rice passed through reproductive and spikelet development phases. However, there was no incidence of crop lodging mainly because of quick drainage of rainwater from the medium to steep sloping uplands.

Grain yield of both the rice landraces varied widely across farms ranging between 133 and 4,020 kg ha^{-1} depending on landraces and fertilizer application (Figure 2). The high variability of grain yields might be associated with variations in soil fertility gradients and soil texture in sloping hilly lands. Results on the effects of applied fertilizers on the grain yields of two rice landraces have been presented in Table 1. Application of fertilizers markedly increased grain yields of both the landraces. Rice grown without fertilizer application (control) produced the lowest grain yield. A high rate of fertilizers (80:20:40 kg NPK ha^{-1}) produced the highest yields which was closely followed by moderate rate (40:22.5:50 kg NPK ha-1), but the difference in yield between two fertilizer rates was slim (<9%). Averaged over fertilizer rates applied and across landraces, fertilizer application increased rice grain yield to the extent of 48.45% over control. Averaged over fertilizer rates Gunda tended to produce higher yield than Maemonsing but the difference was not remarkable. The lower grain yields with control plots, might be related with the depletion of soil fertility due to shortening of fallow length in shifting cultivation and no use of fertilizers. Similar views have been reported by Dalle and Blois (2006). Considering 50th percentile, additional benefits for medium fertilizer packages were about 700-800 kg ha^{-1} with Gunda and 200-600 kg ha^{-1} compared to control plots. On the other hand, considering upper 75th percentile the grain yield benefit could be about 800 kg ha^{-1} with high fertilizer management.

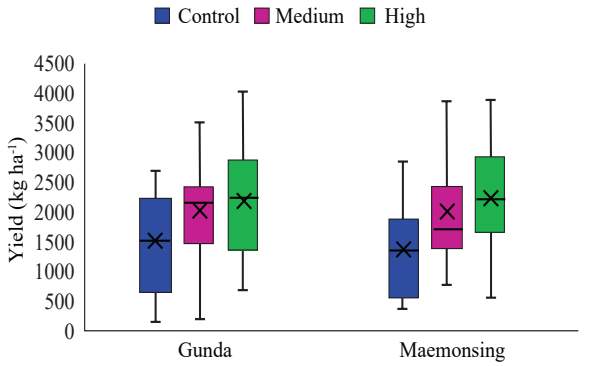


Figure 2. Grain yield of Gunda and Maemonsing as influenced by fertilizer rates in Bandarban, Bangladesh; Control = no fertilizer applied, Medium = 40-10-20 kg ha^{-1} of N-P-K, respectively; High = 80-20-40 kg ha^{-1} of N-P-K, respectively.

Table 1. Variety and fertilizer effects on grain yield upland rice grown in shifting cultivation

Fertilizer treatment	Landraces	
	Gunda	Maemonsing
	Grain yield (kg ha^{-1})	
O: No fertilizers applied	1494	1370
M: Moderate rate of fertilizer	2021	2050
H: High dose of fertilizers	2188	2244

Marked increase in grain yield of upland rice landraces due to fertilizer application might be related with low fertility level of the soil. Degradation of soil quality due to shortening of the crop cycles in shifting cultivation has been widely reported (Ramakrishnan and Toky 1981; Wapongnungsang *et al.* 2021). Rice landraces are characteristically not much responsive to fertilizers (Saito *et al.* 2006). However, recent studies conducted both in lowland (Hamid *et al.* 2016, Mamun *et al.* 2018, Nataraja *et al.* 2021) and upland ecosystems (Saito *et al.* 2006, Bala *et al.* 2016, Riste *et al.* 2017) indicate positive response of fertilizer application in indigenous rice varieties. Our results are in agreement with Nascenter and Kromocardi (2017) who demonstrated grain yield increase to the extent of 300% applying higher rats NPK in Surinam.

Our results indicate that depending on the rate of fertilizers applied overall grain yield could be increased by about 141-151% and 92-109% for Gunda and Maemonsing, respectively (Figure 3) suggesting Gunda was more responsive to added fertilizer than Maemonsing. However, the magnitude of grain yield increase in Gunda, on an average, was about 151% and 141% with medium and high fertilizer rates, respectively compared to no added fertilizer conditions. But it was about 28% with high fertilizer rate compared to medium rate of fertilizer application. In Maemonsing, the increase in grain yield was about 92% and 109% with medium and high fertilizer rates compared to no fertilizer added conditions and about 13.4% yield increased with higher dose compared to medium fertilizer rate.

