ECO-PHYSIOLOGICAL AND DEMOGRAPHIC STUDIES OF WEEDS OF SUCCESSIONAL ENVIRONMENTS AFTER SLASH AND BURN AGRICULTURE IN NORTH-EASTERN INDIA

P. SUDHAKAR SWAMY

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DEDICATED

TO

MY PARENTS

Gram : JAYENU

Phone : Off 652282
Res :

Jawaharlal Nehru University

P. S. Ramakrishnan
M. Sc , Ph. D., F N.A , F.A.Sc. F.N.A.Sc.
Professor of Ecology

SCHOOL OF ENVIRONMENTAL SCIENCES
NEW DELHI - 110067

I certify that the thesis entitled " ECO-PHYSIOLOGICAL AND DEMOGRAPHIC STUDIES OF WEEDS OF SUCCESSIONAL ENVIRONMENTS AFTER SLASH AND BURN AGRICULTURE IN NORTH-EASTERN INDIA" submitted by Shri. P. Sudhakar Swamy, 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 Ph. D. degree. This work has not been submitted for any degree of any other University.

Date: 15 July, 1986

Place: New Delhi.

Signature of the Supervisor

HEAD
Centre For Eco- Development
NORTH-EASTERN HILL UNIVERSITY
Shillong- 793014.

Forwarded.
1/9/86.

R. S. TRIPATHI
Professor & Head
Department of Botany
N. E. Hill University
Shillong-793014, India.

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P. Sudhakar Swamy

(P.S. SWAMY)

Centre for Eco-Development
School of Life Sciences
North-Eastern Hill University,
Shillong.

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PREFACE

Traditional farming such as that under slash and burn agriculture (jhum) in north-east India is based upon a close inter-linkage between agriculture, weed potential and forestry sub-systems. This agroecosystem is based upon the natural soil fertility recovery processes operating during the secondary successional fallow phase, involving weed communities of the early phases and forests of bamboo and broad-leaved shrubs and trees of the later phases. Depending upon the length of the fallow phase, the weed potential is altered with increased weed potential under shorter cycles, accompanied with poor soil fertility recovery of the system, the crop yield is adversely affected. Site degradation and desertification are some of the long-term consequences of successive imposition of shorter cycles. While increased weed potential in this agroecosystem has adverse ecologic and economic consequences, this agro-forestry system is based upon sound management of weeds as part of the crop system where, traditionally, the jhum farmer retain about 20% of the weed biomass as part of the agroecosystem. The remaining 80% weed biomass is also recycled into the agroecosystem during the cropping phase itself. This 'non-weed' concept provides one of the basis for designing new management strategies for tropical agriculture.

The present study, therefore, considers two major aspects of this traditional slash and burn agriculture (jhum) system at lower elevations of Meghalaya in north-east India: (i) the ecology of an important exotic weed such as Mikania micrantha Humbold, Bonapald, Kunth, during the early secondary successional fallow phase and (ii) the agroecosystem function under a 5- and 20-year jhum cycle with respect to the 'non-weed' concept and nutrient budgeting.

The thesis starts with a 'General Introduction' surveying the literature pertaining to the topics of investigation, followed by a description of the study area and climate. Each of the subsequent nine chapters deal with one aspect of the study done on the slash and burn agriculture system. These nine chapters are organized in a crisp and condensed form meant for simultaneous publication in scientific journals. One of them, namely, weed potential of Mikania micrantha H.B.K., and its control in fallows after shifting agriculture (jhum) in north-east India in Agriculture, Ecosystem and Environment. Vol.16 : (1986). Besides the results presented, each chapter has its own brief introduction, methods of study, discussion and summary. Therefore, some amount of repetition (though minimal) was unavoidable. The literature cited in the text, however, has all been put together at the end of the thesis.

The results presented here, apart from its academic value, has applied implications from the point of view of weed management and possible improvement of the traditional agroecosystem so as to remove the recent distortions that have come about due to rapid shortening of the jhum cycle.

GENERAL INTRODUCTION

GENERAL INTRODUCTION

Fire, which occurs frequently in some plant communities plays an important role in the regulation of population of many plant species. A fire of mild intensity may stimulate high seedling establishment and growth by raising the soil temperature and nutrient status and by removal of plant litter and vegetation cover (Buell and Cantlon, 1953; Kelting, 1957; Lemon, 1967; Old, 1969; Sharp, 1970; Whelan and Nain, 1979). Toky and Ramakrishnan, (1983a), and Saxena and Ramakrishnan, (1984b) also observed stimulatory effect of fire on the early phase of secondary succession after slash and burn agriculture (Jhum) in north-eastern India. Kushwaha *et al.* (1983) observed that fire had promotary effect on flowering of an early successional grass, *Imperata cylindrica*.

