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Evaluating second year cropping on jhum fallows in Mizoram, north-eastern India—Phytomass dynamics and primary productivity

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Abstract. **Cropping on jhum fallows in north-eartern India is predominantly done for one year in a jhum cycle. If second year cropping is done, expanse of the forest land required for slashing and burning could be reduced significantly. We tested this hypothesis in a young (6 yr) and an old (20 yr) jhum fallow. We also evaluated if the productivity during second year cropping could be alleviated by auxiliary measures such as tilling the soil or application of fertilizers (chemical or farm-yard manure or both in combination). The results demonstrate that the ecosystem productivity (total dry matter production) and economic yield (rice grain production) decline with shortening of jhum cycle. Second year cropping causes a further decline in ecosystem productivity in old jhum field, but not in young jhum field. Economic yield from second year cropping in its traditional form (without any fertilizer treatment) is not much lower than that in the first year, and can be improved further by manuring the soil. Tilling of soil improves neither ecosystem productivity nor economic yield. Different fertilization treatments respond differently; while inorganic manuring enhances ecosystem productivity, a combination of inorganic and organic manuring improves economic yield.**

Keywords. **Jhum; ecosystem productivity; phytomass; fertilizer application; farm-yard manure; rice cultivation.**

1. Introduction

Slash-and-burn agriculture, locally called Jhum, is the most important mode of raising food for forest farmers in Mizoram, north-eastern India. As much as 2 lakh hectare land is affected by jhum, with approximately 63,000 ha being cultivated in a given year by 50,000 families (Anonymous 1987). The average jhum land per family is about 1·3 ha and the present jhum cycle is four years (Anonymous 1987).

Jhum is the form of agriculture in which a piece of forest land is slashed, burnt and cropped without tilling the soil, and the cropped land is subsequently fallowed to attain preslashed forest status through natural succession (Uhl *et al* 1983; Ramakrishnan 1993). Among the two most conspicuous features of jhum, one is that all the agricultural Operations are performed manually, using only a few traditional and primitive tools. Secondly, regeneration of forest and soil fertility are achieved cost-free and effortlessly. A number of variants of the basic jhum practice occur, particularly in the north-eastern India (Ramakrishnan 1993). For example, there is variation in the number of years for which a slashed-and-burned land is cultivated successively.

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Cropping on jhum lands in Mizoram is predominantly practiced for one year. The second year cropping is scarce, and whenever done, is only on old jhum fallows. Even in other parts of north-eastern India, the land is oft abandoned after first year of cropping, and second year cropping is sometimes practiced with plantations of banana and pineapple (Kushwaha and Ramakrishnan 1987). We hypothesized if second year cropping on jhum fields is essentially introduced, the dependence of the shifting cultivators on the forest could be reduced to almost one-half. Not only would this curtail greatly the slashing and burning of forested areas for cultivation, the jhum cycle would also be lengthened considerably. However, farmers' apprehension that the yields obtained from the second year of cropping are far lesser than those obtained from cropping new areas, is not tested scientifically. While arguing about reduction in yield during second year cropping, the farmers do not take into account the energy invested in slashing and burning newer areas every year, since energy in form of human labour is free for them.

Introduction of second year cropping should be based on scientific principles to ensure wider applicability and acceptability by the farmers. It is necessary that (i) ecological efficiency of the system is maintained, (ii) physical and chemical characteristics of the soil are conserved, and (iii) profit from agricultural activity to the farmer is assured. Therefore, we monitored phytomass dynamics, primary productivity, energy and economic efficiencies, and soil fertility changes during first and second year of cropping. The effect of auxiliary measures to enhance crop productivity during second year such as tilling the soil or application of fertilizers (chemical or farm-yard manure or both in combination) was also examined. In addition, we tested whether second year cropping with or without auxiliary measures is economical in young (6 year) or old (20 year) or both the jhum fields. Here, we present the results on phytomass dynamics and primary productivity during first and second year of cropping.

2. Study site

An inventory of jhum practices in the state of Mizoram in north-eastern India revealed that the most common jhum cycle is 4-6 years and the jhum cycle with more than 20 years is scarce (Tawnenga 1990). The jhum cycle is defined as the intervening fallow period between two successive croppings on a forested land (Kushwaha *et al* 1981). We, therefore, conducted studies on jhum fallows of 6 year and 20 year to represent average and maximum jhum cycle. Henceforth, 6 year fallow will be designated as "young" and 20 year fallow as "old".

Field studies were conducted during 1988 and 1989. Young jhum fallow was located at Seasawng (23° 50' N latitude, 92° 54' E longitude, 1166m altitude) and old jhum fallow at Muallungthu(23°38' N lat., 92°43' E long., 985 m altitude) village (figure 1). The age of the jhum fallows was ascertained with the landholders.

