

**STUDIES ON ECOLOGICAL IMPLICATIONS OF
TRADITIONAL AND INNOVATIVE APPROACHES
TO SHIFTING CULTIVATION
IN MIZORAM**

By

Tawnenga

**THESIS SUBMITTED IN FULFILMENT OF THE DEGREE OF
DOCTOR OF PHILOSOPHY IN BOTANY**



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I certify that the thesis entitled "*Studies on ecological implications of traditional and innovative approaches to shifting cultivation in Mizoram*", submitted by *Mr. Tawnenga, M.Sc.* for the Degree of Doctor of Philosophy of the North-Eastern Hill University, Shillong, embodies the record of original investigation carried out by him under my supervision. He has been duly registered and the thesis presented is worthy of being considered for the award of the Ph.D. Degree. The work has not been submitted for any Degree of any other University.

SHILLONG

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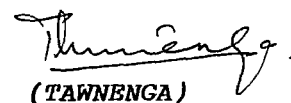
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GENERAL INTRODUCTION

Shifting cultivation as defined by Ruthenberg (1983) is "one of the agricultural systems that involve an alternation between cropping for a few years on selected and cleared plots and a lengthy period when the soil is rested". In shifting cultivation an area of forest is cut, burned and farmed for several years without tilling the soil and then allowed to revert to forest before being cleared again (Uhl, et al. 1983).

Shifting cultivation is frequently referred to as 'slash and burn agriculture' though the term 'Swidden' is preferred by some anthropologists (Exwall, 1955).

Shifting cultivation is differently termed at different places of the world as given below:

<u>Name of the country</u>	<u>Term used</u>
Brazil	Roca
Burma	Taungya
Ghana	Proka
Guedaloupe	Ichli
India	Bewar, Dhya, Dullee, Dippa, Erka, Jhum, Kumri, Panda, Pothu, Podu.
Indonesia and Malaya	Ladang

<u>Name of the country</u>	<u>Term used</u>
Japan, Korea and Taiwan	Karen
Java	Jumah Humah
Laos	Hay
Madagascar	Tavy
Mexico and Central America	Milpa
Philippines	Hanunoo, Caingin
Rhodesia and Tanzania	Chitemene, Citemene
Thailand	Tam-ray, Rai
Vietnam	Ray
Zaire	Masole

The origin of shifting cultivation could be traced back to the Neolithic period (ca. 7000 B.C.) on the basis of archaeological data (Sharma, 1976). It is regarded as the first step in transition from food gathering to food production.

Shifting cultivation involves only human power. All the agricultural operations are performed manually with only a few traditional and primitive tools. The method of cultivation is marked by the following agricultural operations:

1. Selection of forested land
2. Slashing or clearing the forest vegetation
3. Drying of slashed vegetation

4. Burning of dried vegetation
5. Sowing of seeds
6. Weeding for two to four times
7. Watching and protection
8. Harvesting
9. Threshing and storing
10. Fallowing

One of the basic features of shifting cultivation is the cost-free and effortless regeneration of soil productivity during the fallow period.

Shifting cultivation is a common form of agriculture throughout much of the world (Hauck, 1974). In low land tropics it is practised on many different soil types and by people of widely varying cultures (Nye & Greenland, 1960). Shifting cultivation is principally common in humid and semi-humid climates and in thinly populated savannas.

According to Hauck (1974), nearly 30% of the exploitable soils are under shifting cultivation and responsible for meeting the food requirements of about 8% of the world's population.

It is estimated that about 2.6 million tribal people of India, living in the interior hilly areas practice shifting cultivation (Vidyarthi, 1975). The estimated area covered

by shifting cultivation is about 1.3 million acres, spread over different parts of India. It is wide spread among the hill dwellers of north-eastern India, Bihar, Orissa, Madhya Pradesh, Andhra Pradesh and Karnataka.

In the north-eastern region comprising the states of Arunachal Pradesh, Assam, Manipur, Meghalaya, Mizoram, Nagaland and Tripura, shifting cultivation, locally known as 'Jhum' is widely prevalent. This region covers a total geographical area of 25.5 million hectares and forms about 8% of the total geographical area of India.

Forest occupy more than 57% of the geographical area of north-eastern region of India. It is estimated that an area of 19.07 lakh hectares has been affected by 'jhum' and annually 4.69 lakh hectares are under jhum cultivation practiced by 4.43 lakh tribal families. The estimated jhum cycle (the intervening fallow period after which the same forested land is again cultivated), which was nine years in the past decade has been reduced to four years now (Basic Statistics for N.E. Region, 1987).

The socio-cultural life of the tribals of north-eastern states of India is interwoven with the practice of shifting cultivation. The celebration of some of their traditional festivals is linked with different steps involved in jhum

cultivation. House construction and other works are adjusted according to the jhuming operations. Almost all the stages of jhuming are celebrated in the midst of songs and dances along with social and religious rites. They have many songs and folk-tales which deal with different steps of jhuming.

The state of Mizoram, where this study has been carried out covers a total geographical area of 21,087 sq.km. which represents only 0.64% of the country as a whole.

Shifting cultivation is known as 'Lo' in Mizoram. For the purpose of 'Lo', a patch of land is cleared and burned, but this land is generally cultivated for only one year. Very rarely, cropping is done for two successive years on the forest lands cleared for 'Lo'. Such a practice is common only in those areas where the forest vegetation was luxuriant and soil fertility could sustain second year of cropping also.

Each village has its own territory demarcated by rivers, streams and hill ranges. The village territory generally includes considerable forest area. The delienation of the boundary for jhum during each year is the function of the Village Council. By convention, no other villages interfere in the area demaracted for a given village.

The cropping pattern generally followed for 'Lo' in Mizoram is of mixed type. Rice is the main crop grown in the

state. Upland rice of two main varieties locally known as 'buhpui' and 'tai' are grown. Usually one of these is grown, mixed with maize, cucurbits, colocasia, brassica, chillies, sesamum, brinjals and other vegetables and pulses. Sometimes ginger, cotton and tapioca are also grown. The choice of different crops which are grown mixed with rice in jhum lands depends on the requirements of the family.

The method of allotment of jhum sites to individual family is by lottery system locally called 'Lo pawh' conducted by the Village Council. The area to be cultivated is decided by a cultivator on the basis of the size and working capacity of his family. The area of jhum is measured in terms of amount of rice seed that can be sown in a field and the unit in use for this purpose is 'tin'. Approximately two and half tinfull of rice seeds can cover one hectare of land.

Slashing or clearing of forested fallow land is done during December-January and burning in the month of March or April. This is followed by sowing of maize, cucurbits, vegetables etc. Rice is sown mostly during the middle of April to the first part of May.

Sometimes for the protection of forests from fire, a fire-line (meikawng) is made by clearing the surrounding area of the jhum plot. Sometimes due to rain or wind burning

may not be proper. In that case, unburnt plant materials are gathered at several places in the jhum plot and are burnt again. The jhum plots which are within the grazing range of domesticated animals, are protected by bamboo or wooden fencing.

A jhum-hut, locally known as 'Thlam' is constructed in a jhum plot after burning operation. Usually, when jhum plot is at far distance, the cultivators used to stay overnight in 'Thlam' during most of the working days.

The practice of jhuming in Mizoram is as old as their history itself. The village harmony was closely linked with jhum which bound them together as occupationally and economically homogeneous community. Their traditional festivals, folk tales and songs are centered around jhuming. Work-partnership between young men and women was very common and highly cherished. Jhum work and jhum land had a sentimental value. In the traditional setting of Mizos, agriculture meant jhuming and jhuming meant a 'way of life' rather than a mere activity leading to food production.

Though social and economic developmental programmes have changed this 'way of life' among the urban population, it still persists to a certain extent among the rural population which accounts for 73.3% of the total population (Basic

Statistics for N.E. Region, 1987). According to available statistics, at present 1,89,000 hectares of land is affected by jhuming and 50,000 families are involved in it. Area under jhuming in a year is 63,000 hectares. The average area of jhum per family is 1.3 hectares and the present jhum cycle is three years (Basic Statistics for N.E. Region, 1987).

Each state of north-eastern region of India has some schemes for the improvement or control of jhuming. A few surveys made on these schemes have revealed that they are of little success (Singh & Singh, 1980). The Indian Council of Agricultural Research for north-eastern hill region is seized of the problems and accordingly, an extensive study programme on the problems of jhum and its possible alternatives was launched at Burnihat and Barapani. Results from these studies gathered so far have indicated the possibility of a silvi-pastoral-horti-agricultural system as a suitable system for hill slopes from conservation and soil productivity point of view. Inclusion of forest, forage and horticultural plants in the system together with the food crops assures the inherent capacity of the system to meet timber, fuel, fodder, money (from horticultural crops) and food requirements of the rural people. Loss of soil fertility which forces the family to shift is also partly taken care in silvi-pastoral-horti-agricultural system.

In Mizoram, for the control of jhuming 'New Land Use Policy' and 'Jhum Control Schemes' have been launched. Under these schemes selected families are encouraged for permanent settlement by providing occupation of their choice. The desired level of help in cash or in kind is rendered by the State Government to such families. It may be too early to give comments on these efforts. But bringing an abrupt end to this 'way of life' which has been so deeply rooted in them may not be easy. Nevertheless, they may be brought under these schemes as they can get immediate financial help to meet their various requirements.

According to Singh (1986), since the system of jhuming has socio-economic links, any sudden change to some other systems may not be possible. He suggested that introduction of high yielding varieties, fertilizer application technology, water storage and application methods and soil conservation practices suitable to the specific condition may bring encouraging results because a change in the earning capacity will also change the outlook. Besides, through demonstrations the cultivators can be convinced about the advantages of leaving top portion of a terrain untouched and terracing the bottom portion of the adjoining more fertile valley land, as recommended by the ICAR (Shifting Cultivation in North-East India, Published by ICAR, 1983). He further suggested that before

these practices are pushed in, extensive programmes and thorough experimentation would be needed to work them out for specific situations.

Keeping in mind the situations mentioned in the foregoing pages, the present study has been undertaken in the state of Mizoram. This study covers the following aspects.

1. Energy budget of shifting cultivation ('Jhum' or 'Lo') during first year and second year of cropping.
2. Plant biomass and net primary productivity of jhum lands during first year and second year of cropping.
3. Edaphic changes during shifting cultivation.

These aspects have been studied in jhum fallows of two different ages, 6 - year old and 20 - year old referred to in the present thesis as young and old jhum fields respectively.

Apart from gaining an insight into various ecological aspects of jhum cultivation in Mizoram, the study also seeks to suggest innovations in the existing system of jhumming in the state. The innovations or alterations tried in this study includes the introduction of second year of cropping hitherto not practiced in Mizoram, application of chemical fertilizers

and farm-yard manure and application of chemical fertilizers plus farm-yard manure and tilling of the soil.

In Mizoram the forest areas cleared and burned for jhum are normally cropped just for one year. The introduction of second year of cropping on the same jhum plot could be helpful in minimizing the encroachment on the forested ecosystem for agricultural purposes and may even retard the process of deforestation which is taking place at an alarming rate. This may even help in lengthening the jhum cycle. The suspected decrease in crop productivity of the jhum land during second year of cropping due to soil fertility loss could be taken care by the application of fertilizers. The data generated on various aspects mentioned above may be useful in formulating the new packages and recommendations in respect of innovative approaches to jhum cultivation in Mizoram.

The 'General Introduction' which sets out the objectives of the thesis, is followed by the 'Review of literature'. Climate, soil and vegetation of the study sites is contained in Chapter II. The experimental data on various aspects mentioned have been presented in Chapters III, IV, and V with introduction, methods and discussion separately. However, the results obtained on various aspects have been briefly discussed in an integrated manner in Chapter VI under 'General Discussion'.

Plate 1 A panoramic view of forested jhum fallows
of different ages in Mizoram.

Plate 2 An overview of a jhum field during crop-
ping.



PLATE 1



PLATE 2

Plate 3A 'Thlam' (a jhum hut): front view.

Plate 3B 'Thlam' (a jhum hut): side view.



PLATE 3A



PLATE 3B

Plate 4 A shifting cultivator and his wife
in their 'thlam'.



PLATE 4

CHAPTER I

Review of literature

Shifting cultivation is widely practiced in the hills of north-east India. The significant value attached to this system of farming during recent years is chiefly because of the maladies associated with it. Research efforts and studies on shifting cultivation till 1975 were made primarily by the anthropologists and economists. As it is one of the oldest farming systems, it has been extensively studied from various angles throughout the world.

Africa is the largest continent having a great variety of natural conditions and cultural pattern which encouraged shifting cultivation. Harroy (1949) and Worthington (1958) discussed shifting cultivation against a wide background of conservation of natural resources of Africa. Schlippe (1956) described mixed cropping on the border of the Sudan and Congo practiced by Zande tribe. Here the pattern of cropping is of mixed type which included cereals (Eleusine coracana, Zea mays, Pennisetum typhoides, Oryza sp), pulses (Vigna sp. Phaseolus sp.) oil seeds (Arachis hypogea, Sesamum orientals) and starchy crops (Manihot utilissima, Ipomoea batatus, Dioscorea sp., Colocasia antiquorum).

Nye & Greenland (1960) gave a detail account of the shifting cultivation in evergreen and semi-deciduous forests in Africa. According to them over 200 million people, thinly

scattered over 14 million sq. miles of the tropics obtain the bulk of their food by shifting cultivation. They stated that up to a century or so ago shifting cultivation had no very serious effect since the soil and vegetation were given adequate time to regenerate after a period of cropping. But due to rapid increase in population and increase in plantation of export crops like cocoa, coffee and rubber vast areas of tropical forest and woodland have been transformed into less productive savanna grassland. This has led many to condemn shifting cultivation. Nye & Greenland (1960) further stated that 'though primitive and apparently wasteful, when not pushed to excess, shifting cultivation has for centuries given man, his livelihood in the humid tropics; and it is significant that even now, after a quarter of a century of experiment in the African tropics, they have failed to introduce to the forest regions any method of food production superior to the system of natural fallowing used in shifting cultivation'.

Contrary to this, Gourou (1953) says "The disasters brought on by agricultural methods which have taken no account of the treasures of wisdom and experience accumulated in the old tropical system are a sufficient proof of the latter's value. It can be improved, but only if the reason for its processes are fully understood." Nye & Greenland (1960) made an attempt to reveal those 'treasures of wisdom and experience'

which as soil scientists they felt most at ease in seeking; and which have not received systematic treatment elsewhere. They aimed in particular at a quantitative treatment, since they thought it is the surest way of evaluating the many assertions about the effect of this or that factor on the fertility of the soil.

Nye & Greenland (1960) also described shifting cultivation in west African forest where during growth or shortly after the harvest of the first crop, a farmer plants cassava (Manihot utilissima) and starchy crops such as cocoyam (Colocasia antiquorum or Xanthosoma sagittifolium) and plantain (Musa sp.). Small patches of land may be reserved for peppers, spinach and other vegetable crops. The crops grow well ahead of the weeds and by the end of rainy season the land is well covered with vegetation. After first year of cropping the land has always a cover of vegetation. The developing 'bush' springs from the stumps and roots left after clearing and from germination of seeds already lying in the soil or carried in from adjoining areas of forest. The developing secondary forest is soon dominated by light-loving species, among which Musanga ceropioides,, Trema guineese and Macaranga barteri are often prominent. Regrowth is rapid and the secondary forest may well be 20 feet high after five years. According to them, three years of cropping alternating with eight years of fallow

often appears to maintain fertility in semi-deciduous forest. In evergreen forest it is thought that one and half to two years of cropping should be followed by about ten years of fallow.

In the Savanna, the land is without cover during the dry season and it is exposed to the early rains for at least four weeks before a fair cover is formed. When the plot is abandoned, it is dominated by Pennisetum sp. In a year or two the tall perennial - Andropogon gayanus appears and when in about ten years this has supplanted 'lalang' (Imperata cylindrica) the farmer considers the land is fit to clear again. If it is not cleared, the Andropogon gayanus is replaced by other tall members of the Andropogoneae, such as Hyparrhenia rufa to form a fire climax, which is established within 20 years.

In Tropical America the system is practiced both in forest and savannah regions. Cook (1921) described 'Milpa' system of growing maize in Central America and concluded that it is a stable agricultural system if the intervals between successive clearing of the same land are long enough to restore its original condition.

Carneiro (1960) studied shifting cultivation among Kuikuru Indians of Central Brazil, where maniac (Manihot

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esculenta) is the main crop grown. He demonstrated that under shifting agriculture the Kuikuru have been able to remain permanently settled. Watters (1971) described 'Conuco' agriculture in Venezuela where maize and black beans are the main crops grown.

Uhl et al. (1983) studied slash and burn agriculture in the Amazon Basin, where the main crop grown is manioc (Manihot esculenta). Their main focus was on the productivity, energetics, successive and recovery pattern of shifting cultivated lands and also on nutrient dynamics following forest cutting and burning. In the Amazon Basin, an estimated area of 36,000 Km² of forest were cleared by shifting agriculturists from 1966-1975, making this the most common form of agricultural land use in Amazon (Myers, 1979). Uhl et al. (1982) observed that repeated weeding caused woody plants to decline in number and biomass and herbaceous plants to increase. Forbs and grasses dominated immediately following farm site abandonment and after one year fast growing woody species succeeded them. Uhl et al. (1983) discussed several alternative methods of food production which offer promise for the Amazon Basin region.

The tropics of Asia are unlike those of Africa and America, in that the density of population is ten times more as compared to other parts of the world. However, most of

the population lives on alluvial soils of the plains. Dobby (1950) estimated that one-third of the total agricultural area is under shifting cultivation in South East Asia. This system of land use supports a density of 16 individuals per square mile. Conklin (1957) described the 'Hanunoo' system in Philippines where nearly 40-50 different crops are mixed in the same plot.

Recently Andriesse & Koopmans (1984), Andriesse & Schelhass (1987a, 1987b) monitored study of nutrient cycles in soils used for shifting cultivation under various climatic conditions in Tropical Asia. They started this in Sarawak (Malaysia), Sri Lanka and Thailand in 1980. In the first phase, the influence of simulated burning on form and availability of plant nutrients in soil samples was studied in the Laboratory (Andriesse and Koopmans, 1984). The second phase comprised a quantitative study of the main nutrients stored in the living and dead biomass and in the soil, down to a depth of 0.75 metre, for obtaining a reference base for use in monitoring the effect of burning, cropping and regeneration of vegetation. Andriesse & Schelhass (1987b) also studied the effect of land clearing through burning on fertility level.

Mey (1978) studied shifting agriculture in Chittagong Hill tracts of Bangladesh, where rice is the main crop grown. Other crops grown in common are cotton, maize and vegetables

like pulses and gourds, sesamum and chillies. The yields from shifting cultivation here is far from satisfactory due to shortening of the jhum cycle (the intervening fallow period after which the same forested land is again cultivated - Kushwaha et al. 1981).

Rappaport (1971) gave a detail account of 'Swidden' agriculture in the Tsembaga in the central high land of Papua, New Guinea. In making garden the Tsembaga prefer to clear secondary rather than primary forests. The staple crops grown are taro (Colocasia esculenta) and sweet potato (Ipomoea batatas). Other starchy vegetables such as yams, cassava and bananas are also grown. Beans, peas and sugarcane are also grown along with a number of leafy vegetables. They recognised the importance of regenerating trees and call them collectively as 'Dukmi' or 'Mother of gardens' and do not destroy them during weeding.

In the north-east region of India the practice of shifting cultivation locally known as 'Jhum' supports 1.6 million population. Toky & Ramakrishnan (1981, 1982); Misra & Ramakrishnan (1981, 1983); Ramakrishnan (1985); Gangwar & Ramakrishnan (1987) studied jhuming in Meghalaya from various angles. Their main focus is on the soil fertility following jhuming and energy budget under different ages of jhum fallow and other agricultural systems. According to them, the jhum

cycle which was earlier 10-30 years have been shortened to 4-5 years due to population pressure. This short cycle have affected the yield of the crops and the quality of environment both in terms of soil fertility and vegetation cover. They have suggested that only a long jhum cycle of 10 years could be sustained along with valley cultivation, both from an economic and energetic point of view (Misra & Ramakrishnan 1981). Ramakrishnan (1985) has suggested plantation of crops as an alternative to jhuming in north-east India.

Jha et al. (1979) conducted studies on changes in the physico-chemical properties of Tripura soil as a result of jhuming. In Tripura 47,000 hectares of land is under jhuming.

The Indian Council of Agricultural Research for north eastern hill region of India has been doing extensive studies on the problem of jhum and its possible alternatives.

Various attempts have been made to study the energetics of shifting cultivation. Several different methods have been employed to compute human and animal energy to do work. Pimentel et al. (1973) have taken the total food energy input of a full time farm worker (working 40 hours per week) as a measure of the energy utilised in farm labour. Mukhijani and Poole (1975) used the energy in food intake of all persons in a farming village as the gross energy input for human

labour. White et al. (1972) estimated the metabolic energy used in different work activities from measurement of oxygen consumed or carbon dioxide exhaled. The different methods of estimating energy expenditure are compared by Revelle (1976) in terms of an average Indian worker. This estimation is in fair agreement with World Bank's study of cereal production in Bangladesh (1972). He estimated that energy expended in human labour in rural India is 250 Kcal. per hour for adult male and 200 Kcal. per hour for adult female cultivators or agricultural labourers.

Gopalan et al. (1985) used 0.679 MJ per hour per man and 0.523 MJ per hour per woman as energy expenditure for doing heavy works. Mittal et al. (1985) worked out the same as 1.96 MJ for man and 1.57 MJ for woman. Uhl et al. (1981) used caloric expenditure values of 50 Kcal (per 45.4 Kg. human body weight per hour) for light work, 100 Kcal for intermediate work, 150 Kcal for demanding work and 250 Kcal for very demanding work.

Energy values of nitrogen, phosphorus (P_2O_5) and potassium (K_2O) as worked out by Pimental et al. (1973) are 77.28 MJ kg^{-1} , 14.01 MJ kg^{-1} and 9.7 MJ kg^{-1} respectively, whereas for organic manure it has been worked out to be 1.39 MJ kg^{-1} . Energy values of the same categories are also given by Mittal et al. (1985) as 60 MJ kg^{-1} for nitrogen 11.1 MJ kg^{-1} .

for P_2O_5 , 6.7 MJ kg^{-1} for K_2O and 0.33 for farm-yard manure (FYM).

Energy efficiency (output : input) is an indicator of ecological efficiency of a given agricultural system (Rappaport, 1971; Spedding, 1975; Leach, 1976; Mitchell, 1979). The output : input ratios in labour intensive agriculture are generally greater than 1, in contrast to 1 or less in case of fuel based agriculture (Rappaport 1968, 1971).

Golley (1965) suggests that a comprehensive understanding of agriculture production requires to understand that dynamic property hierarchy of systems from leaf (which converts light energy into chemical energy) to globe and between these there are a variety of nested systems such as the crop-plant system, the field system and regional system. Their analysis must include not only the ecological-biological components of these systems but also political, economical, as well as components for a complete understanding.

Energy input-output relations with upland rice in African shifting cultivation system are studied by Spencer (1975), Santen (1974), Lang (1976) and Fotzo (1977). As quoted by Ruthenberg (1983), Possinger (1967) also prepared consumption chart of a shifting cultivator's family in Manhaua, Mozambique. The economics of manioc-maize production in two shift-

ing systems and of maize-sesame-manioc production in a fallow system were also studied in Ghana by Rourke (1974) and in Kenya by Ruthenberg (1983).

Uhl et al. (1983) studied the energetics and productivity of slash and burn agriculture in Amazon Basin where manioc is the main crop grown. They reported that manioc production was 4.3 MT ha^{-1} wet-weight in the first year, 2.8 MT ha^{-1} in the second year and 1.4 MT ha^{-1} in the final year. Although yields are low, farmers maintain a ratio of food energy output to labour input of 13.9 to one. They discussed the energetic efficiency, productivity and the factors which are most important in causing yield declines. They suggested several alternative methods of food production which, according to them offer promise for the Amazon Basin.

Structure and functioning of shifting cultivation in Meghalaya state of north-east India has been extensively studied with main focus on socio-economic aspects by Mishra & Ramakrishnan (1981) and Toky & Ramakrishnan (1981). Gangwar & Ramakrishnan (1987) made a comparative analysis of energetics of the agricultural and animal husbandry of two tribes in Arunachal Pradesh. They also made a comparative study of cropping and yield patterns under different land use systems of the Khasis at higher elevation of Meghalaya in north-east India. According to Mishra & Ramakrishnan (1981) from economic

point of view, a 15-year cycle is most efficient with energy output : input ratio of 26.6, compared to 9.85 for 10-year cycle and only 4.63 for a 5-year cycle.

It may be considered that prediction of agricultural production capacity is not possible from the knowledge of rate of production without detail understanding of the factors influencing production. These factors may be many, such as, reclamation level, physiological plant property, material input etc. Pimental (1984) concluded that soil erosion and deficiency of water are the main problems in reducing yield and energy cost. These factors are also to be considered in addition to factors related to increase of yield in agricultural systems.

Hart (1985) suggests that the changes such as deforestation and soil erosion, accumulation of toxic materials and cost of produce should be evaluated and properly related to agricultural activity. To assess implication of shifting cultivation also, apart from ecological and economical factors, the above factors should also be evaluated, from energetic point of view. From the energetic point of view, jhuming is reported to be very efficient in Meghalaya state of N.E. India (Toky & Ramakrishnan, 1981, 1982). But large scale adoption is not possible due to increasing population pressure which has shortened the jhum cycle, leading to deforestation.

Mittal et al. (1987) has given a detail account of the energy parameters for raising crops under various irrigation systems in Indian agriculture.

Revelle (1976) made a thorough estimation of energy use in rural India on various agricultural activities. He concluded that men and women of rural India are tied to poverty and misery because they use too little energy and use it inefficiently and nearly all they use is secured by their own physical efforts. A transformation of rural Indian society could be brought about by increasing the quantity and improving the technology of energy use.

In north-east India, there is a great confusion regarding the yields of crops from hill agro-ecosystems (Toky & Ramakrishnan 1981). The average yield from jhuming as reported by Agro-economic Research Centre, Jorhat (1961-70) is 800-900 kg ha⁻¹ in Garo Hills and Mizoram and 1200 kg ha⁻¹ in Tripura. Aurora et al. (1977) reported that yields of rice under jhum and dry land cultivation on terraces are not significantly different under comparable situations. A study conducted at Burnihat (Saha, 1976) reveals 3428 kg ha⁻¹ yield under valley cultivation, 738 kg ha⁻¹ under terrace cultivation and 853 kg ha⁻¹ under jhum. According to a report of Indian Council of Agricultural Research (Borthakur et al. 1978), the yield under jhum is very low (190 kg ha⁻¹) compared

to terrace cultivation (1860 kg ha^{-1}). But these studies do not specify fertilizer input, jhum pattern, and the cycle of jhum. Toky & Ramakrishnan (1981) reported that under mixed cropping total yield of rice under jhuming in Burnihat in Meghalaya is 1161 kg ha^{-1} in 30 year jhum cycle, 378 kg ha^{-1} in 10-year jhum cycle and 66 kg ha^{-1} in 5-year jhum cycle, Datta (1977-79), based on his studies on economics of jhum at block level in Meghalaya, reported that on an average 142.09 man-day per hectare are required for the production of 1419 kg ha^{-1} of rice.

Mishra & Ramakrishnan (1983) studied the pattern of secondary succession and the subsequent changes in biomass productivity and litter fall on the different ages of fallow lands developed after jhuming in Meghalaya. They concluded that litter production increases linearly with the age of jhum fallow.

Shifting cultivators aim primarily at an effective use of the existing soil fertility. In humid and semi-humid climates where vegetation tends to be thick, the main store house of nutrients is not the soil, but the standing vegetation (Greenland & Herrera, 1975). The amount of nutrients stored in the vegetation is certainly less in semi-arid climates, but the general principle remains; forest and bush vegetations reduce leaching and store nutrients which are

made available to crops to a significant degree by fire clearance and the resulting temporary increase in the pH (Ruthenberg, 1983).

Under shifting cultivation soils poor in nutrients regularly produce certain yields. This is achieved without manure, terracing or any other means of maintaining fertility that involve a high expenditure of labour. The system is associated with movement of nutrients from the field to the dwelling place, and therefore some change in the location of soil fertility. Nutrients are lost during the years of cultivation because of leaching and erosion (Ruthenberg 1983). Keeping a land fallow for a long period is the most common method of regenerating soil fertility. In some places in addition to this, there are various forms of fertilizing the soil as follows - utilisation of hut refuse, use of compost, green manuring, working with pit system working with heated mounds use of ashes and application of mineral fertilizers.

According to Dokuchaev (1879) and Jenny (1941), genesis of soils under shifting cultivation is governed by the factors of soil formation, viz. climate, organisms, topography, parent material and time. Of these, climate is considered to be the most important factor. Topographic position and degree of slope have greatest influence on changes in particle size distribution and nutrient content (Leite & Ezeta, 1982).

The stability of jhuming depends upon the recovery and maintenance of soil fertility. If the nutrient lost or displaced during cropping period is balanced during the fallow period the system could continue indefinitely. The maintenance of soil fertility in hot humid and high rainfall area is a serious problem and is more severe when the jhum cycle is short. This, in turn, results in reduced crop yield (Nye & Greenland, 1960; Watters, 1971; Toky & Ramakrishnan, 1981; Singh, 1986).

The various physico-chemical properties of soil influenced by the practice of shifting cultivation include — soil-temperature, water repellency, soil aggregation, organic matter, pH, soluble salts, cation exchange capacity (CEC), N, P, K, Ca, Mg, S, etc. (Unger et al., 1973; Dormear et al., 1979; Tiwari et al. 1987).

Slashing and burning of forest vegetation are the first hand operations in jhuming. Burning brings about temporary change in soil temperature at the surface. Deka and Mishra (1983) observed that fire effects were restricted to the top 2 cm of soil. Rasmussen et al. (1986) reported that burning has no effect on temperature below 25 cms soil surface. Soil surface temperature during burning is highly variable. It ranges from 170 to 330°C where slashed plant materials are completely burned (Hrahsel, 1988).

After burning, all the cations are released on the soil surface as ash. Heavy losses of carbon, nitrogen and sulphur occur due to volatilization during burning (Nye & Greenland, 1960; De las Sales & Folster, 1976). Lloyd (1971) reported high loss of total phosphorus due to burning, but Allen (1964) and Viro (1974) reported no losses on account of this. Large proportion of the ash liberated after the burn is blown off by the wind. Chidumayo (1987) reported increase of P, K, Ca, Mg and Na in the top soil immediately after burning in Chitemene shifting cultivation in Zambia.

Burning brings about temporary increase in soil pH (Ramakrishnan & Toky, 1981; Mishra & Ramakrishnan, 1983; Von Uexkull, 198; Kumada et al. 1985). This is more obvious in the surface layers of the soil profile and under older jhum fallow plot (Ahlgren & Ahlgren, 1960; Toky & Ramakrishnan, 1981). Decrease in soil pH with depth is reported by Toky & Ramakrishnan, (1981) and Hrahsel, (1988). Hrahsel (1988) reported an increase of soil pH by 1.1 to 1.7 unit due to burning and a decrease during cultivation in shifting cultivated lands in Mizoram state of north east India. Toky & Ramakrishnan (1981) also reported decline of pH during cultivation in shifting cultivated lands of Meghalaya. Bara & Vega (1983) reported one unit increase in pH due to burning in forest soils of north-west Spain. Kumada et al. (1985) reported rise

of pH till burning but decline during cropping in shifting cultivated soils of Iriomote Island in Okinawa. Slight increase of pH in jhum plot as compared to non-jhum plot in Tripura soils under shifting cultivation is reported by Jha et al. (1979).