Slash and burn agricultural system (Jhum) in north-east India involves the management of fire for temporary improvement of soil fertility for mixed cropping (Ramakrishnan and Toky, 1981a; Mishra and Ramakrishnan, 1983b), before the land is abandoned for natural regeneration of plant communities through secondary succession. The pattern and processes involved during secondary succession, therefore, is dependent upon the perturbation due to fire and due to cropping procedures.

Both frequency and intensity of the burn and the cropping practices also determine to a large degree the pattern of the early phase of secondary succession (Toky and Ramakrishnan, 1983a).

Secondary successional patterns:

The pattern of secondary succession and the rapidity with which forested community develops depends upon the degree of destruction and the clearing of the under-ground propagules of the community that existed prior to this operation. The length of the jhum cycle (intervening fallow phase between two successive croppings at the same site) also determines the pattern of vegetation development. The pattern of secondary succession in the fallows during the first few years when weedy species dominate, varies considerably depending upon the jhum cycle and the intensity and duration of cropping. Thus, Toky and Ramakrishnan (1983a) reported four types of early succession where herbaceous community dominate. This phase is then replaced gradually by bamboo, ~~and~~ shrubs and trees. If the jhum cycle is very short, succession would be arrested indefinitely at the pioneer weed stage (Saxena and Ramakrishnan, 1984b). This was also noted under 'Lua' forest in Thailand where Eupatorium odoratum is a predominant weed (Zinke et al., 1978).

Clements (1916) and Odum (1969) in 'relay floristic model' pointed out that each set of species makes the environment less favourable for itself and more favourable for the following set of species. Such a replacement continues until community reaches its climax stage. While, Egler (1954) proposed 'initial florestic composition' dominates the subsequent stages of succession after a major perturbation. Saxena and Ramakrishnan (1984b) found that the early stages of secondary succession following the burning tended to confirm closely to the initial floristic composition model, under shorter jhum cycles of 4 and 6 years, but followed the relay florestics model under the longer jhum cycles of 10 and 20 years, further, the studies of Toky and Ramakrishnan (1983a) and Mishra and Ramakrishnan (1983c) showed that species diversity increased while dominance decreased during secondary succession.

In the recent past, attempts have been made to understand the processes of vegetation succession in terms of the properties and evolutionary strategies of the individual species. Succession was explained as a displacement of r-strategists adapted to dispersing and colonizing unoccupied sites by k-strategists, emphasizing on the efficient exploitation of the site (Loucks 1970; Pickett, 1976). Pickett (1976) stated that amelioration of the environmental extremes takes place during vegetation development and thus succession is a temporal gradient from high stress to low stress taking into consideration other plant interactions like allelopathy, nitrogen fixation and herbivore-predator effects. Grime (1974; 1977) described three primary strategies in plants which are related to their ability to withstand disturbance, competition and stress. According to him 'stress' is any factor that reduce the biomass including shading and nutrient depletion, except competition. He, explained that succession to be a process leading to a more stressful environment rather than amelioration of the environment as envisaged by Pickett (1976). Grime (1977) described succession as the replacement of species essentially with ruderal strategy by species with increasing stress tolerance. As the productivity of the site increases during succession, the shift is towards a competitive strategy.

Cornell and Slatyer (1977) proposed three distinct successional pathways: (i) facilitation pathway, similar to classical relay floristic pathway and operates in primary succession (Lawrence et al., 1967; Reiners et al., 1971), (ii) tolerance pathway which assumes that later successional species to be successful, whether or not early successional species have preceded them. However, this has not received evidence so far (Noble and Slatyer, 1977), (iii) Inhibition pathway describes situations where later species cannot grow to maturity in the presence of earlier ones (Keever, 1950; Parenti and Rice, 1969).

Whittaker and Lavine (1977) described four types of vegetation succession: (i) replacement succession which is similar to the relay floristic model, (ii) direct succession that assumes re-establishment of the pre-existing species after disturbance as in deserts and tundra, (iii) cyclic succession that refers to the cycles observed in chapparal due to recurrent fires, and (iv) mosaic succession that refers to the localized changes during vegetation succession.

