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Research Paper

Nutrient management in maize (*Zea mays*) under shifting cultivation for higher productivity and sustainability in North-East India

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ABSTRACT

A participatory field experiment was conducted during the rainy (*kharif*) season of 2015 and 2016 at farmer's land of Meghalaya, to identify suitable maize (*Zea mays* L.) varieties and nutrient-management practices for higher maize productivity under shifting cultivation (*jhum*). The experiment was laid out in a factorial randomized block design with treatment combination of 3 maize cultivars, viz. 'JKMH 502' (Hybrid), 'RCM 61A' (Composite) and 'Saru Bhoi' (Local), and 5 nutrient-management practices, viz. N_1, farmers' practice (no manure or fertilizer application); N_2, 50% of recommended dose of fertilizer (RDF) (40, 20 and 20 kg N, P_2O_5 and K_2O/ha) + FYM 2 t/ha + 500 kg lime/ha in furrow; N_3, fertilizer + FYM (50% N from each source to supply 40, 20 and 20 kg N, P_2O_5 and K_2O/ha) + 500 kg lime/ha in furrow; N_4, maize + groundnut (*Arachis hypogaea* L.) intercropping (4 : 2 ratio) with N_3; and N_5, foliar spray of diammonium phosphate (DAP) @ 2% at 30 and 60 days after sowing (DAS) with N_1. Among the cultivars, the composite cultivar 'RCM 61A' produced higher number of rows/cob (13), seeds/cob (271.2), seed weight/cob (67.2 g) and test weight (247.4 g) than hybrid and local cultivars. However, among the nutrient-management practices, N_2 treatment resulted in significantly higher grain yield, straw yield and harvest index than N_1. The soil fertility in terms of SOC, available N, P_2O_5 and K_2O were significantly higher under treatment N_4. Thus, cultivation of maize composite ('RCM 61A') and adoption of maize + groundnut intercropping (4 : 2 ratio) along with application of fertilizer + FYM (50% N from each for total supply of 40, 20 and 20 kg N, P_2O_5 and K_2O/ha + 500 kg lime) is a profitable practices for improving maize productivity in *jhum* lands and sustaining soil health.

Key words: Intercropping, *Jhum*, Maize, Shifting cultivation, Soil organic carbon, Yield

The North-Eastern Region (NER) of India is well known for its natural vegetation, resources, inaccessible terrain, excessive sloping land with rolling topography, and biodiversity (Ngangom *et al*., 2017). Morphologically, the region is marked by the development of series of ridges and valleys, terraces, scraps, and several geomorphologic surfaces at different elevations (50 to 5,000 m and above). Shifting cultivation (*jhum*) is practiced by the hill tribes in an area of 0.76 million ha in the NER of India. This system often involves clearing of a piece of forest land (most often sloping lands) by cutting off bushes and trees followed by burning and cleaning for the cultivation of crops in mixed farming until the soil loses its fertility. The shifting cultivation usually starts during December–January with the cleaning of forest areas. By mid-February to mid-March, before the onset of the monsoon, debris is dried and burnt *in situ*, followed by planting of crops mostly through dibbling. Farming of the plot continues for 1–2 years, in some cases up to 3 years, until the soil fertility exhausted. After the final harvesting, the land is left fallow and cultivators repeat the process in a new virgin forest plot. Due to reduction of *jhum* cycle from 20 to 30 years in past to 2 to 5 years at present, land degradation is taking place (soil erosion and soil-fertility depletion) at a massive scale in the region. The burning of biomass on *jhum* land releases huge CO_2 into the atmosphere which is the major component in greenhouse gas and cause for climate change (Rastogi *et al.,* 2002).

Another major problem of shifting cultivation in the region is the heavy soil erosion and nutrient and biodiversity loss. This is due to slash-and-burn technique of production associated with '*jhum*' along with indiscriminate felling of trees, cultivation in sloping lands associated with high rainfall (>2,000 mm annually). The possible reason for soil loss is large variation within a system due to

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spatial variation in soil properties, as well as the differences in slope and crops cultivated under a particular system. The maximum soil loss of 30.2–70.2 t/ha/year was reported under shifting cultivation and the minimum of 0.04–0.52 t/ha/year under the natural forest system (Saha *et al.,* 2011). Continuous loss of nutrients due to cultivation in sloping lands makes the soil unfit for cultivation in few years. The organic matter of the surface soil is also oxidized, causing reduction in the levels of organic matters and other nutrients in the soil.