The concentration and total quantity of soil carbon was reported to be significantly higher ($P < 0.05$) under longer jhum cycle and significantly low ($P < 0.01$) at lower depths of soil in the shifting cultivated lands of Meghalaya (Toky & Ramakrishnan 1981). Hrahsel (1988) in his studies on Mizoram soils reported that organic matter content in the soil is related to altitude, vegetation cover and textural variation and also reduction of organic matter content after burning and further decrease during cultivation. Decrease in organic matter content by about 40% and decrease of C/N ratio from 20.9 to 12% in surface soil of north-west forest of Spain due to burning is reported by Bara and Vega (1983), although at 5-30 cm depth no significant changes were detected. A net loss of carbon after a year of cropping is reported by various workers (Joachim & Kandiah, 1948; Nye & Greenland, 1960; Zinke et al. 1978; Jha et al. 1979). Juo & Lal (1977) estimated a requirement of $16 \text{ ton ha}^{-1} \text{ yr}^{-1}$ of dry plant material to be added to the soil under slash and burn agriculture, in order to maintain soil organic matter in the surface soil at a level

comparable to soil under secondary forest, as the rate of decomposition is faster under continued cropping. The depletion of organic matter depends upon the intensity of cropping, type of the fallow vegetation and the ratio of cropping to the fallow period. With optimum cropping (1-2 years) and fallow period (8-10 years) the humus in the soil could be maintained at a relatively high level even after many years of shifting agriculture (Coulter, 1950; Brich & Friend 1956; Nye & Greenland 1964). A rapid loss of organic matter in the first year of cropping which may be due to oxidation of unhumified material is also reported by Nye & Greenland (1964) and Jha et al. (1979). Jha et al. (1979) stated that, since soil organic matter is an important constituent influencing soil reaction, its deterioration disturbs the nutrient cycling in the soil. They reported that total sesquioxide, iron, aluminium, Ca, K, P, and CEC are low in jhum plots as compared to non-jhum plots.

Nitrogen concentration is generally higher in surface layer of soil and declines with depth (Mishra & Ramakrishnan, 1983; Andriessse & Schelhaas, 1987a). Concentration of Nitrogen in the soil also increases with increase in age of jhum fallow (Mishra & Ramakrishnan, 1983). After burning nitrogen concentration declines sharply in the surface layer of soil. Such a decline, also observed by Wells (1971), White et al. (1973),

Kumuda et al. (1985) and Hrahsel (1988), could be attributed to the conversion of organic nitrogen to volatile forms during pyrolysis (Allen, 1964; Knight, 1966; Debell & Ralston, 1970). Increase in nitrification after burning is reported by some workers (Ahlgren & Ahlgren, 1965; Deka & Mishra, 1983; Dormear & Schaber, 1985; Polglase et al. 1986). Nitrification after burn is shown to be accelerated due to high microbial activity, rise in pH and temperature of the surface soil (Griffith, 1949; Moor & Jaiyebo, 1963; Ahlgren & Ahlgren 1965). The increase in nitrification after the burn has also been attributed to the removal of chemical inhibitors (Reed, 1951; Smith et al. 1968; Rice, 1974). However, there is decline in nitrogen concentration during cropping (Mishra & Ramakrishnan, 1983; Kumuda et al. 1985; Hrahsel, 1988).

From laboratory burning of selected surface soils (0-2 cm depth) through a temperature range of 20 - 350° C. Andriesse and Koopmans (1984) reported decline in CEC values for most exchangeable cations, whereas values for pH, electric conductivity, base saturation and available phosphorous increased.

CHAPTER I I

Study site, climate, soil and vegetation

Study site

Field studies were conducted in Mizoram, during the year 1988 and 1989. Mizoram occupies the north-east corner of India. It lies between 20°57' N and 24°31' N latitudes and 92°16' E and 93°26' E longitudes. The Tropic of Cancer runs across the state (Fig. 2.1). It is bounded on the north by Cachar district of Assam and the state of Manipur, in the east and south by Chin Hills of Burma and in the west by Chittagong Hill tracts of Bangladesh and the state of Tripura. It has a total international boundary of 1,632 Km.

The population of Mizoram according to 1981 Census was 4,93,757 and the density was 23 persons per sq.km. of land area.

The plots were selected in 1988 for the study of first year and second year of cropping in both young (6-yr. old; cropping done six years ago and since then the plot is left as fallow) and old (20- yr. old; cropping done 20 years ago and since then the plot is left as fallow) jhum lands near Muallungthu village which is about 18 Km south of Aizawl town. It is located on 23°38' N latitude and 92°43' E longitude at an altitude of 985 m.

Fig. 2.1 Map showing the location of Mizoram in India and a magnified map of Mizoram.

LOCATION OF MIZORAM

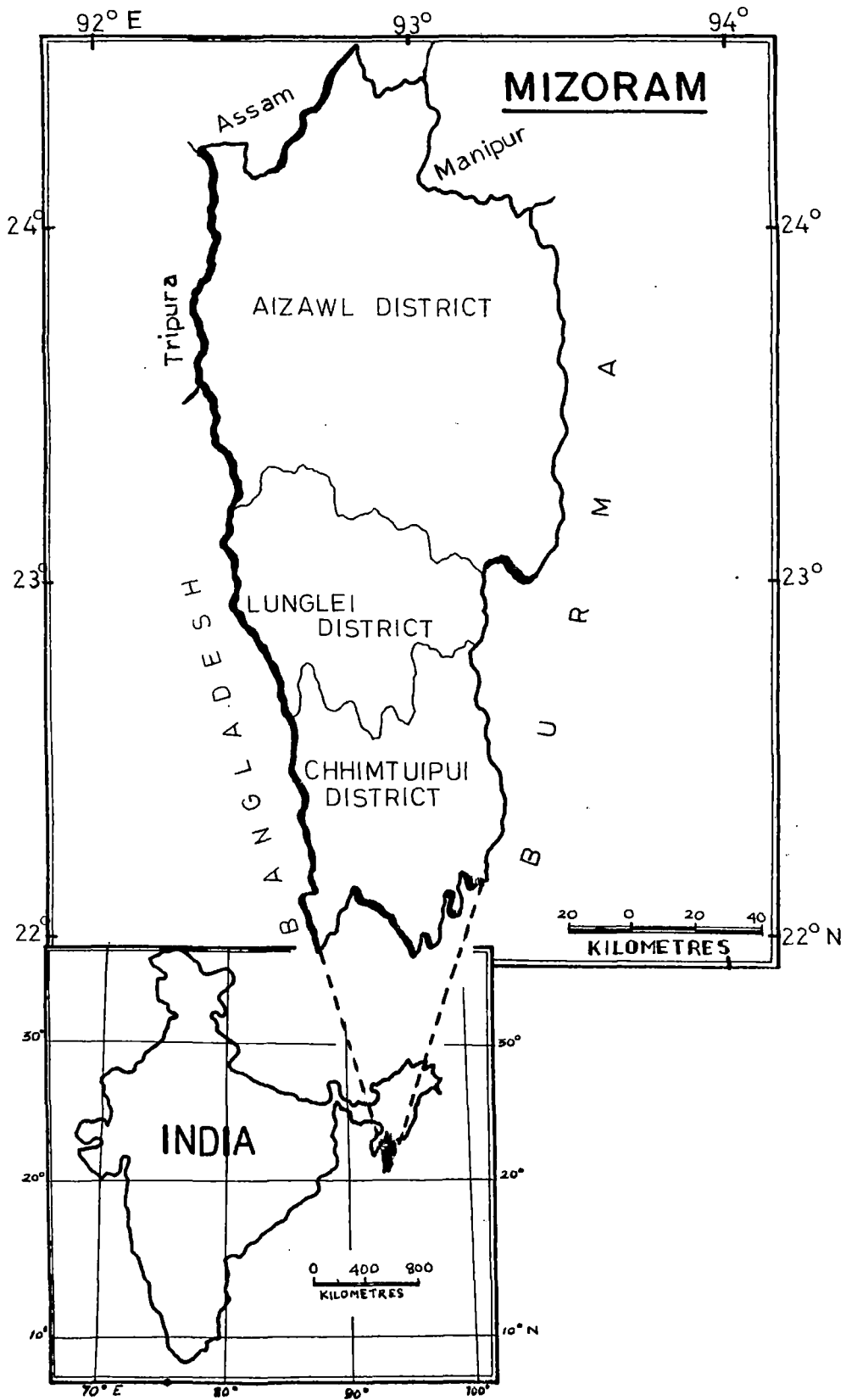
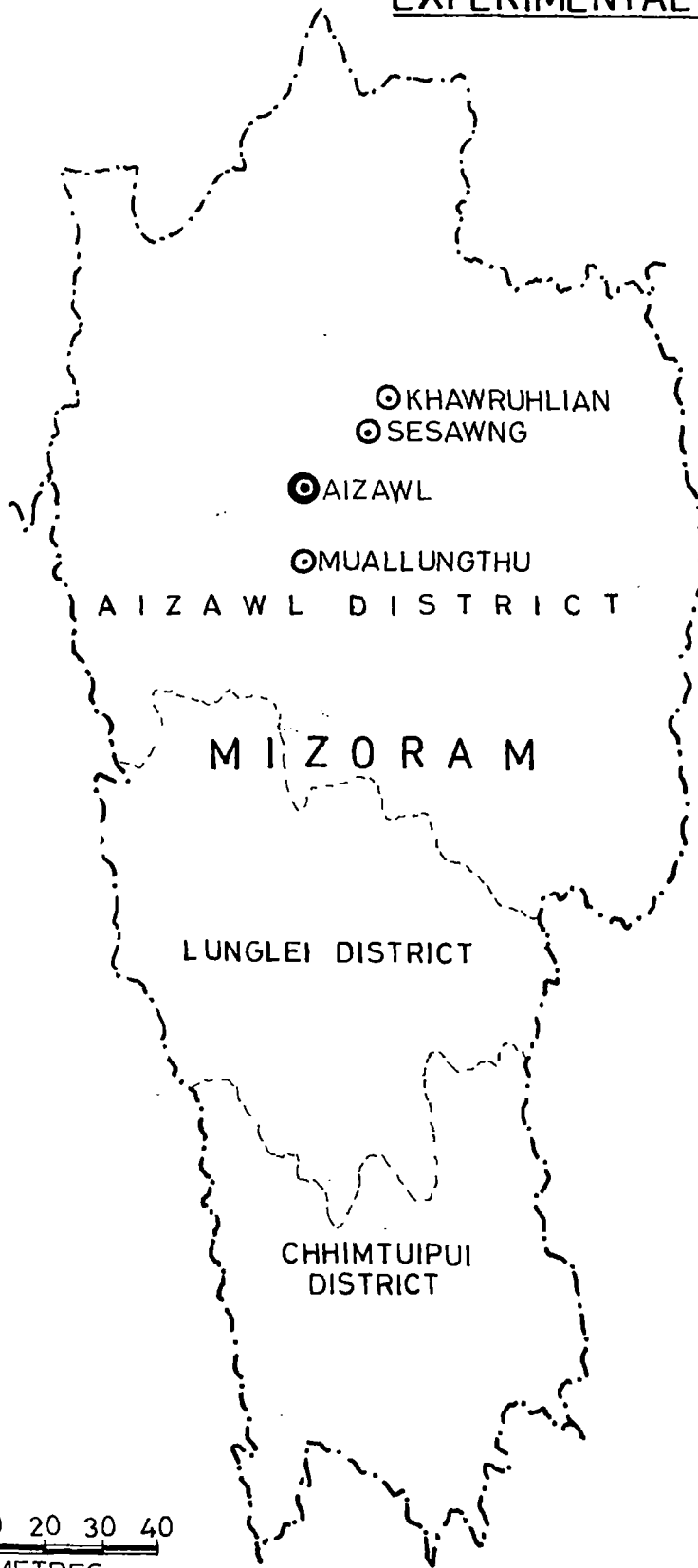


FIG.2.1

Fig. 2.2 Map showing the location of experimental fields in Mizoram.

LOCATION OF
EXPERIMENTAL FIELDS



10 0 10 20 30 40
KILOMETRES

FIG 2.2

In 1989, the same type of studies undertaken in 1988 were again repeated and were conducted near Sesawng and Khawruhlian villages which are situated along the main Aizawl-Tipaimukh road, at 40 Km and 85 Km respectively to the north-east of Aizawl town. Studies pertaining to the first year of cropping in young and old jhum lands were carried out in the cultivated fields of Sesawng village. The study site is about 4 Km from the village proper. This village is located on 23°50' N latitude and 92°54' E longitude at an altitude of 1,166 m. Studies pertaining to the second year of cropping in young and old jhum lands were carried out near Khawruhlian village. This village is located on 23°56' N latitude and 92°54' E longitude at an altitude of 1,060 m. The three villages where the study plots are located are shown in Fig. 2.2.

The ages of jhum fallows were found out with the help of the cultivators. Studies during the first year of cropping were carried out in both young (6-yr. old) and old (20-yr. old) jhum fallow lands. In this case forest vegetation on both young and old fallows were slashed and burned and the plots were cultivated during the study period.

Studies during second year of cropping were also conducted in both young and old fields. For this purpose, young and old jhum plots which had been cultivated in the previous year were selected.

The two different ages of jhum fallows were selected for the sake of comparison. The young (6-yr. old) jhum fallow represents the prevailing average age of jhum fallow after which once again the same land is brought under jhum in Mizoram. According to available statistics (Basic Statistics for N.E. Region, 1987), the jhum cycle is only three years, but personal survey and observations revealed that the average jhum cycle is about six years in Mizoram. This may be due to decrease in number of families involved in jhuming occupation. Urbanisation, education, migration from villages to the town for taking up other kinds of occupation, and various social and economic developmental programmes of the state may be the factors for the reduction in number of people involved in jhuming. At the same time there is reduction in size of jhum area per family from 1.3 hectare to approximately 0.8 hectare. This may be due to reduction in family size and diverse distribution of works among the working members of a family. Whilst all the working members in some families are engaged in jhuming, in other families some of the working members are engaged in education, shop-keeping and other occupations.

The selection of 20-year old jhum lands as the study sites is mainly because of the fact that in Mizoram the longest jhum cycle is of 20 years duration. The forested vegetation older than this represents virgin primary forests.

An area of 0.5 hectare was taken as study plot during first year of cropping in each of the young (6-yr. old) and old (20-yr. old) jhum fallow. The study plots during first year of cropping were referred to as '6 I:C' in 6 yr. old jhum fallow and '20 I:C' in 20 yr. old jhum fallow.

An area of 50 m x 50 m was taken as study plot during second year of cropping in each of the young and old jhum fallows. Each plot was divided into five sets of sub-plots. Each sub-plot measured 10 m x 10 m. The first sub-plot served as the 'control'. In young and old jhum fallows this sub-plot was referred to as 'control sub-plot in young or 6-yr. old jhum fallow or 6 II:C' and 'control sub-plot in old or 20-yr. old jhum fallow or 20 II:C' respectively. Tilling of the soil was introduced in the second set of sub-plots in young and old jhum fallows. These sub-plots were referred to as '6 II:T' in 6-yr. old jhum fallow and '20 II:T' in 20-yr. old jhum fallow. The third set of sub-plot was subjected to the application of chemical fertilizers. In young and old jhum fallows this sub-plot was referred to as '6 II:CF' in 6-yr. old jhum fallow and '20 II:CF' in 20-yr. old jhum fallow.

Farm-yard manure was applied on the fourth sub-plot. This sub-plot was referred to as '6 II:FYM' in the young jhum fallow and '20 II:FYM' in the 20-yr. old jhum fallow. A combination of chemical fertilizer and farm-yard manure was applied

on the fifth set of sub-plots. This sub-plot was referred to as '6 II:CF+FYM' in 6-yr. old fallow and '20 II:CF+FYM' in 20-yr. old jhum fallow.

Chemical fertilizer or farm-yard manure or a combination of both were applied just before sowing of rice seeds as per the dose recommended by the Agriculture department, Government of Mizoram. The chemical fertilizer includes Urea, Diammonium Phosphate (DAP) and Muriate of Potash (MOP). The amount of chemical fertilizer and farm-yard manure applied to the soil on per hectare basis was as follows:

Chemical fertilizer:	Urea - 50 Kg
Diammonium Phosphate	(DAP) - 60 Kg
Muriate of Potash	(MOP) - 65 Kg
Farm-yard manure	- 3000 Kg

Climate

The study site falls under the direct influence of south-west monsoon and enjoys a moderate climate. The climate is characterized by short winter, long summer and heavy rainfall which is mainly received during April to September. Occasional showers of low to medium intensity are also received during other months of the year. The recorded annual rainfall of the study site was 2,423.1 mm in 1988 and 2,340 mm in 1989 (Fig. 2.3).

Fig. 2.3 Monthly rainfall of study sites during 1988 (—) and 1989 (----).

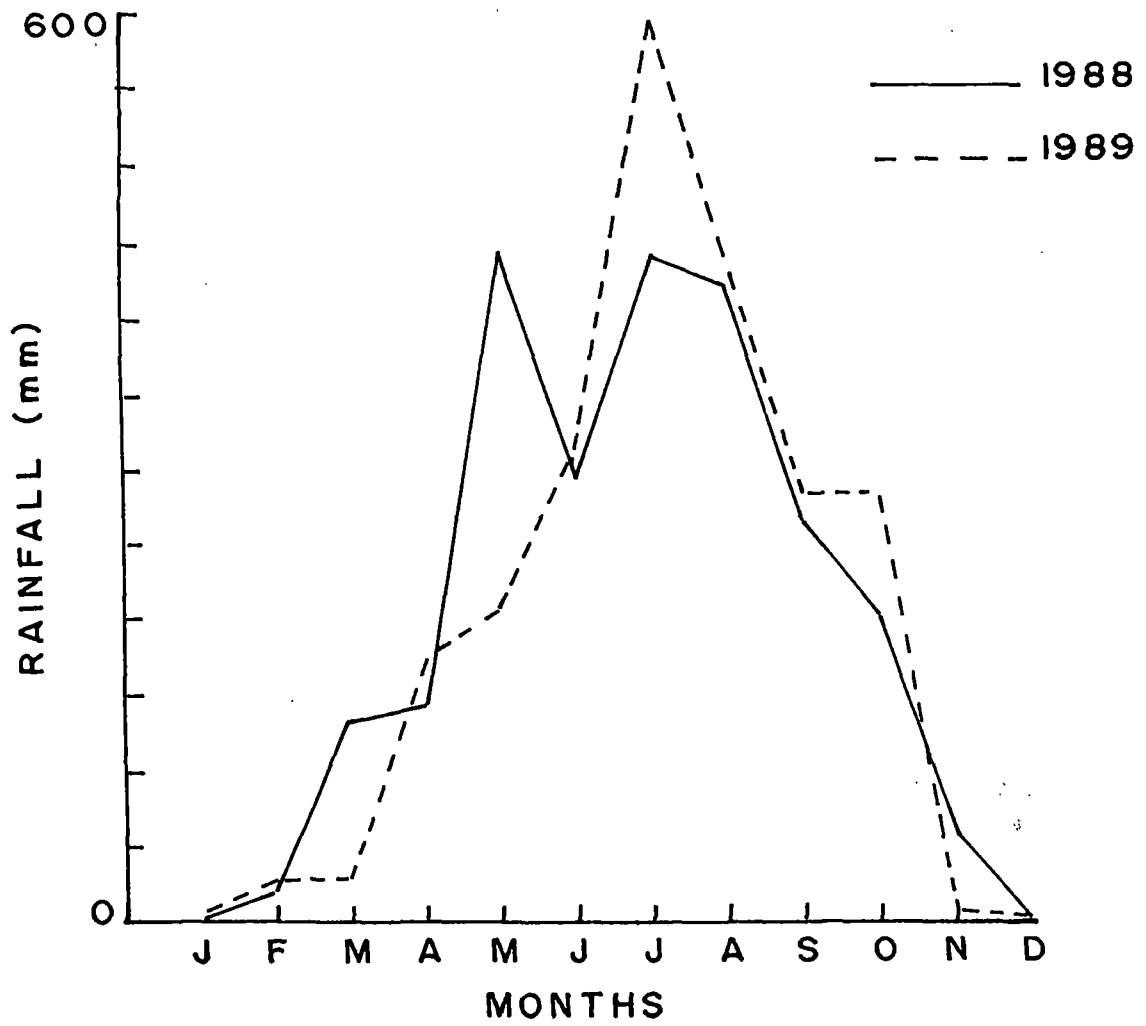


FIG. 2.3

During winter, the average daily temperature ranges between 11°C and 23°C, in autumn it ranges between 18°C and 25°C and in summer between 20°C and 29°C. The average annual temperature is 20.13°C, although it drops down to below 20°C in January and December.

Soil

The soils in Mizoram are of red loamy type characterized by light texture, porous, friable and generally acidic to neutral in reaction (Dwivedi, 1980). The humus and nitrogen contents although generally low depend upon the growth of vegetation.

Vegetation

According to Champion & Seth (1968), the natural vegetation of Mizoram can be grouped under "Tropical semi-evergreen forests". On the basis of common trees of top canopy and underground species, forest of high altitude may be grouped under "East Himalayan sub-tropical wet hill forests" and the forests of low lying areas may be grouped under "Tropical wet-evergreen forests."

The tropical location of Mizoram, supported by adequate rainfall and the prevailing climatic condition favour the luxuriant growth of vegetation. It has an area of 15,935.22 sq.km. covered by vegetation which accounts for about 75%

of the total area (Basic Statistics for N.E. Region, 1987). The natural vegetation has undergone changes mainly due to jhuming, lumbering and extraction of fuel and fodder.

The vegetation of the study sites (jhum fallows) before bringing them under jhum was of secondary successional type dominated by Melocanna bambosoides, and had been disturbed once or more due to jhuming.

The phytosociological analysis of the forest stands of both the young and old jhum fallows selected for the study sites was done in December 1987. Ten quadrats each of 10m x 10m, 5m x 5m and 1m x 1m sizes were placed randomly in each stand for the sampling of trees (>3m height), shrubs and saplings (<3m height) and herbs respectively. Frequency, density, basal cover and importance value index (IVI) were determined according to Misra (1968).

Similarity indices of the two stands and their different components like tree component, shrub and sapling component and herb component were calculated according to Jaccard (1912). Index of dominance among the species was calculated according to Simpson (1949). Species diversity was determined by using Shannon-Wiener (1963) information function.

Vegetation of the young jhum fallow

The vegetation of the young jhum fallow is composed of 46 species, of which Melocanna bambusoides with an IVI of 174.1. This is followed by Musa paradisiaca. The tree component comprises nine species among which Zanthoxylum budrunga, Callicarpa arborea and Sterculia villosa are most common (Table 2.1). The shrub and sapling component of vegetation includes 24 species. The most dominant species is Byttneria pilosa followed by Aporosa roxburghii, Eupatorium odoratum, Ficus sp. and Stereospermum chenoloides (Table 2.2). In the herb component the most dominant species is Mikania micrantha followed by Lonicera japonica, Paspalum distichum and Lonicera angustifolia (Table 2.3).

Vegetation of the old jhum fallow

Vegetation on 20-year old jhum fallow is composed of 37 plant species with Melocanna bambusoides as the most dominant (IVI 191.57). The tree component of the vegetation comprises 16 species of which Toona ciliata, Cyathocalyx martabanicus, Arenga saccharifera, Saraca sp. and Trevesia palmata are quite common (Table 2.4). The shrub and sapling component of the vegetation includes 16 species, the most dominant species being Leea indica followed by Ficus sp. Sapindus attenuatus, Stereospermum chenoloides and Artocarpus chaplasha (Table 2.5). The herb component is represented by only five

species, among which Strobilanthes sp. is the dominant (Table 2.6).

Eleven plant species are common to both young and old fallows. These are Melocanna bambudoides, Musa paradisiaca, Ficus hirta, Ficus sp., Sapindus attenuatus, Stereospermum chenoloides, Artocarpus chaplasha, Hibiscus macrophyllus, Aporosa roxburghii, Dysoxylum grande and Lonicera japonica (Table 2.7).

Degree of similarity is highest between shrub plus sapling component in the two jhum fallows while it was lowest between the herb components. As a whole, similarity between the young and old jhum fallow is as low as 0.26 (Table 2.8).

Indices of dominance were highest for the tree species on both the fallows and lowest for shrubs and saplings. The values for index of dominance on the young and old fallows are 0.187 and 0.206 respectively (Table 2.9).

The index of diversity of species on the young jhum fallow as a whole is 2.682 and on the old fallow it is 2.452. Index of diversity is highest in the shrub and sapling component and lowest in the tree components on both the fallows (Table 2.9).

The vegetation of the study sites during second year

of cropping was dominated by the sprouts of Melocanna bambu-
soides from underground rhizome. Eupatorium odoratum, Mikania
micrantha, Ageratum conyzoides, Conyza auriculata, Cleroden-
drum sp. and Erianthus longisetosus are also common.

Table 2.1. Phytosociological attributes of the tree component of the young (6-yr. old) forested jhum fallow.

Name of plants	Frequency (%)	Density (No. 100Sq.m ⁻¹)	Total basal cover (Cm ² 100 Sq.m ⁻¹)	IVI
<u>CalliCARpa arborea</u> , Roxb.	50	1.0	16.2	15.4
<u>Ficus hirta</u> , Vahl.	40	0.6	17.53	12.38
<u>Melocanna bambusoides</u> , Trin.	100	58.6	700.27	174.1
<u>Musa paradisiaca</u> , Linn.	50	1.3	330.94	42.04
<u>Pterospermum</u> sp.	30	0.7	17.24	10.03
<u>Schima wallichii</u> , Choisy.	20	0.4	5.8	6.1
<u>Sterculia villosa</u> , Roxb.	30	0.4	80.45	14.81
<u>Zanthoxylum budrungea</u> , Wall.	50	0.8	22.62	15.62
<u>Zanthoxylum</u> sp.	50	0.8	11.13	9.51

Table 2.2. Phytosociological attributes of the shrub and sapling component of young (6-yr. old) forested jhum fallow.

Name of plants	Frequency (%)	Density (No. 25 Sq.m ⁻¹)	Total basal cover (25 cm ² 25 Sq.m ⁻¹)	IVI
<u>Adina cordifolia</u> , Hk.f.	20	0.2	0.19	5.0
<u>Aporosa roxburghii</u> , Baill.	70	1.3	4.59	40.25
<u>Artocarpus chaplasha</u> , Roxb.	30	0.3	0.56	7.35
<u>Bridelia tomentosa</u> , Bl.	20	0.2	0.22	5.16
<u>Bursera serrata</u> , Wall.	30	0.3	0.24	7.3
<u>Byttneria pilosa</u> , Roxb.	80	3.1	2.17	43.0
<u>Cassia</u> sp.	30	0.3	0.19	7.05
<u>Clerodendron serratum</u> , Sprang.	60	0.9	1.12	16.6
<u>Dalbergia robusta</u> , Roxb.	10	0.1	0.08	2.4
<u>Dalbergia stipulacea</u> , Roxb.	20	0.2	0.13	4.7
<u>Desmos dumosus</u> , (Roxb). Stafford	10	0.1	0.04	2.25
<u>Dysoxylum grande</u> , Hiern.	10	0.1	0.047	2.28
<u>Embllica officinalis</u> , Gaertn.	40	0.4	0.75	11.73

Table 2.2 (Contd.)

Name of plants	Frequency (%)	Density (No. 25 Sq.m ⁻¹)	Total basal cover (25 cm ² 25 Sq.m ⁻¹)	IVI
<u>Eupatorium odoratum</u> , Linn.	60	2.3	2.34	35.5
<u>Ficus</u> sp.	40	0.9	3.39	27.7
<u>Garunga pinnata</u> , Roxb.	30	0.3	0.16	6.83
<u>Gmelina arborea</u> , Linn.	20	0.4	0.28	6.74
<u>Hibiscus macrophyllus</u> , Roxb.	10	0.1	0.33	3.5
<u>Litsaea semicarpifolia</u> , Hk.f.	20	0.2	0.66	7.2
<u>Maesa montana</u> , A.DC.	20	0.4	0.36	7.24
<u>Melia</u> sp.	20	0.4	0.37	7.27
<u>Rhus semialata</u> , Murr.	40	0.5	0.47	11.55
<u>Stereospermum chenoioides</u> , DC.	40	0.7	2.36	21.4

Table 2.3. Phytosociological attributes of the herb component of the young (6-yr. old) forested jhum fallow.

Name of plants	Frequency (%)	Density (No. m ⁻²)	Total basal cover (cm ² m ⁻²)	IVI
<u>Conyza angustifolia</u> , Roxb.	30	0.6	0.7	22.16
<u>Dioscorea bulbifera</u> , Linn.	40	0.7	0.33	20.19
<u>Dioscorea glabra</u> , Wall.	30	0.6	0.28	16.32
<u>Imperata cylindrica</u> , Beauv.	20	0.7	0.63	19.76
<u>Lonicera ja onica</u> , Linn.	70	1.5	0.94	42.93
<u>Lycodium</u> sp.	30	0.4	0.35	15.46
<u>Mikania micrantha</u> , HKB.	70	3.0	2.1	72.61
<u>Paspalum distichum</u> , Linn.	40	1.8	0.23	28.61
<u>Polygonum chinense</u> , Roxb.	30	0.4	0.4	16.16
<u>Porana vulbillis</u> , Burm.	20	0.5	0.47	15.71
<u>Setaria</u> sp.	10	0.6	0.44	13.86
<u>Smilax prolifer</u> a, Wall.	20	0.2	0.09	7.69
<u>Thysanolaena maxima</u> , Kuntze.	20	0.2	0.15	8.54

Table 2.4. Phytosociological attributes of the tree component of the 20-yr. old forested jhum fallow.

Name of plants	Frequency (%)	Density (No. 100 Sq.m ⁻¹)	Total basal cover (cm ² 100 Sq.m ⁻¹)	IVI
<u>Arenga saccharifera</u> , Labill.	30	0.8	8.2	11.45
<u>Bischofia javonica</u> , Bl.	20	0.2	1.41	4.7
<u>Caryota mitis</u> , Lour.	30	0.3	5.76	7.4
<u>Cyathocalyx martabanicus</u> , Hk, f&T.	40	0.6	45.6	14.53
<u>Dysoxylum pallens</u> , Hiern.	20	0.2	14.2	4.6
<u>Ficus hirta</u> , Vahl.	20	0.3	3.86	5.1
<u>Garunga pinnata</u> , Roxb.	20	0.2	14.7	4.65
<u>Gmelina arborea</u> , Linn.	10	0.1	14.7	3.2
<u>Melocanna bambusoides</u> , Trin.	100	68.3	662.89	191.57
<u>Michelia champaca</u> , Linn.	10	0.1	1.88	2.5
<u>Murraya paniculata</u> , Jack.	10	0.1	1.88	2.5
<u>Musa paradisiaca</u> , Linn.	20	0.2	4.21	5.0
<u>Saraca</u> sp.	40	0.7	6.04	10.1
<u>Toona ciliata</u> , Roem.	50	0.6	68.4	17.15
<u>Trevesia palmata</u> , Vis.	40	0.4	3.39	9.3
<u>Vitex peduncularia</u> , Wall.	20	0.2	16.0	6.29

Table 2.5. Phytosociological attributes of the shrub and sapling component of the 20-yr. old forested jhum fallow.