Noble and Slatyer (1977) identified a variety of vital attributes, that determine: (i) method of arrival or persistance of the species at a site during and after the disturbance (ii) ability to establish and attain maturity in a developing community and (iii) time taken for the species to reach critical stages in the life history. These authors emphasized that vital attributes may form the basis of evolutionary trends during succession.

DEMOGRAPHY AND POPULATION DYNAMICS

Mortality/natality patterns:

The populations of colonizing species pass through a variety of growth phases with time. Initially, the population grows exponentially till the resources become limiting. In due course of time, if natality and mortality become equal, the population size gets stabilized showing fluctuations around a mean value. During this period, growth of such populations with similar resource needs, however brings about certain changes in the environment. This change may prove unsuitable for early colonizers resulting in local extinction due to increased mortality.

Existence and elimination of population of a species, from a given environment solely depends upon its ability to adjust with the changing environment. This change in environment may directly reflect fluctuations in population size. These fluctuations in population size are termed as population dynamics by Elton (1933). According to him it concerns with rate of increase and decrease and the influence of the environmental factors on the size of the population.

Lotka (1931) and Volterra (1931) proposed separately different theoretical equations for calculating population growth rate based on birth, death, immigration and emigration rates which were confirmed by Gause (1934). Gause (1934) put forward the famous 'Gause hypothesis' which suggests that two species having identical ecological niches cannot survive together for a long time; eventually one will replace the other.

The early seedling phase of a plants life is generally considered the most risky and this risk in exaggerated due to increasing density of the same or another species (Harper and White, 1974; Cook, 1979; Smith, 1984). When individuals of a species are released into a favourable environment their number increases rapidly at first and then stabilizes, thus implying, that it is the population size which itself in some way regulates the rate of population growth (Harper and Gajic, 1961). Individuals may respond to density in two ways: (i) a reduction in seed output or lowered rate of vegetative reproduction and (ii) a reduction in the chance of individual survival (Harper and Gajic, 1961; Ramakrishnan and Kumar, 1971). Just as in a population of single species density stress intensifies the expression of small differences (genetic and environmental) between individuals, so too in mixed populations stress may exaggerate and exploit inter-specific differences. The experimental model of deWit (1961) ~~are~~ is superbly designed to study the behaviour of two species in mixture. In this model the two species are grown together at varied proportions while overall density of the mixture is maintained constant.

The behaviour of two or more species growing together and interfering with each others mechanism of population control is of great interest. An understanding of the ways in which one species succeeds at the expense of another and the ways in which plant species may co-habit with in a relatively stable community without one succeeding at the expense of another, must depend on a knowledge of the manner in which populations are controlled (McNaughton and Harper, 1960; Ramakrishnan and Jeet, 1972).

The populations of Avena fatua and Avena barbata have properties of self-regulating systems in which frequency dependent selections allow stable co-habitation of two species. Under experimental conditions regulation in both species acted through a plastic response to density as opposed to a predominantly mortal response involving changes in survival rates (Marshal and Jain, 1969). The studies by Ramakrishnan and Jeet (1972) on the competitive relationship existing between Argemone species indicate that A. mexicana reacts more sensitively to intra-specific competition than A. ochroleuca.

Population regulation operates via density dependent processes of mortality and fecundity. A density-dependent mortality factor is one that relaxes as population density declines, and thereby slows or halts population decrease. When population density increases, a density dependent mortality factor kills an increasing proportion of the population. An example is seen in the relationship between seedling survival and the original density of seeds in the Wisconsin population of Acer saccharum studied by Hett (1971). Density-dependent fecundity may also regulate population size by the production of fewer seeds per plant as population density rises (Watkinson and Harper, 1978; Smith, 1983).

As plants in a dense population become larger with age, the density of individuals in the population decreases due to mortality. For, as long as the relationship between mean plant weight and density is governed by a line with slope -3/2, total plant weight will increase. This is because mean plant weight is increasing faster than density is falling is called 'self-thinning'. White (1980) observed this quantitatively in about eighty species of trees and herbs.

A great deal of literature has accumulated on the mortality rates of plant populations over about two decades. Deevey (1947) on the basis of work with different populations concluded that, in general, the individuals follow three types of death/decay patterns.