Maize (*Zea mays* L.) is the second most important cereal crops of the North-Eastern Region after rice (*Oryza sativa* L.). It occupies an important place under *jhum* system. Maize crop has multiple uses as food for human and feed for animals, and cultivated under rainfed conditions (Layek *et al*., 2015; Babu *et al*., 2020). Nitrogen (N) and phosphorus (P) deficiencies are the most common in *jhum* land/upland conditions. Potassium (K) requirement are met to a great extent through ash from burning after slash-and-burn operation during the first year *jhum* cultivation. Therefore, application of nutrients either through chemical fertilizer or farm yard manure (FYM) can be a good practice to fulfil the maize nutrient requirements, provided, the system is economical. Growing local varieties, no fertilizer or manure application, soil erosion due to cultivation along the slopes etc. are the major constraints of maize production under *jhum*. As a result, productivity of maize in the *jhum* areas hovers around 1.0–1.2 t/ha. Due to decline in soil fertility in *jhum* land, the farmers are not being able to grow nutrient-exhaustive crops like maize in the second year without any manure or fertilizer addition. The objectives of the present study were to identify efficient cultivars and soil-fertility-management practices for sustainable maize production in *jhum* condition in North-Eastern hills region of India.

MATERIALS AND METHODS

A participatory field experiment was conducted at Ri Bhoi District, Meghalaya, during the rainy (*kharif*) season of 2014 and 2015 on *jhum* farm of farmers field in village Sonidan (25°52' 32.8" N, 92°07' 10.9" E, 862 m above sea-level), Meghalaya, with average annual rainfall of 1866 mm. The experimental field was cleaned by slashing during December–January, dried biomass burnt in end of February and tilled in March, 2014 and made ready for sowing in April. The experimental field having a *p*H 4.65, was high in organic carbon (2.5%), medium in available N (302.6 kg/ha), K_2O (240.6 kg K_2O/ha) and low in P_2O_5 (30.9 kg P_2O_5/ha). The experiment consisted of treatment combination of 3 maize cultivars, viz. 'JKMH 502' (Hybrid), 'RCM 61A' (Composite) and 'Saru Bhoi' (Local), and 5 nutrient-management practices, viz. N_1, farmers' practice (no manure or fertilizer application); N_2, 50% of recommended dose of fertilizer (RDF: 40, 20 and 20 kg N, P_2O_5 and K_2O/ha) + FYM 2 t/ha + 500 kg lime/ha in furrow; N_3, fertilizer + FYM (50% N from each source to supply 40, 20 and 20 kg N, P_2O_5 and K_2O/ha) + 500 kg lime/ha in furrow; N_4, maize + groundnut (*Arachis hypogaea* L.) intercropping (4 : 2 ratio) with N_3; and N_5, foliar spray of diammonium phosphate (DAP) @ 2% at 30 and 60 days after sowing (DAS) with N_1. The experiment was laid out in a factorial randomized block design with 3 replications. The spacing for sole maize was 60 cm × 25 cm. Groundnut was planted as an intercrop in maize at 4 : 2 ratio. The spacing for groundnut was 30 cm × 10 cm. Entire dose of P_2O_5 (as single superphosphate) and K_2O (as muriate of potash) was given basal. Fertilizer N through urea was applied in 3 equal splits, i.e. 1/3rd basal along with P_2O_5 and K_2O, 1/3rd at knee-height (30 DAS) stage, and 1/3rd at tasseling (60 DAS) stage. Two hand-weedings were done at 20 and 45 days after sowing (DAS), but in farmers' practice no weeding operation was performed. All other recommended cultural practices for achieving optimum grain yield were followed. The slope length of the land was reduced by dividing into strips of 10 m by planting *Tephrosia* spp., a legume green-leaf manure plant, in contour for soil and water conservation and to generate the green-leaf manure to the succeeding crop. The unburned debris, branches etc. were placed in contour along with legume hedge to conserve soil.

Observations on yield attributes and yield of maize recorded as per the standard procedures. Surface soil samples (0–15 cm) were collected from individual plots after the harvesting of 2nd year crop. The *p*H of the soil was determined by using a digital *p*H meter having glass electrode, in 1 : 2.5 soil : water suspensions, available N by the alkaline permanganate method, available P_2O_5 by Bray's extraction method using spectrophotometer. Soil organic carbon (SOC) content was determined by the Walkley and Black method. Similarly, maize grain-equivalent yield (MGEY) was calculated as per the following formula.

$$\text{MGEY (kg/ha)} = \frac{\text{Productivity of the component crop (kg/ha)} \times \text{Price of component crop (₹/kg)}}{\text{Price of maize (₹/kg)}}$$

The data were subjected to statistical analysis by using the technique of analysis of variance and their significance was tested by "F" test. Standard error of means (SEm±) and critical difference (CD) at 5% probability (*P*=0.05) were worked out for each character studied to evaluate differences between treatment means.

