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Performance of relay crops in different fallow cycles of slash and burn agriculture in Northeast India

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Abstract

The slashing and burning of secondary forest biomass is a key traditional hill agricultural practice, which is locally known as jhum cultivation, followed over the centuries by indigenous people of Northeast India. In this system of farming, farmers cultivate different species of crops in mixture for only one season (March to September). However till today, the performances of relay crops on this system of framings are lacking. With this problem a field experiment was undertaken in Jhum fields of Mokokchung district of Nagaland. Field experimental plots of 3 fallow periods (20 years, 10 years and 5 years) under both burnt (unmulched) and unburnt (mulched) were selected and relay crops (Pea and Rajmah) were sown at 20 days before the harvest of jhum crops in Changki village (Nagaland) during 2 years of consecutive cropping phase.

The yield attributing characters and yield of relay crops pea and rajmah increased with the increase in the length of *jhum* cycle i.e 20 years followed by 10 and 5 years crop phase of *jhum* cycles. The relative higher yields of pea and rajmah grown as relay crops were achieved in burnt *jhum* fields as compared to mulched fields. A substantial yield can be achieved by growing relay crop from *jhum* field with improved soil fertility status. Overall the medium length (10 years) *jhum* cycle under burnt situation seems to be the optimum fallow length for relay crops. In conclusion, It was noticeable that burning treatments and longer fallow cycle supported higher yields of relay crops and also maintained higher soil fertility levels till 2nd year of cropping.

Keywords: Relay crop, Jhum cycle, Yield, Northeast

Introduction

The archaeological evidences and the radio-carbon dated traced back the origin of shifting cultivation to about 8000 BC during the Neolithic period and it witnessed the remarkable and revolutionary changes in the man's mode of food production from hunting and gathering to food producers. On the other hand this system is considered as the first step in transition from food gathering and hunting to settle agriculture is nearly 9000 years old practice (Sharma, 1976) [24]. Presently, different forms of shifting cultivations are practiced in the world probably supports 200 to 300 million people over 300-500 million hectares in the tropics and most of them are in Africa, Asia and South America (Crutzen and Andreae, 1990; Datta *et al.*, 2004) [5, 6]. In Northeast India, it is most prevalent form of agriculture which is locally known as *jhumming* and the cultivators are known as *jhummias*. The system is based on cutting and burning the vegetation in the dry season and planting crops in the wet season. Shifting cultivation as a generic term includes a wide range of crop production practices. After growing the crops for 2-3 years the land is abandoned to revert a cover of natural vegetation for several years before it is further cultivated. The field eventually grows into secondary forest before repetition of the cycle. Thus in *jhumming* the *jhummias* rotate land rather than crops to sustain livelihoods. Therefore, it is called as land to land cycle or it can be also consider as forest - agriculture cycle.

The length of this fallow period varies considerably 5-20 years is common (FAO, 1974) [9]. The *jhum* farming is subsistence in nature where productivity of each component is low. But hill farmers are still depending on it either partly or fully for their livelihoods which is 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. It is believed that adoption of improve / alternative agronomic practices like changing of date of sowing, in situ soil and fertility conservation by mulching and relay cropping can help substantially in restoring soil health via-a vis productive capacity of land. Therefore, in the present investigation, an attempt was made to study on "performance of relay crops in different fallow cycles of slash and burn agriculture in Northeast India''.

Materials & Methods

The annual average rainfall of the district is 250 cm. The maximum rainfall occurs during the months of June and July. Rainfall generally begins from April and continues till the end of September. The area enjoys a cold winter and mild summer. The average temperature during summer is 27ºC and the temperature does not rise beyond 32ºC. Soils found in Mokokchung district mainly include alluvial soil, non laterite red soil and forest soil which are in acidic in nature. The location of the study site is shown in Figure1.