Rice is the main crop in Mizoram. Two upland varieties of rice, namely, "buhpui" and "tai" are popular among farmers. Mostly, rice is grown in monoculture. However, several other crops are also mixed with rice in some cases, depending upon the requirement of the family. These crops may be maize, colocasia, brassica, chillies, sesamum, brinjal, and many other vegetables and pulses. Sometimes ginger, cotton and tapioca are also cultivated. A shifting cultivator is allotted for a jhum field through a lottery system by the Village Council. The area to be cultivated is decided by the cultivator on the basis of size and working capacity of his family. The forested fallow is slashed and cleared during December-January. The burning

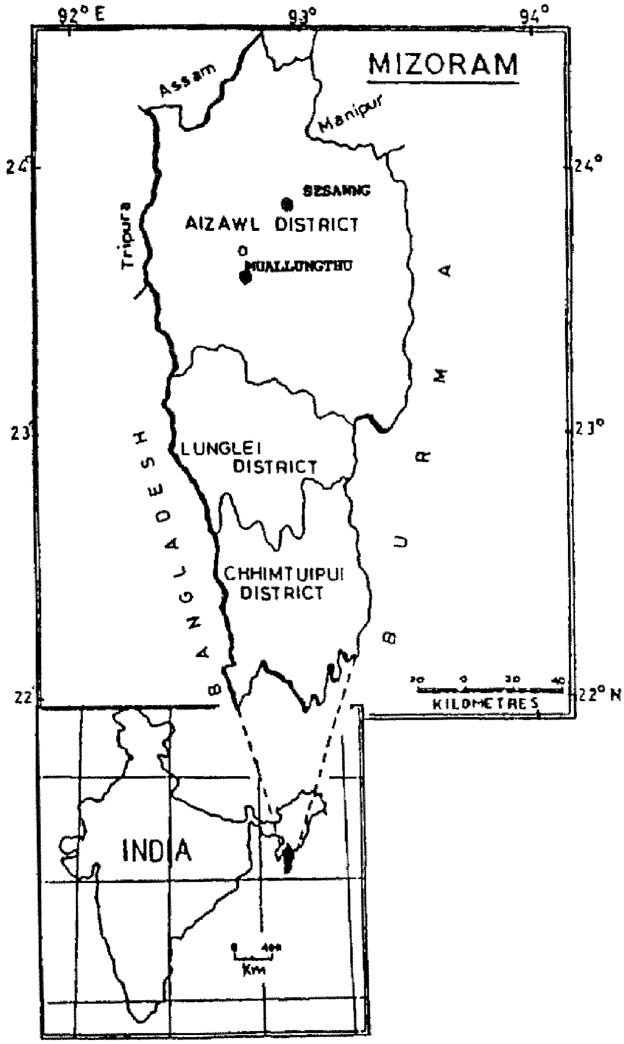

Figure 1. Geographical location of the study sites.

of slash is done in March-April. Rice is sown mostly from the middle of April to the middle of May. The fertilizer responsive variety "buhpui" was used in the present study.

The study area is directly influenced by southwest monsoon and experiences a moderate tropical climate. The monsoon season starts in April and ends in October. Winter extends from mid-October to mid-February, and spring (summer) from mid-February to mid-April. Occasional showers of low to medium intensity are also received during winter months. The recorded rainfall in the area is 2423 mm for 1988 and 2340 mm for 1989 (figure 2). The average daily temperature ranges between 11°C in winter to 29°C in summer.

The soils are red loamy, porous, friable and acidic with light texture. The chemical characteristics of both young and old experimental jhum fields and changes in soil fertility in response to various jhuming operations shall be discussed in an affiliated paper forthcoming. Nevertheless, old field soil is richer in nutrients than young field soil.