A cohort with Deevey type I survivorship has low mortality in early and middle life but a rapid change to high mortality latter on. Type II survivorship is typified by a constant death risk through out the life cycle. Type III is a pattern of high juvenile and low adult mortality by long-lived plant species. Juvenile mortality has been observed in the seedling populations of various weed species (Hett, 1971; Sharitz and McCormick, 1973; Sarukhan and Harper, 1973). This period seems to occur at the transition stage between the dependence of seedlings on seed food reserves, and their establishment when they start independent assimilation. Seedling mortality may be due to factors such as drought Cavers and Harper 1967; Friedman and Graham, 1975;

In most of the plant population studies the survivorship curves have been found to be Deevey type II which implies constant death risk throughout the life span of the population. The studies on the mortality pattern of maize done by Kumar and Ramakrishnan (1971) also showed that mortality is a continuing risk that the population has to put up with throughout its life cycle. However, in Denthoria caespitosa, Williams (1970) observed Deevey type III survivorship curve with heaviest mortality in the young stage. In contrast, Canfield (1957) observed Deevey type I survivorship curve with less risk of death in young and middle period of age and high mortality risk in old age in Trichacha catifornia, Bautelous hirsuta and B. chondrosioides.

Demography:

The life history of annual plants is unique because the actively growing fraction of the population must be derived each year entirely from the seed bank. Annual plant species are excluded from habitats where there is dense cover of perennial species, and they occur mainly on sites where disturbance or physical stress inhibits the formation of a dense community of perennials (Harper, 1977; Grime, 1979; Hickman, 1979).

Annuals commonly colonize temporarily available habitats such as recently disturbed fields. Annuals growing on these habitats exhibit a variety of demographic patterns negatively skewed (Deevey, 1947, Type I) survivorship among individuals following germination comparatively low seed production and few seeds that survive in the soil for more than 9 months (Mack, 1976; Watkinson and Harper, 1978; Leverich and Levin, 1979). In contrast, other species are characterized by high seedling mortality (Deevey Type II and III), have higher fecundity, or have a substantial proportion of seeds that survive in the soil for at least one year (Beatley, 1967; Naylor, 1972; Sharitz and McCormick, 1973; Symonides, 1974; Hickman, 1975; 1977; Jefferies, et al., 1981). Kelmow and Raynal (1983) suggested that survival and percentage repro-duction of plant that emerged in the spring varied markedly depending upon rainfall. Deevey survivorship curves, Type I, II and III were observed in cohorts from a year with abundant rainfall or a year with intermittent rainfall. Zimmerman and Weis (1984) suggested that in a beach population of Xanthium strumarium, seedling survival was largely density independent, while growth and fruit production declined signi-ficantly with increased density. He further suggested that soil moisture and the date of seedling emergence to be impor-tant to the recruitment of seedlings in a natural population.

A number of studies are available now on population dynamics of perennial herbs. Sarukhan and Harper (1973) made a detailed study of demography of three species of Ranunculus in a grassland situation which was subsequently analysed mathe-matically by Sarukhan and Gadgil (1974). Hawthorn and Cavers (1976) studied the demography of the perennial herb, Plantago major and P. rugeli.

Kushwaha et al., (1981) showed that seedling mortality increased with the age of the fallow starting with 1,3,5, 10 and 20 years after slash and burn agriculture in Eupatorium odoratum. No recruitment occurred in 10- and 20-year-old fallows. Ramakrishnan and Mishra (1981) studied the population dynamics of Eupatorium adenophorum in fallows after slash and burn agriculture at higher elevations of north-eastern India and observed a net population increase through both vegetative and sexual reproduction in early successional fallows up to 6-years. Mortality of seedlings was high in 1- and 3-year fallows, low in 6-year fallow and reached 100% in older fallows. Further, they showed that seedling mortality was maximum during monsoon although some seedlings dies in winter too as a result of drought and frost.Kushwaha et al. (1983) studied the population dynamics of Imperata cylindrica in successional communities after slash and burn agriculture in different fallows of 1, 3, and 5 years age and observed that the loss in population in different fallows was due to reduced light penetration and greater moisture stress in these fast developing communities, resulting in complete elemination during the seventh year of fallow regrowth. Only the 0-year old fallow, where the plant cover was sparse, had maximum recruitment. Similar results were observed by Sharma (1985) while studying the population dynamics of Imperata cylindrica related to slash and burn agriculture in north-eastern India at different altitudes. Similarly, a number of studies on the demography of forest herbs are available (Hutchings and Barkham, 1976; Ernst, 1979; Barkham, 1980;

Cook, 1980; Solbrig _et al._, 1980; Holland, 1981; Solbrig, 1981; Wells, 1981; Bierzychudek, 1982a; Cook and Lyons, 1983; Hutchings, 1983).