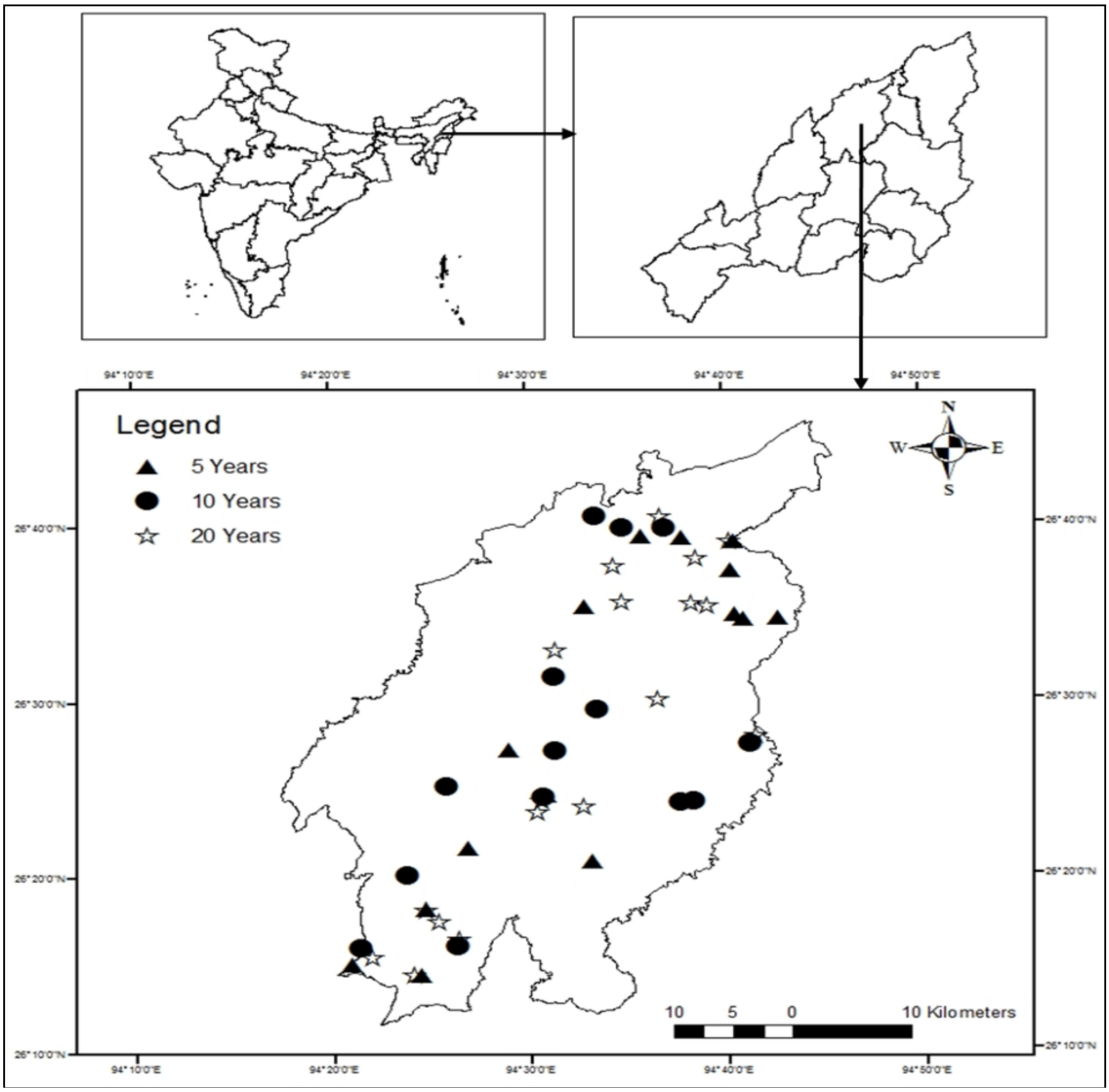

Fig 1: Study sites (5, 10 and 20 years *jhum* cycle) in Mokokchung District of Nagaland, Northeast India.