Name of the plants	Frequency (%)	Density (No. 25 Sq.m ⁻¹)	Total basal cover (cm ² 25 Sq.m ⁻¹)	IVI
<u>Anodendron peniculatum</u> , A.DC.	10	0.1	0.19	9.0
<u>Aporosa roxburghii</u> , Baill.	10	0.1	0.25	9.7
<u>Artocarpus chaplasha</u> , Roxb.	20	0.2	0.38	18.0
<u>Croton</u> sp.	20	0.2	0.28	16.83
<u>Dysoxylum grande</u> , Hiern.	10	0.1	0.19	9.0
<u>Ficus</u> sp.	30	0.5	1.65	45.7
<u>Hibiscus macrophyllus</u> , Roxb.	20	0.2	0.16	15.25
<u>Ilex</u> sp.	10	0.1	0.36	11.0
<u>Leea indica</u> , Roxb.	50	0.6	2.45	65.22
<u>Mahonia nepalensis</u> , DC.	10	0.1	0.4	11.41
<u>Mitragyna rotundifolia</u> , (Roxb) O.Ktze	10	0.1	0.14	8.42
<u>Nephelium longana</u> , Camb.	10	0.1	0.51	12.7
<u>Sapindus attenuatus</u> , Wall.	20	0.2	0.85	23.41
<u>Schefflera venulosa</u> , (W&A). Harms	10	0.1	0.19	9.0
<u>Stereospermum chenolooides</u> , DC.	20	0.2	0.4	18.21
<u>Talauma</u> sp.	20	0.2	0.28	16.83

Table 2.6. Phytosociological attributes of the herb component of the 20-yr. old forest-
ed jhum fallow.

Names of the plants	Frequency (%)	Density (No. m ⁻²)	Total basal cover (cm ² m ⁻²)	IVI
<u>Desmodium</u> sp.	10	0.1	0.06	18.0
<u>Hedychium coccineum</u> , Wall.	20	0.2	0.47	47.5
<u>Lenicera japonica</u> , Linn.	20	0.2	0.31	42.2
<u>Raphidophora decurva</u> , (Roxb).Schott.	20	0.2	0.47	47.5
<u>Strobilanthes</u> sp.	50	0.5	1.73	144.8

Table 2.7. The plant species common to both young (6-yr. old) and old (20-yr. old) forested jhum fallows.

Name of plant species
<u>Aporosa roxburghii</u>
<u>Artocarpus chaplasha</u>
<u>Dysoxylum grande</u>
<u>Ficus</u> sp.
<u>Hibiscus macrophyllus</u>
<u>Lonicera japonica</u>
<u>Melocanna bambusoides</u>
<u>Musa paradisiaca</u>
<u>Sapindus attenuatus</u>
<u>Stereospermum chenoloides</u>

Table 2.8. Similarity indices between different components of vegetation on the young (6-yr. old) and old (20-yr. old) jhum fallow.

Young (6-yr.old) jhum fallow	Old (20-yr. old) jhum fallow			
	Tree component	Shrub and sapling component	Herb component	Total
Tree component	0.24	-	-	-
Shrub and sapling component	-	0.35	-	-
Herb component	-	-	0.11	-
Total	-	-	-	0.26

Table 2.9. Index of dominance and index of diversity among various components of the vegetation on the young (6-yr. old) and old (20-yr. old) forested jhum fallows.

Indices of species structure	Components of vegetation	6-yr. old fallow	20-yr. old fallow
Index of dominance	Tree	0.368	0.414
	Shrub and sapling	0.079	0.102
	Herb	0.117	0.306
	Total	0.187	0.206
Index of diversity	Tree	1.479	1.557
	Shrub and sapling	2.804	2.538
	Herb	2.359	1.379
	Total	2.682	2.452

Plate 5A The view of the pre-jhuming vegetation
in 6-year old jhum fallow.

Plate 5B The view of the pre-jhuming vegetation
in a 20-year old jhum fallow.



PLATE 5A



PLATE 5B

Plate 6A The view of 6-year old jhum fallow
after burning.

Plate 6B The view of 20-year old jhum fallow
after burning.



PLATE 6A



PLATE 6B

Plate 7A The view of 6-year old jhum field during cropping.

Plate 7B The view of 20-year old jhum field during cropping.



PLATE 7A



PLATE 7B

Plate 8 The view of crop-weeds association in
jhum field.

Plate 9 Jhum field after harvest.



PLATE 8



PLATE 9

Plate 10A The view of 6-year old jhum fallow after first year of cropping showing a newly developed vegetation and standing dead biomass.

Plate 10B The view of 20-year old jhum fallow after first year of cropping showing a newly developed vegetation and standing dead biomass



PLATE 10A



PLATE 10B

Plate 11A The view of Plate 10A after slashing.
(The dried up slash (pale colour) accumulated on the ground is clearly visible.)

Plate 11B The view of Plate 10B after slashing.
(The dried up slash (pale colour) accumulated on the ground is clearly visible.)



PLATE 11A



PLATE 11B

Plate 12A The view of Plate 11A after burning.

Plate 12B The view of Plate 11B after burning.



PLATE 12A



PLATE 12B

CHAPTER III

*Energy budget of shifting cultivation
during first year and second year of
cropping in six-year and twenty-year
old jhum fallows*

Introduction

The increasing agricultural yields during the past 50 years could be possible through industrialisation of agriculture involving large fuel energy subsidies, sophisticated chemical control and high yielding crop varieties. Such agricultural systems are efficient in terms of human time and labour but are highly inefficient from an overall energetics point of view as five to ten units of fuel energy are required to produce a single unit of food energy (Steinhard & Steinhard, 1974). The obvious inapplicability of such systems as models for development in an energy-limited world has led to the revival of interest in traditional systems of agriculture which may presumably offer greater ecological efficiency. In particular, shifting cultivation has been held as a model of production efficiency, where, from five to fifteen units of food energy are obtained from each unit of energy used in production (Rappaport, 1971; Steinhard & Steinhard, 1974). The possibility has been suggested (Greenland, 1975; Revelle, 1976; Mutsaer et al. 1981) for increased crop production without departing too much from this traditional system, which has been considered as the most evolved system for the forested areas of the tropics and sub-tropics (Conklin, 1957; Carneiro, 1960; Nye & Greenland, 1960; Watters, 1971).

In Mizoram jhuming is the main agricultural system for the production of rice which is the staple food of the local people. It is the source of livelihood for almost about 60% of the state population.

The energy aspects of traditional agriculture in India have been studied by Mitchell (1979). Such a study on slash and burn agriculture and other agro-ecosystems as practiced traditionally in Meghalaya was undertaken by Toky & Ramakrishnan (1982). The present study aims to analyse energetics of jhum cultivation of young and old jhum fallows. The other major aims of this study is the introduction of second year of cropping in the jhum fields which were cultivated for one year by tilling the soil and through application of chemical fertilizers and farm-yard manure separately and in combination. This introduction of second year cropping with various treatments are considered as innovative approaches to the existing system of traditional jhum cultivation prevalent in Mizoram where cropping is commonly done for only one year in jhum fields. The study quantifies the energy input and output in terms of money (Rupees) and Megajoules (MJ) on per hectare basis during the first year and second year of cropping on young and old jhum fallows. This study may reveal as to which system would be more efficient and what improvements could be suggested in order to make the existing practice of jhum

cultivation more efficient from the energetic and productivity point of view.

The jhum fallows of two different ages, 6-year and 20-year old, were selected for this study. The cropping on these fallows was done for two successive years. During the second year of cropping the jhum fields were subjected to various treatments such as land tilling, application of chemical fertilizers, application of farm-yard manure and application of combination of the latter two. The sites selected for this study represent the same toposequence and have close similarity in so far as the vegetation is concerned.

Methods

The input and output on each study plots were measured in terms of energy (Megajoules) and money (Rupees) taking the mean value of two years experimental data. The energy spent on each of the activities related to jhum cultivation has been expressed as percentage of the total energy input. The agricultural operations during the process of jhuming are slashing (SL), burning (BU), sowing (SO), weeding (W), harvesting (HA) and threshing (TH). Tilling of soil or field preparation (TI) and application of fertilizers (FI) are additional agricultural operations arising out of an endeavour to introduce innovative approaches to jhuming during second year of cropping. Though threshing of rice is not exactly

a step involved in jhuming, in this study, it has been included in this category, because this work is also done in the jhum field itself and the determination of energy output through the production of rice is possible only after threshing.

The rice seeds and the fertilizers (used in the second year cropping), both being the materials have not been considered as an integral component of jhum operation and therefore, they have not been included for the purpose of determining relative proportion of energy spent on various activities of jhuming.

Various forms of energy input in each plot were converted into megajoules (MJ) and money (Rs.) by using the values given in Table 3.1 and 3.2 respectively. As far as energy output is concerned rice was the only crop grown in the jhum fields which contributed the total energy output from each plot. The energy value of rice in terms of megajoules (MJ) as given in table 3.1 and in terms of money (Rs.) as given in table 3.2 are used for the determination of energy output.

To determine the energetic efficiency of each system, the ratio between energy output and input was calculated for each plot by dividing the output values with the corresponding input value.

Table 3.1. Values for various energy input and output components in terms of Megajoules (MJ).

Particulars	Unit	MJ	Author
Human labour	Man-hour	1.046	Revelle (1976)
Chemical Fertilizers			Mittal & Dhawan (1989)
(a) Nitrogen	Kg	60.0	
(b) P ₂ O ₅	Kg	11.1	
(c) K ₂ O	Kg	6.7	
Farm-yard Manure	Kg	0.3	-do-
Rice	Kg	14.518	-do-

Table 3.2. Local market monetary values for various energy input and output components.

Particulars	Unit	Rupees
Human labour	Man-day	40.00
Chemical fertilizers		
(a) Urea	Kg	2.00
(b) Diammonium Phosphate (DAP)	Kg	2.75
(c) Muriate of Potash (MOP)	Kg	1.15
Farm-yard manure (FYM)	Kg	0.15
Rice	Kg	5.00

Table 3.3. Percentage of elements available in the fertilizers

Name of fertilizer	N	P ₂ O ₅	K ₂ O
Urea	46	-	-
Diammonium Phosphate (DAP)	18	46	-
Muriate of Potash (MOP)	-	-	60

Results

Total energy input: The total energy input ranges between 140 and 187.5 man-days ha⁻¹yr⁻¹ or Rs. 5693.75 and Rs. 7593.75 ha⁻¹yr⁻¹ or 1150.85 MJ and 1448.97 MJ ha⁻¹yr⁻¹ as given in Table 3.4 (a-c). Lowest energy input was observed in 20 I:C plot and the highest was observed in 20 II:T plot.

Energy input was slightly more in 6 I:C plot than the corresponding plot during second year cropping (6 II:C). But in case of old jhum fallow, energy input in 20 I:C was much lesser than the corresponding sub-plot of 20 II:C and other sub-plots (20 II:T, CF, FYM and 20 II:CF+FYM) during second year of cropping.

Total energy input was exceptionally high in tilled sub-plot of both the jhum fallows. Among the sub-plots, the highest energy input was recorded in chemical fertilizer

plus farm-year manure treated sub-plot on both the fallows. Each sub-plot in 6-yr. old jhum fallow during second year of cropping required slightly lesser energy input than their corresponding sub-plots in 20-yr. old jhum fallow.

On 6-yr. old jhum fallow, during second year of cropping, energy input in the control sub-plot was more than energy input in the fertilizer treated sub-plots, but lesser than the tilled sub-plot. However, on 20-yr. old jhum fallow during second year of cropping, energy input in the control sub-plot was lesser than in the fertilizer treated sub-plots as well as tilled sub-plot.

Seed input: Amount of seed input was equal in all the plots.

Energy input in jhuming operations: Percentage of energy input contributed by various jhuming operations in each plot is shown in Fig. 3.1 (A-L).

The energy input to the system by way of weeding (W) was comparatively very high. The highest and lowest energy input in this operation were recorded in 6 II:C sub-plot and 20 II:T sub-plot respectively (Fig. 3.1 A and F). Energy input in the control plots via weeding was lesser during the first year of cropping than during the second year of cropping on both the jhum fallows. The control plots on 6-yr.

old jhum fallow (6 I:C and 6 II:C), required more energy for weeding than their counterparts on 20-yr. old jhum fallow.

On young jhum fallow, during second year cropping, energy input in weeding was highest in control sub-plot (6 II:C) and the same trend was observed in 20 yr. old jhum fallow. There was not much variation of energy input in weeding among the fertilizer treated sub-plots on 6-yr. old jhum fallow. But in 20-yr. old fallow a slightly higher energy input was recorded in chemical fertilizer plus farm-yard manure treated sub-plot than other fertilizer treated sub-plots. Energy input on weeding operation was lowest in tilled sub-plot on both the jhum fallows.

The energy input in burning operation was equal in all the plots. This operation demanded the least amount of energy among the various jhuming operations.

Energy input in slashing, sowing and harvesting operation was more or less equal in all the plots.

Slashing required slightly more energy during first year of cropping than during second year of cropping. Same trend was observed with increase in age of jhum fallow, i.e. 20-yr. old jhum fallow required higher energy input than 6-yr. old jhum fallow. For this operation energy input was equal in all the plots on 6-yr. old jhum fallow. Similarly,

energy required for slashing was also equal in all the plots on 20-yr. old jhum fallow. The maximum and minimum percentage contribution of energy input through slashing were recorded in 20 I:C plot and 6 II:T sub-plot respectively (Fig. 3.1 B and E).

Energy input through sowing operation was same in all the plots during second year cropping regardless of age of the jhum land. Energy input on sowing was slightly more in 6 I:C plot than in 20 I:C plot. In terms of percentage of energy input, this operation contributed maximum in 6 II:CF and 6 II:FYM sub-plots and minimum in 20 II:T sub-plot (Fig. 2.1, G, I, and F).

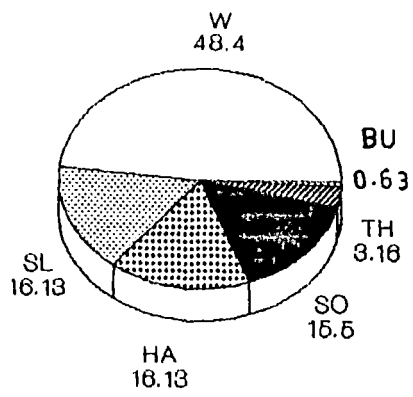
Energy input in harvesting operation was more or less equal in all the plots. Highest input was observed in 6 I:C plot and lowest in 20 I:C plot. The percentage of energy input contributed by this operation was highest in 6 I:C plot and lowest in 6 II:T sub-plot (Fig. 3.1, A and E).

Energy input in tilling or field preparation was highest and equal in 6 II:T and 20 II:T sub-plots. It was equal in all other fertilizer-treated plots on the jhum fallows of both the ages.

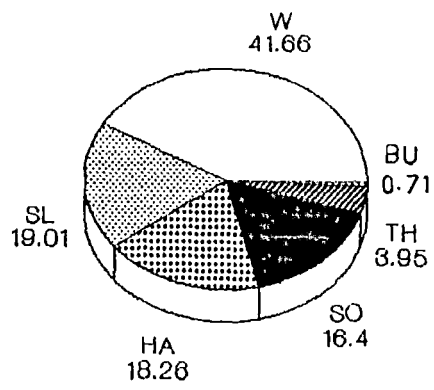
Small amount of energy was also expended for the application of fertilizer in fertilizer-treated plots and

Fig. 3.1 (A-L) Pie chart, showing percentage of energy input contributed by jhuming operations. SL = slashing, BU = burning, TI = tilling or field preparation, FI = fertilizer application, SO = sowing, W = weeding, HA = harvesting and TH = threshing.

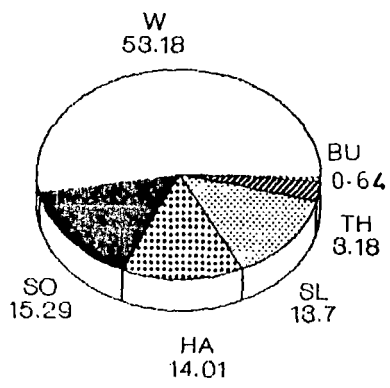
A = 6 I:C, B = 20 I:C, C = 6 II:C,
D = 20 II:C, E = 6 II:T, F = 20 II:T,
G = 6 II:CF, H = 20 II:CF, I = 6 II:FYM,
J = 20 II:FYM, K = 6 II:CF+FYM, and
L = 20 II:CF+FYM.



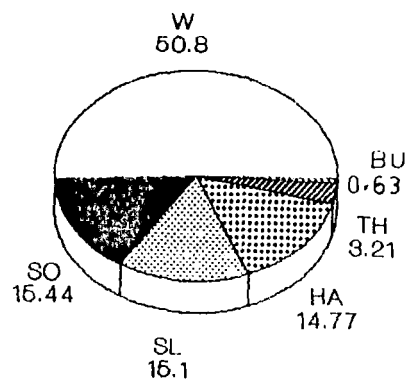
A



B

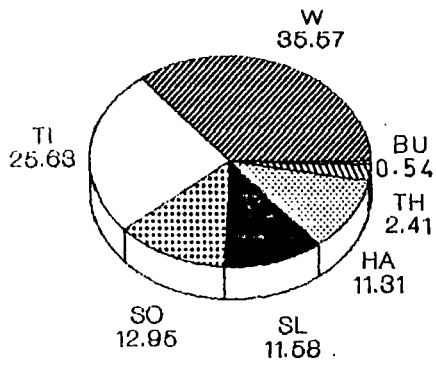


C

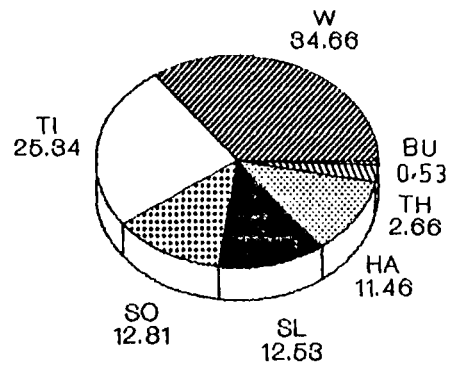


D

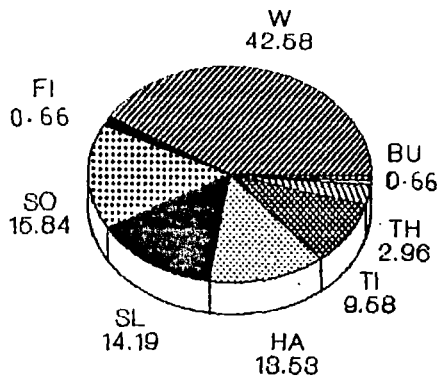
FIG. 3.1



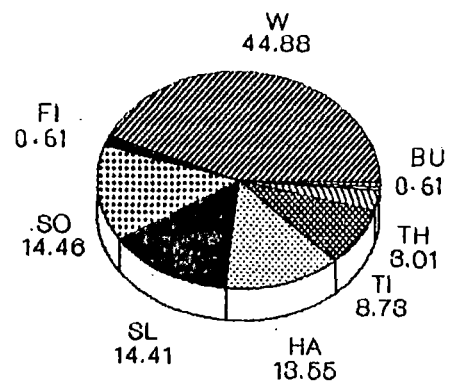
E



F



G



H

FIG. 3.1

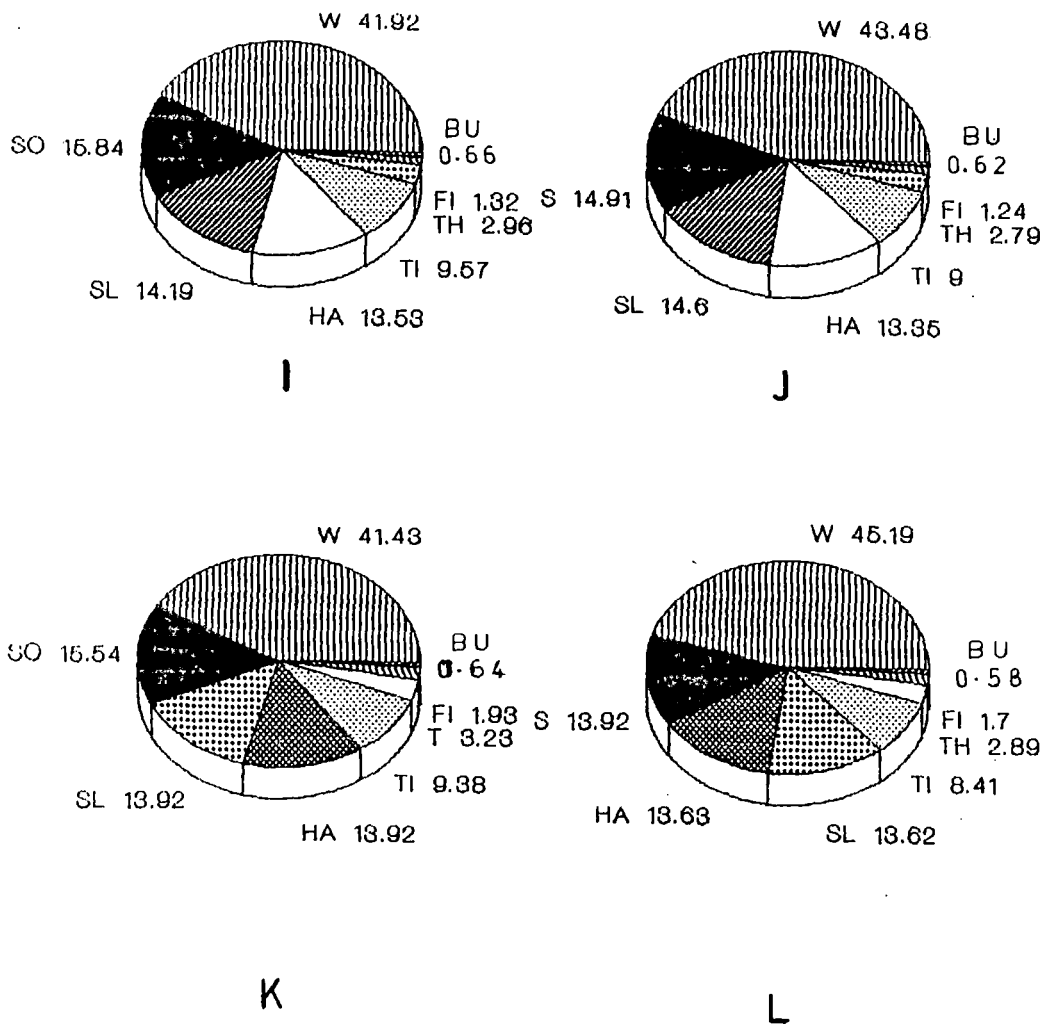


FIG. 3.1

amounts were same for the similar plots of different ages of jhum fallows.

The energy input through fertilizer application was the lowest and almost equal in 6 II:CF and 20 II:CF sub-plots whereas in 6 II:CF+FYM and 20 II:CF+FYM sub-plots, it was the highest.

There was not much difference in energy input on threshing operation in all the plots. It was recorded highest in 20 I:C plot.

Energy output: Total output ranges from 1215 kg ha⁻¹ yr⁻¹ to 1855 kg ha⁻¹ yr⁻¹ in terms of production, Rs. 6075 ha⁻¹ yr⁻¹ to Rs. 9275 ha⁻¹ yr⁻¹ in terms of money and 17639.95 MJ ha⁻¹ yr⁻¹ to 26931.78 MJ ha⁻¹ yr⁻¹ in terms of energy (Table 3.5). Highest and lowest output were recorded from 20 II:CF+FYM and 6 II:T sub-plots respectively.

Energy output was more during first year cropping than during second year cropping from the jhum fallows of both ages. The output was higher from all plots in 20-yr. old jhum fallow than their corresponding plots in 6-yr. old jhum fallow during second year of cropping.

In the case of young jhum fallow the energy output was lowest from the tilled sub-plot. The same trend was true

for the 20-yr. old jhum fallow. The sub-plot 20 II:CF+FYM recorded exceptionally high energy output compared to all other sub-plots in the old jhum fallow during second year of cropping. The same trend was observed in the young jhum fallow also during second year of cropping.

Gain or Loss: Energetically, there was always a gain, but monetarily it was not so in all the plots (Table 3.5). Maximum gain of Rs. 2281.25 $\text{ha}^{-1}\text{yr}^{-1}$ or 25576.95 MJ $\text{ha}^{-1}\text{yr}^{-1}$ was recorded in the 20 II:CF+FYM sub-plot. Maximum monetary loss of rs. 1438.75 $\text{ha}^{-1}\text{yr}^{-1}$ was incurred in the case of 6 II:T sub-plot.

Monetary loss was also recorded in the case of control and tilled sub-plots in both the jhum fallows (6 II:C, 20 II:C, 6 II:T and 20 II:T sub-plots) during second year of cropping.

A gain of Rs. 897.75 $\text{ha}^{-1}\text{yr}^{-1}$ was recorded from the control plot on 6-yr. old jhum fallow, whereas during second year of cropping, a loss of Rs. 173.75 $\text{ha}^{-1}\text{yr}^{-1}$ was incurred from the same plot. A similar trend was observed in the case of 20-yr. old fallow where a gain of Rs. 2237.50 $\text{ha}^{-1}\text{yr}^{-1}$ was recorded in the first year of cropping from the control plot (20 I:C) and a loss of Rs. 13.75 $\text{ha}^{-1}\text{yr}^{-1}$ from the same plot during second year of cropping (20 II:C).

Output : input ratio

Monetary efficiency: The monetary output : input ratio determines the efficiency of each system in terms of money. The higher the output : input ratio the more efficient the system. The highest recorded ratio was 1.39 in 20 I:C plot and the lowest was 0.8 in 6 II:T sub-plot. Table 3.6 shows that this ratio was more than one in all plots except control and tilled sub-plots in both 6-yr. old and 20-yr. old jhum fallows during second year of cropping (Table 3.6).

Energy efficiency: Energy output : input ratio determines the energy efficiency of the system. This ratio was higher in all sub-plots on 20-yr. old jhum fallow than the corresponding sub-plots on 6-yr. old jhum fallow during both first and second year of cropping. The highest ratio recorded was 20.01 in 20 I:C plot and the lowest was 4.41 in 6 II:CF+FYM sub-plot. The control plot during first year of cropping (6 I:C and 20 I:C) recorded higher ratios than the corresponding sub-plots during second year of cropping (6 II:C and 20 II:C). Tilled sub-plots of both young and old jhum fallows recorded exceptionally low ratio as compared with the control sub-plots.

Energy output : input ratio was very low in all the plots that were given fertilizers. Again, among the sub-plots treated with the fertilizers, the ones which received farm-

yard manure (6 II:FYM and 20 II:FYM sub-plots) recorded highest followed by the sub-plots treated with chemical fertilizer (6 II:CF and 20 II:CF sub-plots) while the lowest values were recorded for those plots which received both chemical fertilizer and farm-yard manure (6 II:CF + FYM and 20 II : CF + FYM).

Discussion

The essence of agriculture is the use of energy and material inputs to stimulate productivity of the systems and concentrate it into forms useful to man. The energy output : input ratios in labour intensive agriculture are generally greater than one in contrast to one or less in case of fuel-based agriculture (Rappaport, 1968, 1971). Jhum in north-eastern India has survived all these years chiefly because of the high energy efficiency of the system where human labour is the only energy input. According to Rappaport (1971) the 'Tsembaga' people of the New Guinea Highlands obtained an average of 16 units of food energy for each unit of human energy input during farming and this may increase to 20 under more favourable conditions. Others (Lewis, 1951; Norman, 1978; Uhl & Murphy, 1981) have reported equally high or even higher efficiency. Most of these studies do not mention the length of the jhum cycle and its relationship to energy efficiency.

Table 3.4(a). Labour input (Man-days ha⁻¹ yr⁻¹) in 6-year and 20-year old jhum fallows during first year and second year of cropping.

TREATMENT	J H U M I N G O P E R A T I O N S									
PLOTS	Slashing	Burning	Tilling	Fertilizer application	Sowing	Weeding	Harvesting	Threshing	Total	
6 I:C	25.5	1	-	-	24.5	76.5	25.5	5	158	
6 II:C	21.5	1	-	-	24	83.5	22	5	157	
6 II:T	21.5	1	47.5	-	24	65	21	4.5	185.5	
6 II:CF	21.5	1	14.5	1	24	64.5	20.5	4.5	151.5	
6 II:FYM	21.5	1	14.5	2	24	63.5	20.5	4.5	151.5	
6 II:CF+FYM	21.5	1	14.5	3	24	64	21.5	5	154.5	
20 I:C	26.5	1	-	-	23	58.5	25.5	5.5	140	
20 II:C	23.5	1	-	-	24	79	23	5	155.5	
20 II:T	23.5	1	47.5	-	24	65	21.5	5	187.5	
20 II:CF	23.5	1	14.5	1	24	74.5	22.5	5	166	
20-II:FYM	23.5	1	14.5	2	24	70	21.5	4.5	161	
20 II:CF+FYM	23.5	1	14.5	3	24	78	23.5	5	172.5	

Table 3.4(b). Monetary input (Rs ha⁻¹ yr⁻¹) in 6-year and 20-year old jhum fallows during first year and second year of cropping.

TREATMENT	Slash- ing	Burn- ing	Till- ing	Ferti- lizer appli- cation	I N P U T	S e e d s	S o w i n g	W e e d i n g	H a r v e s t- i n g	T h r e s h- i n g	T o t a l
6 I:C	1020	40	-	-	93.75	980	3060	1020	200	6413.75	
6 II:C	860	40	-	-	93.75	960	3340	880	200	6373.75	
6 II:T	860	40	1900	-	93.75	960	2640	840	180	7513.75	
6 II:CF	860	40	580	40	347.75	93.75	960	2580	820	180	6153.75
6 II:FYM	860	40	580	80	450	93.75	960	2540	820	180	6153.75
6 II:CF+FYM	860	40	580	120	797.75	93.75	960	2560	860	200	6273.75
20 I:C	1060	40	-	-	93.75	920	2340	1020	220	5693.75	
20 II:C	940	40	-	-	93.75	960	3160	920	200	6313.75	
20 II:T	940	40	1900	-	93.75	960	2600	860	200	7593.75	
20 II:CF	940	40	580	40	347.75	93.75	960	2980	900	200	6733.75
20 II:FYM	940	40	580	80	450	93.75	960	2800	860	180	6533.75
20 II:CF+FYM	940	40	580	120	797.75	93.75	960	3120	940	200	6993.75

Table 3.4(c). Energy input ($\text{MJ ha}^{-1} \text{yr}^{-1}$) in 6-year and 20-year old jhum fallow during first year and second year of cropping.

TREATMENT PLOTS	Slash- ing	Burn- ing	Till- ing	I N P U T		C O M P O N E N T S					
				Ferti- lizer appli- cation	Ferti- lizer	Seeds	Sowing	Weeding	Harvest- ing	Thresh- ing	Total
5 I:C	160.03	6.27	-	-	-	272.22	153.76	480.11	160.03	31.38	1263.38
6 II:C	134.93	6.27	-	-	-	272.22	150.62	524.05	138.07	31.38	1257.55
6 II:T	134.93	6.27	298.11	-	-	272.22	150.62	414.21	131.79	28.24	3849.35
6 II:CF	134.93	6.27	91.0	6.27	2626.65	272.22	150.62	404.8	128.65	28.24	2123.0
6 II:FYM	134.93	6.27	91.0	12.55	900.0	272.22	150.62	398.52	128.65	28.24	2123.0
6 II:CF+FYM	134.93	6.27	91.0	18.82	3526.65	272.22	150.62	401.66	134.93	31.38	4768.48
20 I:C	166.31	6.27	-	-	-	272.22	144.36	367.15	160.03	34.52	1150.85
20 II:C	147.48	6.27	-	-	-	272.22	150.62	495.8	144.35	31.38	1248.13
20 II:T	147.48	6.27	298.11	-	-	272.22	150.62	407.94	134.93	31.38	1448.97
20 II:CF	147.48	6.27	91.0	6.27	2626.65	272.22	150.62	467.56	141.21	31.38	3940.66
20 II:FYM	147.48	6.27	91	12.55	900	272.22	150.62	439.32	134.93	28.24	2182.65
20 II:CF+FYM	147.48	6.27	91	18.82	3526.65	272.22	150.62	489.52	147.48	31.38	4880.65

Table 3.5. Output in terms of production ($\text{Kg ha}^{-1}\text{yr}^{-1}$), money ($\text{Rs ha}^{-1}\text{yr}^{-1}$) and energy ($\text{MJ ha}^{-1}\text{yr}^{-1}$) from 6-year and 20-year old jhum fallows during first year and second year of cropping.

