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YIELD PERFORMANCE AND PRODUCTION EFFICIENCY OF MIXED AND SOLE CROPPING UNDER DIFFERENT FALLOW CYCLE OF SHIFTING CULTIVATION IN NORTHEAST INDIA

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ABSTRACT
A field experiment was conducted during 2013-14 on yield performance and production efficiency of crops. The crops were grown as mixed and sole cropping system in 5, 10 and 20 years cycle of shifting and or *jhum* field. The rice equivalent yield (REY) was the highest in ginger sole cropping. It was followed by colocasia, mixed crops, sesamum, okra, brinjal, chilli, maize and rice, respectively. The REY was increased along with increased with fallow length (5, 10 and 20 years). Mixed cropping system increased the production efficiency (PE) from 12.21 to 502.96 percent. The PE of ginger (sole) increased by 20.5, 24.71 and 25.10 percent in 5, 10 and 20 years cycles respectively. Similarly, the PE of colocasia (sole) was increased by 10.13 and 3.23 percent in 5 and 10 years fallow cycle. The total uptake of N, P and K by crops was more in 20 years fallow cycle, followed by 10 and 5 years cycle. The mixed crop removes highest N and P in all cycles than the sole. But K uptake was higher in 20 years cycle by ginger.

INTRODUCTION

The historical background of shifting / *jhum* cultivation is as old as the history of agriculture. It could consider as an early stage in the evolution of agricultural systems. Its nearly 9000 years old practice of traditional agriculture (Sharma, 1976). In recent years different forms of shifting cultivation practiced in the world. This system prevails in 300-500 million hectares in the tropics, supports about 200 to 300 million world population (Crutzen and Andreae, 1990; Datta *et al.*, 2004). In India, approximately 11 million hectares of land is under shifting cultivation. This involves 2 million farmers and 85% total arable land of Northeast India (Singh and Singh, 1992). *Jhum* farming as a generic term includes a wide range of crop production practices. The basic pattern of *jhum* is mixed farming, where crops are grown for few seasons. After which the lands allowed to revert natural cover of vegetation for several years, before it's again used for cultivation by the *jhum* farmers. Different crops mixtures grown under this system according to farmers necessities. Its combination of field crops as rice, maize, sesame, beans, vegetables like brinjal, tomato, cucurbits, pumpkin, okra, chilli, and spices for example ginger and turmeric etc. Shifting cultivation considered as traditional cultivation practice by several workers. They advocated that its only way of subsistence agriculture for traditional farmers. Especially who are farming in remote hilly places (Nye and Greenland, 1960; Toky and Ramakrishnan, 1981; Jordan, 1989; Kleinman *et al.*, 1995).The outcome of *jhum* farming is low compared to settle. But hill farmers are still depend on it either partly or fully for their livelihoods. It ensures staple food for most of the months with rice, vegetables, cash crops, fruits, spices etc. This might be the reason for consideration of *jhum* farming as one of the best livelihood options in hilly tracts. Even, in most of the cases, the fallow periods performed better particularly for spice crops (Ullah *et al.*, 2012). There are many technologies developed for hill agro-ecosystem. Most of the technologies linked with permanent and/or settled agriculture systems. Unfortunately, recognition and adoption of these technologies by *jhum* farmer is poor. There is lack of alternatives for sustainable *jhum* farming for hilly farmers. This leads for its continuation by the *jhum*ias as subsistence alternative food production systems of hilly tropics (Eckholm, 1976). Thus it's attached to their way of life; moreover, its improvement seems to offer a better chance of success. That is rather than its complete replacement with new extrinsic systems. The judicious use of human and natural resource are the major tools for alleviating food insecurity of N.E. hill region. The conservation tillage in mixed cropping system able to maintain good yields (Sanchez, 1976). But the sequential sole cropping is common under valley agro-ecosystem of hilly region. Although many researchers have already worked on yield performance of *jhum* crop, yet the data on production efficiency under different cycle is lacking in N.E. hill agro-ecosystem. Moreover, there is a lack of information on fitness of crop combination in *jhum* farming. It was hypothesized that sole and mix crops alter the production and its efficiency in different fallow cycles of N. E. hill ecosystem. Keeping above points in view, a field experiment conducted to assesses the production efficiency of *jhum* fields.

