Indian Journal of Agricultural Sciences **92** (2): 226–30, February 2022/Article
https://doi.org/ 10.56093/ijas.v92i2.122226

Eco-friendly nutrient management practices for increasing cropping cycle in shifting cultivation

L K BAISHYA[1]*, NINGSHIYANGERLA WALLING[1], TEMJENNA JAMIR[1], S K RAY[1], MANOJ KUMAR[1], CHRISTY SANGMA[1] and D J RAJKHOWA[1]

ICAR-Research Complex for NEH Region, Nagaland Centre, Medziphema, Nagaland 797 106, India

Received: 13 June 2020; Accepted: 27 August 2021

ABSTRACT

A field experiment was conducted in shifting cultivated lands of Nagaland (Wokha and Longleng) during pre-*kharif* season of 2017 and 2018. Experimental results revealed that combined application of organic manure with bio-fertilizer and micro-dosing of NPK in maize (*Zea mays* L.) and upland rice (*Oryza sativa* L.) were the most productive and sustainable eco-friendly nutrient management practices evident by per cent increase in yield by 71.8% and 250%, respectively, over control (*jhum* practices). However, lime with bio-fertilizer and micro-dosing of NPK application in soybean [*Glycine max* (L.) Merr.] and groundnut (*Arachis hypogaea* L.) found productive and sustainable yield with 106% and 62.3% increase, respectively, over control (*jhum* practices). The maximum values of gross and net returns, crop profitability and production efficiency were computed with organic manure with bio-fertilizer and micro-dosing of NPK for all four crops which were closely followed by lime with bio-fertilizer and micro-dosing of NPK. The energy use efficiency was highest for groundnut (177.70%) followed by upland rice (144.28%), soybean (137.47%) and maize (14.20%). Considerable amount of soil organic carbon (1.1–1.2%), available nitrogen (92.50–185.50 kg N/ha), phosphorus (13.89–17.36 kg P/ha) and potassium (500.60–733.00 kg K/ha) were also retained with eco-friendly nutrient management practices after 2nd year *jhum* with a potential to continue cropping for another year in the same plot.

Keywords: Bio-fertilizers, Economics, Energy budget, Lime, Micro-dosing, Shifting cultivation

Shifting cultivation (*jhum*), since time immemorial, is inextricably linked with the socio-economic and cultural life of indigenous people in the Northeast region, closely knit with their rituals and festivals. For the Nagas, agriculture with *jhum* plays an integral part where 61% of the total households (Rajkhowa *et al.* 2017) i.e., about 135339 rural households of the state practice shifting cultivation on 947.37 km^2 of land annually. Exposing about 5.71% of the state's geographical area to soil erosion hazards, thereby, losing an average of 30.62 metric tonnes of soil per hectare annually to soil erosion and turbulent velocity of run-off. *Jhum* cycle has been reported to increase the economic gains from crop production with adoption of 10 years cycle considered economically viable and sustainable, however, reduced *jhum* cycle is being practiced for about 20–30 years leading to accentuated degradation of biodiversity, deforestation, accelerated air pollution (burning), soil erosion, loss of nutrients and reduction in flora, fauna and microbes. Soil fertility is, thus, reduced resulting in low production and productivity (Sati and Rinawma 2014). Despite such consequences, even today *jhum* is considered as a major source of rural economy in the Northeast India (Saha *et al.* 2012). Cultivation without full scientific knowledge and technological backup in traditional shifting have put jhumias' livelihoods at stake due to low productivity and low profit as a result of detrimental effects of soil erosion, loss of soil nutrients and biodiversity (Ray *et al.* 2019). Estimates indicate that one unit of energy in agronomic production costs loss of greater energy from the forests (Rajkhowa *et al*. 2017). So, there is a need for greater integration of the age-old traditional knowledge and modern techniques in developmental planning and decision making, focussing on agro-biodiversity enhancement and their livelihoods improvement. However, it remains challenging for many small scale farmers because of lack of; knowledge of the fertility status of their soils; proper education on fertilization; equipment and applying less than recommended or none at all due to cost issues. In order to make *jhum* lands of Eastern Himalayan region more profitable and sustainable, several combination of nutrient management practices, viz. biofertilizer, lime and micro dosing of NPK have been incorporated in the present study.