PLOTS	O U T P U T		
	Production	Money	Energy
6 I:C	1462.5	7312.50	21233.27
6 II:C	1240.0	6200.00	18002.91
6 II:T	1215.0	6075.00	17639.95
6 II:CF	1375.0	6875.00	19962.91
6 II:FYM	1300.0	6500.00	18874.02
6 II:CF+FYM	1450.0	7250.00	21051.79
20 I:C	1586.25	7931.25	23029.93
20 II:C	1260.0	6300.00	18293.28
20 II:T	1247.5	6237.50	18111.80
20 II:CF	1505.0	7525.00	21850.31
20 II:FYM	1402.5	7012.50	20362.16
20 II:CF+FYM	1855.0	9275.00	26931.78

Table 3.6. Output/input ratio (Rs. and MJ) in 6-year and 20-year old jhum fallows during first year and second year of cropping.

PLOTS	OUTPUT : INPUT	
	Rs.	MJ
6 I:C	1.14	16.8
6 II:C	0.97	12.53
6 II:T	0.8	12.28
6 II:CF	1.11	5.18
6 II:FYM	1.05	8.89
6 II:CF+FYM	1.15	4.41
20 I:C	1.39	20.01
20 II:C	0.99	14.65
20 II:T	0.82	12.49
20 II:CF	1.11	5.54
20 II:FYM	1.07	9.32
20 II:CF+FYM	1.32	5.51

Toky & Ramakrishnan (1982) reported energy output : input ratios of 31.1 to 47.9 under three different jhum cycles in Meghalaya.

In the present study, the energy efficiency (output : input ratio) during first year of cropping were 16.8 and 20.01 in young and old jhum fallows respectively. Lower energy efficiency in 6-yr. old jhum fallow is mainly due to relatively greater labour input in weeding operation. In the 20-yr. old fallow, weeding was required to be done twice whereas in the 6-yr. old jhum fallow it was required to be done three times in a year. A high degree of weed infestation associated with short jhum cycle is also reported by Toky & Ramakrishnan (1982). According to Freeman (1955), Cutting et al. (1959), Zinke et al. (1978) and Toky & Ramakrishnan (1982) weeds are the major cause of decline in crop yield under slash and burn agriculture.

Higher energy input and lower production during first year of cropping in 6-yr. old fallow compared to 20-yr. old jhum fallow observed in the present study is also due to greater weed infestation in the former. But, during second year of cropping, there had not been much difference in energy efficiency between the two fields. This condition may be attributed to the non-differentiable problem of weeds between

the two fields mentioned elsewhere in the present study. The weeds are thus mainly responsible for the difference in energy efficiency between first year and second year of cropping on the jhum fallow of a given age. The difference was, however, more prominent in case of 20-yr. old than in 6-yr. old jhum fallow. As revealed by the data, weeds are largely responsible for decline in energy efficiency in young jhum fallow during first year of cropping and also in both young and old jhum fallows during second year of cropping.

The high energy efficiency of shifting cultivation systems contrasts sharply with mechanized agriculture (Uhl & Murphy, 1981). For example, Pimentel et al. (1973) estimated that the ratio of food produced to energy input was 2.82 : 1 for mechanized corn cultivation in U.S.A. Mechanized agriculture is relatively less efficient energetically because of the large amount of energy subsidy required in the form of machinery, fertilizer, electricity and transportation. Earth work (terracing and tilling) always requires high labour input in terrace cultivation. Toky & Ramakrishnan (1982) reported that in terrace cultivation in Meghalaya, terracing during first year was one of the major operations involving high energy input. Due to this, even if the output is high, energy efficiency of such systems where extensive earth works are involved could never be high. In the present study also

the energy efficiency of the tilled sub-plots is relatively low due to high labour input in tilling of the soil. At the same time, unlike terrace system of cultivation, the output is rather low. This shows that introduction of tilling of soil during second year of cropping as a means of improvement over the existing traditional method of jhuming cannot be recommended as this would not increase production and energy efficiency.

The energy efficiency of fertilizer treated sub-plots are relatively high when only human labour inputs are considered as total energy input in the system. Basing upon this, all the fertilizer treated plots of young and old jhum fallows may be considered relatively more productive and energy efficient systems. At the same time, these fertilizer treated sub-plots are also comparable to mechanized systems, because of high energy input through fertilizers which are not applied under traditional method of jhuming, as is the case with the control plot. Even if the output is relatively high in the fertilizer treated sub-plots, the high energy input brings down the energy efficiency in these plots. Viewed from this angle, the new approaches which were introduced with a view to improve the traditional method of jhum cultivation, can hardly be considered as improvements.

Relatively high monetary input in tilled sub-plots

is due to labour input in soil tilling operations. The monetary input in the fertilizer treated sub-plots is pushed up due to the cost of fertilizers and their applications. An additional agricultural operation of field preparation also contributed to increase input in these sub-plots. The increased input caused decline in monetary efficiency of these sub-plots. There has not been much variation in monetary input among the plots on account of various traditional jhumming operations except weeding. Relatively high monetary input in weeding in the control plots of both 6-yr. old and 20-yr. old jhum fallows during second year of cropping is linked with high intensity of weed problem in these plots. The data also indicates that degree of weed infestation and loss in crop yield and monetary input in weeding operation are greater in 6-yr. old than in 20-yr. old jhum fallow.

The output of rice from each study plot (average yield $1408 \text{ Kg ha}^{-1}\text{yr}^{-1}$) is quite satisfactory when compared with the average yield of $1145 \text{ kg ha}^{-1}\text{yr}^{-1}$ for the country as a whole. The rice production recorded in the present study is greater than the average yield of 800 to 900 $\text{kg ha}^{-1}\text{yr}^{-1}$ reported earlier for Mizoram by Borthakur et al (1978). The tilled sub-plots involving highest monetary input recorded lowest output. Further, the untilled control plots on the two jhum fallows during both first year and second year of

cropping gave relatively higher output even though the monetary input was low.

On the basis of output in terms of production and monetary gain, the fertilizer treated sub-plots appear to be relatively more sound systems and therefore, fertilizer application during second year of cropping could be suggested as a definite improvement over the method of jhum cultivation hitherto being practiced in the state of Mizoram.

It may be noted that increase in monetary input does not necessarily increase the monetary output.

It is to be noted that the readily available energy input components like solar energy, forest vegetation, soil nutrients and accumulated litter in the system are not accounted for, while computing the energy efficiency of each study plot. At the same time, the 'left behind energy' after harvesting like, litter, vegetation and solar energy are not included in the energy output also. In any case, as all these factors are excluded in all the study plots, the energy budget as worked out in the present study may serve the purpose of comparing the energy efficiency of various kinds of jhum plots representing traditional jhum cultivation and the one modified in the light of suggested improvements and innovative approaches.

CHAPTER IV

*Plant biomass and net primary productivity
in young and old jhum fallows during first
year and second year of cropping*

Introduction

Biomass studies are fundamental to the understanding of the dynamics of ecological systems. Estimation of biomass is essential in determining the distribution and circulation of materials in ecosystem and is necessary to understand the dynamics of these systems (Andersson, 1971). Biomass studies may be employed to describe quantitatively the static distribution of materials in ecological systems (Santantonio et al., 1977).

In Mizoram cropping season of rice on jhum lands begins with sowing of seeds during middle of April to the first week of May. During the course of burning of slashed vegetation most of the seedlings, saplings and live plants of other categories are also consumed. Thus the jhum fields become more or less devoid of any live plants. Some of the weedy species start invading the jhum fields in between burning and sowing operation. First weeding is usually done after about ten days from sowing. The uprooted weeds are spread over the surface of jhum field, so that the same may be dried up and decomposed and act as green manure. However, more and more weeds grow in the agro-ecosystems and compete for various resources available in the jhum fields. Some of these weeds may be facultative heliophytes and therefore, can manage to grow even under the crop canopy. As argued by Tripathi

(1977), the weeds may increase the total organic production by utilizing the light energy which is not intercepted by the crop plants and reaches the lower stratum of agro-ecosystems which is mostly occupied by a number of weeds. The biomass accumulation by the weeds and crops may give an indication of the partitioning of inputs to the jhum fallows between them.

The present chapter deals with the biomass and productivity studies of rice and weeds in 6-yr. old and 20-yr. old jhum fallows during first year and second year of cropping. Biomass (above ground and below ground separately), percentage contribution by weeds to total biomass, and productivity were estimated for rice and weeds.

Methods

In the present study, biomass and productivity were measured by harvesting the plants from known area at periodic intervals (Odum, 1960). For estimation of biomass three monoliths of 25 x 25 x 25 cm were excavated on each sampling date (just before weeding) from each study plot. The roots of plants were washed thoroughly with running water. All weeds encountered in the sample were separated from the rice plants. Below ground parts of rice and weeds were chopped off from their corresponding shoot system. Sampling was done

at monthly intervals, starting from one month after sowing of rice seeds till the earing time. The sampling was done in June, July, August and September.

Biomass of aboveground and belowground parts of rice and weeds were determined on the basis of dry weight. For the determination of biomass the plant material was oven-dried at 80°C to constant weight and weighed. The net primary productivity was estimated by summing the positive differences in biomass on successive sampling dates as described by Singh & Yadava (1974). While estimating the aboveground biomass standing dead and standing live were not separated, but they were considered together. The net primary production and rate of productivity were estimated for aboveground and belowground parts of rice and weeds separately. Percentage contribution of weeds biomass to the total biomass was also calculated.

Results

Biomass

Monthly variation of total biomass (rice plus weeds) during the study period on 6-yr. old and 20-yr. old jhum fallows are shown in Fig. 4.1 and 4.2 respectively. In general, a positive increase from first sampling date to the last sampling date was evident on all the study plots. The peak value in the case of all plots was observed at the last har-

vest taken in September. The biomass production was slightly more during first year of cropping than in the second year on both fallows. The peak biomass was comparatively higher on older jhum fallow than on the younger fallow in both years of cropping.

The monthly changes in biomass of rice and weeds during the study period are shown in Fig. 4.3 and 4.4. Biomass (g. m^{-2}) of aboveground and belowground parts of rice and weeds in each month during the study period is given in Table 4.1 and 4.2 respectively. Generally, the total crop biomass showed a gradual increase till the last harvest. The same trend was also evident in the case of weeds except on the sub-plots treated with chemical fertilizers and farm-yard manure in 20-yr. old jhum fallow where slight decline at the last harvest was observed.

Percentage contribution of weeds to total biomass

Percentage contribution by weeds to the total biomass in different months during the study period is given in Table 4.3. Generally, the contribution of weeds to total biomass decreased with time, being maximum in June and minimum in September on all plots, except the tilled, and fertilized sub-plots in 20-yr. old jhum fallow where the minimum contribution of weeds to total biomass was recorded in July.

Productivity

The aboveground and belowground production of rice plus weeds during the growing season on 6-yr. old and 20-yr. old jhum fallows is shown in Fig. 4.5. Generally, total production was slightly greater during first year of cropping compared to the second year of cropping on both the fallows. The older (20-yr. old) fallow showed greater aboveground and belowground production during both years of cropping.

Among the treated sub-plots, the highest total production was recorded in the sub-plot treated with chemical fertilizers and the lowest was recorded in the tilled sub-plot on the fallows of both ages. In 20-yr. old jhum fallow total production was comparatively higher in the control plot during first year of cropping in comparison to the corresponding control plot as well as the sub-plots in the second year. However, in 6-yr. old fallow the first year control plot gave a much lower total production compared to the treated sub-plots of the second year cropping, although it outyielded the tilled and control sub-plots.

The total production of rice and weeds are shown separately in Fig. 4.6 and 4.7 respectively. In general, both aboveground and belowground production of rice followed the same trend as shown by total production (rice plus weeds). However, weeds showed the reverse trend. Weeds showed lower

production in the tilled and fertilizer-treated sub-plots on both jhum fallows during second year as compared to the corresponding control plots.

In 20-yr. old jhum fallow weeds showed a much higher production during second year of cropping than in the first year, while the converse was true in 6-yr. old fallow. Among the treated sub-plots, weeds showed the lowest production in the chemical fertilizer-treated sub-plots on both fallows.

Rate of productivity

Rates of productivity ($\text{g. m}^{-2} \text{ day}^{-1}$) of rice and weeds in each month of the growing season are given in Table 4.4 and 4.5 respectively. In general there was a marked increase in productivity rate during September in both 6-yr. old and 20-yr. old jhum fallows during first year cropping. Rate of productivity of the crop increased on all the plots in 6-yr. old jhum fallow during second year of cropping. The same trend was also observed in all treated sub-plots of 20-yr. old fallow.

Rate of productivity ($\text{g. m}^{-2} \text{ day}^{-1}$) of the crop (rice) and weeds separately, and rice plus weeds during the entire growing season are given in Table 4.6. The rate of productivity (weeds and crop considered together) was higher during

Table 4.1. Biomass (g. m^{-2}) of above and belowground parts of rice in different months during the growing season of the crop.

TREATMENT PLOTS	ABOVEGROUND BIOMASS				BELOWGROUND BIOMASS			
	June	July	August	September	June	July	August	September
6 I:C	11±1	98±2	386±15	731±26	3.5±0.5	21±1	70±4	101±6
6 II:C	10.5±1	88±5	361±10	717±55	4±0.6	19±1	64±3	98±9
6 III:T	10±0.5	78±0.5	239±19	617±34	3.5±0.5	20±1	62±4	92±4
6 II:CF	12±1	114±2	374±8	1164±50	4±0.2	38±1	91±5	132±10
6 III:FYM	11±0.5	126±6	331±13	1061±64	3.8±0.1	40±2	84±2	123±5
6 III:CF+FYM	12±1	98±10	349±23	1096±60	4±0.3	23±2	89±6	128±6
20 I:C	13±1.5	101±15	379±24	1325±51	5±0.5	25±1	91±3	148±8
20 II:C	11±0.5	96±8	313±14	908±21	4±0.2	26±1	78±8	109±11
20 III:T	12±0.5	295±9	346±14	909±39	5.5±0.4	75±4	84±4	99±2
20 III:CF	28±2	336±6	405±18	1230±50	5.5±0.6	82±4	96±2	144±2
20 III:FYM	21±2	341±4	386±17	1158±52	5.5±0.6	83±3	87±1	133±7
20 III:CF+FYM	28±1	308±4	435±7	1176±32	6.5±0.4	72±5	98±2	128±4

Table 4.2. Biomass (g. m^{-2}) of above and belowground parts of weeds in different months during the growing season of the crop.

TREATMENT PLOTS	ABOVEGROUND BIOMASS			BELOWGROUND BIOMASS				
	June	July	August	September	June	July	August	September
6 I:C	13±2	36±4	77±7	97±6	4.5±0.7	12±1	15±3	28±3
6 II:C	8±1	33±5	88±8	102±4	3.5±0.7	12±1	17±1	12±2
6 II:T	7.5±0.5	17±1	70±11	74±6	5±0.7	6±1	16±2	21±2
6 II:CF	8±1.5	32±4	75±5	87±5	6±1	11±1	14±1	21±4
6 II:FYM	16±3	24±1	84±6	91±7	8±2	9±2	17±2	25±2
6 II:CF+FYM	16±1.5	30±5	83±9	89±10	7±0.4	11±1	21±2	21±1
20 I:C	16±3	27±3	47±3	56±4	6.5±1	9±1	10±1	11±1
20 II:C	13.5±3	34±2	132±8	145±4	5±0.7	11±1	27±1	29±3
20 II:T	6±0.5	14±3	106±5	119±8	3.5±0.4	5±1	21±1	18±2
20 II:CF	13±4	38±1	120±6	110±14	5.5±0.5	14±2	22±2	23±3
20 II:FYM	18.5±3	34±8	131±8	130±12	7.5±2	10±1	24±2	22±3
20 II:CF+FYM	19.5±2	38±3	133±4	131±6	8±2	13±1	23±3	30±4

Table 4.3. Percentage contribution of weeds to total biomass in different months during crop growing season on 6-yr. old and 20-yr. old jhum fallows during first year and second year of cropping.

TREATMENT PLOTS	MONTHS			
	June	July	August	September
6 I:C	54.6	28.74	16.78	13.06
6 II:C	42.3	29.6	19.81	12.15
6 II:T	48.07	19.0	22.22	11.8
6 II:CF	46.66	22.05	16.06	7.69
6 II:FYM	60.0	16.5	19.57	8.92
6 II:CF+FYM	57.5	25.3	19.18	8.24
20 I:C	55.5	22.22	10.81	4.3
20 II:C	55.2	26.94	25.27	12.93
20 II:T	35.18	4.88	22.8	11.96
20 II:CF	34.61	3.82	22.08	8.82
20 II:FYM	49.52	9.4	24.56	10.53
20 II:CF+FYM	44.35	11.97	22.8	10.98

Table 4.4. Productivity ($\text{g. m}^{-2} \text{ day}^{-1}$) of aboveground and belowground parts of rice in different months, during the growing season of the crop on 6-yr. old and 20-yr. old jhum fallow during first year and second year of cropping.

TREATMENT PLOTS	ABOVEGROUND				BELOWGROUND			
	June	July	August	September	June	July	August	September
6 I:C	0.36	2.9	7.6	18.5	0.11	0.58	1.6	1.03
6 II:C	0.35	2.58	5.76	15.2	0.13	0.5	1.5	1.13
6 II:T	0.33	2.26	5.36	12.6	0.11	0.55	1.4	1.0
6 II:CF	0.4	3.4	8.86	26.53	0.13	1.13	1.76	1.36
6 II:FYM	0.38	3.85	6.8	24.33	0.12	1.2	1.46	1.3
6 II:CF+FYM	0.4	2.86	8.36	24.9	0.13	0.63	2.2	1.3
20 I:C	0.43	2.93	9.26	31.53	0.16	0.66	2.2	1.9
20 II:C	0.36	2.83	7.23	27.16	0.13	0.73	1.73	1.03
20 II:T	0.4	1.7	9.43	18.83	0.18	0.3	2.3	1.66
20 II:CF	0.93	2.3	10.2	27.5	0.18	0.46	2.55	1.6
20 II:FYM	0.7	1.6	10.6	25.63	0.18	0.13	2.59	1.53
20 II:CF+FYM	0.93	4.23	9.33	24.7	0.21	0.7	2.18	1.16

Table 4.5. Productivity of above and belowground parts of weeds (g. m⁻² day⁻¹) in different months during growing season of the crop 6-yr. old and 20-yr. old jhum fallows during first year and second year of cropping.

TREATMENT PLOTS	ABOVEGROUND			BELOWGROUND				
	June	July	August	September	June	July	August	September
6 I:C	0.43	0.79	1.36	0.66	0.15	0.25	0.1	0.43
6 II:C	0.26	0.83	1.83	0.46	0.11	0.26	0.16	0.13
6 II:T	0.25	0.31	1.76	0.13	0.16	0.03	0.33	0.16
6 II:CF	0.26	0.8	1.43	0.4	0.2	0.16	0.1	0.23
6 II:FYM	0.53	0.26	2.0	0.23	0.26	0.03	0.26	0.26
6 II:CF+FYM	0.53	0.46	1.76	0.2	0.23	0.13	0.33	0.00
20 I:C	0.53	0.36	0.66	0.3	0.21	0.08	0.03	0.03
20 II:C	0.45	0.68	3.26	0.43	0.16	0.2	0.53	0.06
20 II:T	0.2	0.26	3.06	0.43	0.11	0.05	0.53	-0.1
20 II:CF	0.43	0.83	2.73	-0.33	0.18	0.28	0.26	0.03
20 II:FYM	0.61	0.51	3.23	-0.03	0.25	0.08	0.46	-0.06
20 II:CF+FYM	0.65	0.61	3.16	-0.06	0.26	0.16	0.33	0.23

Table 4.6. Productivity (g. m⁻² day⁻¹) of rice, weeds and rice plus weeds during the study period on 6-yr. old and 20-yr. old jhum fallows during first year and second year of cropping.

TREATMENT PLOTS	RICE		Total	WEEDS		Total	RICE AND WEEDS	
	Above- ground	Below- ground		Above- ground	Below- ground		Total	WEEDS
6 I:C	6.09	0.84	6.93	0.8	0.23	1.03	7.97	
6 II:C	5.97	0.81	5.78	0.85	0.175	1.02	7.81	
6 II:T	5.14	0.76	5.9	0.61	0.175	0.78	6.7	
6 II:CF	9.7	1.1	10.8	0.72	0.175	0.89	11.7	
6 II:FYM	8.84	1.02	9.86	0.75	0.2	0.95	10.83	
6 II:CF+FYM	9.13	1.06	10.19	0.74	0.175	0.91	11.11	
20 I:C	11.04	1.23	12.27	0.46	0.09	0.55	12.8	
20 II:C	7.56	0.9	8.46	1.2	0.24	1.44	11.92	
20 II:T	7.37	0.82	8.19	0.99	0.15	1.14	9.54	
20 II:CF	10.25	1.2	11.45	0.91	0.19	0.10	12.55	
20 II:FYM	9.65	1.1	10.75	1.08	0.18	1.26	12.02	
20 II:CF+FYM	9.8	1.06	10.86	1.09	0.25	1.34	12.2	

Fig. 4.1 Standing biomass (g. m^{-2}) in different months during the crop growing season on 6-year old jhum fallow in the first year and second year of cropping. M, J, J, A and S stand for May, June, July, Agusut and September respectively.

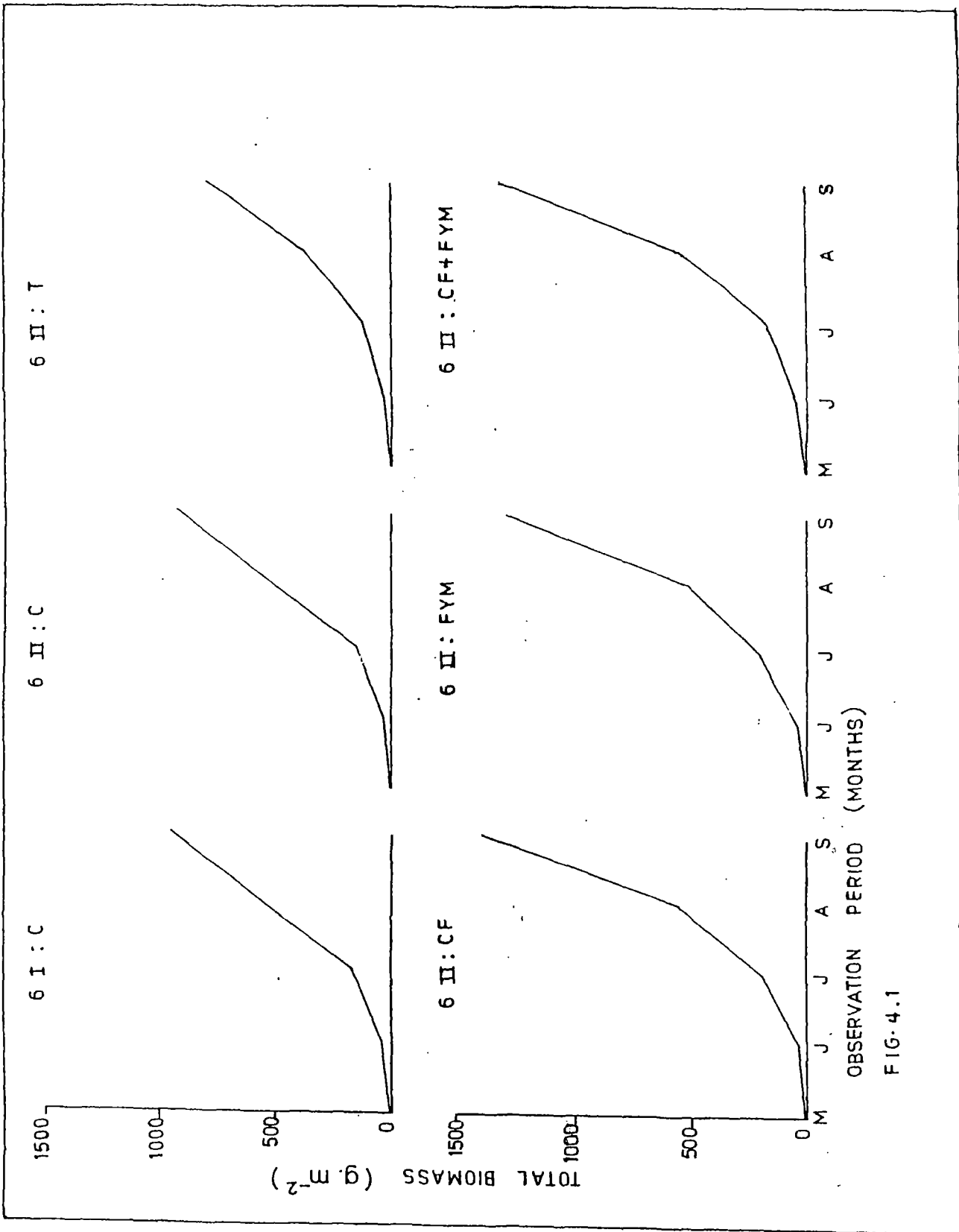


FIG. 4.1

Fig. 4.2 Standing total biomass (g. m^{-2}) in different months during the growing season of the crop on 20-year old jhum fallow in the first year and second year of cropping. M, J, J, A and S stand for May, June, July, August and September respectively.

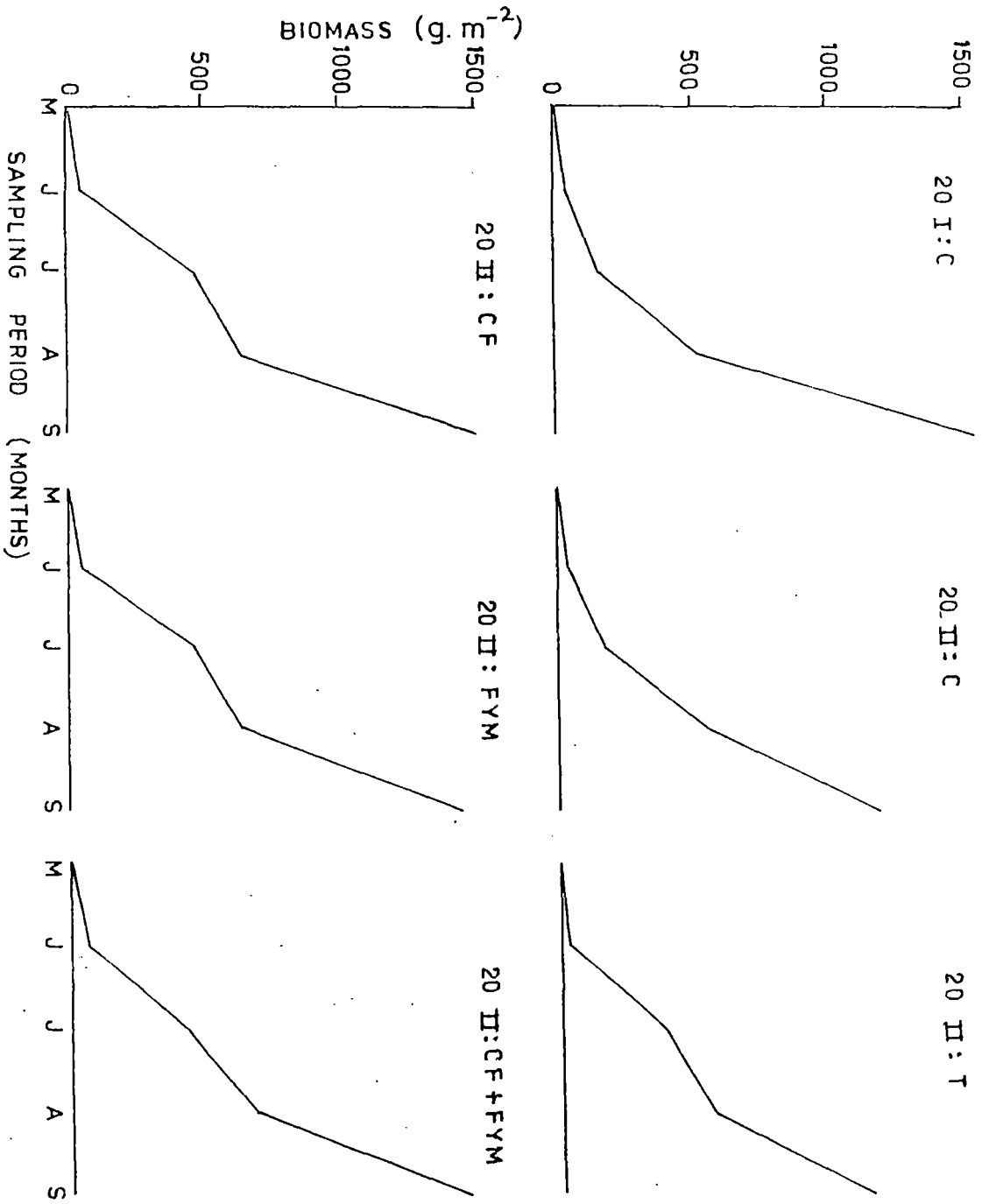


FIG. 4.2

Fig. 4.3 Standing biomass (g. m^{-2}) of rice (—) and weeds (o----o) in different months during the growing season of the crop on 6-year old jhum fallow in the first year and second year of cropping. M, J, J, A and S are observation period as May, June, July, August and September. The difference in the scales used for the crop and weed biomass may be noted.