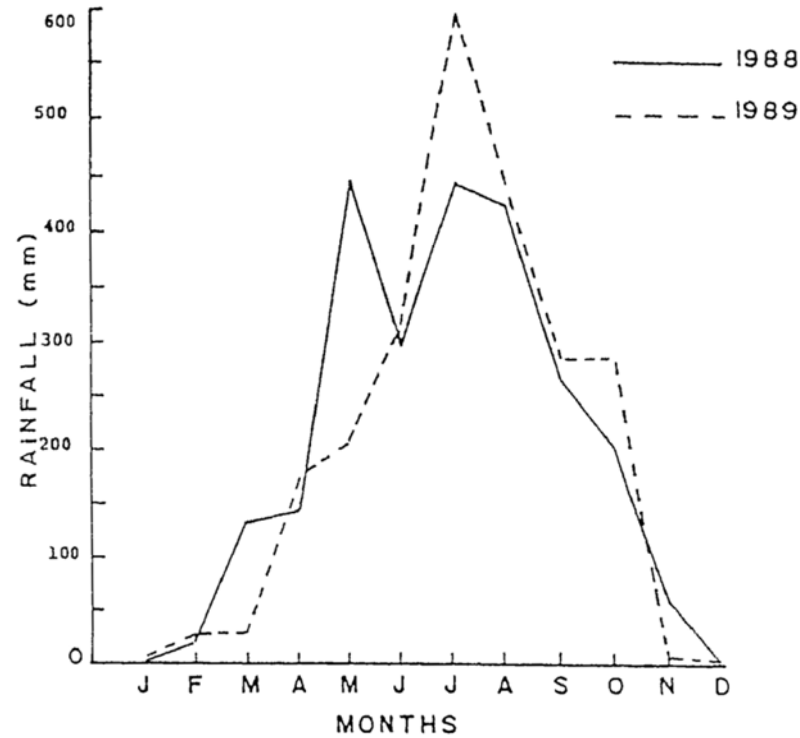

Figure 2. Monthly rainfall of study sites suring 1988 (———) and 1989 (– – –).

The natural vegetation of Mizoram is a typical of "East-Himalayan subtropical wet hill forests" at high altitude and "tropical wet evergreen forests" at low altitude (Champion and Seth 1968). About 75% of total geographical area is under forest cover. The vegetation of both young and old experimental jhum plots before slashing was of "secondary successional type" with the dominance of *Melocanna bambusoides* (Tawnenga 1990). The young field contained 45 species (9 tree, 23 shrub, 13 herb) and the old field contained 38 species (16 tree, 16 shrub, 5 herb). The vegetation which grew during the intervening fallow period between first and second year of cropping was dominated by the sprouts of *Melocanna bambusoides, Eupatorium odoratum*, *Mikania micrantha, Ageratum conyzoides* and *Conyza auriculata* in both the fields.

3. Methodology

An area of 5000 m^2 was selected as study plot both in young (6 year) and old (20 year) fallows. The thriving vegetation on these fallows was slashed and burnt prior to the start of agricultural activities. For first year cropping, the whole plot was used and referred to as 6:I:C (6 years age, first year cropping, control plot) for young and as 20:I:C (20 years age, first year cropping, control plot) for old fallow. For second year cropping, the herbaceous vegetation which grew during intervening fallow period between the first year's crop harvest and the initiation of second year's agricultural activity was slashed and burnt again. Each plot was then divided into five sub-plots of approximately 1000 m^2 area along the slope. One of these five sub-plots was cultivated without any treatment which thus served as control (6: II: C for young and 20: II: C for old fallow). Tilling of soil was introduced in the second sub-plot (6: Π :T for young and 20:II:T for old fallow). In the third sub-plot chemical fertilizers were applied (6: II: CF for young and 20: II: CF for old fallow). Farm-yard manure (FYM) was supplied to the fourth sub-plot (6: II: FYM for young and 20: II: FYM for old fallow). The fifth sub-plot was treated with a combination of chemical fertilizer and farm-yard manure (6: II : CF + FYM for young and 20: II: CF + FYM for old fallow).

Chemical fertilizer or farm-yard manure or a combination of both was applied just before sowing of rice seeds following the dose recommendations by the State Agriculture Department,Government of Mizoram.The composition of chemical fertilizer was 50 kg urea, 60 kg diammonium phosphate (DAP) and 65 kg muriate of potash (MOP) in a hectare. Farm-yard manure was applied at the rate of 3000 kg ha^{-1}. Several workers contend however that the application of nitrogen fertilizer is of limited value on sloppy sites, since it is wasted through runoff.

The phytomass in crop fields was determined by monolith excavation technique. The sampling was done at monthly interval on four dates (June, July, August and September) both in 1988 and 1989, starting from one month after sowing of rice seeds. Five randomly selected monoliths of 25 × 25 × 25 cm were excavated on each sampling date from each study plot. The underground parts were separated from the soil by gentle washing in running water. The crop tillers were separated from those of weeds. The underground parts of both rice and weeds were separated from their respective aboveground parts by cutting the individuals at ground level. The senesced parts of plants were not separated from the live parts. Also, the weeds were not classified to the species level. The phytomass samples were brought to the laboratory, oven dried at 65 ± 5°C till constant weight, and weighed.