MATERIALS AND METHODS

Field trials were conducted in *jhum* lands of Wokha (Yanthamo village) and Longleng (Hukphang village)

[1]ICAR Research Complex for NEH Region, Medziphema, Nagaland. *Corresponding author email: lkbicar@gmail.com

of Nagaland during pre-*kharif* of 2017 and 2018. The experimental sites were located at 26.0696°N, 94.2872°E (Yanthamo village) and 26.4692° N, 94.8050°E (Hukphang village) at the respective altitude of 973 m and 1165 m amsl. During the experimental years the respective areas received an average rainfall of 363 mm and 298.3 mm with a prevailing temperature of 16–27°C and 49.5–87.1% relative humidity. Soil texture of Yanthamo and Hukphang was sandy loam and initial soil test values exhibited acidic *p*H (5.25, 5.33), high organic carbon (1.8%, 2.37%), available nitrogen (230.25–381.54 kg/ha), available P (9.15–21.23 kg/ha) and available K (86.96–206.98 kg/ha).

The experiment comprised four distinct crops, viz. maize (RCM-76), upland rice (Bhalum-3), soybean (JS-9650) and groundnut (ICGS-74), grown in strips of cereals alternating with legumes as maize/soybean/rice/groundnut in next year. Each crop received six nutrient management practices, viz. T_1: control (traditional *jhum* practices), T_2: lime (250 kg/ha), T_3: lime (250 kg/ha)+bio-fertilizer (500 g/ha : *Azospirillum* for cereals; *Rhizobium* for legumes), T_4; lime (250 kg/ha)+bio-fertilizer (500 g/ha)+micro-dosing of NPK (17-17-17) (20 kg/ha), T_5: organic manure (FYM 2.5 t/ha)+bio-fertilizer (500 g/ha)+micro-dosing of NPK (17-17-17) (20 kg/ha), T_6: organic manure (2.5 t/ha) +spraying of 2% DAP+micro-dosing of NPK (17-17-17) (20 kg/ha). The treatments were laid out in a randomized block design (RBD) with three replications. In both the experimental years, crops were sown during the first week of May and harvested at maturity pertaining to the cropping period. All the crop specific agronomic practices and intercultural operations were performed in accordance to treatments. However, liming of soil prior to sowing, bio-fertilization as seed treatment and micro-dosing; a precision farming technique involving application of small, affordable quantities of fertilizer as top dress (3–4 weeks after emergence) was done. This is an efficient way of enhancing fertilizer-use instead of spreading it all over the field.

Biometric observations of all the crops were recorded at harvest through standard procedures. Soil samples from 15 cm depth were collected after harvest and soil nutrient status was determined for soil organic carbon, available soil nitrogen, phosphorus and potassium as per the standard methods. Economics were worked out as per the prevailing market prices of the commodities and the minimum support price (MSP) released by the government during the respective crop seasons. The energy inputs pertaining to both renewable and non-renewable energy; energy outputs refer to economic and by-product yield. Input and output energies were obtained using conversion factors and expressed in mega joules (MJ) based on the energy equivalents of different inputs and outputs given by Dheebakaran (2019).

Net energy (MJ/ha) = Energy output (MJ/ha)–Energy input (MJ/ha);

$$\text{Energy use efficiency} = \frac{\text{Energy output (MJ/ha}}{\text{Energy input (MJ/ha)}}$$

$$\text{Energy productivity (MJ/ha)} = \frac{\text{Output (Grain + By–product) (kg/ha)}}{\text{Energy input (MJ/ha)}}$$

$$\text{Energy intensity (MJ/₹)} = \frac{\text{Energy output (MJ/ha)}}{\text{Cost of cultivation (₹/ha)}}$$

Two years' data were pooled for each parameter and subjected to statistical analysis of variance for RCBD to compare the treatment means. Significant differences were judged on F-test results and the means were separated by least significant difference (LSD) at 5% probability level.