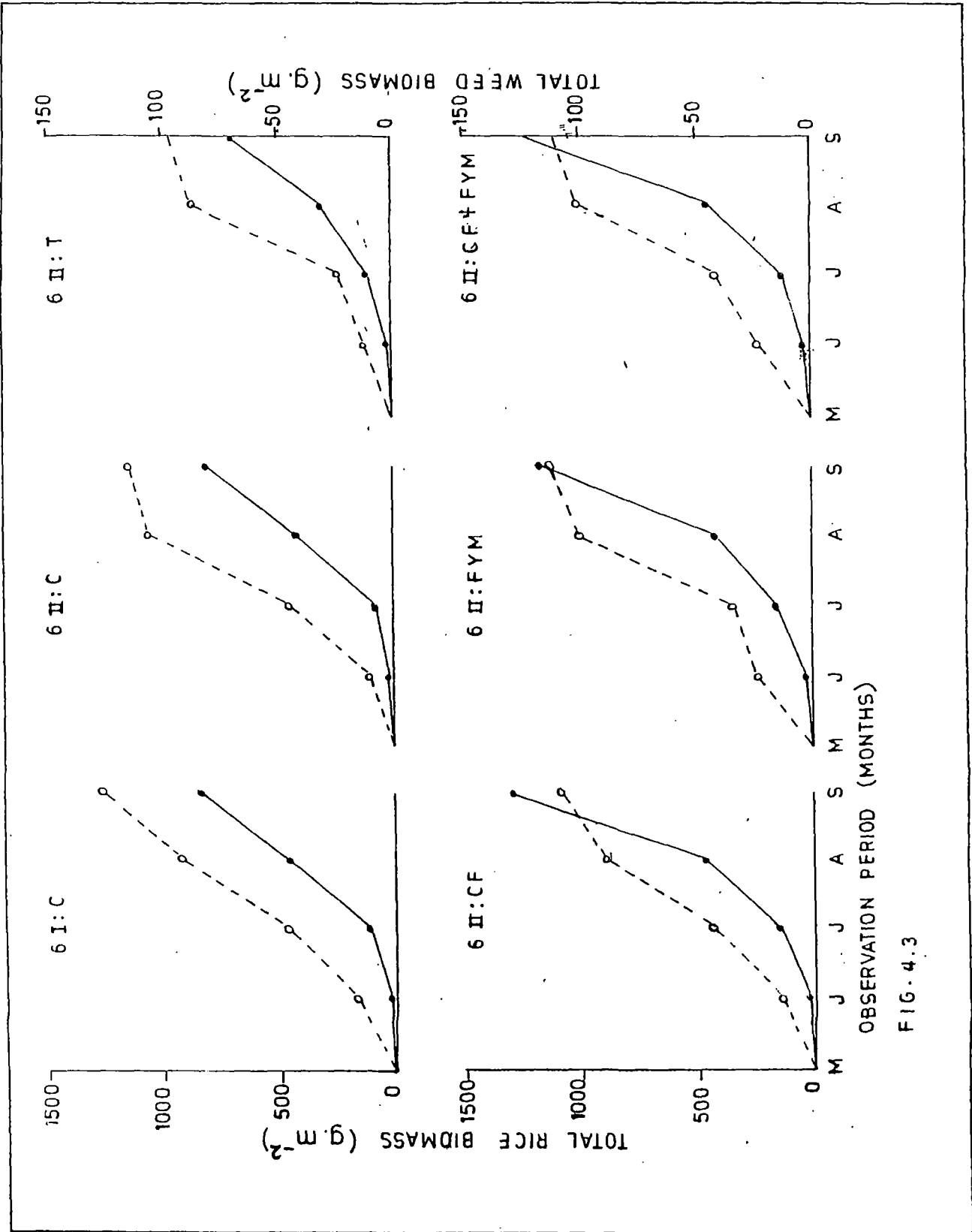
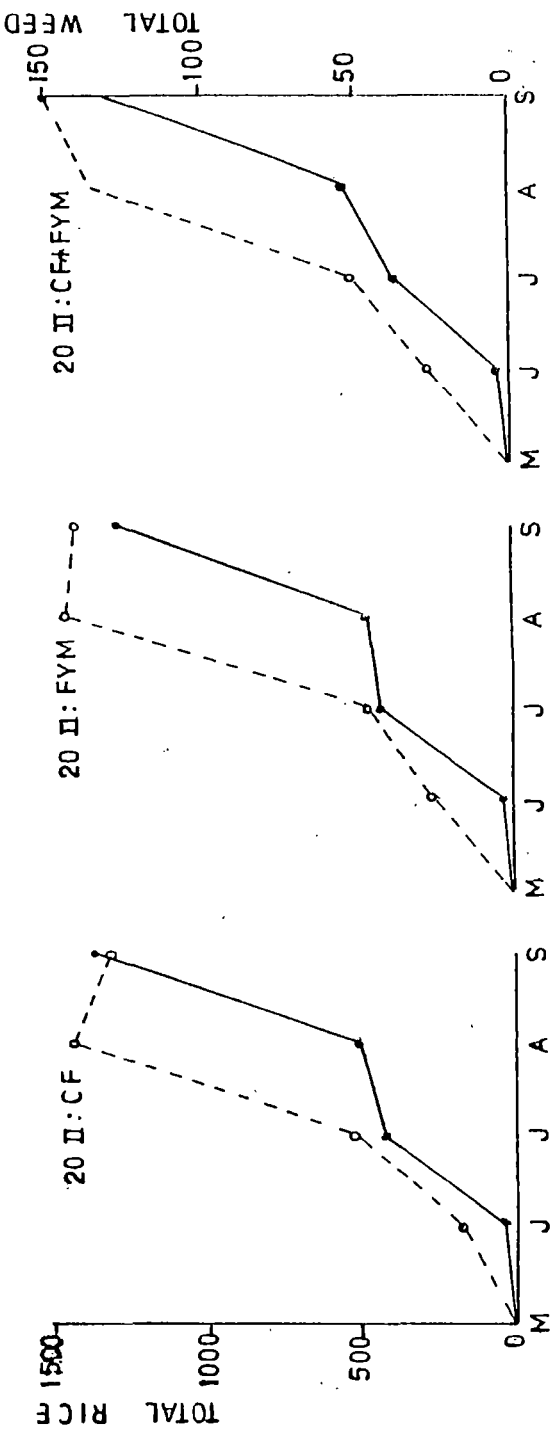
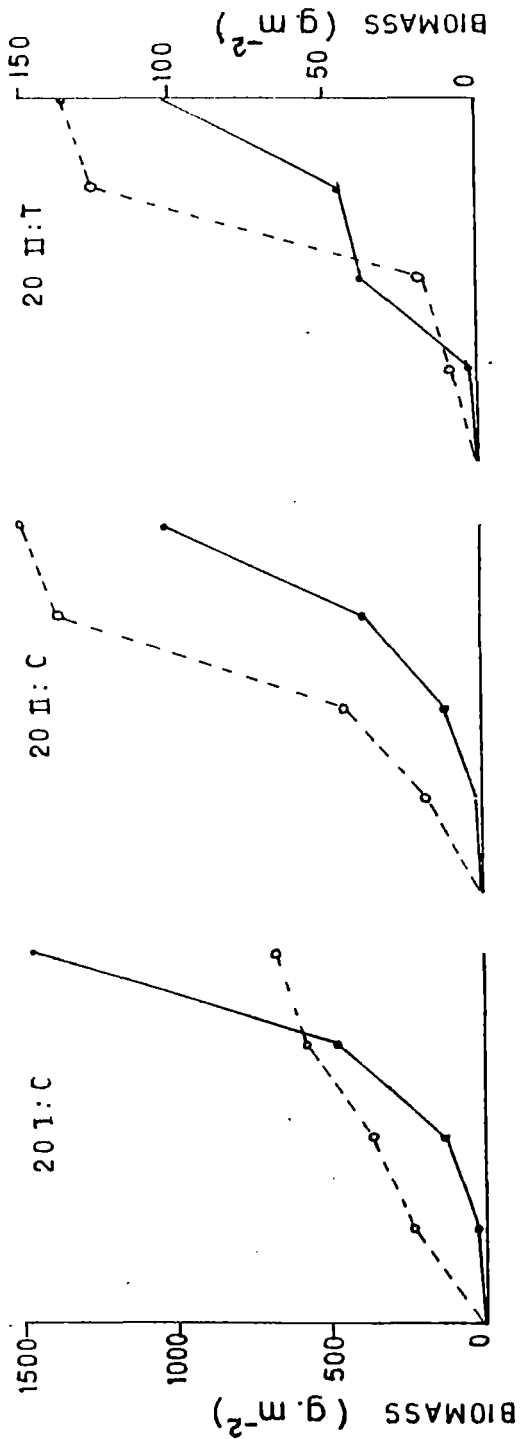


FIG. 4.3

Fig. 4.4 Standing total biomass (g. m^{-2}) of rice (—) and weed (o----o) in different months of the crop growing season on 20-year old jhum fallow during first year and second year of cropping. M, J, J, A and S are observation period as May, June, July, August and September respectively. The difference in the scales used for crop and weed biomass may be noted.



OBSERVATION PERIOD (MONTHS)

FIG-4.4

Fig. 4.5 Total aboveground (□) and belowground production (▨) of rice plus weeds during the crop growing season on 6-year and 20-year old jhum fallows during first year and second year of cropping.

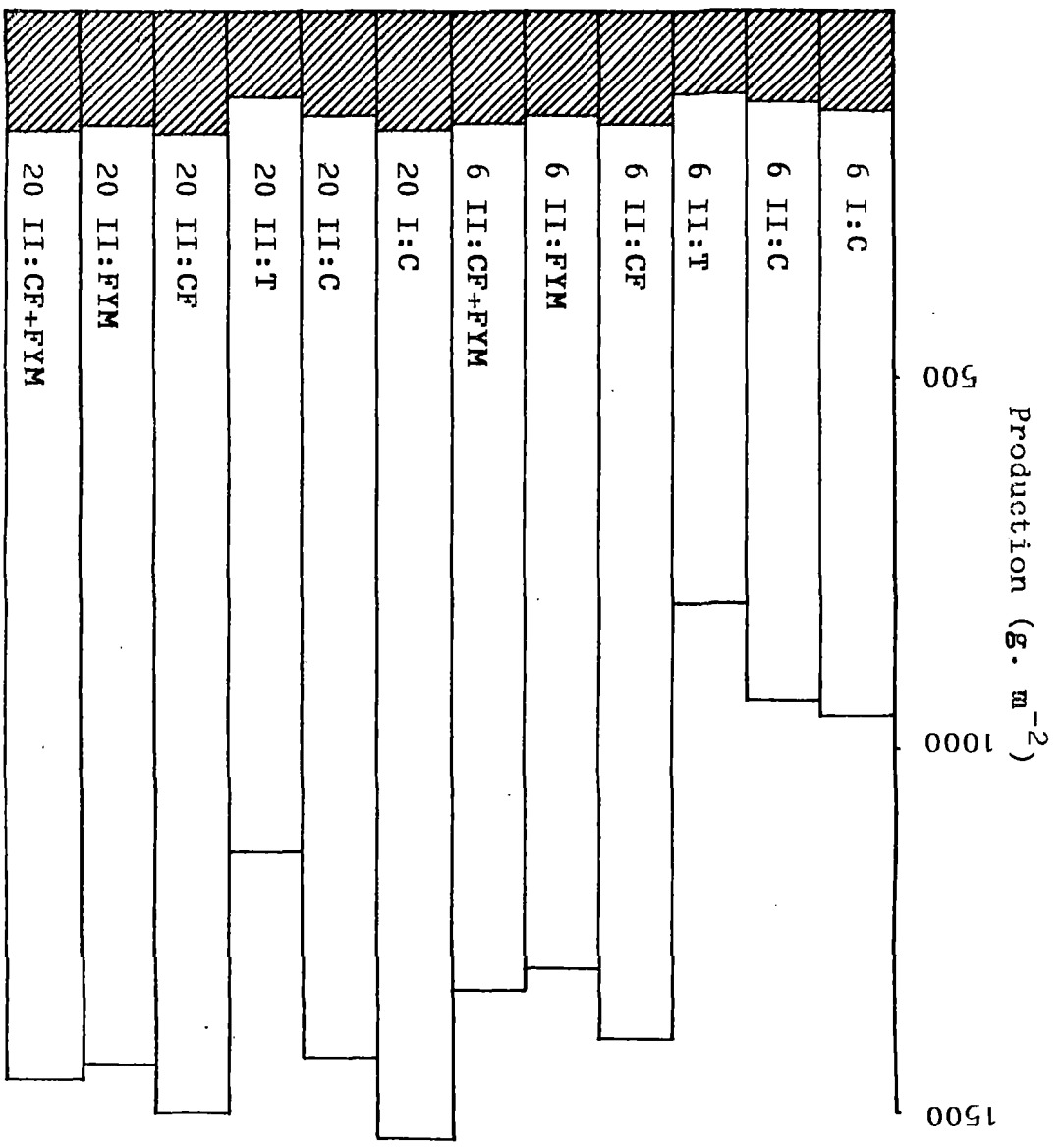


FIG. 4:5

Fig. 4.6 Aboveground (□) and belowground (▨) production of rice during the crop growing season in 6-year old and 20-year old jhum fallows in the first year and second year of cropping.

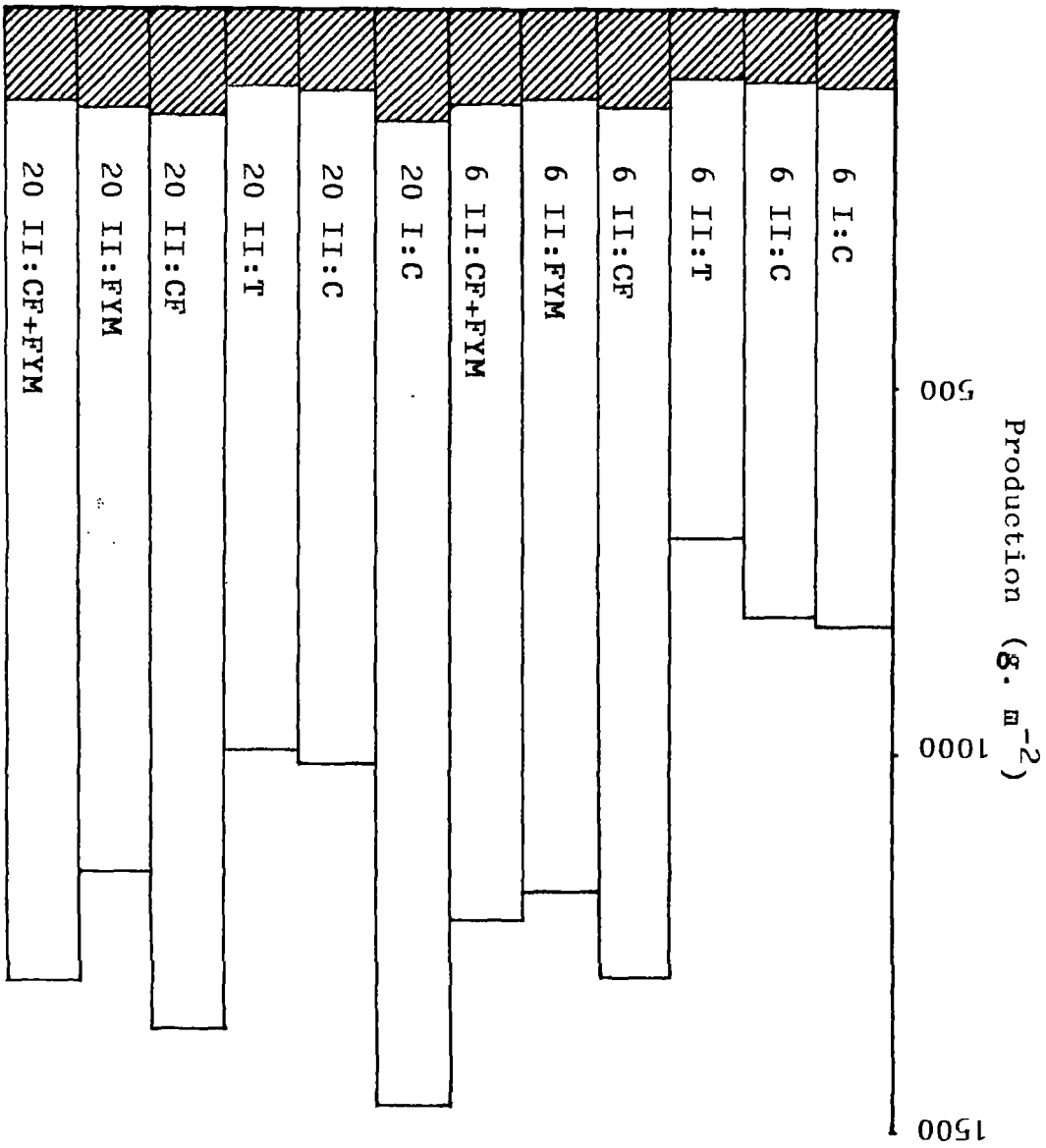


FIG. 4.6

Fig. 4.7 Aboveground (□) and belowground (▨) production of weeds during the crop growing season in 6-year old and 20-year old jhum fallows during first year and second year of cropping.

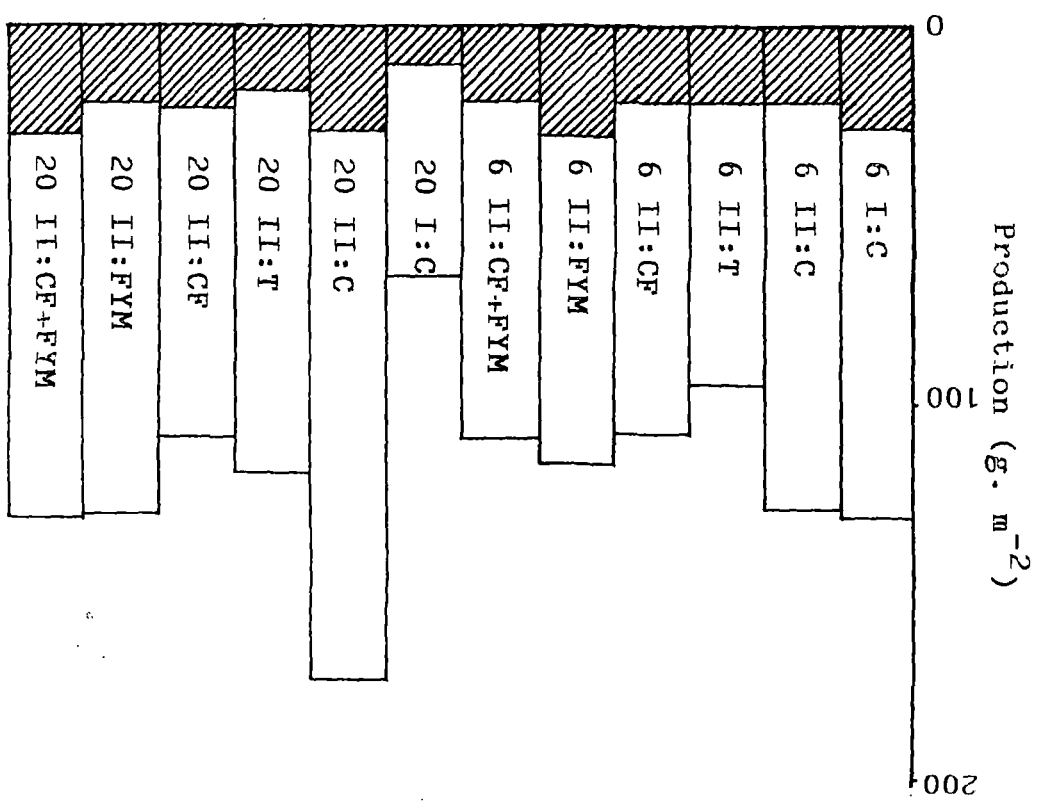


FIG. 4.7

Fig. 4.8 Productivity of rice (—) and weeds (o----o) in different months on 6-year old jhum fallows during first year and second year of cropping. M, J, J, A and S stand for May, June, July, August and September respectively.

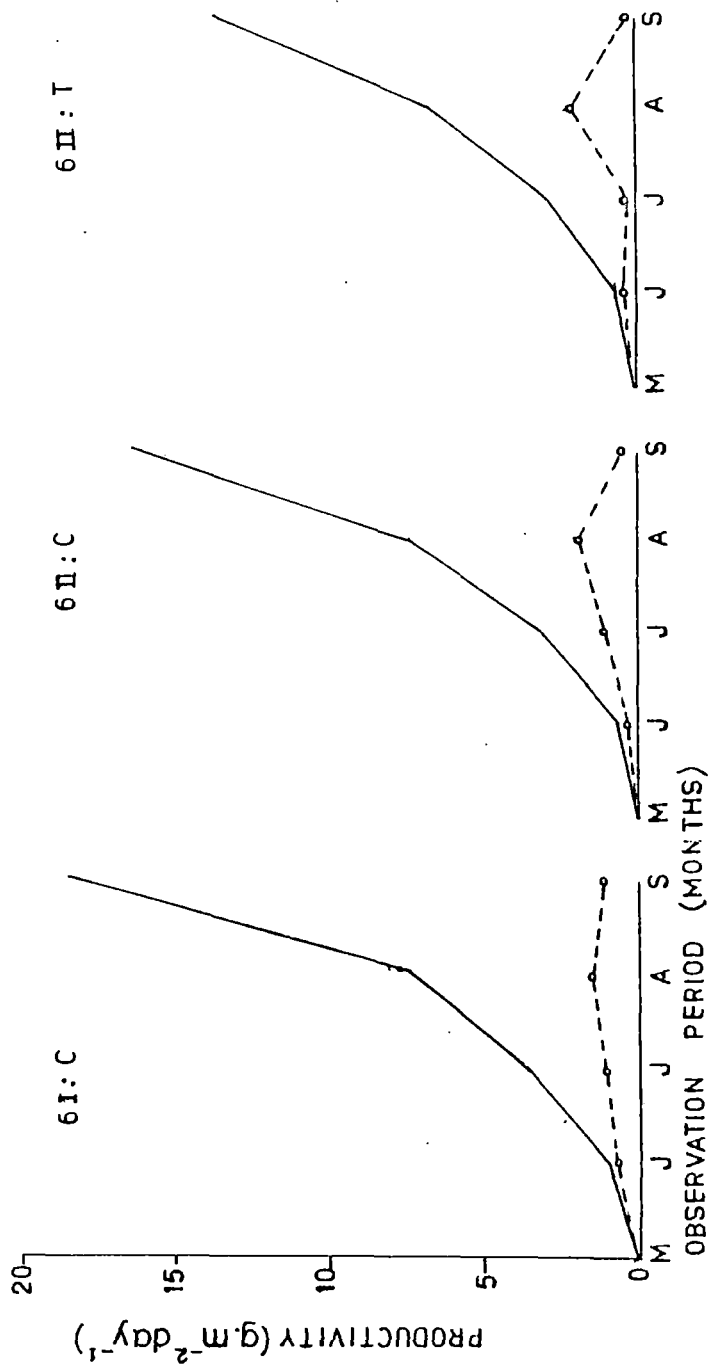


FIG. 4.8

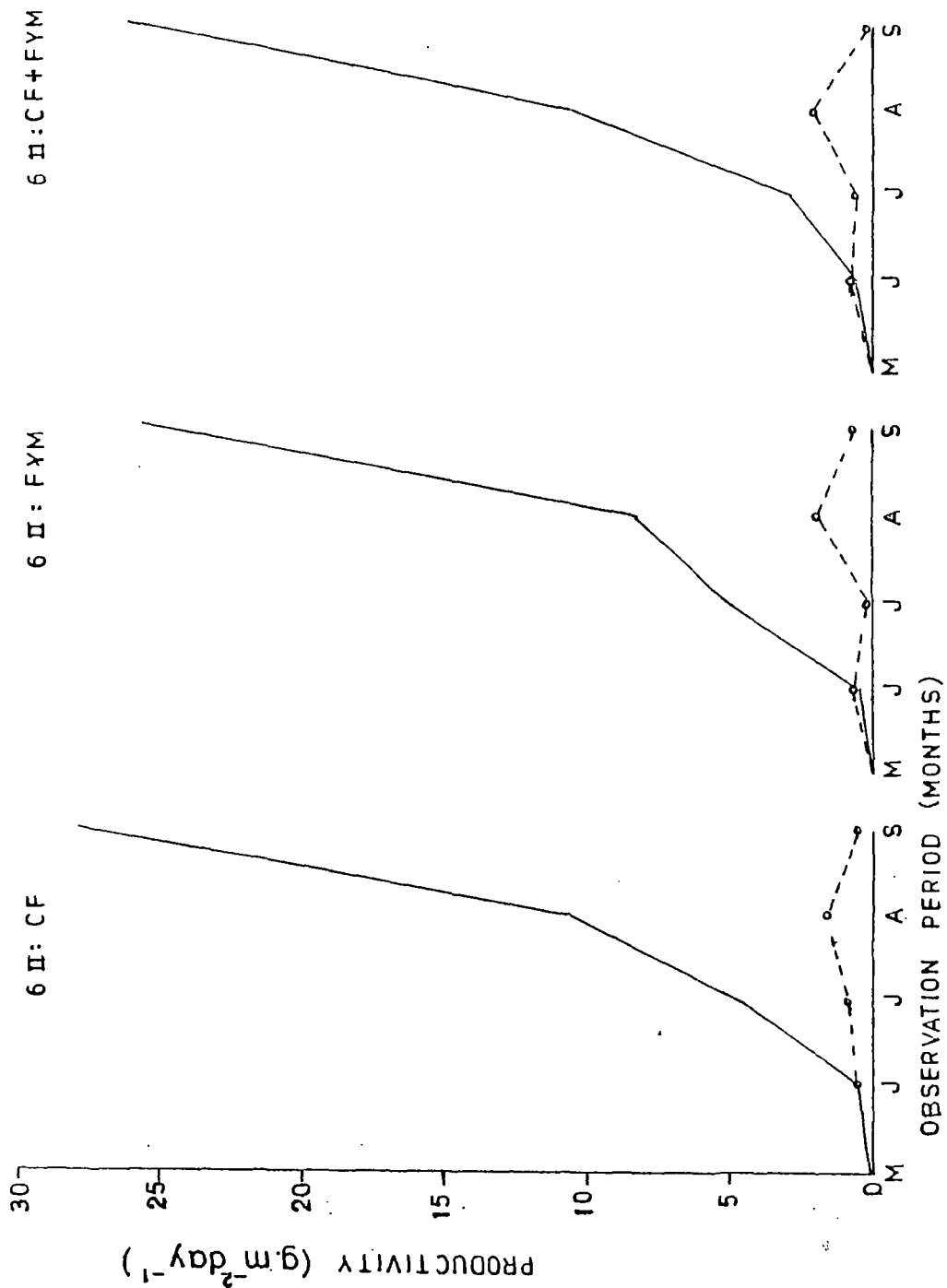


FIG. 4.8

Fig. 4.9 Rate of productivity of rice (—) and weeds (o----o) in different months on 20-year old jhum fallow during the first year and second year of cropping. M, J, J, A and S stand for May, June, July, August and September respectively.

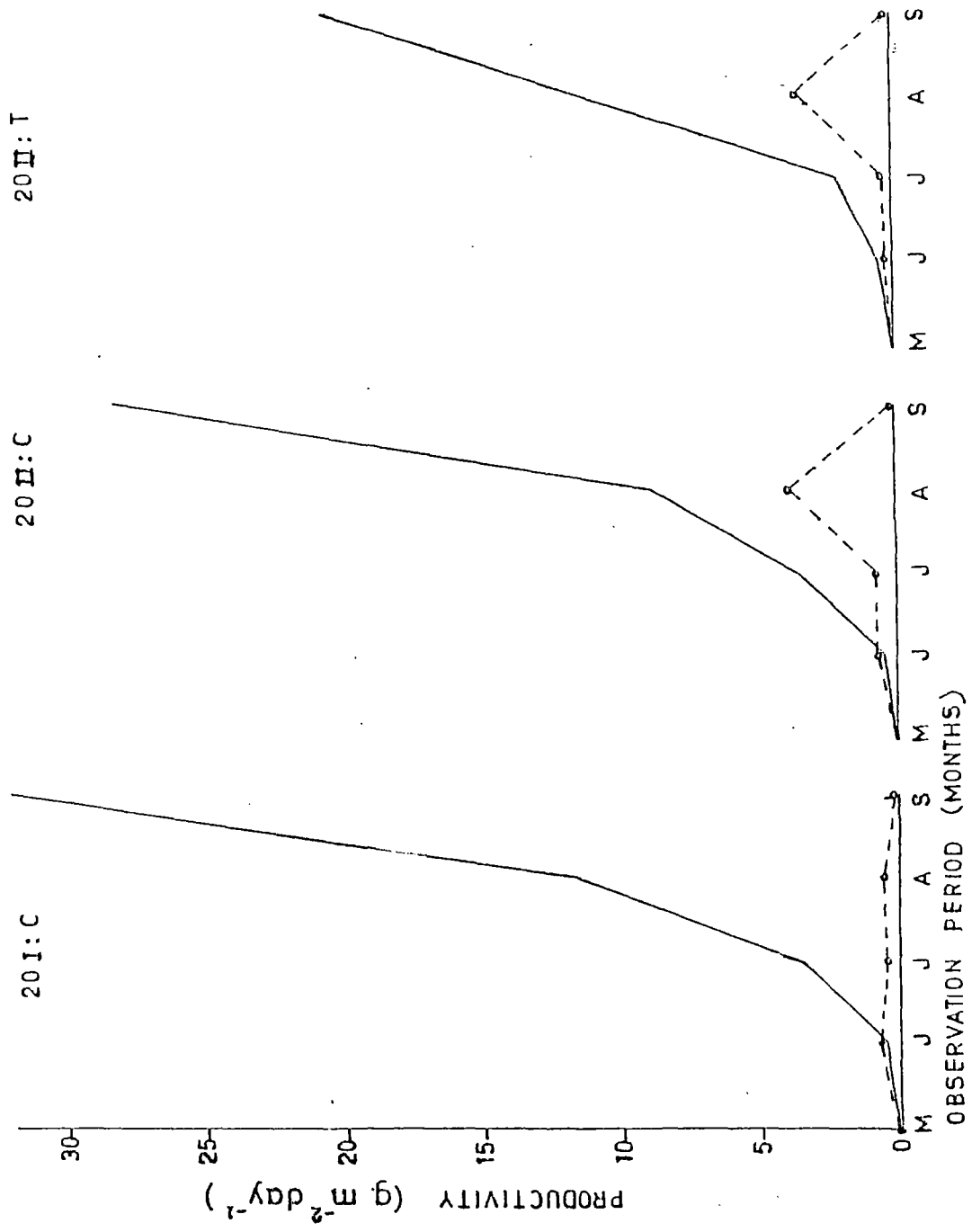


FIG. 4.9

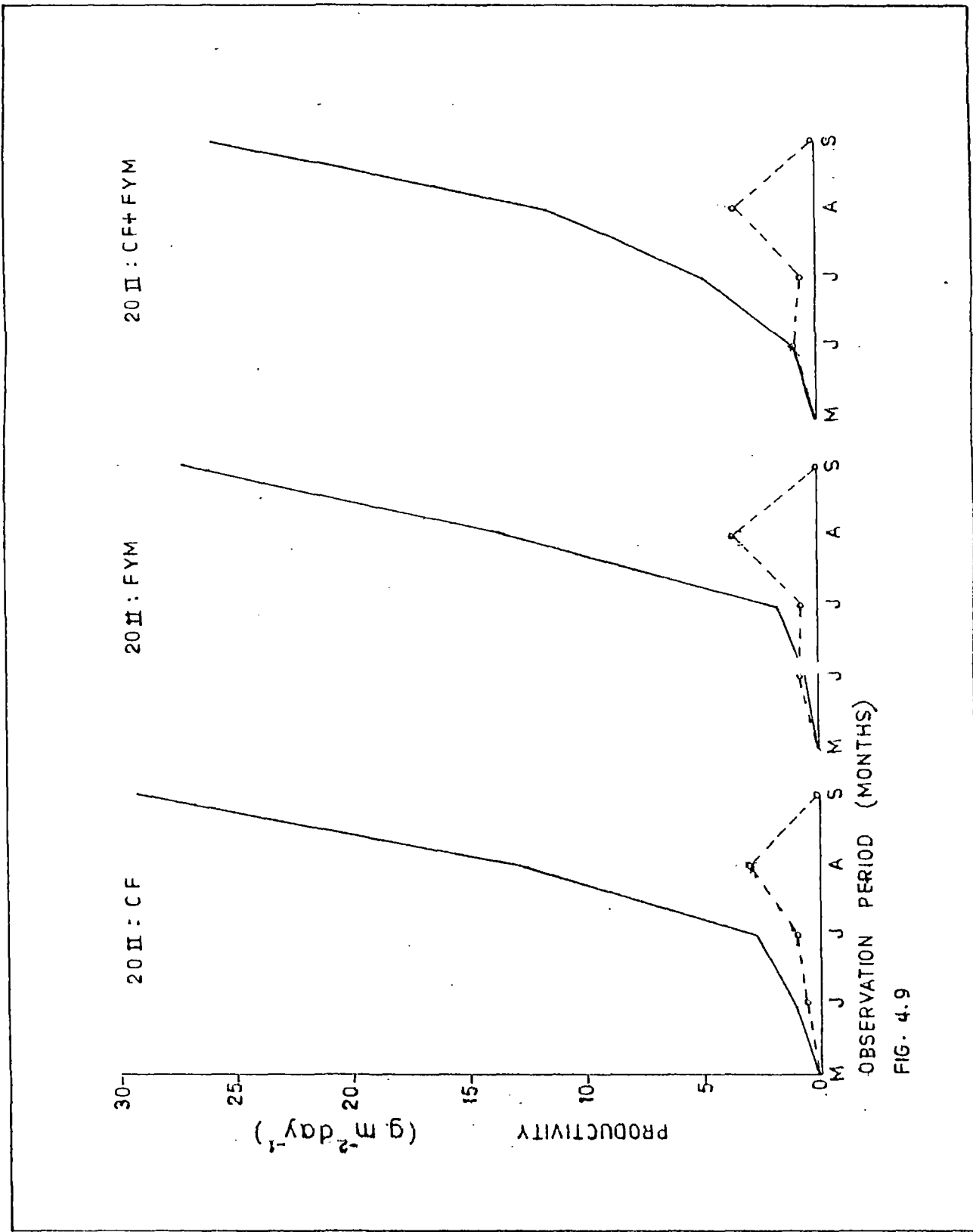


FIG. 4.9

first year than during second year of cropping. The rate of productivity was maximum in the chemical fertilizer treated sub-plots and lowest in the tilled sub-plots during second year of cropping.