MATERIALS AND METHODS

A field experiment was conducted for two cropping seasons (2013-14) at Changki range of Mokokchung district of Nagaland, India. The GPS location of the experimental site were 94º22.75′ E longitude and 26º23.80′ N latitude (20 years cycle), 94º22.5′ E longitude and 26º24′ N latitude (10 years cycle) and 94º22.26′ E longitude and 26º23.75′ N latitude (5 years cycle) and altitude of 634 m to 752 m above the mean sea level. The annual means of rainfall and temperatures in the district is 250 cm and 26.5°C, respectively. The soils was alluvial, non laterite red soil, low in phosphorus and medium in nitrogen and potash with acidic in nature. The initial physic-chemical properties of soil were estimated as per the methods given in Table 1. Three *jhum* cycles (5, 10 and 20 years) were selected for the study as described by Young (1994). Crops were grown in mixed cropping system in three *jhum* cycle sites. The crop combination in mixed cropping were rice, maize, colocasia, okra, sesamum, pumpkin, brinjal, ginger and chilli, which were grown in the proportion of 100, 0.65, 1.3, 3.2, 4.5, 3.9, 5.6, 3.2 and 4.03, respectively. All the mentioned crops were also grown in sole cropping system at same site. In both situations, (mixed and sole) crops were grown under farmer managed rainfed condition. At each study site a test plot of 5 m x 5 m was delineated. At the time of the harvest the yield from each test plot was measured randomly in eight replications.

The yield of all crops was converted into rice equivalent yield based on the local market price of the product. The rice equivalent yield (REY) and production efficiency (PE) were calculated as equation used by (Gangwar *et al.*, 1999; Singh *et al.*, 2008). Rice equivalent yield was calculated using the following formula

REY = $\sum_{i}^{n}(Yixei)$

Y = Economic yield of 1 to 'n' number of crops (t ha^{-1}), e = Rice equivalent factor which can be calculated as Pe/Pc where, Pe = price of a unit weight of concerned crop, Pc = price of unit weight of intercrops, i = 1 to 'n' number of crops.

Sale price of crop commodities for calculating equivalent yield were: Rice grains = Rs. 12,500/t; Maize = Rs. 10,900/t; Colocasia corm = Rs. 21,250/ t; Okra = Rs. 15,570/t; Sesamum = Rs. 29,890/t; Pumpkin = Rs. 5,050/t; Brinjal = Rs. 7,150/t; Ginger = Rs. 19,950/t; Chilli = Rs. 17,250/t; and Rice straw = Rs. 550/t.

Production efficiency (PE) was computed by the following formula

PE (%) = {(REYMC – REYSC) /REYSC} x 100

Where, REYMC is REY in mixed cropping system, REYSC is REY in sole cropping system.

Nitrogen, Phosphorous and Potassium content in plant sample was estimated by modified micro Kjeldahl method, vanadomolybdo-phosphoric yellow colour method and using flame photometer respectively (Jackson, 1973).The respective content (%) of different nutrient in plant samples were analyzed on dry weight basis and were multiplied by the corresponding dry matter yield to estimate the nutrient uptake. The N, P and K uptake by individual crop was determined and summed up for calculating total uptake.

Nutrient uptake (kg ha^{-1}) = Nutrient content (%) X Dry matter yield (kg ha^{-1}).

Statistical analysis

The data on REY and PE of individual crops were analyzed applying the one way ANOVA in SPSS v19 and means were compared with LSD and Duncan test. Data was tested for homogeneity of variance by means of the multiple comparisons, and histograms were used to confirm assumptions of normality.