RESULTS AND DISCUSSION

Growth and yield attributes: Nutrient management practices were observed to enhance the crop growth, and also for significantly increased yield of all the crops under study. The combined application of lime+bio-fertilizer+micro-dosing of NPK resulted in the tallest plants of maize, rice and soybean while tallest plants of groundnut were obtained with organic manure+bio-fertilizer+micro-dosing of NPK. Application of lime+bio-fertilizer+micro-dosing of NPK recorded significantly maximum crop and stover yield for maize, upland rice, soybean and groundnut (Table 1) as compared to the control (traditional *jhum* practices). Fertilization improved the overall growth due to increased net photosynthesis and greater mobilization of photosynthates towards reproductive structures that might have increased the yield attributes significantly (Meena and Yadav 2015). Micro-dosing was found to increase productivity and yield, especially for small scale farmers as reported by Kubheka (2015) and more efficient than banding and broadcasting methods of fertilizer application (Arbab and Dagash 2017). Bio-fertilizer could have produced phytohormones that further enhanced growth and yield (Panwhar *et al.* 2016). The per cent increase in yield over control (traditional *jhum* practices) for all the crops under study was recorded to be highest under lime+bio-fertilizer+micro-dosing of NPK. It was 250%, 106.09%, 71.79% and 62.73% for upland rice, soybean, maize and groundnut, respectively. This was in line with Ibrahim *et al.* (2016). Micro-dosing alone was not adequate to meet crop requirements for crop biomass production, thus integration with organic sources remains a better alternative reported by Tovihoudji *et al.* (2019). The growth and yield trend of the crops were in line with Baishya *et al.* (2016) where improved management practices i.e. bio-fertilizer and micro-dosing recorded better growth and higher yield as compared to *jhum* practices. Micro-dosing adoption increasing yields to double and even triple in Africa has been reported by ICRISAT (2015). Synergistic benefit of bio-fertilizers on productivity was best described by Rao (2018).

Economics: Higher and varying production cost was incurred among crops and nutrient management practices owing to variable costs of seed, labour and nutrient sources. Application of organic manure+bio-fertilizer+micro-dosing of NPK incurred the highest cost of production but was

Table 1 Effect of eco-friendly nutrient management practices on economics of the various crops in *jhum*

Treatment	Maize								Upland rice							
	Grain yield (kg/ha)	Straw yield (kg/ha)	Cost of cultivation (₹/ha)	Gross return (₹/ha)	Net return (₹/ha)	Return per rupee invested	Crop profitability (₹/ha/day)	Production efficiency (kg/ha/day)	Grain yield (kg/ha)	Straw yield (kg/ha)	Cost of cultivation (₹/ha)	Gross return (₹/ha)	Net return (₹/ha)	Return per rupee invested	Crop profitability ₹/ha/day)	Production efficiency (kg/ha/day)
T_1	1950	5200	13950	34450	20500	1.47	205	19.50	900	2250	14600	16875	2275	0.16	23	9.0
T_2	2560	6660	16650	45185	28535	1.71	285	25.60	1500	3500	17300	28000	10700	0.62	107	15.0
T_3	2650	6900	16880	46775	29895	1.77	299	26.50	1780	4100	17530	33200	15670	0.89	157	17.8
T_4	2950	7670	15980	52068	36088	2.26	361	29.50	2500	5110	16430	46305	29875	1.82	299	25.0
T_5	3350	8590	17780	59098	41318	2.32	413	33.50	3150	6,850	18430	58550	40120	2.18	401	31.5
T_6	2840	7400	15360	50130	34770	2.26	348	28.40	2350	4800	16110	43525	27415	1.70	274	23.5
SE (m)±	441	1,048							317	1389						
LSD (0.05)	1235	2935							914	3999						
	Soybean								*Groundnut*							
T_1	1150	2100	19750	39614	19864	1.01	166	9.58	1100	2850	26700	54503	27803	1.04	214	8.4
T_2	1255	3050	19250	43420	24170	1.26	201	10.46	1300	3350	29400	64408	35008	1.19	269	10.0
T_3	1700	4120	22450	58813	36363	1.62	303	14.17	1650	3980	29630	81680	52050	1.76	400	12.6
T_4	2370	5900	21580	58833	37253	1.73	310	14.17	1790	4400	28530	81685	53155	1.86	409	12.6
T_5	1700	4200	22680	82031	59351	2.62	495	19.75	1650	4000	30530	88631	58101	1.90	447	13.7
T_6	1631	3950	21260	56425	35165	1.65	293	13.59	1450	3500	28210	71780	43570	1.54	335	11.1
SE(m)±	108	125							0.39	193						
LSD (0.05)	31	360							1.11	550						