Field experimental plots of 3 fallow periods (20 years, 10 years and 5 years) under both burnt (unmulched) and unburnt (mulched) were selected and relay crops (Pea variety "Arkel" and Rajmah variety "Arun") were sown at 20 days before the harvest of jhum crops in all plots of three jhum cycle during 2 years of consecutive cropping phase. The experiment was conducted without any chemical or synthetic fertilizer or pesticides. The experiment was designed in split plot design with three replications. The yield attributing character, yield, and nutrient contents in soil were recorded and analyzed by following the standard methods. Test of significance of the treatment difference was done on the basis of t-test. The SPSS V-19 was used to perform the analysis of variance for the data of various parameters. The mean were separated using critical difference value CD at 5% level of significance.

Selection of *Jhum* Cycle

Three *jhum* cycle viz. 20 years, 10 years and 5 years were selected with some criteria which were formulated on the basis of using the number of time the plots were cultivated in the past, the number of year cultivated and in fallow during each cycle that is adopted from Young (1994) [34]. The cycle is referred to the sum of years in cultivation plus years in fallow. The mathematical equation followed as

LU-Intensity=

$$t \times \frac{c}{(c+f)}$$

Where,
LU = Land Used
t = number of cycle
c = Years in cultivation in each year
f = years under fallow in each year

The various observations on plants recorded in the experiment and procedures followed in recording them are given below.

Plant height: From each net plot five number of plant were selected randomly. The heights of these plants were recorded from ground level to the tip of the plant before harvesting of the crop and averages were reported.

Number of branches per plant: The total number of branches per plant was counted for ten randomly selected plants from each net plot and averages were taken.

Number of flower per plant: Total number of flower per plant was recorded for ten randomly selected plants from each plot and averages were taken.

Number of pods per plant: The total number of filled pods per plant was recorded for ten randomly selected plants from each plot and the averages were taken.

Number of seeds per pod: Ten pods from each of the selected sample plants were taken and the average number of seeds per pod was recorded separately for each plot.

Number of nodules per plant: The total numbers of nodules per plant were counted for ten randomly selected plants from border row and average was taken.

Test Weight: One hundred (pea and rajmah) healthy seeds from each net plot harvest were counted and the weights were recorded in grams.

Number of fresh seeds per 100 gram: The total number of healthy fresh seeds per 100 gram was counted from each net plot and weights were recorded in grams.

Pod yield: The economic parts (pod) of the individual crops were separated from plants by hand or using sickle. The product was sundried to get constant weight as well as cleaned or shelled out and further per plot seed weight was taken. The plants in border sides discarded for getting the yield of each net plot and were converted in to t ha^{-1}.

Stover or straw yield: The roots were removed by cutting from base of the plant. The harvest from border (50 cm) was neglected in calculating the stover yield per net plot. After separating the grain or and economic parts, the stover or straw part was dried properly in sun. The weight were taken per plot and treatment wise and expressed in t ha^{-1}.

Results and Discussion

The growth and yield of crops are determined by the weather conditions and the presence of sufficient quantities of available form of nutrients in soil for plant uptake. It is also dependent on the competition for resources in crop or crop mixtures. In the present study, pea and rajmah were grown as relay crops in 5, 10 and 20 years *jhum* cycle and the effect of fallow cycles on growth, yield attributing character and yield of relay crops (pea and rajmah) found significant.

Relay crop pea and rajmah grown under 20 years fallow (F20) showed the maximum growth characters followed by 10 years (F10) and 5 years (F5) fallow sites. However, the individual crop yield of this crop was found to significantly higher in 20 years cycle over 5 years cycle (Table 2). This may be due to fact that higher organic matter accumulation and nutrient availability in burnt longer fallow sites helps the crops for better uptake of nutrients and ultimately effect on growth and yield. Several workers like, Toky and Ramakrishnan, (1981) [30]; Mishra and Ramakrishnan (1981) [19]; Swamy and Ramakrishnan, (1988) [29]; Silva- Forsberg and Fearnside (1997) [27]; Kato *et al*. (1999) [15]; Bruun *et al*. (2006) [4] reported higher yield of crops in long fallow cycle. The marked reduction in yield of crops in short fallow cycle probably related to the physic-chemical properties of soil. Soil organic carbon is considered one of the most important indicators of the productivity of low input farming systems. Shifting cultivation system has been considered as a soil organic carbon management system (Nye and Greenland, 1960) [20]. Several studies documented the positive relationships between fallow length and soil organic carbon content (Ramakrishnan and Toky, 198; Roder *et al*., 1995; Kleinman *et al*. 1996) [22, 23, 16], indicating that soil organic carbon stocks build up during the fallow period. The nutrient availability in soil after burning of vegetation increases but the amount of nutrient found in ash are primarily depends on the total nutrient content in the biomass.