RESULTS AND DISCUSSION

Yield attributes

Yield attributes of maize like rows of grains/cob, seeds/cob, seed weight and test weight are the resultant of the vegetative development of the plant and determine the maize yield. The yield attributes of maize like seeds/cob and seed weight/cob were significantly influenced by cultivars and nutrient-management practices. However, rows/cob did not vary significantly with different cultivars and nutrient-management practices (Table 1). Among the cultivars of maize grown in *jhum* field, the composite cultivar 'RCM 61A' showed the highest seeds/cob, seed weight/cob and test weight as compared to hybrid and local cultivars. The lowest values for all the yield attributes were recorded for local maize cultivar 'Saru Bhoi'. However, rows/cob did not vary significantly by the cultivars as this character is mainly governed by genetic factors. However, application of 50% RDF through fertilizer (40, 20 and 20 kg N, P_2O_5 and K_2O/ha) along with FYM 2 t/ha + 500 kg lime resulted in significantly higher seeds/cob and seed weight/cob than the other nutrient-management practices, while the test weight (g) of maize was not significantly influenced by the nutrient-management treatments. The lowest values of most the yield attributes under farmers practice (N_1) indicate the potential for enhancing the yield by adopting suitable nutrient-management options in *jhum* field. Supply of nutrients through FYM, fertilizer or both and N fixed by associated legume groundnut helped in optimizing the growth of maize and resulted in higher number of seeds/cob and seed weight/cob. Combination of organic manure (FYM) and inorganic fertilizer helps in better performance of crops by providing need-based nutrients over the entire growth period of maize over sole application of either source (Sujatha *et al*., 2008).

Grain yield, stover yield and harvest index

The grain and stover yields of maize were significantly influenced by the cultivars and nutrient-management practices (Table 2). The grain yield was recorded significantly highest under composite variety 'RCM 61A' (2.95 and 2.74 t/ha, respectively for 2014 and 2015) as compared to hybrid and local cultivar (Table 2). Adoption of composite cultivar 'RCM 61A' enhanced the grain yield of maize by 30%. Harvest index and system productivity were also significantly higher in composite variety than the other cultivars for both the seasons. Among the nutrient-management practices, treatment N_2 recorded higher grain yield, straw yield and harvest index than farmers' practice but remained statistically at par with N_3 and N_4 treatments. Biological N fixation by groundnut under N_4 might have helped in getting similar yield under N_4 as that of N_2 or N_3 treatments. Significantly higher grain and straw yields under integrated application of fertilizer and FYM along with lime and intercropping with groundnut as compared to farmers' practice might be owing to increased availability of nutrients in soil which might have increased nutrient uptake and effective utilization of nutrients thereby enhanced crop yield (Layek *et al*., 2018). The lowest grain yield, stover yield and harvest index of maize were noticed under farmers' practice (Table 2). The minimum grain yield obtained under the control was attributed to fewer nutrients available to crop plants and poor yield-attributing characters. Simple application of 2% DAP spray twice enhanced the maize yield by 130 kg and 120 kg/ha in 1st and 2nd year, respectively. Under framers' practice (no manure or fertilizer

Table 1. Effect of cultivars and nutrient-management practices on yield attributes of maize (2 years pooled data)

Treatment	Row/cob	Seeds/cob	Seed weight/cob (g)	Test weight (g)
Cultivars				
'JKMH 502' (Hybrid)	12.7	221.1	59.6	268.9
'RCM 61A' (Composite)	13.0	271.2	67.2	247.4
'Saru Bhoi' (Local)	12.9	191.6	48.5	244.2
SEm±	0.27	8.00	1.83	3.85
CD (P=0.05)	NS	23.17	5.30	11.10
Nutrient-management practices				
N_1	12.8	175.5	43.5	247.8
N_2	13.1	272.0	70.4	255.7
N_3	12.7	239.0	61.3	256.3
N_4	12.8	240.8	63.4	258.7
N_5	12.9	212.3	53.6	248.7
SEm±	0.35	10.30	2.36	4.95
CD (P=0.05)	NS	29.90	6.84	NS

N_1, Farmers' practice (no manure or fertilizer application); N_2, 50% recommended fertilizer (40, 20 and 20 kg N, P_2O_5 and K_2O/ha) + FYM 2 t/ha + 500 kg lime/ha in furrow); N_3, Fertilizer + FYM (50% N from each source to supply 40, 20 and 20 kg N, P_2O_5 and K_2O/ha) + 500 kg lime; N_4, Maize + groundnut intercropping (4 : 2 ratio) with N_3; N_5, Foliar spray of diammonium phosphate @ 2% on 30 and 60 days after sowing with N_1.