In plant populations, there are two levels of population behaviour: the number of plants and the number of shoot units per plant. This dualism is particularly conspicuous in clone-forming plants, where not only does the plant develop from single seedling as a sub-population of parts, but some of these parts may also root and eventually become severed from the original. The result is a sub-population of wholly discrete functional units, "ramets" with the genetic identity of the single individual, the "genet". Thus, the clonal growth of rhizomatous plant involves the continued reduplication of discrete modular units, the 'ramets' the sum of these units representing the 'genet' or product of single zygote (Harper and White, 1974). Recruitment of new genets is often rare among clonal plants, and the dynamics of their population is dominated more by the birth and death of clonal modules than of whole genets. The ability of single genotype to form fragmented phenotypes is just one of the variants in the life-history patterns of modular organisms (Harper and Bell, 1979).

In most of the studies available on clonal perennials, ramets were treated as units of population (Sarukhan and Harper, 1973; Solbrig et al., 1981; Cook 1983; Pitelka _et al._, 1985; Harnett and Bazzaz, 1985). Lovett-Doust (1981) studied the population dynamics of Ranunculus repens in contrasting habitats but growing on the same substrate. She concluded that despite the presence of large viable seed bank in the grassland soil, germination and establishment of new genets was rare in both sites. Further she stated that the birth rate of ramets per rosette was apparently density-independent, but death rate per rosette was density dependent, particularly in summer. She also observed woodland populations follow an opportunistic strategy for rapid spread and sampling of the environment where as the conservative one for consolidation and slower radial spread as in the adjacent grassland. Pitelka et al. (1985) too found similar results, while dealing with Clintonia borealis. Here too no seedling recruitment was observed, while ramet mortality was found to be density-dependent.

Plant demography has been used to elucidate aspects of ecological succession (Sharitz and McCormick, 1972; Raynal, 1979; Kushwaha et al., 1981; 1983; Mishra and Ramakrishnan, 1981; Cook and Lyons, 1983), Comparison of closely related species (Sarukhan and Harper, 1973; Hawthorn and Cavers, 1976; Solbrig, 1981; Yadav and Tripathi, 1981), differences between populations of the same species growing on contrasting soil types (Bishop et al., 1978) populations growing on the same substrate but in contrasting vegetation (Lovett-Doust, 1981) and populations growing at different altitudes (Sharma, 1985).

Age structure:

The most reliable method for estimating the age of perennial species is to follow the fate of labelled seedling or tillers of known age in permanent quadrats. This method has been successfully used by Tamm (1956). In *Anthoxanthum odoratum*, Antonovics (1972) observed that different populations have different longevity according to their adaptation to a particular habitat and suggested that differences in longevity of individuals of different populations may be related to environmental conditions.

Age structure of a population refers to the categorization of individuals into various groups representing different age classes in a population. Age structure of a species may largely determine its survivorship. Williams (1970) and Antonovics (1972) observed differential decay rates for the individuals recruited at different times. It also give valuable information about the recruitment of new individuals to the population, the transition of individuals from one age-group to another age-group, the number of individuals reproducing and also the mortality rate as influenced by age (Rabotnov, 1978).

PLANT STRATEGY ANALYSIS

Growth and nutrition:

Light has been recognized as a major factor influencing the replacement of species during secondary succession (Kushwaha and Ramakrishnan 1982; Bormann et al., 1968; Marks, 1974; Bazzaz, 1979). Competition for light and nutrients increases through succession, in general. In early succession rapid growth, which depends upon abundant resources, is advantageous. Later in succession such resources may be less available, and those plants with inherently high growth rates and resource requirements may not survive.