Table 1.a: Effect of fallow cycle and resource conservation on growth parameter of pea as relay crop

Treatment	Plant height (cm)			No of flower plant^{-1}			No of Nodule plant^{-1}		
	1st year	2nd year	Pooled	1st year	2nd year	Pooled	1st year	2nd year	Pooled
Fallow Cycles									
5	31.01	30.56	30.78	5.26	4.03	4.65	6.79	6.69	6.74
10	32.64	32.12	32.38	5.97	4.40	5.18	9.37	8.29	8.83
20	35.68	34.13	34.91	5.26	4.57	4.92	8.66	7.59	8.13
S.E(m)±	0.42	0.30	0.36	0.07	0.12	0.10	0.98	0.51	0.78
C.D. (p=0.05)	1.44	1.05	1.12	0.25	0.40	0.29	NS	NS	NS
Resource Conservation									
Mulching	32.93	31.96	32.45	5.55	4.31	4.93	9.71	7.85	8.78
Burning	33.29	32.58	32.93	5.45	4.36	4.91	6.84	7.20	7.02
S.E(m)±	0.34	0.30	0.32	0.05	0.11	1.45	0.78	0.42	0.63
C.D. (p=0.05)	NS	NS	NS	NS	NS	NS	2.49	NS	NS
* significant at 5% of significance level									

Table 1.b: Effect of fallow cycle and resource conservation on yield attributing character of pea as relay crop.

Treatment	No of pod plant^{-1}			No of seed pod^{-1}			Fresh wt of 100 g seed			No of fresh seed 100^{-1} g		
	1st year	2nd year	Pooled	1st year	2nd year	Pooled	1st year	2nd year	Pooled	1st year	2nd year	Pooled
Fallow Cycles												
5	4.10	3.45	3.77	4.55	4.50	4.52	40.65	40.60	40.63	251.08	251.59	251.34
10	4.45	3.75	4.10	4.60	4.56	4.58	40.69	40.56	40.63	250.75	251.33	251.04
20	4.42	3.60	4.01	4.65	4.55	4.60	40.69	40.59	40.64	251.58	251.71	251.65
S.E(m)±	0.07	0.12	0.10	0.03	0.06	0.05	0.01	0.06	0.04	0.39	0.09	0.29
C.D. (p=0.05)	0.25	NS	0.30	0.09	NS	NS	NS	NS	NS	NS	0.31	NS
Resource Conservation												
Mulching	4.23	3.59	3.91	4.58	4.51	4.55	40.60	40.54	40.57	251.13	251.68	251.40
Burning	4.42	3.61	4.02	4.61	4.55	4.58	40.76	40.63	40.70	251.15	251.41	251.28
S.E(m)±	0.08	0.08	0.08	0.04	0.05	0.05	0.03	0.06	0.05	0.50	0.23	0.39
C.D. (p=0.05)	NS	NS	NS	NS	NS	NS	0.08	NS	NS	NS	NS	NS
* significant at 5% of significance level												

Table 1.c: Effect of fallow cycle and resource conservation on growth and yield attributing character of rajmah as relay crop.