In 20-yr. old jhum fallow the control plot in the first year of cropping showed the highest rate of productivity (calculated on the basis of whole growing season) while in case of 6-yr old fallow the rate of productivity in the control sub-plot was lower than in the treated sub-plots.

Discussion

The standing total biomass (rice plus weed biomass) increased with time, the highest value being recorded at the final harvest in all plots. The bulk of the total standing biomass was contributed by the crop plants as jhum fields provided the conditions for more vigorous growth of the crop plants compared to the weeds. Therefore, an increase in standing biomass of the crop, more or less determined the total biomass of the crop plus weeds. A similar trend has also been reported for maize (Williams et al., 1965; Khokhar, 1985), wheat (Singh, 1971) and paddy (Nayar, 1972; Khokhar, 1974; Khokhar & Pandey, 1976) fields. The storage of dry matter in the crop root increased with age while in the case of weeds there was no appreciable increase in root biomass with age.

The highest productivity of the crop observed in September (Table 4.4) was also reflected in the highest total biomass observed in this month. The percentage contribution of weeds to the total biomass incidentally happened to be the lowest in September (Table 4.3) which indicates that a high rate of productivity of the crop brings about suppression in weed growth. It has been demonstrated that weeds and crops growing together modify or suppress the growth of each other (Bleasdale, 1960; Tripathi, 1967, 1968). The density of crop plants and weeds play a crucial role in the outcome of competition between them (Tripathi, 1977).

In the present study the weeds do not really pose much of a problem by way of competition for available resources on account of frequent weeding operations in the agroecosystems under study. However, as the sampling of plants for biomass determination was done mostly before weeding, the competition between weeds and crop is expected to influence their biomass production to some extent. Competition may be more severe during early part of the cropping season (i.e. June) when rice plants are small. During this period the percentage contribution of biomass by weeds is also relatively high (34 - 60%). The low crop biomass observed in the plots where the contribution of weeds to total biomass was more may be attributed to the competitive suppression caused by

weeds. However, as mentioned earlier, in September when the crop biomass was highest, the contribution of weeds to total biomass decreased tremendously which shows a strong smothering effect of vigorously growing crop plants on weeds. Smothering effect of dense crop on weeds has also been reported by other workers (e.g. Donald, 1958, 1963).

In the present study, a steady increase in weed biomass observed on 6 I:C plot may be attributed to high infestation of weedy species before jhuming (Table 2.2 and 2.3) which might have contributed to an increase in weed seed population in soil. Comparatively greater biomass of weeds produced during second year of cropping than in the first year on 20-yr. old jhum fallow, may be attributed to the larger size of weed seed bank that contributed to greater weed infestation during second year of cropping in comparison to the first year of cropping. It may be mentioned that the weed community declines as the shrubs and trees develop on the abandoned fallows (Kushwaha et al., 1981, Yadav & Tripathi, 1981). In 20-yr. old fallow the population of different weeds which are generally present in the agro-ecosystems were really very small and so, when such a fallow is once again brought under cultivation, the weed community development is bound to be poor.

The soil fertility is one of the most important factors

determining plant productivity. The biomass and productivity of the crop showed positive correlation with the soil nutrient status in the present study. Relatively lower crop biomass on younger (6-yr. old) jhum fallow during first year of cropping compared to that on 20-yr. old fallow where the input of ash (nutrients) was more, also depicts the dependence of biomass on soil nutrient status.

CHAPTER V

Edaphic changes during shifting cultivation

Introduction

The physico-chemical characteristics of the soil varies in time and space. Some of the important factors which determine the soil characters are the parent rock, climate, biotic influences, land use, vegetation type and topography. Dynamic equilibrium of nutrients in the soil is maintained by the phenomenon of nutrient uptake, return of nutrients and retention of nutrients within the bodies of plants, soil, animals and microorganisms.

Under shifting cultivation, soil is used for food production and then the land is fallowed for fertility restoration. This system has a built-in mechanism to restore the physical, nutritional and biological properties of soil. The use of land for seasonal crop production by shifting cultivation causes decline in soil quality. The rate of decline, however is low if the duration of cultivation is short. The rate of decline is also less with manual than mechanized farming methods and differs widely among soil and crop management practices, cropping systems and the land-use.

Lal (1987) reported that there are contradictory reports about the effect of shifting cultivation on soil properties and land degradation. Some reports indicate that shifting

cultivators are destroying the forest resources and have accelerated soil erosion hazard. Others believe that shifting cultivators maintain ecological stability which is the only solution to the problem of rapid soil degradation. The controversy obviously exists because of the lack of quantitative data describing the effects of shifting cultivation on soils and environments. The effects vary widely among soils, rainfall, vegetation, duration of cultivation and fallow period etc. The duration of cultivation is usually longer for soils of high inherent fertility. As the productivity decline to below the sustenance level occurs slowly in such soils, farmers can cultivate the same land for a number of years before abandoning it as fallow.

In Mizoram, for the purpose of jhuming, an average of 6-year old forested jhum fallows are cleared, burned and cultivated for only one year. Present chapter deals with the changes in soil fertility and other characters at two soil depths (0 - 10 cm and 10 - 20 cm) during jhum cultivation on a 6-yr. old and a 20-yr. old jhum fallow during first year of cropping. The soil nutrient levels at the two soil depths were also determined in the treatment plots supplied with fertilizers and/or farm-yard manure during second year cropping.

As stated in chapter II, jhum fields cultivated during 1988 were again cultivated during 1989 by introducing various innovative approaches such as, tilling of land, application of chemical fertilizer, application of farm-yard manure and application of a combination of chemical fertilizer and farm-yard manure.

Several soil characters were determined to monitor the effect of jhum cultivation on the dynamics of soil nutrient status.

Materials and Methods

Soil analysis were carried out during 1988 and 1989 and the mean values for different parameters were calculated from the data collected during the two years of cropping. Soil sampling was done three times in a year i.e., before slashing (January), after burning (May), and after harvesting (October) in both young and old jhum fallows during first year and second year of cropping. Soil samples from each study site were collected from 0 - 10 cm and 10 - 20 cm soil depths separately and various soil characters as mentioned below were determined.

Determination of pH: The pH of 1:2.5 soil-water suspension was read in an electric pH meter.

Determination of organic carbon: Walkley and Black's

(1934) rapid titration method was followed for the determination of organic carbon.

Determination of total nitrogen: Kjeldahl's method as given in Jackson (1973) was followed for the determination of nitrogen.

Determination of available phosphorus: Molybdenum blue method described by Allen (1974) was followed for the determination of available phosphorus.

Determination of exchangeable potassium, calcium and magnesium: These elements were extracted with ammonium acetate solution having pH 7 (Allen, 1974) and their concentrations were determined by atomic absorption spectrophotometry.

Determination of cation exchange capacity (CEC): The cation exchange capacity of the soil sample was determined by leaching it with ammonium acetate solution (pH 7) as described by Jackson (1973).

Results

pH

In general there was not much variation in pH among the plots (Table 5.1). pH was always a little higher at 0-10 cm than at 10-20 cm soil depth. Peak value was observed in the samples collected after burning. pH value was slightly

higher in 20-yr. old jhum fallow during first year cropping than in 6-yr. old fallow. Similar trend was observed during second year of cropping. pH at the two soil depths in both jhum fallows was slightly higher during the first year than during the second year of cropping.

pH was same in all the treated sub-plots during second year of cropping.

The soils collected after the crop harvest showed slight decrease in pH in the tilled sub-plot of both fallows and in the sub-plot treated with a combination of fertilizer and farm-yard manure in 20-yr. old fallow.

Organic Carbon

The organic carbon content of the soil at 0-10 cm and 10 - 20 cm depths in 6-yr. old and 20-yr. old jhum fallows is shown in Fig. 5.1.

In general, organic carbon content was higher in 20-yr. old than in 6-yr. old jhum fallow during both first and second year of cropping. It showed higher concentration in the surface soil in both the fields. There was a gradual decrease in organic carbon content of the soil with sampling time in both young and old jhum fallows during the first and second year of cropping. There was also a decrease in soil organic carbon from first year to second year of cropping.

The organic carbon was less in the tilled sub-plot compared to the other sub-plots particularly on 20-yr. old jhum fallow. The sub-plots treated with chemical fertilizer and with a combination of chemical fertilizer and farm-yard manure showed significant increase in organic carbon concentration.

Nitrogen

Concentration of nitrogen at 0-10 cm and 10-20 cm soil depths in different plots and sub-plots in the two jhum fallows is shown in Fig. 5.2.

In general, soil nitrogen content was significantly higher during first year of cropping compared to second year cropping in the jhum fields of both ages. However, no marked difference in nitrogen concentration was observed between 6-yr. old and 20-yr. old jhum fallows during second year of cropping. The surface soil always showed higher nitrogen concentration than the soil of 10-20 cm depth. The soil nitrogen content decreased gradually with sampling time in both the fields during first year of cropping. Decrease in soil nitrogen concentration from first year cropping to second year cropping was evident in both the jhum fields. This decrease was more pronounced in 20-yr. old jhum fallow.

It is to be noted that during second year of cropping all the sub-plots in both jhum fields had the same concentration of nitrogen as their corresponding control sub-plots.

Tilled sub-plots showed marked decrease in soil nitrogen, particularly on 20-yr. old jhum fallow. All the fertilizer treated sub-plots as expected showed marked increase in soil nitrogen concentration.

Phosphorus

Concentration of available phosphorus at 0-10 cm and 10-20 cm soil depths in 6-yr. old and 20-yr. old jhum fallows is given in Fig. 5.3.

In general, higher concentration was observed in the upper layer (0-10 cm) of soil compared to 10-20 cm layer. The soil phosphorus was generally higher in 20-yr. old jhum fallow than in 6-yr. old fallow during both first and second year of cropping.

In both jhum fallows, the phosphorus content of soil was significantly greater during first year than second year of cropping. Significant increase in soil phosphorus from the first sampling (before slashing) to the second sampling (after burning) was observed during both years of cropping, irrespective of the age of the fallow, whereas it declined after the crop harvest. This trend was also evident in the tilled sub-plots on both fallows.

As expected during second year cropping the soil phosphorus content was higher in the sub-plots treated with chemical fertilizer or farm-yard manure.

Generally, the phosphorus content showed gradual increase with sampling date. The phosphorus content in chemical fertilizer treated and farm-yard manure treated sub-plots increased with sampling time, while in the non-fertilized sub-plots the increase in phosphorus content observed after burning showed a decrease at the third sampling date, i.e. after the crop harvest. The sub-plots treated with chemical fertilizer plus farm-yard manure showed greater increase in soil phosphorus in 0-10 cm soil layer compared to the other treatments.

Burning seems to have caused significant increase in soil phosphorus content which dropped markedly after the crop harvest in all the treated sub-plots during second year of cropping. The same trend was also observed in the lower layer of soil except in the farm-yard manure treated sub-plot in which a gradual increase was observed. No marked changes from second sampling (after burning) to last sampling (after harvest) was observed in the surface soil of the sub-plot treated with chemical fertilizer plus farm-yard manure, whereas the lower layer of the soil showed significant increase in soil phosphorus from second to third sampling date.

Potassium

The concentration of potassium at 0-10 cm and 10-20 cm soil depths in 6-yr. old and 20-yr. old jhum fallows is shown in Fig. 5.4.

In general, the concentration of potassium was higher in the surface soil and on 20-yr. old jhum fallow than at 10-20 cm depth and 6-yr. old jhum fallow during both years of cropping. Highly significant increase in potassium concentration was observed in the upper layer of soil after burning. However, its concentration decreased during the period of crop growth as is evident from its lesser concentration after the crop harvest compared to the concentrations in the soil samples collected after slashing and burning. However, lower layer of soil did not show marked changes in potassium concentration with time.

In 6-yr. old jhum fallow, the upper layer of soil showed significant increase in potassium concentration from first year to second year of cropping. The treated sub-plots did not show significant difference in soil potassium concentration from the control sub-plot.

In 20-yr. old jhum fallow, there was no marked difference in potassium concentration between first year and second year of cropping. The potassium concentration in the upper layer of soil in all sub-plots during second year of cropping increased greatly due to burning, although again it dropped down to a level lower than the initial concentration observed before the burning of the slashed vegetation. The lower layer of soil showed the same trend, but increase in soil potassium due to burning was not that significant.

Calcium

Concentration of exchangeable calcium at the two soil depths (0-10 cm and 10-20 cm) in 6-yr. old and 20-yr. old jhum fallows is shown in Fig. 5.5.

In general, the concentration of calcium was higher at 0-10 cm than at 10-20 cm soil depth. Highly significant increase in the upper layer of soil after burning was evident in both the jhum fields during first year and second year of cropping. Similar trend in soil calcium concentration was also observed at 10-20 cm depth in 6-yr. old jhum fallow. Initial concentration of calcium was higher at both soil depths in 20-yr. old jhum fallow during first year and second year of cropping. Gradual increase with time was evident in lower soil layer except in tilled sub-plot of young jhum fallow and first year cropping plot of old field.

In 6-yr. old fallow, the soil calcium content after slashing and after the crop harvest was slightly higher during first year of cropping than during second year of cropping. However, burning of the slash caused significant increase in soil calcium during second year of cropping. Significant decrease in final concentration of calcium in both soil layers was observed in the tilled sub-plot. The chemical fertilizer treated sub-plot showed more or less the same trend, though the decrease was not significant. The soil calcium at both

soil depths was, however, more in the sub-plots treated with farm-yard manure and with chemical fertilizer plus farm-yard manure.

In 20-yr. old fallow, the soil contained more calcium both before and after burning during first year of cropping compared to the second year cropping. But the concentration of calcium after the crop harvest was significantly higher during second year of cropping. This increase was noticed at both soil depths in the case of all sub-plots except the tilled one. The highest increase was observed in the sub-plot treated with farm-yard manure.

Magnesium

In general, magnesium showed higher concentration at 0-10 cm soil depth compared to the lower depth. The soil magnesium content was greater in the older jhum fallow than the younger one (Fig. 5.6). The peak concentration was observed after burning. The increase in soil magnesium after burning was more pronounced in the surface soil as compared to the subsoil. However, there was increase in soil magnesium content with sampling time in the latter.

During second year of cropping, the peak level of magnesium concentration due to burning showed a marked decreasing tendency in all the sub-plots except farm-yard manure



treated sub-plot in 6-yr. old fallow. Compared to the control sub-plot the magnesium content of soil after the crop harvest was higher in the sub-plots treated with chemical fertilizer and farm-yard manure whereas in the tilled sub-plot there was a decrease and in the sub-plot treated with chemical fertilizer plus farm-yard manure, there was no marked difference.

In 20-yr. old jhum fallow no significant changes were observed in magnesium concentration from control to the other sub-plots at 0-10 cm soil depth. However, slight decrease was observed in the tilled sub-plot. At lower soil depth, however, in the sub-plot treated with chemical fertilizer the magnesium content showed an increase and in the farm-yard manure treated sub-plot it showed a decrease over the control sub-plot.

C.E.C.

Cation exchange capacity (CEC) of soil at the two depths in both jhum fallows during first year and second year of cropping is shown in Fig. 5.7.

Generally, CEC was higher in the upper layer of soil than in the lower. It was higher in older jhum field than in 6-yr. old jhum fallow during first year of cropping. But no marked difference was observed between 6-yr. old and 20-

yr. old jhum fallows during second year of cropping. A decrease in CEC after burning operation was observed in both the fields during first year cropping. During second year cropping too, the same trend was observed in 6-yr. old jhum fallow, although in 20-yr. old fallow there was an increase in CEC after burning. A gradual increase in CEC was observed in the tilled sub-plot and sub-plot treated with chemical fertilizer plus farm-yard manure in both fallows during second year cropping. The increase in CEC observed after the burning operation showed a decrease after the crop harvest particularly at lower soil depths in the control, chemical fertilizer treated and farm-yard manure treated sub-plots in both the fallows.

In 6-yr. old jhum fallow, the CEC was higher during first year cropping than second year cropping. A gradual decrease in the CEC of the surface soil was observed with sampling date in all the sub-plots during second year of cropping.

In 20-yr. old jhum fallow, the CEC at 0-10 cm soil depth showed an increase in the tilled sub-plot over the values obtained for the control sub-plot, while in the other sub-plots the CEC showed a decrease.

C:N Ratio

The C:N ratios at the two soil depths in 6-yr. old and 20-yr. old jhum fallows during first year and second year of cropping is given in Table 5.2. After harvest there was increase in C:N ratio in 6-yr. old jhum fallow during first year and second year cropping. A similar trend was observed in 20-yr. old jhum fallow during first year cropping. However, a slight decrease during second year cropping especially at lower layer of soil was clearly evident.

The burning operation caused reduction in C:N ratio during both first year and second year of cropping in 6-yr. old jhum fallow while in 20-yr. old fallow, the reduction caused by burning was evident only during second year of cropping.

The C:N ratio in 6-yr. old jhum fallow was higher in chemical fertilizer treated and chemical fertilizer plus farm-yard manure-treated sub-plots than in the control sub-plot. Similar trend was observed in 20-yr. old jhum fallow. However, the 10-20 cm soil layer in 20-yr. old jhum fallow showed lower C:N ratio than the same layer of soil in 6-yr. old jhum fallow.

Fig. 5.1 Concentration (%) of organic carbon at 0-10 cm (□) and 10-20 cm (▨) layers of soil in 6-year old and 20-year old jhum fallows during first year and second year of cropping. 1, 2 and 3 refer to sampling done before slashing, after burning and after harvesting respectively.

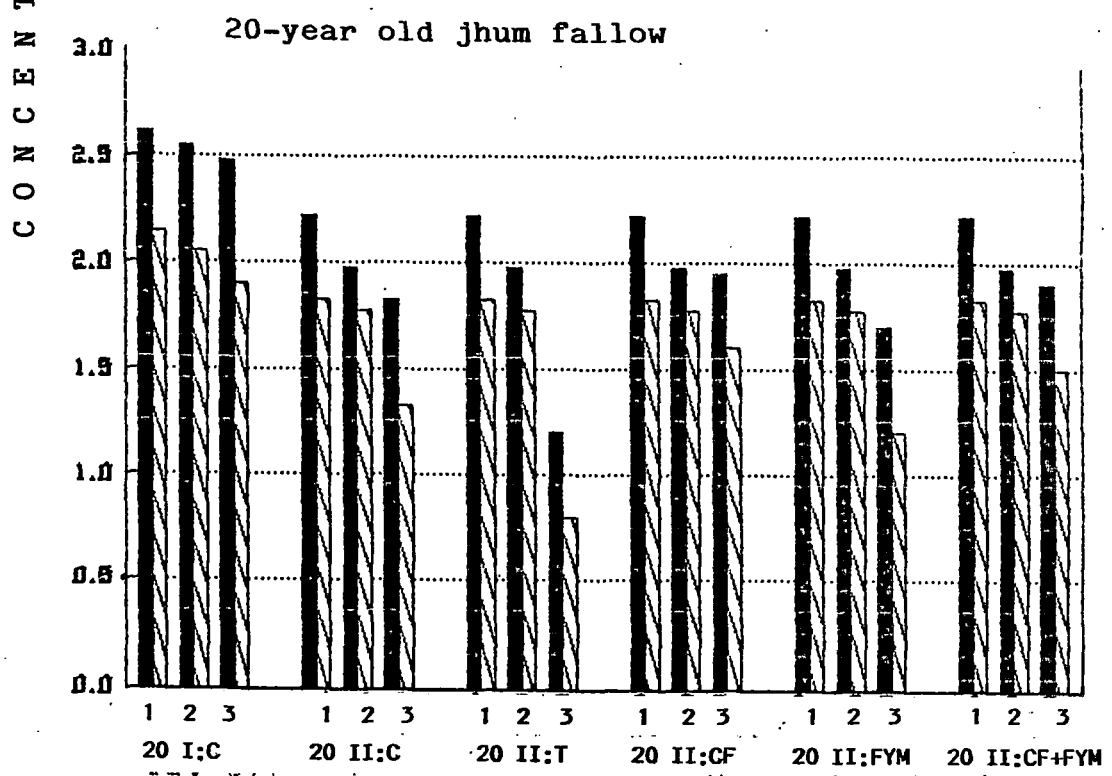
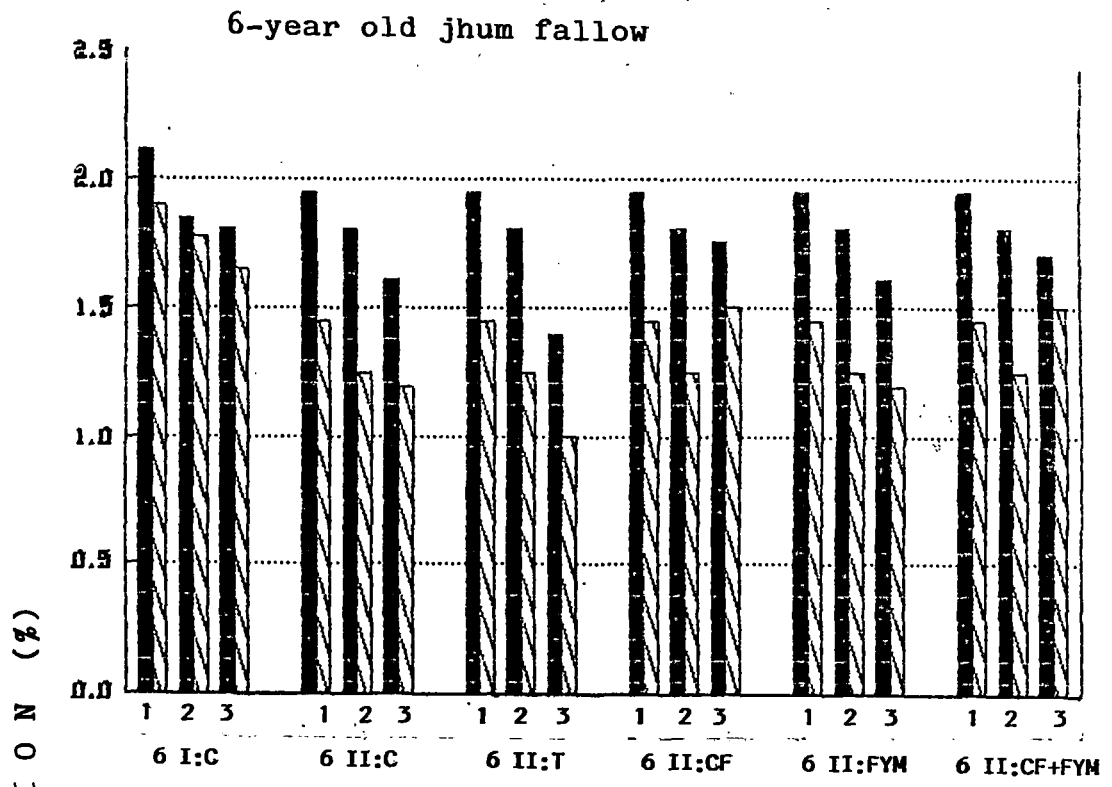


FIG. 5.1

Fig. 5.2 Concentration (%) of total nitrogen at 0-10 cm (□) and 10-20 cm (▨) layers of soil in 6-year old and 20-year old jhum fallows during first year and second year of cropping: 1, 2, and 3 refer to sampling done before slashing, after burning and after harvesting respectively.

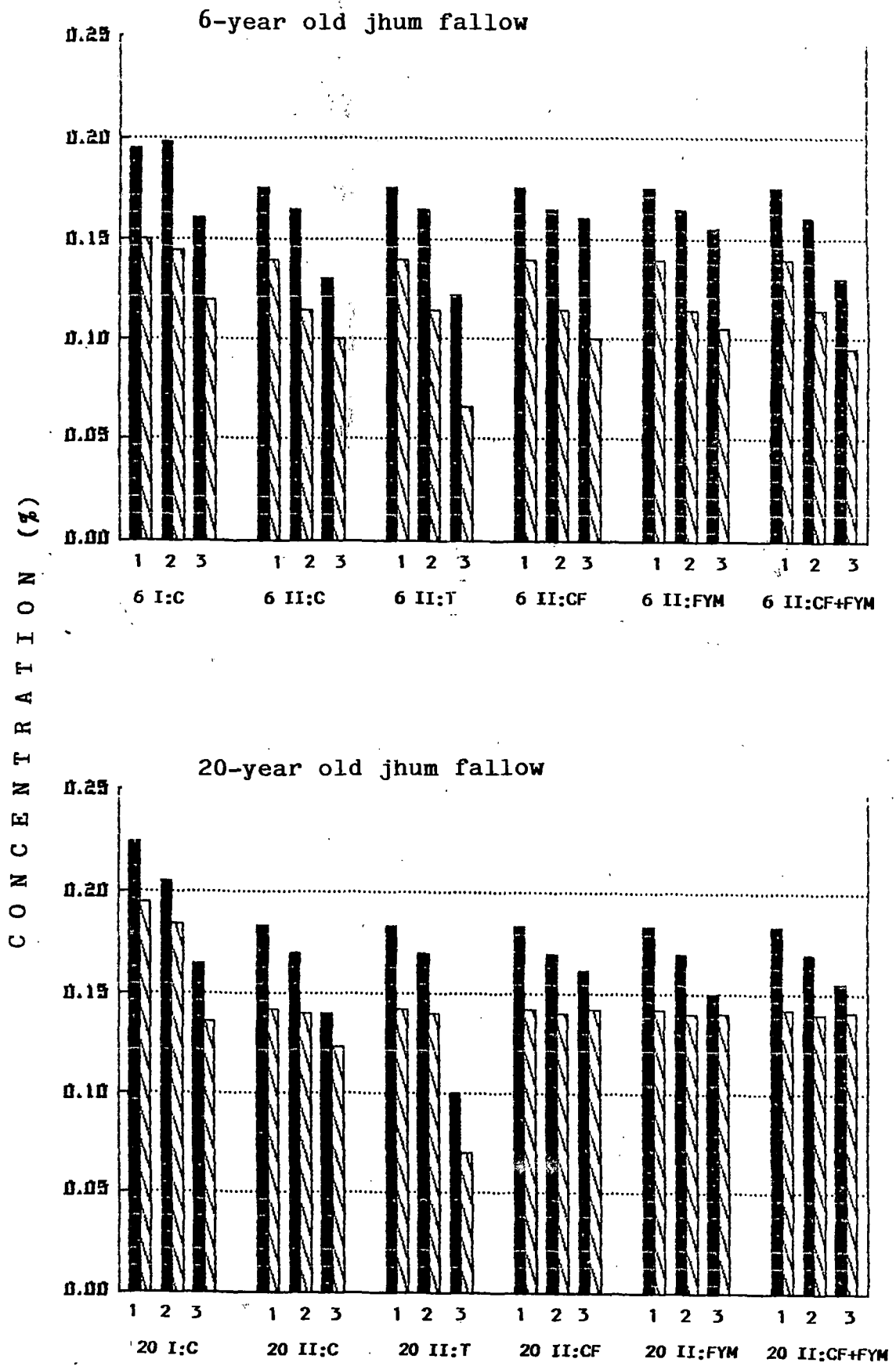


FIG. 5:2

Fig. 5.3 Concentration (%) of available phosphorus at 0-10 cm (□) and 10-20 cm (▨) layers of soil in 6-year old and 20-year old jhum fallows during first year and second year of cropping. 1, 2 and 3 refer to sampling done before slashing, after burning and after harvesting respectively.

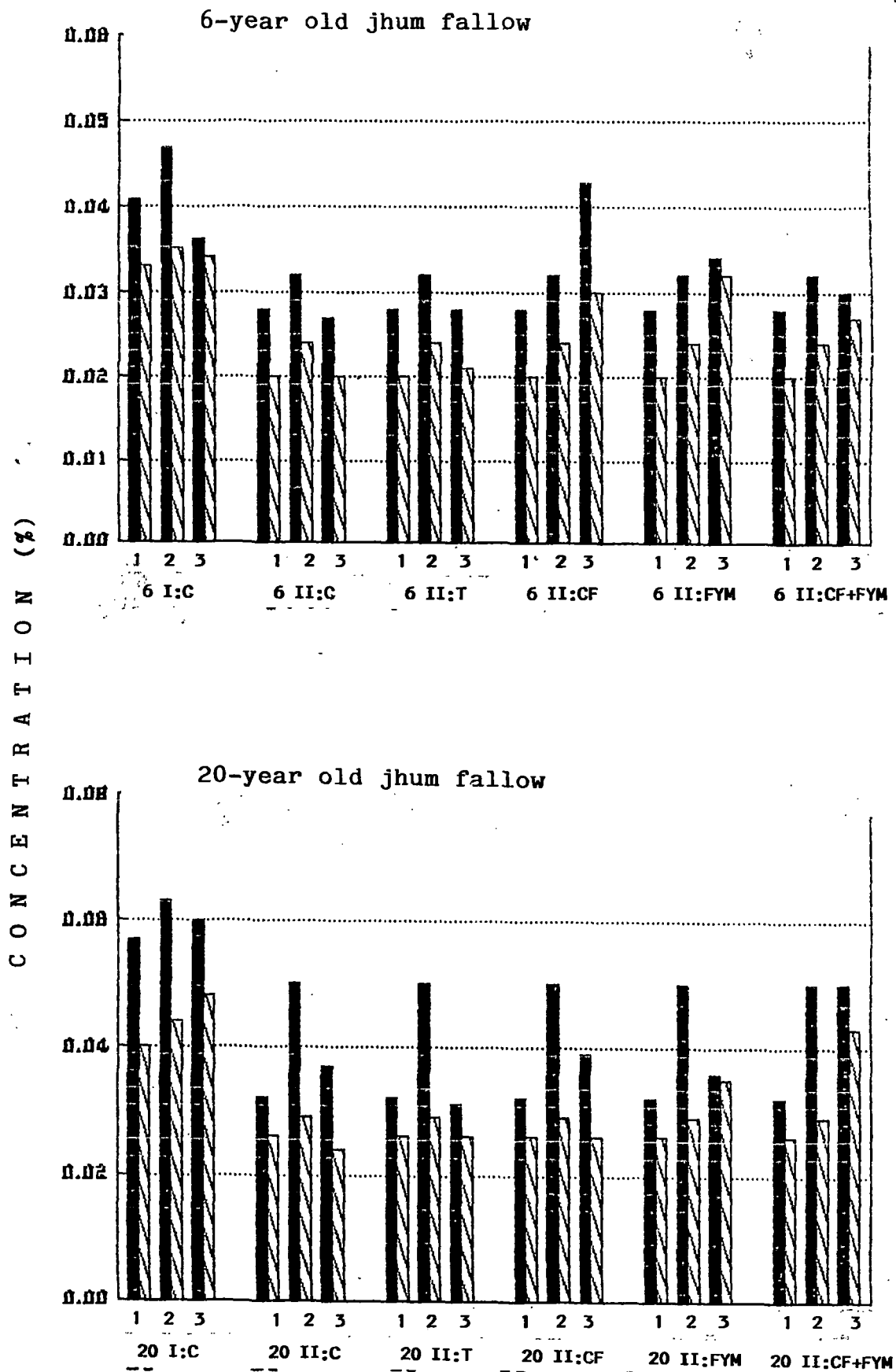


FIG. 5.3

Fig. 5.4 Concentration (%) of exchangeable potassium at 0-10 cm (□) and 10-20 cm (▣) layers of soil in 6-year old and 20-year old jhum fallows during first year and second year of cropping. 1, 2 and 3 refer to sampling done before slashing, after burning and after harvesting respectively.