The primary productivity was calculated following trough-peak analysis approach, i.e., by summing all positive increments in the phytomass on successive sampling dates all round the sampling period (Uma Shankar *et al* 1993). The production was calculated separately for aboveground and underground parts of both rice crop and weeds for all study plots. The economic yield was considered in terms of rice grain production.

In agroecosystems such as jhum, weeds pose considerable problem during cropping. Weeding was required twice in old field and thrice in young field. Hand-hoeing is the usual way of weeding.

4. Results

4.1 *Phytomass dynamics*

The phytomass dynamics of aboveground parts of rice and weeds in young (figure 3) and old (figure 4) jhum fields exhibit a general unimodal pattern of growth; a positive increase in phytomass from the first to last sampling date with the peak at final harvest. The phytomass dynamics of underground parts also followed the unimodal growth pattern, though it was more pronounced for rice than weeds. The phytomass is significantly greater in aboveground than underground compartment both for rice crop and weeds in all the treatment plots (t-test, $P < 0{\cdot}01$). Similarly, phytomass is significantly greater for rice crop than weeds for aboveground as well as underground parts in all the treatment plots (t-test, $P < 0{\cdot}01$).

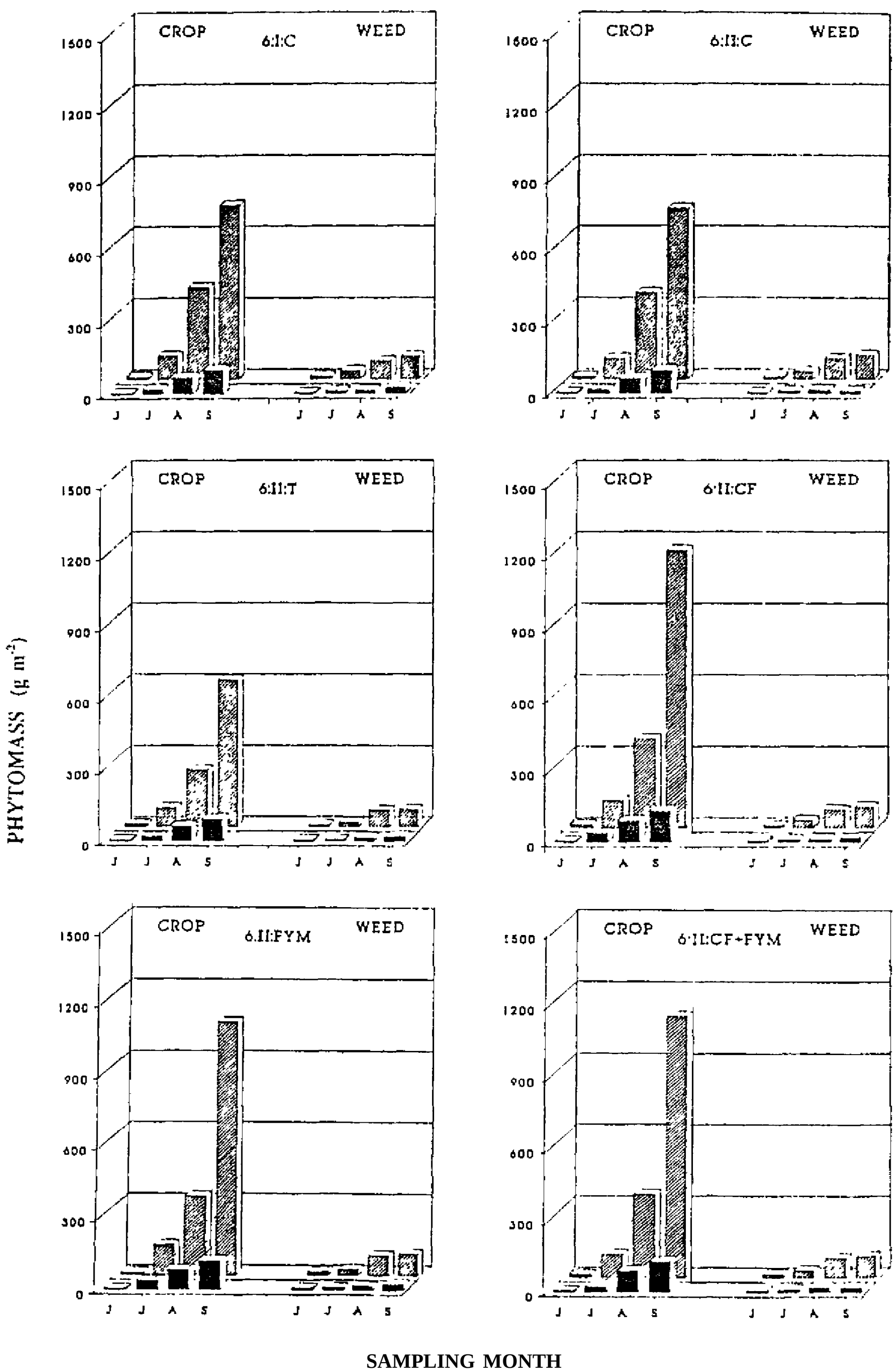

Figure 3. Aboveground (hatched) and belowground (filled) phytomass dynamics of rice crop and weeds in different experimental plots of young jhum field.