RESULTS AND DISCUSSION

Rice equivalent yield

The average REY of mixed and individual crop was highest in 20 years fallow cycle followed by 10 and 5 years. This might be due to suitable micro climate as biogeochemical properties of the respective sites. In fact, there was more vegetative plant biomass in longer fallows. Parts of the nutrients stored in the vegetation and further returned to soil surface in the form of litter. The physio-chemical properties of soil improved in the site of the longer fallow cycles. Its attributed by adding more organic matter and ensuing more productive. But the narrow fallow cycles reduced the crop yields as dominates with problematic weeds. Thus these cycles are more exhaustive and cause lower yields (de Rouw, 1995; Dingkuhn *et al.*, 1999; Johnson *et al.*, 1991). The findings of present study were in close conformity of the results of Arnason *et al.* (1982), Hansen (1995) and Kato *et al.* (1999). The mean total REY of sole ginger (13.55, 16.25 and 19.17 t ha^{-1}) was higher in 5, 10 and 20 years cycle, respectively. It's followed by colocasia with REY of 11.96, 12.66 and 12.79 t ha^{-1} in 5, 10 and 20 years cycle respectively. Further the REY of mixed crops (combination) was 10.79, 12.23 and 14.35 t ha^{-1} under 5, 10 and 20 years fallow cycles (Fig. 1). But the lowest REY recorded in sole cropping of rice with production of 1.79, 2.36 and 2.74 t ha^{-1} under 5, 10 and 20 years fallow cycle. The REY indicates production performance of agro-ecosystems in N.E. hilly tracts. Similar trend of REY for other crops obtained in 5 and 10 years fallow cycle. Its highest value found in sole cropping of ginger. It was followed by colocasia, mixed crops, sesamum, okra, brinjal, chilli, maize, pumpkin and rice, respectively.

The higher REY of ginger observed in 20 years cycles followed by in order of mixed crops, colocasia, sesamum, okra, brinjal, chilli, maize, rice and pumpkin. The increased REY of ginger and colocasia credited due to its higher production and price of the rhizome and corm.

Increment of yields from mixed cropping attributed by the presence of complimentary effects. Mixed cropping increased resources use efficiency and buffering effects against diseases and weeds. Compatible crops combination is necessary for the highest use of growth resources (Anderson, 2005). Diversification of crops by mixed cropping gives higher

Table 1: Phisico-chemical properties of the surface soil (0-20 cm) of the experimental field

Soil property	Value	Method employed
A. Mechanical composition		
Coarse sand (%)		International pipette method (Khanna and Yadav, 1979)
5 years cycle	2.8	
10 years cycle	2.6	
20 years cycle	2.1	
Fine sand (%)		
5 years cycle	55.2	
10 years cycle	53.6	
20 years cycle	54.3	
Silt (%)		
5 years cycle	26.5	
10 years cycle	27.5	
20 years cycle	27.6	
Clay (%)		
5 years cycle	15.5	
10 years cycle	16.3	
20 years cycle	16	
Textural classification	Sandy loam	
B. Chemical properties		
Soil reaction (pH)		1:2.5 Soil : water suspension, Glass electrode pH meter (Jackson, 1973)
5 years cycle	4.82	
10 years cycle	5.35	
20 years cycle	5.62	
Available N (kg ha^{-1})		Alkaline permanganate method (Subbiah and Asija, 1956)
5 years cycle	268.36	
10 years cycle	294.15	
20 years cycle	312.7	
Available P_2O_5 (kg ha^{-1})		Bray-1 method (Jackson,1973)
5 years cycle	5.44	
10 years cycle	6.15	
20 years cycle	10.75	
Available K_2O (kg ha^{-1})		Flame Photometric method (Jackson, 1973)
5 years cycle	109.25	
10 years cycle	118.46	
20 years cycle	122.32	
Organic carbon (%)		Walkley and Black rapid titration method (Piper, 1966)
5 years cycle	2.22	
10 years cycle	2.28	
20 years cycle	2.4	

yields (Mandal *et al.,* 1990). Several workers like Patra and Chatterjee (1986), Nazir *et al.* (1997), Willey (1997), Choudhary *et al. (*2013), Mandal *et al.* (2014) and Choudhary *et al.* (2014) suggested suitable crops combinations of mixed cropping for higher yield in different agro-ecosystems. Qayyum *et al.* (1995) stated that maize + rice intercropping gave the highest grain equivalent yield of 3.35 t ha^{-1}. Similar result reported by Banik and Bagchi (1994), Saeed *et al.* (1999) and Ahmad *et al.* (2007) on rice equivalent yield of intercropping over sole cropping of rice.