Treatment	Plant height (cm)			No of Branches plant^{-1}			No of pod plant^{-1}			No of seed pod^{-1}			Test weight (g)		
	1st year	2nd year	Pooled	1st year	2nd year	Pooled	1st year	2nd year	Pooled	1st year	2nd year	Pooled	1st year	2nd year	Pooled
Fallow Cycles															
5	29.17	28.25	28.71	2.96	2.87	2.91	4.34	4.30	4.32	2.75	2.72	2.73	26.57	26.55	26.56
10	31.45	29.33	30.39	3.52	3.30	3.41	5.02	4.74	4.88	3.51	3.48	3.49	27.12	27.10	27.11
20	31.83	29.62	30.73	3.71	3.47	3.59	5.11	5.01	5.06	3.58	3.55	3.57	27.14	27.12	27.13
S.E(m)±	0.44	0.53	0.49	0.07	0.08	0.07	0.13	0.09	0.11	0.06	0.05	0.06	0.05	0.03	0.04
C.D. (p=0.05)	1.54	NS	1.51	0.23	0.27	0.22	0.46	0.30	0.35	0.21	0.18	0.17	0.18	0.11	0.14
Resource Conservation															
Mulching	30.44	28.07	29.25	3.26	3.06	3.16	4.59	4.47	4.53	3.15	3.11	3.13	26.80	26.78	26.79
Burning	31.20	30.06	30.63	3.53	3.36	3.44	5.05	4.90	4.98	3.41	3.39	3.40	27.09	27.06	27.07
S.E(m)±	0.36	0.27	0.32	0.07	0.05	0.06	0.08	0.06	0.07	0.06	0.05	0.06	0.04	0.04	0.04
C.D. (p=0.05)	NS	0.85	0.95	0.21	0.15	0.17	0.26	0.19	0.21	0.19	0.18	0.17	0.12	0.13	0.11
* significant at 5% of significance level															

Table 2: Effect of fallow cycle, mulching on pod yield and stover yield (t ha^{-1}) of relay crops.

Treatment Pea Pod				Pea Stover			Rajmah Seed			Rajmah Stover		
	1st year	2nd year	Pooled	1st year	2nd year	Pooled	1st year	2nd year	Pooled	1st year	2nd year	Pooled
Fallow Cycles												
5	1.075	0.892	0.983	1.934	1.862	1.898	0.227	0.212	0.219	0.321	0.306	0.313
10	1.158	0.950	1.054	2.001	1.971	1.986	0.238	0.228	0.233	0.333	0.318	0.326
20	1.168	0.974	1.071	2.030	1.989	2.010	0.242	0.232	0.237	0.336	0.323	0.330
S.E(m)±	0.007	0.016	0.012	0.007	0.005	0.006	0.002	0.001	0.002	0.000	0.003	0.002
C.D. (p=0.05)	0.026	0.054	0.038	0.025	0.018	0.019	0.008	0.004	0.005	0.002	0.010	0.006
Resource Conservation												
Mulching	1.126	0.932	1.029	1.979	1.928	1.953	0.228	0.217	0.222	0.323	0.309	0.316
Burning	1.142	0.945	1.043	1.998	1.953	1.976	0.243	0.231	0.237	0.337	0.323	0.330
S.E(m)±	0.004	0.003	0.004	0.010	0.009	0.010	0.001	0.001	0.001	0.001	0.144	0.102
C.D. (p=0.05)	0.014	0.010	0.011	NS	NS	NS	0.004	0.002	0.003	0.003	NS	NS
* significant at 5% of significance level												

A large amount of inorganic N has been found in the ash after low to medium severity fires (Sanchez 1976; Andriesse 1989; van Reuler and Janssen, 1993; DeBano *et al*. 1998) [24, 1, 32, 7]. Ramakrishnan and Toky (1981) [22] reported that the plant available N and P in soil was increasing with increasing length of fallow in shifting cultivation. A higher amount of available N, P and K content in soil after burning was also recorded at 20 and 10 years cycle than 5 years in the present study (Table 3). A positive relation has also been reported by Swamy and Ramakrishnan (1988) [29] who found the post burn, added more base cations in long fallow (more than 20 years) than 5 years. Yield increases significantly with fallow length; fewer stocks of plant-available N and P were the main causes of yield variations (Bruun *et al*., 2006) [4].

The yield attributing character plant height and number of branches of the studied crop was significantly higher under burning treatment over mulching. Similarly number of flower, number of pod, number of seed per plant and pod yield of Rajmah was significantly higher in burned treated plots. However, no significant difference was observed in case of number of flower and pod yield of Pea under burned and mulched treated plots. Further, the number of nodules per plant was significantly higher in mulched treated plots over burning plots.