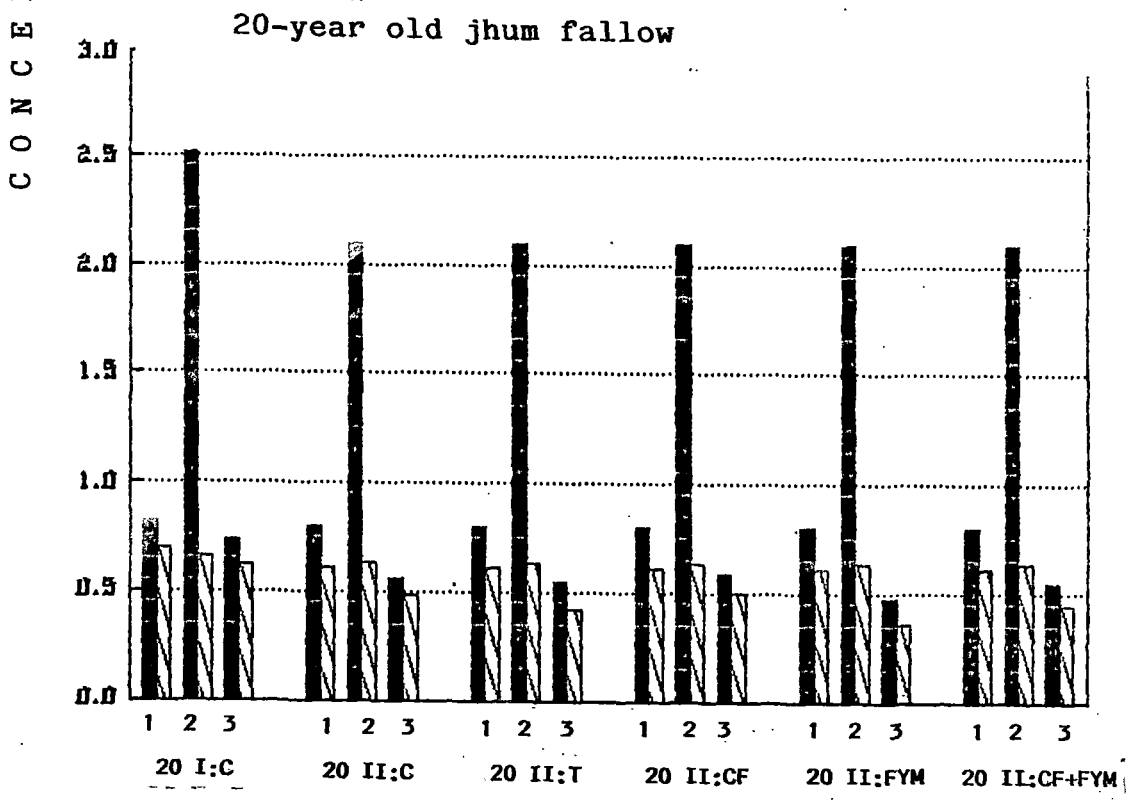
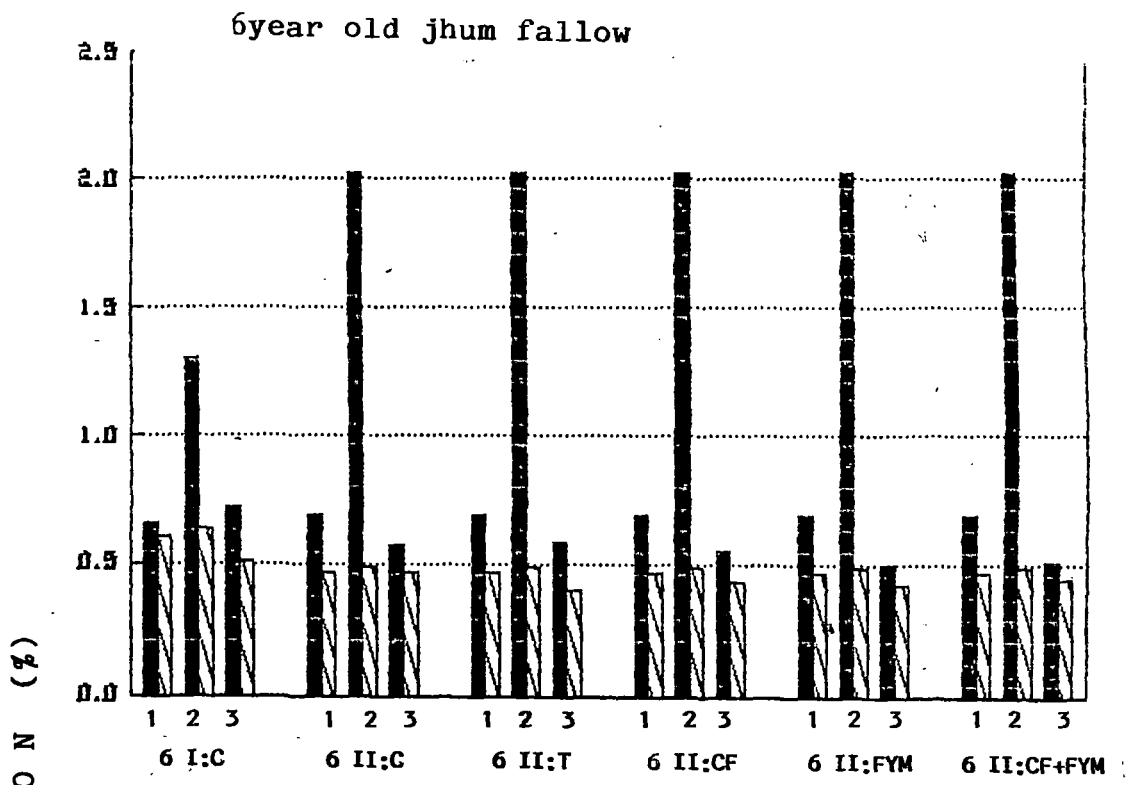


FIG. 5:4

Fig. 5.5 Concentration (%) of exchangeable calcium at 0-10 cm (□) and 10-20 cm (▨) layers of soil in 6-year old and 20-year old jhum fallows during first year and second year of cropping. 1, 2 and 3 refer to sampling done before slashing, after burning and after harvesting respectively.

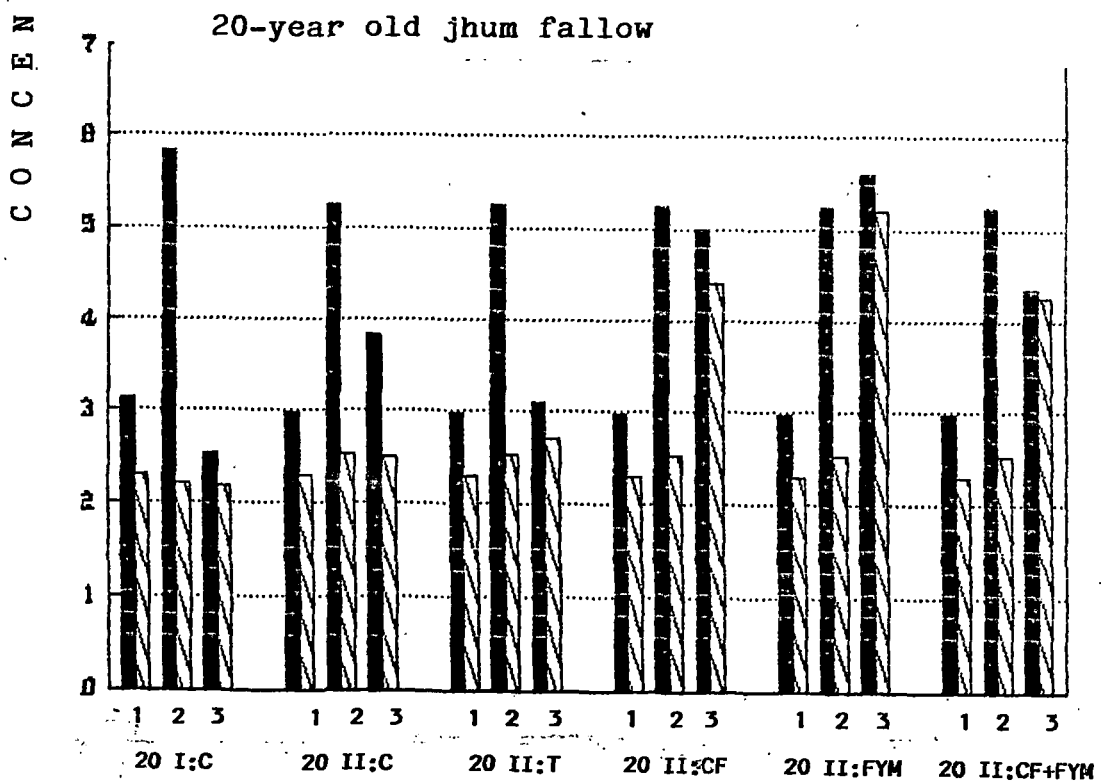
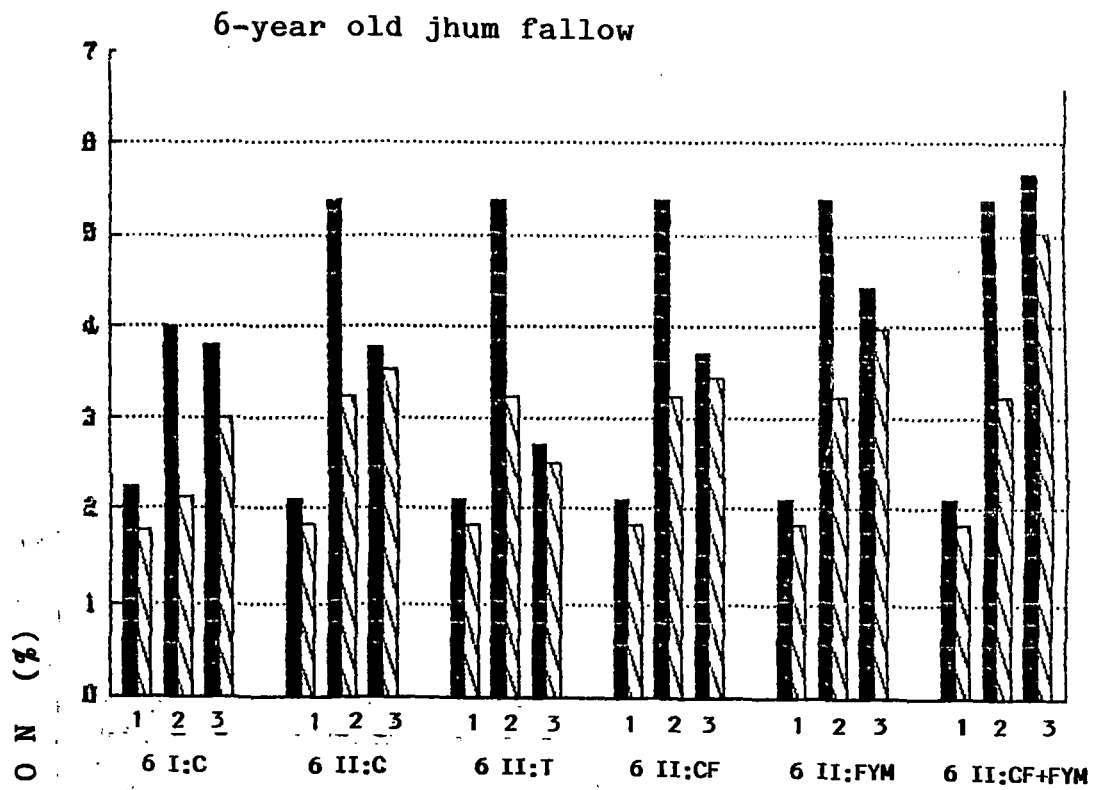


FIG. 5:5

Fig. 5.6 Concentration (%) of exchangeable magnesium at 0-10 cm (□) and 10-20 cm (▨) layers of soil in 6-year old and 20-year old jhum fallows during first year and second year of cropping. 1, 2 and 3 refer to sampling done before slashing, after burning and after harvesting respectively.

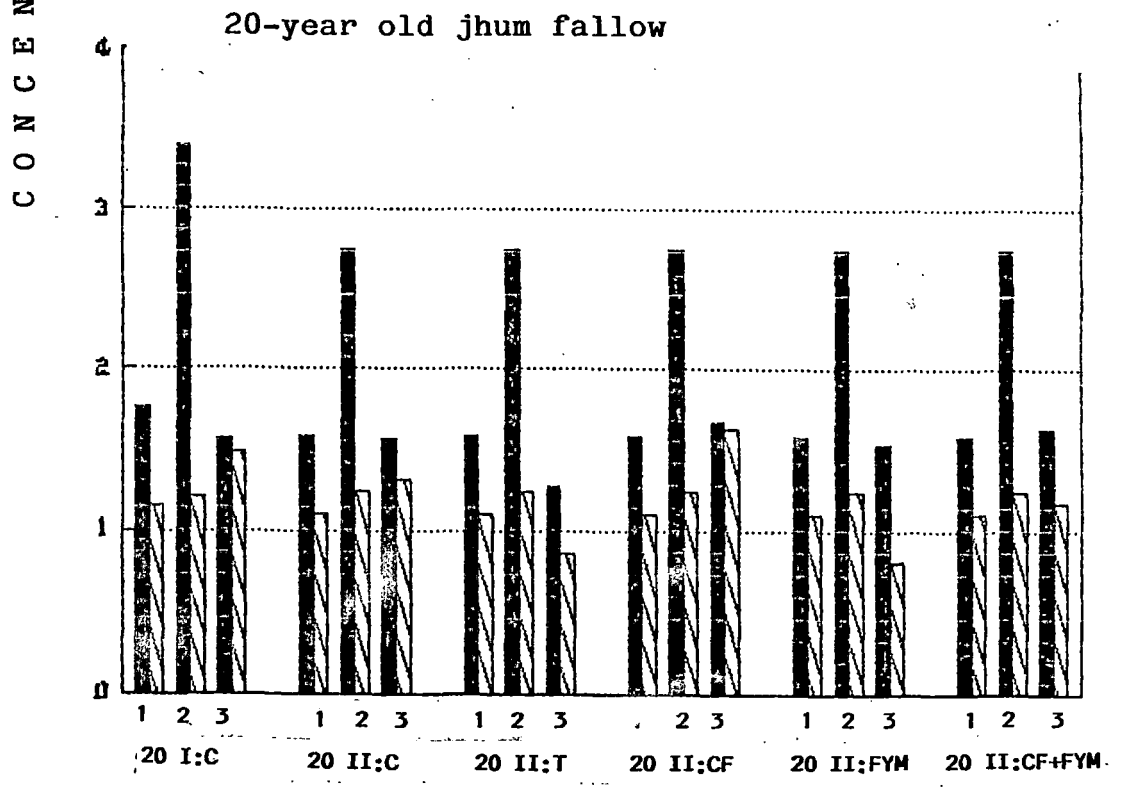
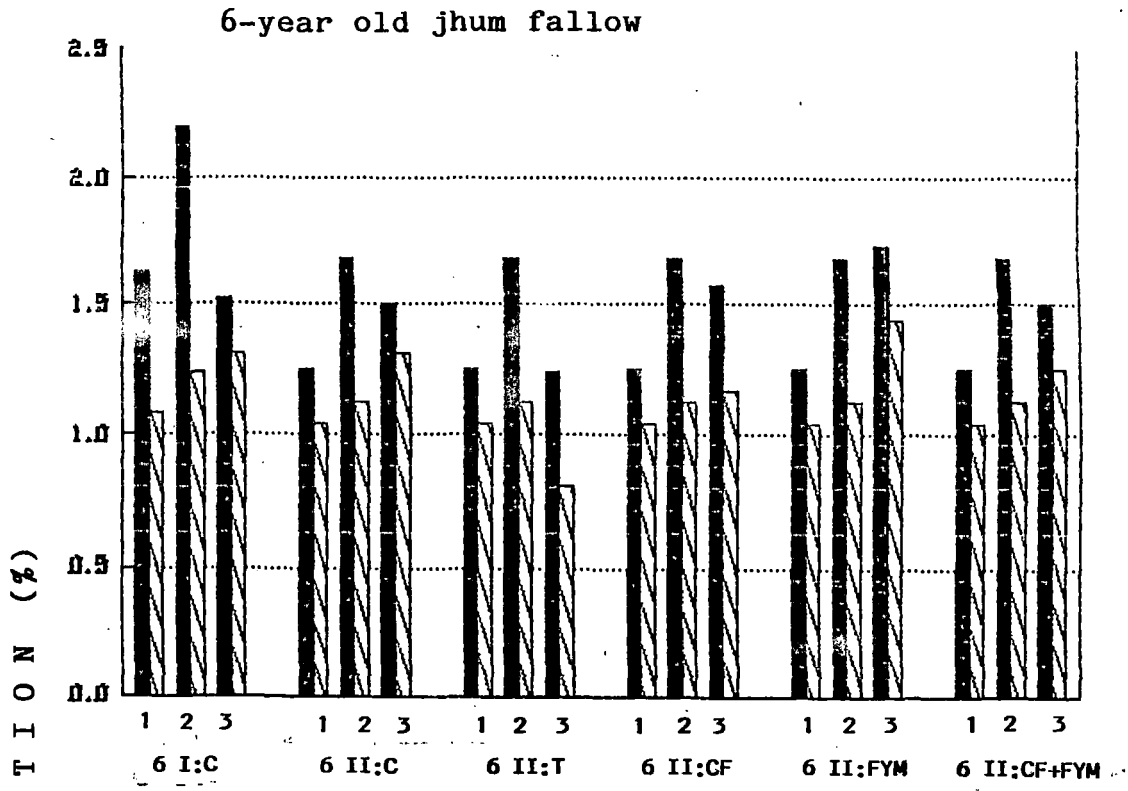


FIG. 5:6

Fig. 5.7 Concentration (meq. 100g^{-1}) of CEC at 0-10 cm (\square) and 10-20 cm (\boxtimes) layers of soil in 6-year old and 20-year old jhum fallows during first year and second year of cropping. 1, 2 and 3 refer to sampling done before slashing, after burning and after harvesting respectively.

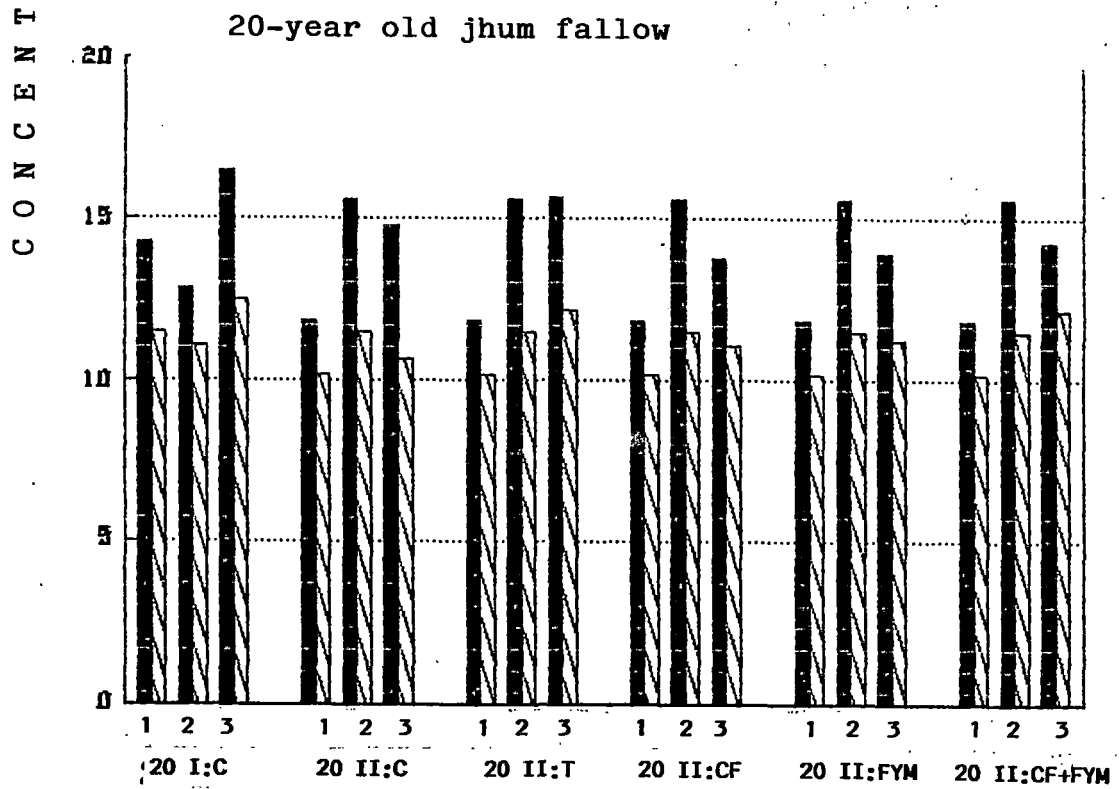
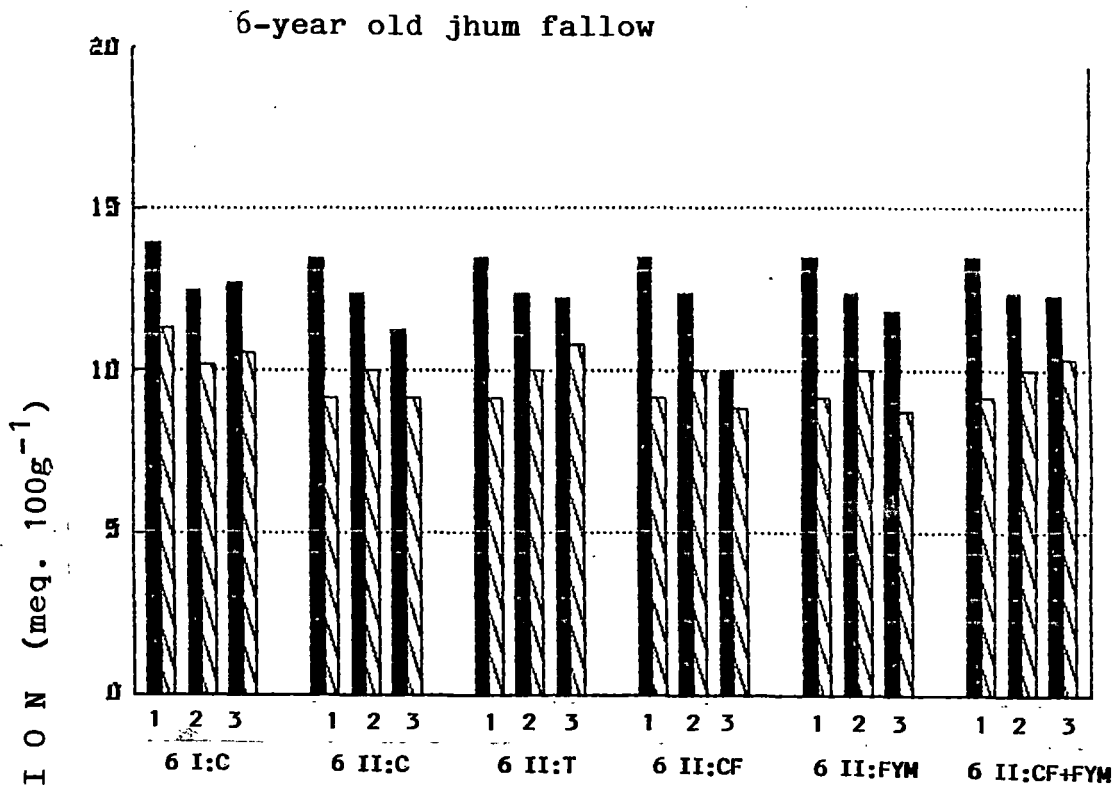


FIG. 5:7

Table 5.1. Changes in pH at the upper (0-10 cm) and lower (10-20 cm) layers of soil in 6-year old and 20-year old jhum fallows during first year and second year of cropping.

TREATMENT PLOTS	SAMPLING TIME					
	<u>Before slashing</u>		<u>After burning</u>		<u>After harvest</u>	
	0-10 cm	10-20 cm	0-10cm	10-20cm	0-10cm	10-20cm
6 I:C	5.9	5.7	6.3	5.9	6.6	6.2
6 II:C	6.3	6.0	7.0	6.2	6.6	6.0
6 II:T	6.3	6.0	7.0	6.2	6.6	5.5
6 II:CF	6.3	6.0	7.0	6.2	6.4	6.3
6 II:FYM	6.3	6.0	7.0	6.2	6.5	6.3
6 II:CF+FYM	6.3	6.0	7.0	6.2	7.0	6.6
20 I:C	6.3	5.8	6.6	6.0	7.0	6.6
20 II:C	6.4	6.2	6.9	6.4	7.0	6.3
20 II:T	6.4	6.2	6.9	6.4	6.1	5.9
20 II:CF	6.4	6.2	6.9	6.4	7.0	6.9
20 II:FYM	6.4	6.2	6.9	6.4	6.6	6.3
20 II:CF+FYM	6.4	6.2	6.9	6.4	6.6	6.0

Table 5.2. Changes in C:N ratio at upper (0-10cm) and lower (10-20cm) layers of soil in 6-year old and 20-year old jhum fallows during first year and second year of cropping.

TREATMENT PLOTS	SAMPLING TIME					
	<u>Before slashing</u>		<u>After burning</u>		<u>After harvest</u>	
	0-10cm	10-20cm	0-10cm	10-20cm	0-10cm	10-20cm
6 I:C	10.78	12.66	10.27	12.20	11.25	13.75
6 II:C	11.14	10.35	10.90	10.86	12.30	12.00
6 II:T	11.14	10.35	10.90	10.86	11.47	15.30
6 II:CF	11.14	10.35	10.90	10.86	10.90	15.00
6 II:FYM	11.14	10.35	10.90	10.86	10.32	11.42
6 II:CF+FYM	11.14	10.35	10.90	10.86	13.00	15.70
20 I:C	11.64	10.87	12.43	10.08	15.03	14.07
20 II:C	12.13	12.81	11.64	12.64	12.62	10.73
20 II:T	12.13	12.81	11.64	12.64	12.00	11.42
20 II:CF	12.13	12.81	11.64	12.64	12.03	11.26
20 II:FYM	12.13	12.81	11.64	12.64	11.30	8.58
20 II:CF+FYM	12.13	12.81	11.64	12.64	12.25	10.63

Table 5.3. Total nitrogen, available phosphorus, exchangeable potassium, calcium and magnesium content ($\text{kg ha}^{-1} \pm \text{S.D.}$, $n=3$) in soil at two depths (0-10cm and 10-20cm) before slashing in Young (6 yrs.) and Old (20 yrs.) jhum fields during first year and second year of cropping in Mizoram.

TREATMENT	NITROGEN		PHOSPHORUS		POTASSIUM		CALCIUM		MAGNESIUM	
	0-10	10-20	0-10	10-20	0-10	10-20	0-10	10-20	0-10	10-20
6 I:C	3900±457	3000±360	25.77±3.1	20.61±1.9	508.3±36.4	469.2±36.4	901.8±70.1	713.4±82.3	396.4±39.4	262.6±32.6
6 II:C	3500±410	2800±310	17.31±2.0	12.45±2.1	539.5±52.3	367.5±50.8	837.6±69.8	733.4±63	304.0±38	252.9±28
6 II:T	3500±410	2800±310	17.31±2.0	12.45±2.1	539.5±52.3	367.5±41.0	837.6±69.8	733.4±63	304.0±38	252.9±28.1
6 II:CF	3500±410	2800±310	17.31±2.0	12.45±2.1	539.5±52.3	367.5±41.0	837.6±69.8	733.4±63	304.0±38	252.9±28.1
6 II:FYM	3500±410	2800±310	17.31±2.0	12.45±2.1	539.5±52.3	367.5±41.0	837.6±69.8	733.4±63	304.0±38	252.9±28.1
6 II:CF+FYM	3500±410	2800±310	17.31±2.0	12.45±2.5	539.5±52.3	367.5±41.0	837.6±69.8	733.4±63	304.0±38	252.9±28.1
20 I:C	4500±472	3900±410	35.74±5.0	24.56±4.1	641.2±43.6	492.6±37.6	1250.5±122	921.8±110.6	425.6±46.4	277.2±18.4
20 II:C	3660±424	2840±268	20.42±3.1	16.81±2.6	625.6±61.0	477.0±39.4	1190.3±104	921.8±85.7	381.8±29.2	267.5±25.3
20 II:T	3660±424	2840±268	20.42±3.1	16.81±2.6	625.6±61.0	477.0±39.4	1190.3±104	921.8±85.7	381.8±29.2	267.5±25.3
20 II:CF	3660±424	2840±268	20.42±3.1	16.81±2.6	625.6±61.0	477.0±39.4	1190.3±104	921.8±85.7	381.8±29.2	267.5±25.3
20 II:CF+FYM	3660±424	2840±268	20.42±3.1	16.81±2.6	625.6±61.0	477.0±39.4	1190.3±104	921.8±85.7	381.8±29.2	267.5±25.3
20 II:CF+FYM	3660±424	2840±268	20.42±3.1	16.81±2.6	625.6±61.0	477.0±39.4	1190.3±104	921.8±85.7	381.8±29.2	267.5±25.3

Table 5.4. Total nitrogen, available phosphorus, exchangeable potassium, calcium and magnesium content ($\text{kg ha}^{-1} \pm \text{S.D.}$, $n=3$) in soil at two depths (0-10cm and 10-20cm) after burning in Young (6 yrs.) and Old (20 yrs.) jhum fields during first year and second year of cropping in Mizoram.

TREATMENT PLOTS	NITROGEN		PHOSPHORUS		POTASSIUM		CALCIUM		MAGNESIUM	
	0-10	10-20	0-10	10-20	0-10	10-20	0-10	10-20	0-10	10-20
6 I:C	3600±450	2900±320	28.65±4.2	21.44±3.0	938.4±120.4	492.6±85.1	1603.2±202.0	849.7±125.0	535.0±76.7	301.5±45.8
6 II:C	3300±450	2300±215	19.48±2.8	14.9±1.9	1579.6±240.0	383.1±40.2	2148.28±311.1	1294.5±150.1	408.5±58.8	272.3±36.0
6 II:T	3300±450	2300±215	19.48±2.8	14.9±1.9	1579.6±240.0	383.1±40.2	2148.28±311.1	1294.5±150.1	408.5±58.8	272.3±36.0
6 II:CF	3300±450	2300±215	19.48±2.8	14.9±1.9	1579.6±240.0	383.1±40.2	2148.2±311.1	1294.5±150.1	408.5±58.8	272.3±36.0
6 II:FYM	3300±450	2300±215	19.48±2.8	14.9±1.9	1579.6±240.0	383.1±40.2	2148.2±311.1	1294.5±150.1	408.5±58.8	272.3±36.0
6 II:CF+FYM	3300±450	2300±215	19.48±2.8	14.9±1.9	1579.6±240.0	383.1±40.2	2148.2±311.1	1294.5±150.1	408.5±58.8	272.3±36.0
20 I:C	4100±480	3700±402	38.0±6.8	26.52±3.8	1962.8±261.5	516.1±68.3	2336.6±282.4	889.7±107.2	826.8±122.1	291.8±46.7
20 II:C	3400±374	2800±203	31.62±4.7	18.32±3.8	1642.2±247.2	492.6±72.4	2108.2±282.4	1014±107.2	668.8±162.7	299.1±48.7
20 II:T	3400±374	2800±203	31.62±4.7	18.32±3.8	1642.2±247.2	492.6±72.4	2108.2±282.4	1014±107.2	668.8±162.7	299.1±48.7
20 II:CF	3400±374	2800±203	31.62±4.7	18.32±3.8	1642.2±247.2	492.6±72.4	2108.2±282.4	1014±107.2	668.8±162.7	299.1±48.7
20 II:FYM	3400±374	2800±203	31.62±4.7	18.32±3.8	1642.2±247.2	492.6±72.4	2108.2±282.4	1014±107.2	668.8±162.7	299.1±48.7
20 II:CF+FYM	3400±374	2800±203	31.62±4.7	18.32±3.8	1642.2±247.2	492.6±72.4	2108.2±282.4	1014±107.2	668.8±162.7	299.1±48.7

Table 5.5. Total nitrogen, available phosphorus, exchangeable potassium, calcium and magnesium content ($\text{kg ha}^{-1} \pm \text{S.D.}$, $n=3$) in soil at two depths (0-10cm and 10-20cm) after harvesting in Young (6 yrs) and Old (20 yrs) jhum fields during first and second year of cropping in Mizoram.