Grime (1976) suggested that shade adapted climax tree species may have lower growth rate than the sun adapted early successional ones. Such a differential strategy for early vs. late successional trees have been shown by Ramakrishnan et al. (1982) through a series of studies. Ruderal and competitive species have higher relative growth rates compared to stress tolerant species (Grime, 1976). This indicates slower relative growth rate in late succession, both due to the high expenditure of carbon in maintenance of living but non-productive tissues and to decreased mineral availability to support further growth. Late successional species seldom exhibit high relative growth rate of early invaders. Their low relative growth rate puts them at a disadvantage in early succession, but because of their higher tolerance limits of low annual resources these species maintain a positive relative growth rate even in late succession and eventually become dominant (Grime, 1977; Connell and Slatyer, 1977, Ramakrishnan et al., 1982).

Nutrient requirement of secondary successional species is important to predict the successional changes specifically in nutrient poor soil fields abandoned after cultivation. Such species are expected to have efficient system to withstand the lower nutrient availability in the soil (Vazques-Yanes and Gomez-Pompa, 1974). Kellman (1969) suggested low nutrient requirements for early secondary species and an increase in the resource apparently did not affect the course of succession. A similar conclusion was also made by Harcombe (1972) through his studies on Cercopia obtusifolia. West and Chilcote (1968) explained that the disappearance of Senecio sylvaticus in the second year after slash and burn of douglas fir areas was due to its high nutrient requirement but decrease in nutrient availability particularly of nitrogen and phosphorus, in soils after one year of vegetation development.

Chapin (1980) stated that plants with high relative growth rate have high nutrient requirement to support new tissue production and rapid root production and leaf turnover.

At the opposite extreme, infertile soils are most successfully exploited by stress tolerant species whose inherently low growth rates can be adequately maintained by their low capacities for photosynthesis and nutrient absorption. Fast growing tree species such as Pinus kesiya in nutrient poor soils however, adapt a strategy for rapid nutrient turnover rates so that a high flux of soil nutrient pool is maintained (Ramakrishnan and ~~Kumar~~ Das, 1983; ~~Kumar~~ Das and Ramakrishnan, 1985).

A high efficiency of nutrient use, generally expressed as drymatter production per gram nutrient (inverse of tissue concentration) has been suggested to be an adaptation to nutrient stress (Loneragan and Asher, 1967; Jefferey, 1968; White, 1972; 1973; Garten, 1978). However, such evolution may be sometimes misleading when there is luxury uptake and large vacuolar storage of nutrients (Bieleski 1973; Brady, 1973; Haynes and Goh, 1978). Small (1972) suggested that respiration photosynthetic or net assimilation rates per gram nutrient uptake may be a more strong expression of nutrient use efficiency. Infact, information on these aspects are meagre. Recently through a series of studies on nutrient uptake and use efficiencies of species, Ramakrishnan and co-workers (Saxena and Ramakrishnan, 1984; Ramakrishnan, 1985) drew attention to the adaptive value of this parameter over a successional gradient of environment.

Resource allocation and reproductive strategy:

Cody (1966) put forth a concept based on the principle allocation, which says that organisms have certain limited energy available to spend for different life purposes. Harper and Ogden (1970) applied it for the first time to Senecio vulgaris, and pointed out that the proportion of allocation of biomass may reflect the pattern of energy allocation provided there is strong correlation between total biomass and total calories. This was later supported by others (Gadgil, 1973; Hickman and Pitelka, 1975). Harper and Ogden (1970) also suggested certain major patterns of energy allocation in annual, biennial and perennial plants based on quantitative analysis. In annual plant species much of the energy is devoted to reproductive structures whereas in perennials emphasis is given on storage of energy for future growth and development, at the expense of the reproductive budget (Hickman, 1975; Peterson and Bazzaz, 1978; Bell *et al.*, 1979).

McArthur and Wilson (1967) pointed out that organisms in an open environment are selected for greater reproductive potential (r-selection) where as organisms in a closed environment are selected for greater competitive ability (k-selection). Gadgil and Solbrig (1972) expanded the concept of r- and k-selection in plants and tried to formulate them more rigorously. They emphasized on the r-strategy by invoking patterns of mortality rather than 'fullness' of habitat. The central idea of r- and k-selection has been considered from a number of other aspects like duration of life cycle and propagation ability in a crowded of uncrowded environment (Fischer, 1958; Williams, 1966; Gadgil and Bossert, 1970; Pinaka, 1970; Wilber et al., 1974). Abrahamson and Gadgil (1973) suggested that the reproductive effort should decrease under shaded condition as more emphasis is given for vegetative grwoth, for survival of the plants here. Similar resource allocation patterns have also been shown by a number of other workers (Abrahamson and Gadgil, 1973; Gaines et al., 1974; Roos and Quinn, 1977; Saxena and Ramakrishnan, 1984a).