The product of ash from burning of plant biomass increased the nutrient content immediately in soil of slash and burn agriculture system. Burning increases the availability of some nutrients such as phosphorus and potassium in the short run (Erenstein, 2002) [8] and it may increase the productivity of the crop in the next season (Haider, 2012) [12]. However, it can also result in the loss of plant nutrients such as nitrogen, potash, sulphur (Gupta *et al*., 2004; Heard *et al*., 2006) [11, 14] and negatively affect the local microbial population and organic carbon (Heard *et al*. 2006) [14]. On the other hand, non–burning of residue and its incorporation can, in the long run, improve soil chemical properties (Sidhu and Beri, 1989;

Gupta *et al*., 2004) [26, 11]. Residue incorporation can increase nitrogen uptake (Verma and Bhagat, 1992) [33], result in higher soil organic matter, organic carbon and microbial biomass, increase the potential for nutrient recycling (Hartley and Kessel, 2005; Malhi and Kutcher, 2007; Ganwar *et al*., 2006) [13, 17, 10] and contribute to higher crop yields (Surekha *et al*., 2003; Tripathi *et al*., 2007; Bahrani *et al*., 2007) [28, 31, 3].

Table 4. Effect of fallow cycle and resource conservation on soil reaction, OC and available N, P_2O_5, K_2O before sowing of relay crops.

Treatment	Soil pH			Soil OC (%)			Available N (kg ha^{-1})			Available P_2O_5 (kg ha^{-1})			Available K_2O (kg ha^{-1})		
	1st year	2nd year	Pooled	1st year	2nd year	Pooled	1st year	2nd year	Pooled	1st year	2nd year	Pooled	1st year	2nd year	Pooled
Fallow Cycles															
5	4.58	4.540	4.560	1.985	1.693	1.839	271.991	257.105	264.548	4.646	3.080	3.863	106.379	97.781	102.080
10	4.805	4.844	4.824	2.039	1.767	1.903	301.858	284.709	293.283	6.849	4.006	5.427	117.882	107.858	112.870
20	5.168	5.133	5.150	2.095	2.013	2.054	321.605	303.573	312.589	9.674	5.418	7.546	125.783	118.963	122.373
S.E(m)±	0.007	0.004	0.006	0.004	0.001	0.003	0.277	0.476	0.390	0.047	0.065	0.056	0.317	1.128	0.829
C.D. (p=0.05)	0.026	0.014	0.021	0.013	0.005	0.010	0.960	1.649	1.349	0.161	0.224	0.195	1.098	3.904	2.868
Resource Conservation															
Mulching	4.611	4.589	4.600	1.897	1.717	1.807	280.509	266.986	273.748	5.822	3.960	4.891	106.766	99.331	103.048
Burning	5.090	5.089	5.089	2.183	1.931	2.057	316.459	296.606	306.532	8.290	4.376	6.333	126.597	117.070	121.834
S.E(m)±	0.007	0.004	0.145	0.002	0.002	0.093	0.314	0.240	1.168	0.027	0.048	0.153	0.340	0.528	0.748
C.D. (p=0.05)	0.021	0.012	0.465	0.008	0.007	NS	1.006	0.766	3.736	0.086	NS	0.490	1.088	1.689	2.391
* significant at 5% of significance level															

Table 5: Effect of fallow cycle, resource conservation and relay crops on soil pH, OC, available N, P_2O_5 and K_2O after harvest of relay crop in *jhum* field.