Production efficiency

The PE of sole crops showed different trend in three different fallow cycles when compared with mixed crops. In totality the PE of sole cropping decreased in three cycles (Fig. 2). But it increased for sole cropping of ginger and colocasia. For ginger the PE enhanced by 25.10, 24.71 and 20.65 percent in 20, 10 and 5 year cycles, respectively. In case of colocasia, it increased by 3.32 and 10.13 percent in 10 and 5 years cycle. The lowest PE observed in sole cropping of rice under all cycles. It was as low as 502.96 percent in 5 years followed by 420.10 percent in 20 years. The mixed crops increased the mean PE over sole crops. The PE of mixed crops increased by 502.96, 367.38, 350.23 120.15, 103.81, 33.02 and 22.12 per cent over sole crop rice, pumpkin, maize, chilli, brinjal, okra, and seamum in 5 year cycle, respectively . The percent increased in PE of mixed cropping over sole crop of rice, pumpkin maize, chilli, brinjal, okra, and sesamum in 10 years cycle was 418.47, 398.69, 306.87, 115.84, 90.88, 34.56 and 18.00, respectively. The higher PE of mixed crop in 20 years fallow cycle was recorded against the sole crop of pumpkin. Its PE was statistically at par with rice, followed by maize, chilli, brinjal, okra, sesamum and colocasia as 430.92, 424.10, 349.00, 133.62, 107.71, 50.52, 31.30 and 12.21, respectively. Lithourgidis *et al.* (2011) and Jha *et al.* (2015) reported that mixed or intercropping practices increased productivity as compare to sole crop. It might be due to efficient use of available natural resources for crop growth. That would otherwise not be utilized by each single crop growing alone. Similar types of findings were also reported by Dallal (1974), Andrews and Kassam (1976) in shifting cultivation practices. Bastia *et al.* (2008), Kumar *et al.* (2008) and Sharma *et al.* (2004) also reported that inclusion of vegetable or cash crops

Table 2: N, P and K uptake by crops (kg ha^{-1}) under 5, 10 and 20 year's fallow cycle in mixed and sole cropping.

Crops	Fallow cycle (years) N (kg ha^{-1})			P (kgha^{-1})			K (kg ha^{-1})		
	5	10	20	5	10	20	5	10	20
Mixed crops	95.86[a]	127.14[a]	142.22[a]	20.86[a]	24.35[a]	30.56[a]	70.77[b]	96.83[b]	104.67[c]
Rice	51.01[d]	62.65[d]	78.25[d]	9.32[e]	12.89[e]	16.25[d]	32.63[e]	44.25[g]	61.68[e]
Maize	57.77[c]	66.26[d]	71.74[d]	12.23[b]	15.13[c]	16.25[d]	26.99[g]	31.45[h]	35.66[g]
Colocasia	43.73[e]	52.51[e]	59.20[e]	8.18[g]	8.65[g]	8.74[g]	71.10[b]	92.77[c]	100.67[d]
Okra	61.58[c]	94.34[b]	117.94[b]	10.21[d]	15.63[c]	21.29[b]	31.21[f]	44.39[g]	50.48[f]
Sesamum	80.26[b]	95.39[b]	111.89[b]	10.65[d]	13.09[e]	13.33[e]	46.92[d]	57.40[e]	61.63[e]
Pumpkin	48.33[d]	52.90[e]	60.33[e]	2.85[h]	3.04[h]	3.51[h]	22.96[h]	27.67[i]	33.41[g]
Brinjal	62.96[c]	71.17[c]	91.2[c]	11.13[c]	14.13[d]	16.82[c]	33.60[e]	42.96[f]	49.80[f]
Ginger	82.02[b]	90.28[b]	106.76[b]	8.72[f]	9.25[f]	11.29[f]	124.51[a]	139.10[a]	148.06[a]
Chilli	58.16[c]	79.57[c]	98.13[c]	11.58[c]	19.92[b]	30.24[a]	62.91[c]	86.83[d]	113.82[b]