Response of rice yield to three treatments (M2-M4) involving variable fertilizer application methods was compared with no fertilizer control (M1) treatment

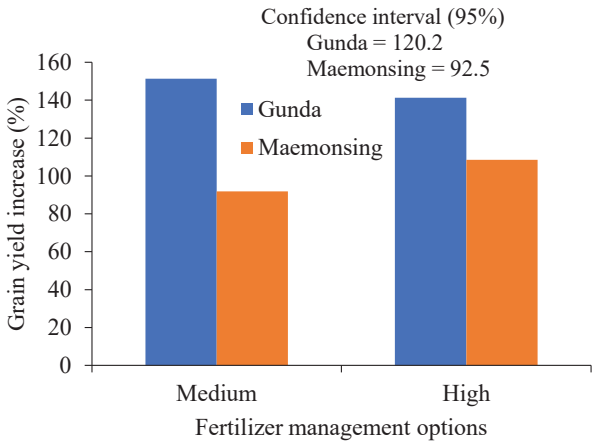


Figure 3. Grain yield increase of local rice landraces as affected by medium and high fertilizer rates compared to control in Bandarban, Bangladesh. Control = no fertilizer applied, Medium = 40-10-20 kg ha^{-1} of N-P-K, respectively; High = 80-20-40 kg ha^{-1} of N-P-K, respectively.

(Figure 4). Application of fertilizer generally increased grain yield which is in consistent with the results obtained from Experiment 1. Fertilizer application gave an average increase of 1,213 kg ha^{-1} translating to a yield advantage of about 90% over no fertilizer control. Basal application of the whole amount of P and K and 50% N and topdressing of the remaining 50% N 45 days after planting gave the highest yield (2,928.8 kg ha^{-1}), which was followed by M4 i.e. basal application of the whole amount of fertilizers at planting (2,432.6 kg ha^{-1}).

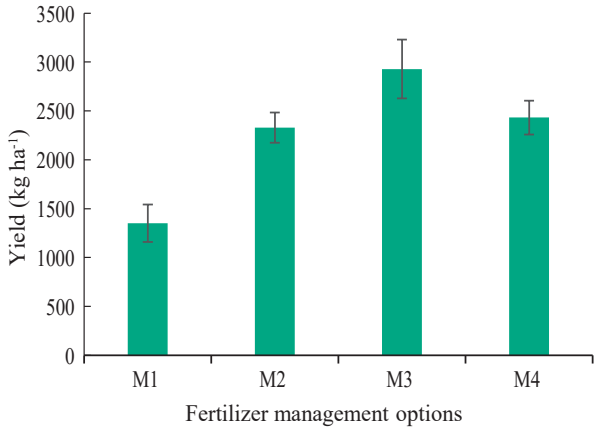


Figure 4. Grain yield of rice as affected by fertilizer application methods under shifting cultivation in Bandarban, Bangladesh. M1 = no fertilize application, M2 = no fertilizer application at planting but band placement and incorporated 10 cm away from rows at 9 days after rain, M3 = basal application of P and K, and 50% N at basal and 50% N at 45 days after planting and M4 = basal application of the whole amount of fertilizers at planting.

(M1) produced the lowest yield (1,350 kg ha^{-1}). Band placement of fertilizers 9 days after planting (M2) gave higher yield than control but was identical with basal application of the whole amount of fertilizers at planting (M4).

Variation in grain yield due to fertilizer management may be explained from the variation in yield components. Shifting cultivators apparently do not maintain regular configurations in planting seeds; but experience suggests minimal variation in planting densities, particularly in rice. The amount of seeds planted was similar in all the land parcels and the number of plants was assumed to be similar in all the sub-plots. Since the plants could not be separated from tillers at the time of counting at harvest, data on tiller density is presented (Table 2). Fertilizer applications nearly doubled the number of tillers per unit area compared with that of unfertilized control plots (M1). Number of tillers varied from 7.02 and 12.92 m^{-2}; but the tiller densities among the three fertilizer treatments remained identical. Likewise, the number of panicles m^{-2} also did not differ appreciably among the fertilizer management treatments. Fertilizer management treatments doubled the number of panicles per m^2 compared with crops growing without fertilizer application. On an average, fertilizer application increased the number of panicles m^2 by 70%. Fertilizer application rate or methods of application methods had significant influence on the number of spikelets and number of filled spikelets per panicle compared with untreated control (M1). Number of spikelets per panicle varied between 6.63 and 12.19 across the treatments. Rice grown without applied fertilizers (M1) produced the lowest number of spikelets panicle^{-1} which was identical with rice treated with band placement of fertilizers. A similar trend was observed in the number of filled spikelets panicle^{-1}. Grain size (1000-grain weight) was not significantly influenced by the method of fertilizer application. Results reveal that the variation in grain yield was largely associated with the differences in the tiller and panicle densities. The number of spikelets per panicle and the number of filled spikelets per panicle also had significant influence on the variation in grain yield. Riste *et al.* (2017) also reported that higher grain yield was associated with higher filled grain percentage and larger number of spikelets panicle^{-1}.