Treatment	Soil pH			OC (%)			Avail. N (kg ha^{-1})			Avail. P_2O_5 (kg ha^{-1})			Avail. K_2O (kg ha^{-1})		
	1st year	2nd year	Pooled	1st year	2nd year	Pooled	1st year	2nd year	Pooled	1st year	2nd year	Pooled	1st year	2nd year	Pooled
Fallow Cycles															
5	4.57	4.55	4.56	1.91	1.63	1.77	268.07	255.44	261.75	3.79	2.86	3.33	102.85	95.52	99.19
10	4.79	4.84	4.81	1.92	1.67	1.79	297.37	281.16	289.26	4.67	3.09	3.88	114.94	103.29	109.12
20	5.17	5.12	5.15	1.99	1.83	1.91	317.85	300.61	309.23	6.48	4.05	5.27	124.29	114.43	119.36
S.E(m)±	0.005	0.003	0.172	0.004	0.003	0.080	0.120	0.450	11.462	0.096	0.024	0.375	0.852	0.411	6.184
C.D. (p=0.05)	0.016	0.009	0.596	0.012	0.011	0.279	0.414	1.557	39.664	0.333	0.084	1.298	2.949	1.422	21.401
Resource Conservation															
Mulching	4.60	4.59	4.60	1.80	1.63	1.72	276.67	264.57	270.62	4.24	3.25	3.75	104.98	95.98	100.48
Burning	5.08	5.08	5.08	2.08	1.79	1.93	312.19	293.57	302.88	5.73	3.41	4.57	123.08	112.85	117.96
S.E(m)±	0.005	0.003	0.004	0.003	0.001	0.002	0.147	0.423	0.317	0.047	0.015	0.035	0.673	0.557	0.618
C.D. (p=0.05)	0.017	0.009	0.013	0.009	0.004	0.007	0.470	1.354	0.941	0.152	0.047	0.104	2.153	1.782	1.835
Relay crop															
Pea (P)	4.85	4.84	4.84	1.94	1.71	1.83	294.21	278.83	286.52	4.98	3.33	4.16	113.78	104.36	109.07
Rajmah (R)	4.84	4.84	4.84	1.94	1.71	1.82	294.65	279.30	286.98	4.99	3.33	4.16	114.27	104.47	109.37
S.E(m)±	0.003	0.001	0.002	0.002	0.002	0.002	0.294	0.137	0.229	0.004	0.003	0.004	0.154	0.064	0.118
C.D. (p=0.05)	NS	NS	NS	NS	NS	0.006	NS	0.407	NS	NS	NS	NS	0.458	NS	NS
* significant at 5% of significance level															

The relay cropping system can be considered as a type of intensified shifting cultivation by means of introducing commercial crops and improving fallow management. The relay-cropping of viny legumes could be considered as a locally evolved type of accelerated seasonal fallow management in Thailand aimed at soil fertility replenishment and income generation in an intensified shifting cultivation system (Ongprasert and Prinz, 2004) [21].

In the present study the soil pH, OC, available N, P_2O_5 and K_2O after harvest of relay crops were found to be higher in 20 years cycle followed by 10 and 5 years cycle (Table 5). The increased soil pH in longer cycle (20 and 10 years) may be due to the residual effect of higher amount of biomass burning. However, higher value of OC, available N, P_2O_5 and K_2O after harvest of relay crops in longer fallow may be due to luxuriant growth of relay crops, which attributed more nodulation and biomass. Marinus (2014) [18] reported that benefits of the cowpea crop (financial and N-contributions) were more favourable for the higher fertility fields and less for lower fertility fields. Aweto (2013) [2] reported that the introduction of *Glycine max* as relay crop with maize into small scale farm has the advantage of improvement of soil fertility status, in addition to farmers' boosting income as cash crop.

Conclusion

Increase in population and other socio economic pressure on land have resulted in a shortening of the fallow period of shifting cultivation in Northeast India. This may cause decline in agricultural productivity and increased vulnerability to environment hazards. One measure to cope with a shorter fallow period is to improve fallow management, which may help to mediate the pressure on land and also to upgrade the livelihood of shifting cultivators. The relay cropping system can be considered as a type of intensified shifting cultivation by means of introducing commercial crops and improving fallow management.

Relay cropping of pea and rajmah into slash and burn agriculture system has the advantage of farmers' boosting income as cash crop, in addition to improvement of soil fertility status, Overall, the medium to longer length (10 -20 yrs) jhum cycle under burnt situation seems to be the optimum fallow length in terms of yields of relay crops.

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