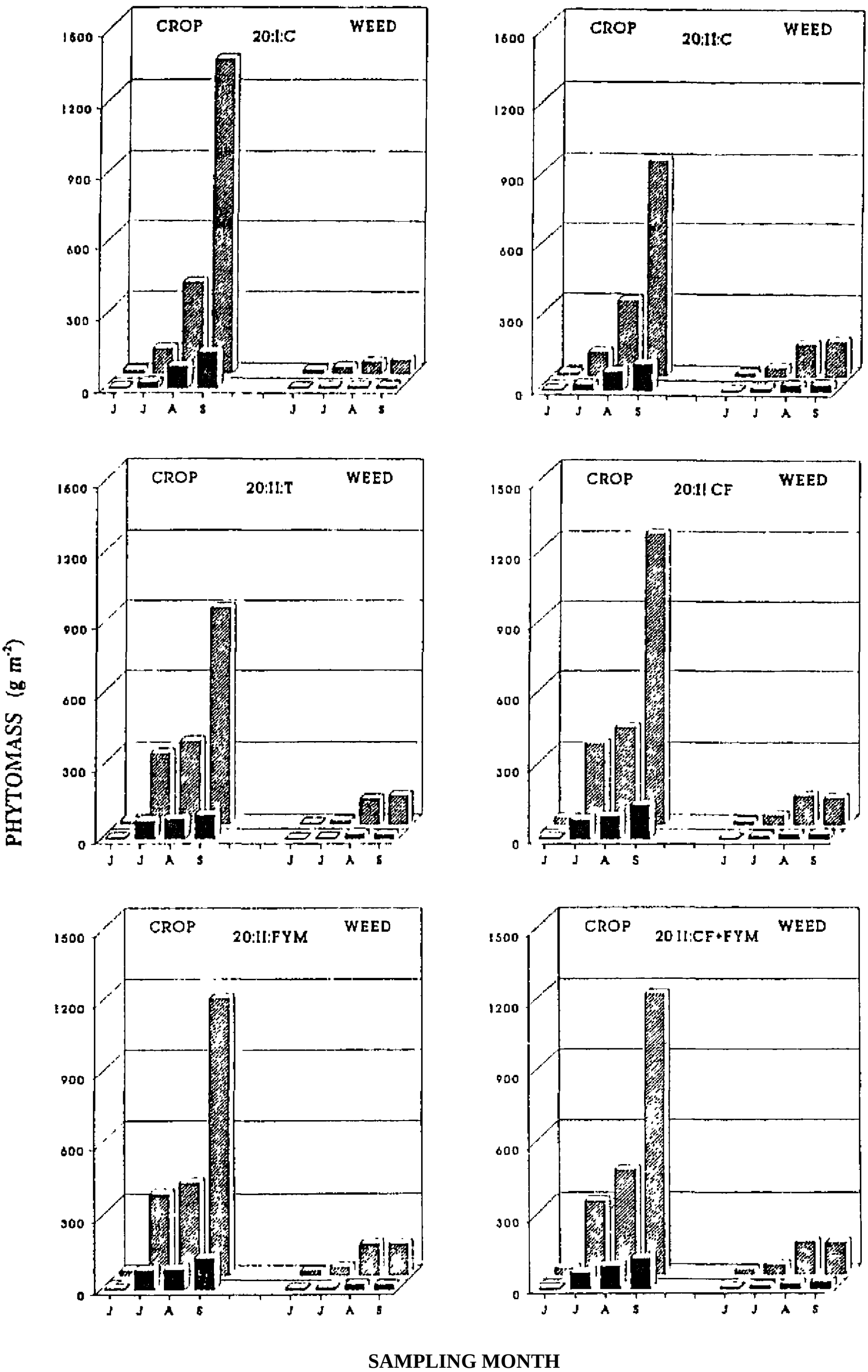

Figure 4. Aboveground (hatched) and belowground (filled) phytomass dynamics of rice crop and weeds in different experimental plots of old jhum field.