(Mean of 2 years)

also found most profitable due to the highest gross and net return, per rupee return, crop profitability and production efficiency followed by lime+bio-fertilizer+micro-dosing of NPK and OM+spraying of 2% DAP+bio-fertilizer (Table 1). Increase in farm profitability through micro-dosing with reduction in recommended fertilizer dose was reported by Saidia *et al.* (2018).

Soil nutrient status: Integration of several nutrient sources had significant effect on the post-harvest soil nutrient status i.e. available soil nitrogen, phosphorus and potassium (Table 2). Whereas, the soil organic carbon after crop harvest with various nutrient management techniques was recorded positive, which was an added advantage over control *jhum* practices. The reports were in conformity with the findings of Dey and Nath (2015). Available soil nitrogen status significantly increased in maize, rice and groundnut with the application of organic manure+bio-fertilizer+micro-dosing of NPK over the rest of the nutrient management practices. However, the highest available N (185.50 kg N/ha) was recorded with lime+bio-fertilizer+micro-dosing of NPK in soybean. Sikka *et al* (2013) reported that combined application of FYM along with NPK helps in maintaining higher levels of available N, P and K. The added benefit of all treatments over control was observed with increased amount of available nitrogen still left to be harnessed for another cropping cycle. All nutrient management practices had higher available N over the existing *jhum* practices.

Maize and rice that received organic manure+bio-fertilizer+micro-dosing of NPK recorded the highest available soil phosphorus over the rest of the nutrient management practices. However, soybean with lime+bio-fertilizer+micro-dosing of NPK and groundnut with lime+bio-fertilizer resulted in higher available soil phosphorus compared to the rest of the nutrient management techniques. Application of lime+bio-fertilizer+micro-dosing of NPK exhibited significantly higher available soil potassium over the traditional *jhum* practices for all the crops. The study also recorded an added increase in available soil potassium with the nutrient management practices when compared to the traditional *jhum* practices. Liming increases the efficiency of fertilizers governing nutrient release and reduces phosphorus adsorption, thereby, enhancing root growth (Vanlauwe *et al.* 2015). Also, liming with regular additions of organic manure and bio-fertilizer in combination with inorganic chemical fertilizers improved the soil fertility status (Saha *et al.* 2010).

Energy budget: The per cent increase in energy use-efficiency over the existing traditional *jhum* practice was highest for groundnut (177.70%) followed by upland rice (144.28%), soybean (137.47%) and maize (14.20%); and per cent increase in energy productivity over control was recorded maximum for upland rice (143.48%) followed by soybean (89.30%), groundnut (36.73%) and maize (14.05%) with lime+bio-fertilizer+micro-dosing of NPK. As per ICRISAT (2015) report micro-dosing saves fertilizer of about 15 kg/ha that would have been lost through conventional method of broadcasting, thus contributes a substantial part in energy budgeting economics. Suresh kumar and Pandian

Table 2 Available soil nutrients status after crop harvest under eco-friendly nutrient management practices