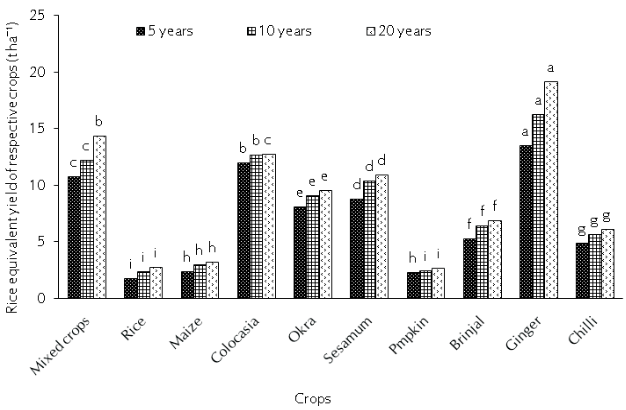

Figure 1: Rice Equivalent Yield (t ha^{-1}) of crops under 5, 10 and 20 years fallow cycle in mixed and sole cropping.

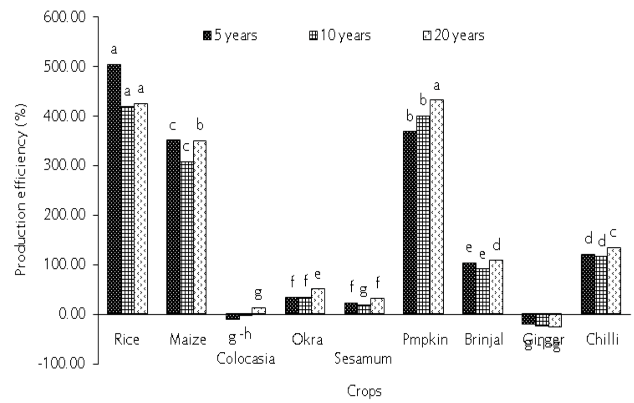

Figure 2: Production efficiency of crops in terms of REY under three cycle

in crop sequences increased the production efficiency of the eco-system.

Total NPK uptake

Information on total uptake of NPK, fallow cycle and crops is presented in Table 2. The total uptake of N, P and K by crops increased with longer fallow cycle. This might be due to more availability of nutrients to crops. In general, the above ground biomass is more in longer fallows. The higher amount of nutrients released during burning of biomass in these fallows. Mishra and Ramakrishnan (1991) reported that nutrients losses were more in short fallow cycle. That reduced nutrient uptake and yield of crops in shifting cultivation. Seubert (1975) also revealed that soils under long fallow forest contain more total N, P and Ca in the surface horizon (0-12 cm) than in the lower horizon. During the fallow period, more nutrients are accumulated in the vegetation than in the topsoil. Thus there is a net transfer of nutrients from the subsoil to the topsoil as a result of it; this enhanced the pumping effect of deep roots. After an enough longer fallow period, the exchangeable nutrients in the topsoil would restore at par to their original levels. Total N and P uptake was highest in mixed crops under three cycles. But total K uptake was highest of ginger plants in 20 years fallow cycle. The lowest uptake of N was observed in colocasia under 5 year cycle and lowest P and K uptake was found in pumpkin in all the fallow cycles. An important aspect of mixed cropping is the utilization of nutrients more efficiently. Growing of different types of crops in same piece of land called mixed cropping. They are having different nutritional requirements. Further, each component crops were distinct for their morphological character and rooting habits. These characters help the crops to absorbed nutrients from different soil horizons. Moreover, the rising temperature during burning of vegetation helps for rapid mineralization process. After cleaning and burning, it provides a sharp increase of available nutrients to crops. (Sanchez, 1973). The complementary use of growth resources by the crops attributed to higher nutrient uptake (Willey, 1979; Benites *et al.*, 1993). Christanty (1986) also reported that after long period of fallow, the exchangeable nutrients in the topsoil revert to its original status.

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