The total phytomass (aboveground + underground) of crop and weeds at peak growth (recorded on final sampling date in all cases) varied greatly between young and old jhum fields during first year cropping. The crop phytomass was 1·7 times higher in old (1473 gm $^{-2}$) than young (832 gm $^{-2}$)jhum field. Similarly, weed phytomass was 1·9 times higher in young (125 gm $^{-2}$) than old (66 gm $^{-2}$) jhum field. When second year cropping was practiced, the crop and weed phytomass in young control plot was comparable with that during first year cropping (table 1). But, in old control plot, crop phytomass decreased and weed phytomass increased significantly ($P < 0{\cdot}01$) compared to that during first year cropping (table 1). Tilling of soil during second year cropping resulted in a decline in crop and weed phytomass in young field, but crop phytomass remained unaffected in old field. The application of fertilizers (CF, FYM, CF + FYM) increased crop phytomass both in young and old jhum fields. Furthermore, the increase was greater in young (1·34 to 1·59 times) than old (1·27 to 1·35 times) field. However, the response of different fertilizer treatments was comparable between young and old fields. The weed phytomass remained unaffected in young field but declined marginally in old field consequent to fertilizer application.

Percentage contribution of weeds to total phytomass declined as the crop attained maturity (table 2). The weeds during first year cropping shared about 55% phytomass at the first sampling date both in young and old fields and declined up to 4% in old and 13 % in young field at the final sampling date. This trend was more or less similar during second year cropping for control as well as treatment plots.

4.2 *Primary productivity*

The total phytomass production (including aboveground and underground parts of both rice crop and weeds) in first year control plot was comparable with that in second year control plot in young jhum field (figure 3), but it declined from first to second year cropping in old jhum field (figure 4). Tilling of soil did not show any improvement in total phytomass production in young as well as old field. The treatment of plots with fertilizers showed an increase in total phytomass production both in young and old

Table 1. Phytomass production in different treatment plots of young and old jhum fields during second year of cropping as compared to the phytomass production in first year of cropping·

Ratio	Crop	Weed	Total
Young jhum field			
6:II:C/6:I:C	0·98	0·91	0·97
6:II:T/6:II:C	0·87	0·83	0·87
6:II:CF/6:II:C	1·57	0·95	1·51
6:II:FYM/6:II:C	1·45	1·02	1·40
6:II:CF + FYM/6:II:C	1·50	0·97	1·44
Old jhum field			
20:II:C/20:I:C	0·69	2·64	0·77
20:II:T/20:II:C	0·99	0·79	0·96
20:II:CF/20:II:C	1·35	0·76	1·27
20:II:FYM/20:II:C	1·27	0·87	1·21
20:II:CF + FYM/20:II:C	1·28	0·93	1·23

Table 2. Percentage contribution of weeds to total phytomass in different months during cropping period in young and old jhum fields·

Plot	June	July	August	September
Young jhum field				
6:I:C	54·6	28·7	16·8	13·1
6:II:C	42·3	29·6	19·8	12·2
6:II:T	48·1	19·0	22·2	11·8
6:II:CF	46·7	22·1	16·1	7·7
6:II:FYM	60·0	16·5	19·6	8·9
6:II:CF + FYM	57·5	25·3	19·2	8·2
Old jhum field				
20:I:C	55·5	22·2	10·8	4·3
20:II:C	55·2	26·9	25·3	12·9
20:II:T	35·2	4·9	22·8	12·0
20:II:CF	34·6	3·8	22·1	8·8
20:II:FYM	49·5	9·4	24·6	10·5
20:II:CF + FYM	44·4	12·0	22·8	11·0

fields. This increase, mostly with CF treatment, was closely followed by FYM and CF + FYM treatments in both young and old jhum fields. When underground parts were excluded from the analysis, the aboveground phytomass production (crop + weed) showed a pattern very similar to that described for total production (figure 4).

The rice grain production was about 9% more in old (1586 kg ha^{-1}) than young (1463 kg ha^{-1}) field during first year cropping (figure 5). When second year cropping was done without any treatment, the grain production declined by 15% in young and 20% in old field. Tilling of soil did not affect grain production both in young and old field. However, grain production increased consequent to fertilizer application in young as well as old fields (figure 5). The CF + FYM treatment caused maximum increase in grain production (17% in young and 48% in old field) followed by CF treatment (11 % in young and 20% in old field). The FYM treatment was least affective, causing only 5% increase in young and 11 % in old field.