Treatment	Maize						Upland rice					
	Organic Carbon (%)	N	P	K	EUE	Energy productivity (kg/MJ)	Organic Carbon (%)	N	P	K	EUE	Energy productivity (kg/MJ)
T_1	0.44	95.7	11.5	354.3	72.73	5.55	1.12	97.0	7.1	365.7	21.16	1.61
T_2	0.77	98.2	11.7	577.7	75.62	5.77	1.17	114.6	9.9	432.4	29.05	2.21
T_3	1.43	117.8	12.9	653.6	78.08	5.96	1.21	123.2	11.1	664.2	34.10	2.59
T_4	1.70	125.3	14.6	713.0	83.06	6.33	1.27	153.3	13.9	733.0	51.69	3.92
T_5	1.15	154.2	19.2	683.4	59.49	4.54	1.23	174.6	15.2	715.4	33.46	2.53
T_6	1.10	148.7	13.9	667.2	60.09	5.55	1.31	139.2	11.9	644.2	32.59	2.46
SE(m)±	0.49	20.4	0.69	41.00			0.49	20.41	0.69	41.0		
LSD (0.05)	NS	58.2	1.95	116.85			NS	58.56	1.96	98.0		
	Soybean						*Groundnut*					
T_1	0.95	154.5	12.8	378.5	23.75	1.87	1.09	62.0	12.9	224.1	10.27	0.98
T_2	1.00	165.0	13.3	450.0	32.06	2.10	1.09	92.8	12.3	351.7	15.17	1.07
T_3	1.10	174.5	13.5	547.0	37.63	2.83	1.12	92.5	22.1	228.6	17.82	1.30
T_4	1.50	185.5	17.4	578.6	56.40	3.54	1.16	92.5	16.7	500.6	28.52	1.34
T_5	1.20	178.5	16.1	573.2	36.01	2.11	1.60	123.2	12.9	500.3	19.81	1.11
T_6	1.10	164.0	14.9	540.9	35.17	2.08	1.30	95.0	12.4	358.8	19.01	1.00
SE(m)±	0.49	20.4	0.68	41.0			0.49	20.41	0.69	41.0		
LSD (0.05)	NS	NS	1.95	118.0			NS	56.93	1.91	110.0		

(Mean of 2 years)

(2018), Jayadeva *et al.* (2010) also corroborated the resulting higher grain and straw yield to increased energy output. Therefore, the said treatment comparatively proved best in terms of energy output, net energy, energy use efficiency, energy productivity and energy intensity than the others (Table 2).

The crop management systems need to be designed to help farmers maintain economic profitability while conserving external energy resources and farming in an environmentally responsible manner. From the study, it may be concluded that the combined effect of organic manure (2.5 t/ha)+bio-fertilizer (500 g/ha: *Azospirillum*/ *Rhizobium*)+micro-dosing of NPK (17-17-17) (20 kg/ha), and lime (250 kg/ha)+bio-fertilizer (500 g/ha: *Azospirillum*/ *Rhizobium*)+Micro-dosing of NPK (17-17-17) (20 kg/ha) technique of nutrient management in maize, rice, soybean and groundnut under shifting cultivation (*jhum)* were most profitable and sustainable. Both practices increased the amount of soil organic carbon, available nitrogen, phosphorus and potassium to continue cropping for another year.

ACKNOWLEDGEMENT

The authors are grateful to Director, ICAR RC for NEH Region, Umiam, Meghalaya and field staff of the Nagaland Centre for giving necessary support and help for conducting the research under Institute project with special funding from TSP.

REFERENCES

Arbab M B M and Dagash Y M. 2017. Micro dosing technology of fertilizer for sorghum production at Shambat, Sudan. *Cell Biology and Development* **1**(1): 18–22.

Baishya L K, Ansari M A, Sarkar D, Ghosh M, Kumar S, Prakash N. 2016. Productivity enhancement in shifting cultivated lands through biofertilizer and micro-dosing of NPK in Eastern Himalayan Region. *Research on Crops* **17**(2): 268–75.

Dey D and Nath D. 2015. Assessment of effect of liming and integrated nutrient management on groundnut under acidic soil condition of West Tripura. *Asian Journal of Soil Sci*ence **10**(1):149–53.

Dheebakaran G. 2019. TNAU Energy Soft (User friendly tool to identify energy efficient agriculturaltechnologies).Retreived from http://www.agritech.tnau.ac.in/agrometeorologicaladvisory/pdf/manual.pdf Accessed 15 June 2019.

ICRISAT. 2015. Fertilizer-microdosing increases agriculture productivity. Project Policy Brief 2. Achieving Pro-Poor Green Revolution in Drylands of Africa: Linking Fertilizer Microdosing with Input-Output Markets to Boost Smallholder Farmers' Livelihoods. *Soil Health of the Alliance for a Green Revolution in Africa (AGRA)* Accessed on 11 July 2019.

Jayadeva H M, Shetty T K P, Bandi A G and Gowda R C. 2010. Water use efficiency, energetics and economics of rice as influenced by crop establishment techniques and sources of nitrogen. *Crop Research* **39**(1, 2&3): 14–9.