TREATMENT	NITROGEN		PHOSPHORUS		POTASSIUM		CALCIUM		MAGNESIUM	
	0-10	10-20	0-10	10-20	0-10	10-20	0-10	10-20	0-10	10-20
6 I:C	3200±480	2400±275	22.26±5.2	21.62±3.1	563.0±52.4	398.8±39.2	1523.0±123	1198.3±133	369.6±32	318.5±38
6 II:C	3600±455	2000±305	17.33±3.4	13.0±2.1	445.7±61.3	367.5±29.4	1507.5±108	1414.8±201	364.8±34	318.5±27
6 II:T	2440±320	1300±185	17.5±4.1	13.4±3.2	453.5±42.3	312.8±45.5	1082.1±98	1002.0±105	301.5±29	194.5±20
6 II:CF	3200±390	2000±205	27.0±9.3	18.8±3.8	430.1±37.8	336.2±61.2	1478.9±173	1378.7±154	381.8±38	284.5±27
6 II:FYM	3100±465	2100±287	21.62±4.6	20.11±4.2	391.0±49.3	328.4±50.1	1659.3±194	1591.1±187	420.7±27	350.2±34
6 II:CF+FYM	2600±294	1900±340	18.64±5.4	17.34±2.9	398.8±28.4	344.0±28.4	2272.5±213	2016.0±216	364.8±29	304.0±39
20 I:C	3300±362	2700±265	37.3±11.4	30.4±8.6	578.6±63.6	484.8±33.5	1014.0±88	869.7±99	376.9±51	357.5±37
20 II:C	2900±373	2460±356	23.29±7.8	15.32±4.8	437.9±39.0	375.3±41.2	1535.0±207	1002.0±126	374.5±53	313.7±28
20 II:T	2000±316	1400±235	19.41±6.0	19.65±4.6	422.2±51.4	328.4±26.7	1242.4±119	1082.1±131	306.4±42	196.9±22
20 II:CF	3240±411	2840±375	22.8±6.6	16.42±3.2	461.3±44.6	383.1±40.3	2028.0±146	1783.5±134	406.1±48	391.5±42
20 II:FYM	3000±244	2800±408	22.8±8.4	21.9±3.4	367.5±28.6	281.5±26.3	2244.4±185	2084.1±189	369.6±27	196.9±33
20 II:CF+FYM	3100±388	2820±378	31.66±10.3	28.6±5.2	430.1±32.7	344.0±36.5	1767.4±153	1711.4±165	391.5±38	282.1±28

Table 5.6. Analysis of variance of organic carbon content at upper (0-10cm) and lower (10-20cm) layers of soil during first year and second year of cropping in 6-year and 20-year old jhum fallows.

Source of variation	df	6-year old		20-year old	
		MSS	f ratio	MSS	f ratio
Plots	5	0.101	32.87**	0.219	182.12**
Sampling time	2	0.212	69.05**	0.686	429.01**
Depth	1	0.5	487.7**	1.269	793.04**
Plot x Sampling time	10	0.016	5.25	0.06	37.6
Plot x Depth	5	0.025	8.22**	0.008	5.13*
Sampling time x Depth	2	0.053	8.66*	0.033	20.74**
Residual	10	0.03	-	0.001	-

** = Significant at $P < 0.01$

* = Significant at $P < 0.05$

Table 5.7. Analysis of variance of nitrogen concentration upper (0-10cm) and lower (10-20cm) layers of soil during first year and second year of cropping in 6-year old and 20-year old jhum fallows.

Source of variation	df	6-year old		20-year old	
		MSS	f ratio	MSS	f ratio
Plots	5	0.00053	14.54**	0.00162	79.05**
Sampling time	2	0.00481	129.87**	0.00392	190.97**
Depth	1	0.01677	452.42**	0.00783	381.55**
Plot x Sampling time	10	0.00012	3.48	0.00048	23.76
Plot x Depth	5	0.00002	0.74	0.00001	0.52
Sampling time x Depth	2	0.00009	2.66	0.00025	12.2**
Residual	10	0.00003	-	0.00002	-

** = Significant at $P < 0.01$

* = Significant at $P < 0.05$

Table 5.8. Analysis of variance of phosphorus concentration at upper (0-10cm) and lower (10-20cm) layers of soil during first year and second year of cropping in 6-year old and 20-year old jhum fallows.

Source of variation	df	6-year old		20-year old	
		MSS	f ratio	MSS	f ratio
Plots	5	0.00012	32.35**	0.00035	30.55**
Sampling time	2	0.00006	16.08**	0.00027	23.43**
Depth	1	0.00049	125.34**	0.00124	106.15**
Plot x Sampling time	10	0.00002	5.56	0.00004	3.54
Plot x Depth	5	0.000013	0.63	0.00001	1.24
Sampling time x Depth	2	0.000007	1.87	0.00017	15.18**
Residual	10	0.000004	-	0.00001	-

** = Significant at $P < 0.01$

Table 5.9. Analysis of variance of exchangeable potassium concentration at the upper (0-10cm) and lower (10-20cm) layers of soil during first year and second year of cropping in 6-year old and 20-year old jhum fallows.

Source of variation	df	6-year old		20-year old	
		MSS	f ratio	MSS	f ratio
Plots	5	0.00178	0.09	0.02524	5.28*
Sampling time	2	1.7546	84.85**	2.56822	536.66**
Depth	1	2.90702	140.58**	3.30633	690.90**
Plot x Sampling time	10	0.01658	0.8	0.00379	0.79
Plot x Depth	5	0.02427	1.17	0.00298	0.62
Sampling time x Depth	2	1.50992	73.02**	1.93827	405.03**
Residual	10	0.02067	-	0.00478	-

** = Significant at $P < 0.01$

* = Significant at $P < 0.01$

Table 5.10. Analysis of variance of exchangeable calcium concentration at upper (0-10cm) and lower (10-20cm) layers of soil during first year and second year of cropping in 6-year old and 20-year old jhum fallows.

Source of variation	df	6-year old		20-year old	
		MSS	f ratio	MSS	f ratio
Plots	5	0.94	7.37**	0.8518	15.67**
Sampling time	2	16.8	130.95**	5.926	109.03**
Depth	1	6.31	49.19*	16.823	309.52**
Plot x Sampling time	10	0.71	5.54	0.967	17.81
Plot x Depth	5	0.12	0.94	0.047	0.88
Sampling time x Depth	2	3.53	27.62**	5.146	94.69**
Residual	10	0.13	-	0.054	-

** = Significant at $P < 0.01$

* = Significant at $P < 0.05$

Table 5.11. Analysis of variance of exchangeable magnesium concentration at upper (0-10cm) and lower (10-20cm) layers of soil during first year and second year of cropping in 6-year old and 20-year old jhum fallows.

Source of variation	df	6-year old		20-year old	
		MSS	f ratio	MSS	f ratio
Plots	5	0.089	0.04*	0.0669	2.44
Sampling time	2	0.224	12.72*	1.8658	68.1**
Depth	1	1.578	89.37*	6.0106	219.38**
Plot x Sampling time	10	0.048	2.73	0.031	1.13
Plot x Depth	5	0.017	1.00	0.0152	0.56
Sampling time x Depth	2	0.104	5.89*	1.5198	55.47**
Residual	10	0.017	-	0.0273	-

** = Significant at $P < 0.01$

* = Significant at $P < 0.05$

Table 5.12. Analysis of variance of cation exchange capacity (CEC) at upper (0-10cm) and lower (10-20cm) layers of soil during first year and second year of cropping in 6-year old and 20-year old jhum fallows.

Source of variation	df	6-year old		20-year old	
		MSS	f ratio	MSS	f ratio
Plots	5	1.09	7.48**	0.58	1.46
Sampling time	2	1.98	13.54**	15.37	38.71**
Depth	1	68.31	467.73**	76.74	193.28**
Plot x Sampling time	10	0.51	3.52	1.4	3.53
Plot x Depth	5	0.12	0.83	0.09	0.22
Sampling time x Depth	2	3.58	24.54**	2.89	7.27*
Residual	10	0.15	-	0.4	-

** = Significant at $P < 0.01$

* = Significant at $P < 0.05$

Discussion

As depicted by the pH values, the soil of the study sites is acidic. Singh et al. (1986) also reported the acidic nature of the hill soils of Mizoram. The difference in soil pH between 6-yr. old and 20-yr. old jhum fallows during first year of cropping may be attributed to the differences in microbial activity in the two jhum fallows caused by the differences in the micro-environment, which regulates the microbial population and activities in soil (Mishra, 1966; Unger et al., 1973; Dormear et al., 1979; Clinic, 1984; Tiwari et al., 1987). As pointed out by Lindsay and Monk (1981) a more exposed forest floor has increased mineralization of organic matter through increased temperature, aeration and more extreme wetting and drying cycles which may ultimately result into increase in pH of the soil. The vegetation cover of 6-yr. old jhum fallow was thinner than 20-yr. old jhum fallow as mentioned elsewhere, and this might be responsible for slightly higher acidic nature of soil in the former compared to the latter.

The application of chemical fertilizer did not change the pH significantly. Chemical fertilizers minimize the long decomposition cycle and enhance the availability of essential nutrients to plants (Swift et al., 1981).

The observed increase in soil pH after burning is

in conformity with the findings of some other workers (Ramakrishnan & Toky, 1981; Von Uexkull, 1983; Andriessse & Koopman, 1984; Dormear & Schaber, 1985; Kumada et al., 1985). Burning increase soil pH, presumably due to incorporation of ashes and addition of bases. Nye & Greenland (1964) reported that the pH increased from 5.2 to 8.1 in the top 5 cm layer right after burning.

In the present study, the general trend of greater soil organic carbon content in the upper layer appears to be due to cooler climate maintained in the upper layer through the presence of vegetation (Singh & Datta, 1986). The observed decrease in organic carbon at 10-20 cm compared to the surface soil agrees with Toky & Ramakrishnan (1981) who also reported low organic carbon content in lower depths of soil under shifting cultivated lands of Meghalaya. Witkamp (1971) has underlined the role of climate, especially the microclimate of the soil surface, where the increased temperature and aeration enhanced mineralization of organic matter. A thicker vegetation cover in the 20-yr. old fallow and the litter layer being comparatively less exposed to the atmosphere than in the 6-yr. old fallow seem to be the probable causes of the greater organic carbon in the former.

The decreasing trend of organic carbon after the crop harvest in the present investigation may be due to the

fast mineralization and subsequent uptake of nutrients by crops and weeds during cropping. A net loss of organic carbon after a year of cropping has also been reported by various workers (Joachim & Kandiah, 1948; Nye & Greenland, 1960; Zinke et al., 1978; Jha et al., 1979). According to Nye & Greenland (1964) and Jha et al., (1979) loss of organic carbon after a year of cropping may be due to the oxidation of humified material.

The percentage of soil organic carbon reflected a significant ($P < 0.01$) variation between the plots (Table 5.6). The application of chemical fertilizer and/or farm-yard manure caused greater increase in organic carbon in 20-yr. old jhum fallow which may be due to slower mineralization of organic matter in 20-yr. old jhum fallow than in 6-yr. old fallow, thus allowing more organic carbon to remain in the soil pool even after harvesting. This is clearly evident from the greater soil organic carbon content observed in the sub-plot treated with farm-yard manure compared to other sub-plots after the crop harvest..

The general trend of lower concentration of nitrogen in young jhum field than old jhum field in the present study agrees with Mishra & Ramakrishnan (1984) who reported that soil nitrogen content increases with age of the fallow. Another reason for the decline in nitrogen concentration

in young jhum field may be the high leaching of nitrates and microbial transformation from the soil surface due to decreased plant cover (Mitchell et al., 1975; Borman et al., 1968).

Depthwise variation in soil nitrogen content was significant ($P < 0.01$) in both jhum fields (Table 5.7) the surface soil contained more nitrogen which conforms with the findings of other workers (Mishra & Ramakrishnan, 1983; Andriessse & Schelhaas, 1987b). Soil nitrogen showed significant ($P < 0.01$) variation with sampling time and between the sub-plots. Decrease in nitrogen concentration in the tilled sub-plots may be due to greater leaching and microbial transformation due to loosening of soil particles. This decrease was, however, not as severe in the sub-plots treated with chemical fertilizer or farm-yard manure as it was in the control and tilled sub-plots, mainly because of the replenishment of nitrogen due to fertilizer application in the treated sub-plots.

Weeds are an important component in agro-ecosystems and they play an important role in conservation of nutrients (Tripathi, 1977; Chacon & Gliessman, 1982). A good fraction of nitrogen and other nutrients absorbed by weeds from the crop field are returned back to the soil when the weed residues decompose and mineralise and thus once again, they become

available to the crops. The weeds therefore, provide an important mechanism for optimum utilization of nutrients. The frequent weeding done during cropping followed by their biomass being ploughed back into soil or being used for compost which eventually comes back into the system as organic manure, provides recycling of nitrogen (Gliessman, 1982). There are reports that the weed component ploughed back increases with the shortening of the fallow cycle due to severe weed problem associated with short cycles (Ramakrishnan & Mishra, 1981; Saxena & Ramakrishnan, 1984). Comparatively higher concentration of nitrogen in 20-yr. old than in 6-yr. old jhum fallow in the present study indicates that age of fallow plays greater role than the weed biomass in determining the size of nitrogen pool in soil. The severe weed infestation on the 6-yr. old jhum fallow, of course resulted into higher input of weed biomass and consequently, the soil nitrogen content increases. But, this increase in nitrogen through weed biomass input in the case of 6-yr. old jhum fallow never exceeded the soil nitrogen content in the older jhum fallow. In 20-yr. old fallow the contribution by the weed biomass ploughed back in the system was of lesser importance due to low weed development in this field, and so the greater concentration of nitrogen in soil of this fallow could be attributed to better build-up of nitrogen brought about by longer fallow period.

Concentration of phosphorus in both 6-yr. old and 20-yr. old jhum fallows was significantly ($P < 0.01$) higher (Table 5.8) in surface layer than at 10-20 cm depth, which may be due to accumulation of this element in abundantly available organic matter in the surface layer. Singh & Datta (1987b) have shown phosphorus accumulation in soil organic matter of some hill soils of Mizoram. It may be the probable reason for higher concentration of phosphorus in 20-yr. old jhum field where organic debris were more than in the young jhum fallow. A decrease in phosphorus concentration at 10-20 cm depth in the older fallow may be due to its uptake by roots. Tilling as mentioned elsewhere makes the soil loose which accelerates the downward movement of nutrient. This is clearly evident from the low concentration of phosphorus recorded in the tilled sub-plots in the present study.

As expected, application of chemical fertilizer and farm-yard manure singly or in combination caused significant ($P < 0.01$) increase in phosphorus concentration. However, the soil phosphorus content showed a decreasing trend as the crop developed, which may be ascribed to greater uptake with increase in biomass production over a period of time. A greater decrease in soil phosphorus in older jhum fallow compared to the younger fallow may also be linked with greater production of biomass in the former.

The general trend of higher concentration of exchangeable potassium, calcium and magnesium in 20-yr. old than in 6-yr. old jhum fallow may be due to the thicker vegetation in the former which contributed more slash and ash during jhum cultivation as also reported by Hrahsel (1988) who studied soil fertility changes during jhum cultivation in Mizoram. Sanchez (1979) has shown that ash causes dramatic increase in exchangeable calcium, magnesium and potassium levels after burning. A significant sudden increase ($P < 0.01$) of these elements just after burning (Table 5.9, 5.10 and 5.11) is due to the incorporation of ash in the soil. Increase in exchangeable bases due to burning has earlier been reported by other workers (Bara & Vega, 1983; Oya & Tokashiki, 1984). A decrease in the concentration of these elements in soil after harvesting might be due to leaching and uptake by the crop and weed plants.

The concentration of potassium after the crop harvest did not vary significantly between the control and the sub-plots treated with fertilizers. The vigorous growth of weed and crop plants probably placed greater demand in these sub-plots on the available potassium than the less vigorously growing plants in the control, and thus the expected difference in potassium level of soil between the control and treated sub-plots was narrowed down.

The concentration of calcium and magnesium in the tilled sub-plots showed a decreasing trend whereas such a trend was not shown by potassium which can be replaced more readily from the surface of the colloidal particles compared to calcium and magnesium cations. It may be mentioned that there was substantial input of potassium and negligible input of calcium and magnesium in the soil after burning. This differential input of these three elements after burning operation could be considered to be an important factor determining their concentrations in the soil after the crop harvest, even though the rate at which calcium and magnesium can be lost from the soil (especially in the tilled sub-plots) is slower than is the case with potassium.

CHAPTER VI

General discussion

One of the important ecodynamics of shifting cultivation is the succession of different plant communities and their species composition and soil nutrient status during the fallow period. The vegetation developing during fallow period covers the soil and facilitates cool temperature of the soil. During the fallow period, the fallow land gradually undergoes phytosociological as well as soil fertility changes. Provided the fallow periods are long enough, a shifting cultivation system proves to be in no way harmful to the soil (Ruthenberg, 1983).

A comparative phytosociological studies of the vegetation on young (6-year old) and old (20-year old) jhum fallows clearly depicted that the shorter the jhum cycle, the lesser the dominance and the greater the species diversity (Table 2.9). More tree species with lesser number of shrubs, saplings and herbs characterized the 20-year old jhum fallow vegetation, whereas a 6-yr. old jhum fallow is characterized by lesser number of tree species with more shrubs, saplings and herbs. However, a close physiognomic similarity seems to exist between young and old jhum fallows because Melocanna bambusoides is dominant in both fallows. This species is one of the important components of secondary successional communities developing on jhum fallows in most part of Mizoram and its replace-

ment by tree species requires a long period as evident from its dominance on both 6-yr. old as well as 20-yr. old jhum fallows.

Subsequent to burning of fallow vegetation, pH of the upper soil layer increases (Table 5.1). The increase in pH due to burning is also reported by Lal & Cummings (1979) and Ramakrishnan & Toky (1981). Dramatic increase in exchangeable potassium, calcium and magnesium was also evident especially on the older jhum fallow. Available phosphorus also increased slightly. Young & Golledge (1948) observed that the ash formed by burning of plant cover supplies Ca P, K, Mg and S to the soil. As reported by Corbet (1934), ash of plants is generally very rich in potassium. The decrease in organic carbon after burning especially at the upper (0-10 cm) layer of soil may be attributed to high intensity of fire which depletes organic carbon. This is in conformity with the earlier report by Ramakrishnan & Toky (1981) who studied soil nutrient status after slash and burn agriculture in Meghalaya. Lal & Cummings (1979), however, reported that organic matter in soil is not affected by burning of vegetation.

A net loss of carbon after first year of cropping was also reported by other workers (Jha et al., 1979; Nye & Greenland, 1964; Zinke et al., 1978). Jou & Lal (1977) con-

cluded that the depletion of organic matter depends upon the intensity of cropping, type of vegetation and the ratio of cropping to fallow period. With optimum cropping and fallow period, the humus in the soil could be maintained at a relatively high level even after many years of shifting cultivation (Birch & Friend, 1956; Coulter, 1950; Reed, 1951).

Like organic carbon, the total soil nitrogen content also declined after burning. The decrease in soil nitrogen was less prominent in younger (6-yr. old) jhum fallow, which may be attributed to lower intensity of fire because of smaller quantity of slash available for burning on this jhum fallow. Under longer jhum cycle, the build up of nitrogen was greater during the fallow period, and due to thicker pre-jhuming vegetation, the soil experienced a high intensity burn, resulting in greater loss of nitrogen through volatilization from the surface soil as also reported by other workers (Normann & Wetselaar, 1960; Rosswall, 1980; Ramakrishnan & Toky, 1981). However, an increase in total nitrogen was observed from the last sampling (i.e. after crop harvest) during the first year of cropping to first sampling (i.e. before burning) during the second year of cropping. This may be due to the decomposition of litter contributed by the weed and crop plants that grow during the first year of cropping.

A comparatively higher status of the soil in older (20-yr. old) jhum fallow during first year of cropping is due to the presence of thicker pre-jhuming vegetation cover which conserves and builds nutrients in the soil. The present study depicts the importance of jhum fallow vegetation in determining the nutrient status of the soil expressed mainly through litter accumulation and burning operation. Ruthenberg (1983), also reported that in humid and semi-humid climates, where there was thick vegetation cover, the main store house of nutrients is not the soil but the standing biomass. Thus, the general principle of shifting cultivation may be formulated that fallow vegetation cover reduces leaching and stores nutrients which are made available to crops to a significant degree through their rapid transformation brought about by burning.

Initially during the cropping season, the total biomass is more or less equally partitioned between crop and weeds (Table 4.3). The contribution of weeds to total biomass declined with the passage of time presumably due to suppression in weed growth due to luxuriant growth of the crop. Another cause of decreased contribution by weeds is their removal from the fields during weeding operation. The bulk of the standing biomass was contributed by the crop as jhum fields provided the conditions for more vigorous growth of

the crop plants compared to the weeds as the agro-ecosystems are always manipulated in favour of crops. The production of much reduced weed biomass in the plots which recorded greater crop biomass (Table 4.3) also lends support to this argument.

The productivity of crop plus weeds was considerably higher in 20-yr. old jhum fallow than in 6-yr. old jhum fallow which indicates that the longer the jhum cycle the greater is the productivity (Table 4.6).

During the second year of cropping, among the treatments which were tried with a view to suggest innovation methods over the existing shifting cultivation, the application of chemical fertilizers was found to be most favourable as revealed by crop production in the chemical fertilizer treated plots in both 6-yr. and 20-yr. old jhum fallows (Table 4.5).

As revealed by energetic and productivity studies, jhum cultivation on the 20-yr. old fallow gives better return than on 6-yr. old fallow. The greater crop biomass accompanied by lower weed biomass, better crop yield and greater energy efficiency of 20-yr. old fallow during first year of cropping, as compared to 6-yr. old jhum fallow signify the role of longer jhum cycle in regenerating the system making it more

productive and efficient. The decline in crop yield with shortening of jhum cycle has also been reported by other workers (Ramakrishnan & Toky, 1981; Ruthenberg, 1983).

A more or less equal soil nutrient status on both young and old jhum fallows during second year of cropping is due to the greater utilization of the soil nutrients brought about by vigorous growth of plants (both crop and weeds) and better crop yield on the older fallows. Comparatively greater biomass production on older jhum fallow depicted greater nutrient uptake which narrowed down the difference between the nutrient status of the two fallows that existed during the first year of cropping. Thus, from the energetic and productivity point of view, the 20-yr. old jhum fallow was only marginally better than the 6-yr. old jhum fallow during second year of cropping.

Effect of land tilling

Comparatively low crop yield and decrease in biomass production and energy efficiency on the tilled sub-plots on both jhum fallows during second year of cropping may be attributed to an increased loss of soil nutrients through erosion as a result of adverse effect of tilling on physical structure of soil. A study of the physico-chemical characters of the soil revealed comparatively low concentration of various elements in the tilled sub-plot. The inherent soil fertility

level, after a year of cropping was drastically reduced by the end of second year cropping. The present study revealed that low crop yield, less biomass production and less energy efficiency is due to loss of soil nutrient through erosion in all sub-plots particularly, the tilled sub-plot where erosion was most severe. The high energy input on tilling operation brought down the output : input ratio in terms of money and energy. Data revealed that land tilling during second year of cropping as a means to improve the existing shifting cultivation practice in Mizoram is not a sound proposition and hence cannot be recommended as an innovative approach.

Effect of fertilizers

A comparatively better crop yield and greater biomass production with high monetary output : input ratio was achieved through the artificial addition of the chemical fertilizers during second year of cropping. The treatment also ensured that there was not much decline in the soil fertility of the jhum fallow after one year of cropping subsequent to the first year of cropping. However, the output : input ratio in terms of energy is very low due to high energy value of chemical fertilizers. The results of the present study clearly indicate that the addition of chemical fertilizers after the first year cropping, could be a promising means of innova-

ting the traditional shifting agriculture system in Mizoram from the productivity point of view.

Effect of farm-yard manure

Addition of farm-yard manure increased crop yield and biomass production, and maintained the inherent capacity of the soil to some extent. The output : input ratio in terms of money is also quite high, but in terms of energy it is a bit low, though not as low as observed in the sub-plot treated with chemical fertilizers. Thus application of farm-yard manure to the jhum field during second year of cropping could be strongly recommended as a means to improve shifting cultivation in Mizoram, especially in view of the fact that it is easily available in sufficient quantity.

Effect of chemical fertilizers plus farm-yard manure

The sub-plots treated with a combination of fertilizers and farm-yard manure gave a higher crop yield (Table 3.5), but the output : input ratio of energy was comparatively very low. On account of low energetic efficiency of such plots which received both chemical fertilizer and farm-yard manure, this treatment may not be recommended as a means of improvement in the existing shifting cultivation in Mizoram. However, if the increase in crop yield is the sole consideration, this too could be given a fair trial.

On the whole, the 20-yr. old jhum fallow is more responsive to the various treatments than 6-yr. old jhum fallow during second year of cropping. The application of fertilizers and/or farm-yard manure on the jhum fallows during second year of cropping promised good returns and thus, the cultivation of jhum fallow just for one year which is commonly practiced in Mizoram could be replaced by a practice whereby the same jhum fallow could give good return at least for two successive years and this can be achieved only by following the innovative approaches indicated above.

SUMMARY

1. The present study, apart from gaining an insight into various ecological aspects of shifting cultivation seeks to suggest innovations in the existing practice of 'Jhuming' locally called 'Lo' in Mizoram. The innovations or alterations tried in this study include the introduction of second year of cropping on the same jhum land, hitherto not commonly practiced in Mizoram. During second year of cropping, the jhum land is subjected to tilling and application of chemical fertilizers, farm-yard manure (FYM) and a combination of chemical fertilizer and FYM. This introduction of second year of cropping will help in lengthening the present jhum cycle in the state and thus would retard deforestation which is taking place at an alarming rate.

2. The experimental studies were conducted during 1988 and 1989 in Mizoram. The experimental data collected during these two years have been processed and analysed using appropriate statistical methods.

3. The study sites included two jhum fallows of different ages — 6-yr. old and 20-yr. old. Various aspects of the study were conducted during first year and second year of cropping on both the 'jhum' fallows.

4. Phytosociological studies of selected jhum fallow forests showed that vegetation on 20-yr. old jhum fallow is composed of 37 plant species and that on 6-yr. old jhum fallow is composed of 46 plant species. Melocanna bambusoides is a dominant species with IVI of 191.57 and 175.1 in 20-yr. old and 6-yr. old jhum fallows respectively. This study reveals a higher index of dominance with lower index of diversity of species on 20-yr. old jhum fallow whereas inverse was true on 6-yr. old jhum fallow. More tree species and less shrub/herb species are found to be present in 20-yr. old jhum fallow whereas less tree species and more shrub/herb species are present in 6-yr. old jhum fallow.

5. Studies on the physico-chemical characteristics of soil clearly depicted slightly higher pH value and higher concentration of nutrient elements in upper layer (0-10cm) than in lower layer (10-20cm) of soil.

6. As a whole, the soil fertility level in 20-yr. old jhum fallow is higher than in 6-yr. old jhum fallow.

7. The pre-jhuming vegetation plays an important role in determining soil nutrient status mainly through burning operation. Increase in soil pH and various elements like available phosphorus, exchangeable potassium, calcium and magnesium was evident after dried slashed pre-jhuming vegeta-

tion was burned. Exchangeable potassium showed the highest degree of increase due to burning. However, no increase was observed in organic carbon and total nitrogen contents of soil after burning. This has been attributed to the combustion of organic matter and volatilization of nitrogen during burning.

8. Decline in soil fertility during cropping was evident. This may be due to nutrient uptake by plants and losses brought about by erosion and percolation. Erosion loss was most severe on land where tilling was introduced.

9. The present study reveals that forest vegetation growing on jhum fallows reduces leaching and stores nutrients which are made available to crops to a significant degree through their rapid transformation brought about by burning during shifting cultivation.

10. Soil fertility level can be properly maintained by the application of chemical fertilizers, farm-yard manure and a combination of chemical fertilizers and farm-yard manure during second year of cropping.

11. Annual biomass production and net primary productivity were higher in 20-yr. old than 6-yr. old jhum fallow during first year and second year of cropping. The highest values for biomass and productivity were recorded when chemical

fertilizers were applied to the treatment plots, while the lowest values were recorded from the sub-plots where the tilling of land was introduced during second year of cropping.

12. Nutrient status of the soil is the main factor determining the biomass production and rate of productivity of crop (rice) and crop plus weeds.

13. Due to frequent weeding operation during shifting cultivation competition between crop (rice) and weeds do not play significant role as far as biomass production of crop or crop plus weeds is concerned.

14. Among various jhuming operations, weeding requires the highest energy input. Though the introduction of tilling of the land on jhum fallows required extra input of energy it did not increase the output. In fact, the energetic efficiency of the sub-plot was lowered due to introduction of ploughing.

15. The 20-yr. old jhum fallow was more efficient than 6-yr. old jhum fallow from energetic and productivity point of view during first year of cropping. However, not much difference between the two was evident during second year of cropping.

16. A greater production of crop biomass, better economic

yield considerably low weed biomass production and higher energy efficiency of 20-yr. old fallow during first year of cropping as compared to 6-yr. old jhum fallow depict the positive role of longer jhum cycle in regenerating the system and in making it more productive and efficient.

17. Among the treated sub-plots, the one which received chemical fertilizers plus farm-yard manure showed highest output in terms of money. However, these sub-plots showed lowest output : input ratio in terms of energy because of high energy value of fertilizers. Tilled sub-plots showed lowest output : input ratio in terms of money.

18. Among the treated sub-plots during second year of cropping the highest crop yield was obtained from the chemical fertilizers plus FYM treated sub-plots, followed by chemical fertilizers treated sub-plots and then by FYM treated sub-plots. Tilled sub-plot showed lowest crop yield. Control sub-plots slightly exceeded tilled sub-plots on both 20-yr. old and 6-yr. old jhum fallows.

19. As a whole, application of fertilizers, whether it be chemical, farm-yard manure or combination of both, caused an increase in crop yield and helped in maintaining the inherent soil fertility to some extent during second year of cropping. These treatments are therefore, recommended for

the improvement or to innovate the existing practice of shifting cultivation from productivity and soil fertility point of view. But the energetic efficiency of the sub-plots with these treatments is rather low as the high energy value of fertilizers drastically brought down the energetic output : input ratio.

20. Tilling of the soil as a means to innovate existing practice of jhum in Mizoram is not worth suggesting as this treatment did not increase the productivity and energetic efficiency of the system.

21. The inherent soil fertility level after a year of cropping was drastically reduced by the end of second year of cropping even when treated with chemical fertilizer and/or farm-yard manure during second year.

22. The present study provides factual and quantitative data on the ecological implications of traditional shifting cultivation and innovative approaches that were tried on an experimental basis with a view to minimise the ill effects of shifting cultivation in Mizoram. The study examines the merits and demerits of the innovative approaches that could be introduced as a means to improve the existing practice of 'Lo' in Mizoram, so that the deforestation and land degradation which are largely caused by shifting cultivation due to shortening of jhum cycle in the state could be controlled to some extent.

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