5. Discussion

The primary productivity under slash-and-burn agriculture (jhum) can be viewed at three levels: (i) ecosystem productivity, (ii) farm-use productivity, and (iii) economic productivity. The ecosystem productivity is the sum of production of phytomass in all aboveground and underground compartments of both crop and weed in the present case. Although not all compartments of an agroecosystem are harvested and utilized by the farmers, the primary production in them together represents the ecological efficiency of the system. Therefore, interpretation of data at this level assumes importance. In the present study, ecosystem productivity is related to the length of jhum cycle; the longer the jhum cycle, the greater the ecosystem productivity. This pattern is in agreement with Toky and Ramakrishnan (1981). Comparatively better soil fertility in old than young field carves such a trend.

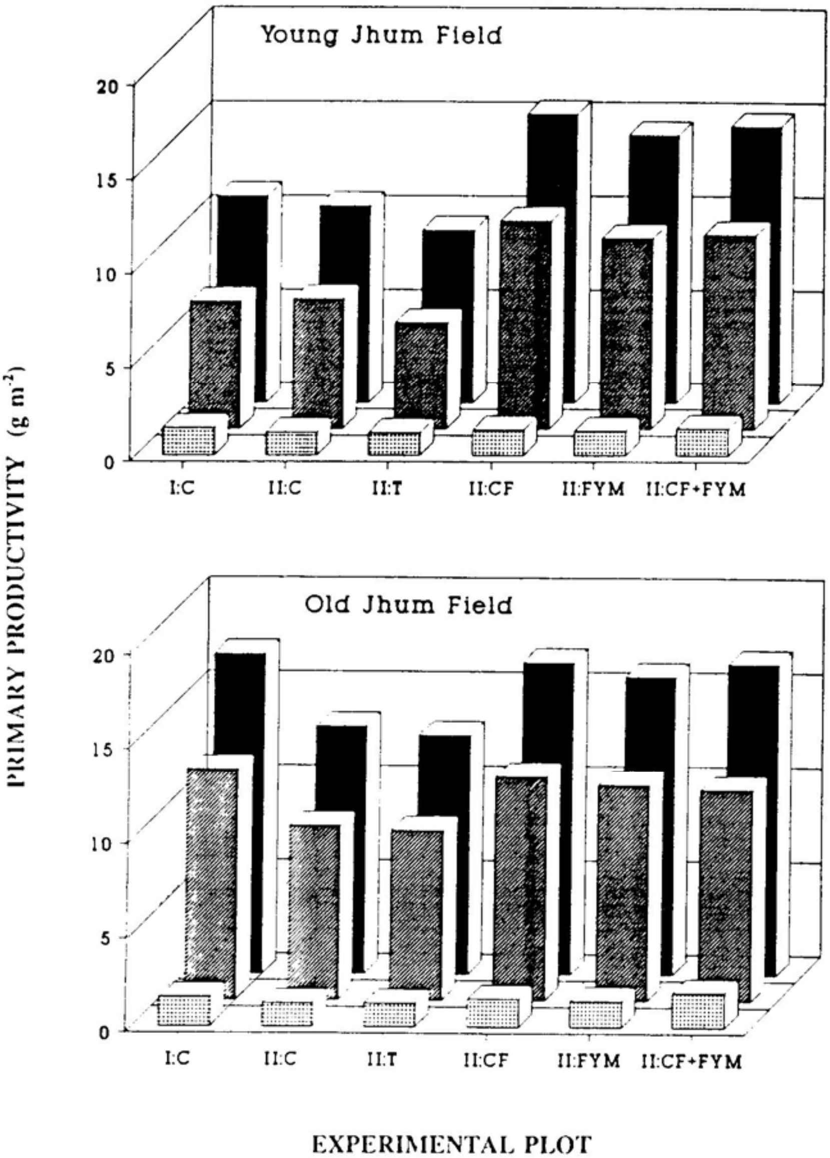

Figure 5. Primary productivity in different experimental plots of young and old jhum fields. Filled bars represent ecosystem productivity, hatched bars represent farm-use productivity, and dotted bars represent economic yield (rice grain production)·

Ecosystem productivity during second year cropping remained unchanged in young field, but declined in old field. Addition of nutrients through slashing and burning is more in old than young field in the first year, due to better standing crop in former than latter (Tawnenga 1990). Since added nutrients remain on soil surface, they are vulnerable to loss in runoff and leaching under the influence of high rainfall (Ramakrishnan *et al* 1981; Pandey *et al* 1993). Added nutrients though enhanced productivity during first year, an appreciable proportion of them might have been lost through outflowing water. This could impoverish the soil and hamper the yield, particularly in old field. Ecosystem productivity though increased consequent to fertilizer application both in young and old fields, the per cent increase in young field was almost twice that of old field. This result indicates that the young field exhibits greater fertilizer use efficiency. In other words, productivity in young field is primarily limited by nutrient deficiency.