Kubheka B P. 2015. 'Integrating Micro dosing of Fertilizers with Biological Control Agents for Maize Production in the Eastern Cape, South Africa'. PhD Thesis, University of KwaZulu-Natal Pietermaritzburg, South Africa.

Meena R S and Yadav R S. 2015. Yield and profitability of groundnut (*Arachis hypogaea* L.) as influenced by sowing dates and nutrient levels with different varieties. *Legume Research* DOI:10.5958/0976-0571.2015.00107.1

Panwhar Q A, Naher U A, Shamshuddin J, Othman R and Ismail M R. 2016. Applying Limestone or Basalt in Combination with Bio-Fertilizer to Sustain Rice Production on an Acid Sulfate Soil in Malaysia. *Sustainability* **8**: 700.

Rajkhowa D J, Baishya L K, Ray S K, Sharma Ph R, Barman J and Ezung N K. 2017. Challenges, scope and opportunities of *jhum* rejuvenation in Nagaland. *Jhum Improvement for Sustaining Farm Livelihood and Natural Resource Conservation in North Eastern Hill Region: Vistas And Frontiers*, pp 42–56. Prakash N, Roy S S, Ansari M A (Eds.), ICAR Research Complex for NEH Region, Meghalaya, India.

Rao D L N. 2018. Promoting biofertilizers in IPNS with improved technology and extension in India. *SAARC Training Manual on Integrated Nutrient Management for Improving Soil Health and Crop Productivity*, pp 71–82. Dey P, Srivastava S, Lenka NK (Eds.) ICAR-Indian Institute of Soil Science, Bhopal, India.

Ray S K, Chatterjee D, Rajkhowa D J, Baishya S K, Hazarika S and Paul S. 2019.Effects of integrated farming system and rainwater harvesting on livelihood improvement in North-Eastern region of India compared to traditional shifting cultivation: evidence from an action research. Agroforestry Systems. DOI: 10.1007/s10457-019-00406-3

Saha R, Chaudhary R S and Somasundaram J. 2012. Soil Health Management under Hill Agroeco system of North East India. *Applied and Environmental Soil Science* DOI :10.1155/2012/696174.

Saha R, Mishra V K, Majumdar B, Laxminarayana K and Ghosh P K. 2010. Effect of Integrated Nutrient Management on Soil Physical Properties and Crop Productivity under a Maize (*Zea mays*)-Mustard (*Brassica campestris*) Cropping Sequence in Acidic Soils of Northeast India. *Communications in Soil Science and Plant Analysis* **41**: 2187–200.

Saidia P S, Graef F, Rweyemamu C L, Semoka J M R, Kimaro A A, Mwinuka L, Mutabazi K D and Sieber S. 2018. Nitrogen and Phosphorus Fertilizer Micro-doses on Maize and Its Effect on Profitability: An Evidence from Sub-humid Farming Systems, Tanzania. *Journal of Economics, Management and Trade* **21**(9): 1–10.

Sati V P and Rinawma P. 2014. Practices of Shifting Cultivation and its Implications in Mizoram, North-East India: A Review of Existing Research. *Nature and Environment* **19**(2): 179–87.

Sikka R, Singh D and Deol J S. 2013. Productivity and nutrient uptake by soybean as influenced by integrated nutrient and some other agronomic management practices. *Legume Research* **36**(6): 545–51.

Sureshkumar R and Pandian B J. 2018. Energy Production, Utilization and Yield of Rice under Different Methods of Transplanting and Irrigation Management Practices. *International Journal of Pure and Applied Bioscience* **6**(1): 611–17.

Tovihoudji P G, Akponikpè P B I, Agbossou E K and Bielders C L. 2019. Using the DSSAT Model to Support Decision Making Regarding Fertilizer Microdosing for Maize Production in the Sub-humid Region of Benin. *Frontiers in Environmental Science* **7**(13) DOI: 10.3389/fenvs.2019.00013.

Vanlauwe B, Descheemaeker K, Giller K E, Huising J, Merckx R, Nziguheba G, Wendt J and Zingore S. 2015. Integrated soil fertility management in sub-Saharan Africa: unravelling local adaptation. *Soil* **1**: 491–508.