Table 2. Yield of maize as influenced by cultivars and nutrient-management practices

Treatment	Grain yield (t/ha)		Stover yield (t/ha)		Harvest index (%)		System productivity (t/ha)	
	2014	2015	2014	2015	2014	2015	2014	2015
Cultivars								
'JKMH 502' (Hybrid)	2.62	2.44	6.41	6.13	28.8	28.3	2.75	2.56
'RCM 61A' (Composite)	2.95	2.74	6.59	6.51	30.7	29.5	3.07	2.86
'Saru Bhoi' (Local)	2.29	2.10	5.96	5.96	27.8	26.0	2.43	2.23
SEm ±	0.09	0.08	0.15	0.14	0.79	0.77	0.09	0.08
CD (P=0.05)	0.27	0.24	0.43	0.41	2.29	2.24	0.27	0.23
Nutrient-management practices								
N_1	2.13	1.91	5.34	5.11	28.4	27.3	2.13	1.91
N_2	3.08	2.89	7.05	7.04	30.2	28.9	3.08	2.89
N_3	2.77	2.59	6.62	6.64	29.4	27.9	2.77	2.59
N_4	2.86	2.71	6.75	6.76	29.7	28.6	3.51 (325*)	3.32 (307*)
N_5	2.26	2.03	5.83	5.46	27.9	27.0	2.26	2.03
SEm ±	0.12	0.10	0.19	0.18	1.02	1.00	0.12	0.10
CD (P=0.05)	0.35	0.30	0.55	0.54	NS	NS	0.35	0.30

N_1, Farmers' practice (no manure or fertilizer application); N_2, 50% recommended fertilizer (40, 20 and 20 kg N, P_2O_5 and K_2O/ha) + FYM 2 t/ha + 500 kg lime/ha in furrow); N_3, Fertilizer + FYM (50% N from each source to supply 40, 20 and 20 kg N, P_2O_5 and K_2O/ha) + 500 kg lime; N_4, Maize + groundnut intercropping (4 : 2 ratio) with N_3; N_5, Foliar spray of diammonium phosphate @ 2% on 30 and 60 days after sowing with N_1.

Figures in the parentheses are groundnut yield in kg/ha.

application in *jhum* field), the maize yield declined significantly in 2nd year (1.91 t/ha) as compared to 1st year of experiment (2.13 t/ha). In *jhum* field, after 1 or 2 years of cultivation, the soil fertility depletes severely and could not provide sufficient amount of nutrients for good crop yield (Layek *et al*., 2018). Hence, application of manure or fertilizer or legume incorporation either through intercropping or in cropping sequence is must for cultivation of maize for minimum 3–4 years in the same field after jhuming.

The system productivity (3.5 t/ha and 3.3 t/ha, respectively, for 2014 and 2015) was significantly higher under maize + groundnut intercropping (4 : 2 ratio) along with N_3 treatment as compared to farmers' practice and 2% foliar application of DAP. The groundnut kernel yield during 2014 (325 kg/ha) under maize + groundnut intercropping (4 : 2 ratio) with N_3 treatment was slightly higher than that of 2015 (307 kg/ha). Enhancement in maize productivity with combined application of nutrients through organic and inorganic resources was reported by Shanwad *et al*., (2010). Further, the grain yield of maize mainly depends on the final plant population and yield of individual plant, which in turn depends on the weight of seeds/cob and resulted in to higher grain yield. However, grain yield in 2015 was lower than those obtained in 2014. Reduction in grain yield in the 2nd year may be attributed to difference in rainfall amount and distribution pattern, decline in soil-nutrient availability in *jhum* 1 year after cultivation etc.

Soil properties

Compared to initial nutrient status of soil there was significant variation in available N, P_2O_5, K_2O and SOC contents of soil under different varieties and nutrient-management practice (Table 3). Under farmers' practice (N_1) and DAP spray (N_5), the soil-available N, P_2O_5 and SOC declined significantly after 2 cropping cycles; available N was reduced by 27.4 kg and the SOC by 0.15% under farmers' practice. Cultivation of maize for 2 continuous years without adding anything as source of nutrients declined the soil fertility. This is exactly the reason why farmers change the plots after every 2–3 years of cultivation of crops in *jhum* fields (Layek *et al*., 2018). However, the soil *p*H was slightly increased under the cultivars and as well as nutrient-management practices as compared to initial *p*H status.