Table 2. Fertilizer management effects on yield components of upland rice grown in shifting cultivation

Management	Tillers m^{-2}	Panicles m^{-2}	Total spikelets $panicle^{-1}$	Filled spikelets $panicle^{-1}$	1000- grain wt (g)
M1	7.02	6.63	104	84.54	24.61
M2	12.55	11.74	130.34	114.78	24.58
M3	12.38	12.19	157.67	139.02	25.09
M4	12.92	11.9	136.08	118.66	24.83
$LSD_{0.01}$	2.44	1.83	11.02	16.24	1.12 ns

M1 = no fertilize application, M2 = no fertilizer application at planting but band placement and incorporated 10 cm away from rows at 9 days after rain, M3 = basal application of P and K, and 50% N at basal and 50% N at 45 days after planting and M4 = basal application of the whole amount of fertilizers at planting

Basal application of the whole amount of P and K and 50% N and topdressing of remaining 50% N (M3) produced significantly higher number of spikelets per panicle while other two methods of applications (M2 and M4) gave identical numbers of spikelets per panicle but higher than M1.

GHG emission varied greatly depending on fertilizer rates (Figure 5). The estimated GHG emission ranged between 164.0 to 731.0 kg CO_2 equiv. ha^{-1} across landraces and applied fertilizer rates. Fertilizer application generally increased GHG emission in both the landraces with Gunda consistently showing higher emission compared with Maemongsing but the magnitude of the difference was not great. On average the quantum of emission of GHG was 4.22 times higher with high rate of fertilizer application than in control plots.

Based on lifecycle assessment, Champrasert *et al.* (2020) reported much higher GHG emission from upland rice culture compared to our estimate. Similar studies are needed for finding out real carbon footprint for growing rice under shifting cultivation in Bangladesh. Fig. 5 shows that the amount of GHG emission increased by about 2.6-4.3 times with application of fertilizers at higher rates compared to traditional practices followed by the tribal community in hilly areas of Bangladesh. The present study did not take into account of the GHG emission due to slashing and burning of forest and bushes for preparing land prior to dibbling seeds in shifting cultivation. Add to the GHG emission due to slashing and burning forest and bushes the total GHG would have been much higher. Comprehensive assessment of GHG emission addressing agronomic operations, inputs used and forest clearing might a clear understanding of shifting cultivation effect on environmental effect.

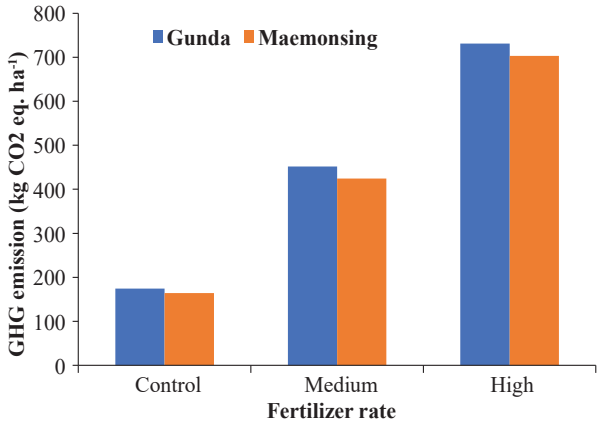


Figure 5. Greenhouse gas emission patterns under upland conditions as influenced by fertilizer rates and rice landraces in Bandarban, Bangladesh. Control = no fertilizer applied, Medium = 40-10-20 kg ha^{-1} of N-P-K, respectively; High = 80-20-40 kg ha^{-1} of N-P-K, respectively.

Conclusion

Farmers practicing shifting cultivation in the CHT and also elsewhere in the upland ecosystems in Southeast Asia, for their household food security, based largely on upland rice grown as the major component in the system. Phenomenal shortening of fallow length between two cycles of cropping leads to depletion of soil fertility and consequential yield decline. So long better varieties with promising higher yield are not available; agronomic management remains the only viable option to increase rice yield in shifting cultivation. Results in this study clearly indicates greater yield increase by applying fertilizers and appropriate management. High rates of fertilizers i.e. 80-20-40 NPK kg ha^{-1} gave the highest yield but the yield difference due to moderate and high rates was not great. Results also indicates that basal application of whole amount of P and K and split application of N (M3) produced the highest yield. In view of farmers' economic conditions and slow uptake of technology, a moderate dose of fertilizers (40-10-20 kg NPK ha^{-1}) and

split application of N may be recommended. Shifting cultivation is often blamed for soil and environmental degradation. Fertilizer application even at moderate rate will substantially increase GHG emission. But compared to emission of GHG including methane in lowland rice ecosystem, emission from shifting cultivation will remain much lower. The experiments on fertilizer rates and methods were conducted in Bandarban for one season only. A multi-year study covering areas representative of three hill districts and estimation of GHG emission through measurements will be required for developing policy on shifting cultivation in the CHT.

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