The percentage contribution of weeds to total phytomass declined with crop age. An important factor fabricating this trend is the faster rate of crop productivity with a strong smothering effect on growing weed seedlings (Donald 1958,1963). Depletion of germinable fraction of weed seeds in soil also influences successive emergence of weed seedlings such as *Galinsoga ciliata* and *G. parviflora* (Rai and Tripathi 1984), *Parthenium hysterophorus* (Pandey and Dubey 1989), and many others (Misra *et al* 1992). Comparatively greater production of weed phytomass in young than old field in the first year of cropping may be due to shorter jhum cycle in the former than the latter. Under short jhum cycle, such as 5-6 years, community is maintained more or less in permanent state of arrested succession (Kushwaha *et al* 1981; Zinke *et al* 1978). However, when succession progresses for a longer period, such as 10 years or more, weed growth is suppressed by immigration of boreal elements (Saxena and Ramakrishnan 1984). In old field, much higher weed phytomass produced during second than first year of cropping indicates the vulnerability of jhum lands to weed infestation.

The agricultural residue (total aboveground weed plus crop production-grain production) represents the farm-use productivity. The farm-use production in general was about two-third of the ecosystem productivity, and its pattern across different treatment plots was very similar to the trend observed for ecosystem productivity. Farm-use productivity can be utilized in several ways depending upon the farmer's needs. For example, it could be mulched for enrichment of soil through natural decomposition, burnt to release alkaline ash containing inorganic elements to combat the acidity, fed to livestock, or consumed in biogas producing units. Use of crop residue as livestock feed lengthens nutrient cycle by enhancing the residence time of nutrients in biotic component of the ecosystem, which is an effective nutrient conservation strategy (Russell 1982; Xu and Luo 1980).

While ecosystem productivity was much higher (61%), economic yield (rice grain production) was only marginally higher (9%) in old than young jhum field during first year cropping, indicating that greater nutrient addition to soil through slash-and-burn in old field is not essentially channelled to greater seed set. The grain yield in young and old control plots declined from first to second year cropping, and was nearly equal between the two. Tilling did not have a noticeable impact on grain yield, but fertilizer application caused an increase. The increase was maximum due to CF + FYM treatment in young as well as old field. It is in contrast with the ecosystem productivity, the maximum increase in which was obtained from CF treatment. Is it that the different forms of manuring (inorganic and organic) have differential effect on various ecosystem components? Nambiar (1992) noticed that organic manuring responds differently than inorganic manuring. He recorded 0·81 t ha^{-1} rice yield without manuring, which increased to 1·3 t ha^{-1} with organic (FYM) and to 2 t ha^{-1} with inorganic (NP) manuring. But the yield with a combination of organic and inorganic manuring was comparable to that with inorganic manuring alone (1·9 t ha^{-1}). This has implication in management of agroecosystems. For example, to achieve higher productivity in form of rice grain, the fertilizer recommendations may be different from that if higher yield is to be achieved in other phytomass components.

The rice grain productivity under jhum cultivation reported from north-eastern India is highly variable, from as low as 190 kg ha $^{-1}$ (Borthakur *et al* 1978) to as high as 1200 kg ha $^{-1}$ (Misra 1976). The average rice yield from jhum cultivation as reported by Agro-Economic Research Centre, Jorhat (1961-70) is 800-900 kg ha $^{-1}$ in Tripura. In a study of rice yield at low elevation in Meghalaya under different land use, Sahu (1978) obtained yearly outputs of 853 kg ha $^{-1}$ under jhum, 738 kg ha $^{-1}$ under terrace, and 3428 kg ha $^{-1}$ under valley cultivation. Per hectare rice yield obtained in our study surpassed the yield recorded for any other jhum system of cultivation in north-eastern India. However, these yields are much lower than those obtained under valley-land cultivation by Sahu (1978). Since grain yield declines with reduction in jhum cycle, as in present study, the farmers at low elevation in Meghalaya practice mixed cropping, and maximise economic yield by decreasing the proportion of grain crops and increasing leafy and tuberous crops with shortening in jhum cycle (Toky and Ramakrishnan 1981).

The following conclusions can be narrated from this study. Ecosystem productivity and economic yield decline with shortening of jhum cycle. Second year cropping causes a further decline in ecosystem productivity in old jhum field, but not in young jhum field. Economic yield from second year cropping in its traditional form (without any treatment) is not much lower than that in the first year, and can be improved by manuring the soil. Tilling is not much useful for improving either ecosystem productive-ity or economic yield. Inorganic and organic manuring in isolation and in combination respond differently; while inorganic manuring has greater impact on ecosystem productivity, a combination of inorganic and organic manuring is more suitable to improve economic yield during second year cropping.

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