Except for available P in soil, cultivars grown in *jhum* field did not change the soil available N, K, SOC and soil *p*H even after 2 cropping cycles (Table 3). Cultivation of maize cultivar 'RCM 61A' resulted in the lowest soil-available P_2O_5 (28.6 kg/ha). Among the nutrient-management practices, the available N was significantly highest under maize + groundnut intercropping with N_3 as compared to farmers' practice. Cultivation of legume as an intercrop with maize biologically fixed N in soil (Layek *et al*., 2014) which ultimately enhanced the soil-available N under N_4 treatment. The application of N_2 resulted in significantly higher available P_2O_5, soil *p*H and SOC content of soil as

Table 3. Available N, P_2O_5, K_2O, soil organic carbon (SOC) and *p*H as influenced by cultivars and nutrient-management practices (in 2015, after 2 years of experiment)

Treatment	Available N (kg/ha)	Available P_2O_5 (kg/ha)	Available K_2O (kg/ha)	SOC (%)	*p*H (1 : 2.5)
Cultivars					
'JKMH 502' (Hybrid)	292.5	28.3	236.6	2.45	4.65
'RCM 61A' (Composite)	291.1	28.6	236.2	2.48	4.66
'Saru Bhoi' (Local)	299.0	30.6	237.2	2.51	4.66
SEm±	5.03	0.30	3.09	0.04	0.03
CD (P=0.05)	NS	0.88	NS	NS	NS
Nutrient-management practices					
N_1	274.6	28.0	228.1	2.39	4.58
N_2	309.9	29.8	239.0	2.59	4.71
N_3	299.9	29.4	244.3	2.47	4.68
N_4	310.5	29.4	240.6	2.58	4.72
N_5	276.3	29.1	231.5	2.36	4.60
SEm±	6.49	0.39	3.99	0.05	0.04
CD (P=0.05)	18.80	1.13	11.57	0.13	0.11

N_1, Farmers' practice (no manure or fertilizer application); N_2, 50% recommended fertilizer (40,20 and 20 kg N, P_2O_5 and K_2O/ha) + FYM 2 t/ha + 500 kg lime/ha in furrow); N_3, Fertilizer + FYM (50% N from each source to supply 40,20 and 20 kg N, P_2O_5 and K_2O/ha) + 500 kg lime; N_4, Maize + groundnut intercropping (4 : 2 ratio) with N_3; N_5, Foliar spray of diammonium phosphate @ 2% on 30 and 60 days after sowing with N_1

compared to farmers' practice. Since the N fertilizer speeds up the mineralization of organic matter and facilitates slow but steady release of nutrients to crops, integrated application of chemical fertilizers and organic manure could enhance nutrient availability and increased the crop yield (Das *et al*., 2020). Treatment N_4, being at par with N_2 and N_3, increased the soil *p*H compared to farmers' practice (N_1). In the present investigation, SOC, available N, P_2O_5 and K_2O contents were significantly influenced by integrated application of organic and inorganic sources of nutrients. The SOC content increased owing to addition of FYM in respective treatments. Combined application of manure and fertilizer resulted in the higher N content in soil than the farmers' practice which may be owing to the addition of organic matter through organic manures (Busari *et al.,* 2008) like FYM and was attributed to more biomass addition and slow release of N. The available N content might have also increased because of increase in population of beneficial micro-organisms and also higher nitrogenase and urease enzyme activity in soil. Higher buildup of available phosphorus might be owing to the release of organic acids during microbial decomposition of organic matter which might have helped in the solubility of native phosphates, thus increasing the available phosphorus content in soil. In addition, the organic anions compete with phosphate ions for the binding sites on the soil particles. The buildup of available potassium in soil was owing to the beneficial effect of organic manures in releasing potassium due to the interaction of organic matter with clay and direct addition of potassium to the available pool of soil.

There is good scope to increase the productivity of maize under shifting cultivation by adoption of appropriate variety and nutrient-management options. Cultivation of maize composite ('RCM 61A') and adoption of maize + groundnut intercropping (4 : 2 ratio) along with application of minimum 40, 20 and 20 kg N, P_2O_5 and K_2O/ha either through fertilizer or fertilizer and FYM combination can maintain the soil fertility and enhance the maize yield.

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