The importance of stress and disturbed condition in the allocation of biomass was considered by Grime (1974). 'Disturbance' was defined by them as any factor that limits and cause destruction of biomass like herbivory, pathogenicity and human activities. Thus, Grime (1974, 1979) recognized stress tolerance as a strategy of plants under unproductive environments.

While considerable work has been done on the allocation of biomass or energy to different life purposes, very few studies are available on the allocation of nutrients which is also equally important in the evolution of reproductive strategy, particularly in situations with limited supply of nutrients (Harper and Ogden, 1970; Van Andel and Vera, 1977). Saxena and Ramakrishnan (1983a) studied the growth allocation pattern and nutritional status of some dominant annual weeds under successional environment and observed differences in their biomass and nutrient allocation pattern. Reproductive allocation of nitrogen and phosphorus was higher than that of biomass and potassium in these annuals. They further showed that allocation of biomass and nutrients to leaves decreased during growth and this was more pronounced at the time of reproduction. Saxena and Ramakrishnan (1983b) also studied the growth and allocation pattern of drymatter and nutrients in four important perennial weeds. They observed that the perennials often tend to allocate more to vegetative reproductive organs compared the allocation to sexual reproduction. Further, C_4 perennials such as Imperata cylindrica and Thysonolenna maxima were shown to be adapted to survive under nutrient poor micro-sites of a heterogenous soil as opposed to C_3 species which were often confined to nutrient rich micro-sites. This is because of the high nutrient use efficiency of C_4 species particularly with respect to nitrogen compared with C_3 species.

PRODUCTIVITY AND NUTRIENT CYCLING UNDER
EARLY SUCCESSIONAL ENVIRONMENT

A sharp increase in the aboveground biomass occurs during secondary succession. According to Lugo (1973) maximum biomass value for tropical forests is approached in about 30 years at a level of 250 t. ha^{-1}, where for temperat forests it was about 490 t. ha^{-1} is about 170 years only (Borman and Likens; 1979). Thus, a steady-state for biomass is reached over a shorter time period in the tropics than in the temperate forests.

The rate of accumulation of biomass is faster in the early stages of succession but may decline in the subsequent years the rate also depends upon the type of initial vegetation established and other environmental conditions. (Uhl and Jordan, 1983; Toky and Ramakrishnan, 1983; Mishra and Ramakrishnan, 1983).

During development of vegetation, a part of the nutrient pool is stored in the vegetation and part is returned to the surface soil by rain wast from leaves and twigs, by litter and twig fall, and in the form of dead roots and root exudates. The soil humus is increased during fallow period, chiefly as a result of litter fall. High litter production during secondary successional stages compared to the mature stage was reported by many workers (Ewel, 1976; Toky and Ramakrishnan, 1983a; Mishra and Ramakrishnan, 1983c; Uhl and Jordan, 1983).

A large body of information is available on nutrient cycling in forested ecosystems (Laudelot and Meyer 1954; Greenland and Kowal, 1960; Odum, 1970; Stark, 1970; Golley et al., 1977; Toky and Ramakrishnan, 1983a; Mishra and Ramakrishnan, 1983c). Though the information is limited, some patterns are suggested: (i) the uptake and return of nutrients may be greater per year in tropical forests than in other type of vegetation, (ii) a larger proportion of the entire chemical inventory of the system is held in the vegetation, (iii) in tropical forests the percentage of the vegetation in green parts, the proportion lost per year as litter, and the rate of decomposition of the litter are greater than in temperate forests and (iv) the rate of uptake is strongly influenced by the rate of evapotranspiration.

Mineral cycling probably varies with the nutrient supply to the system, with the time available for the system to develop on the site, and also the environmental conditions. The accumulation of nutrients and their release through litter fall increases with the age of the fallow and become stabilized in mature forests (Stark, 1971a,b; Toky and Ramakrishnan, 1983a; Mishra and Ramakrishnan, 1983c).

The role of rapidly growing successional species in the restoration of disturbed ecosystems has recently become a problem of considerable interest. In general, rapid revegetation of a disturbed site decreases nutrient losses by an interaction of several factors (Marks and Bormann, 1972). The channelling of water into evapotranspiration cuts down on losses of nutrients in run-off and erosion. Shading decreases soil temperature, which results in lowered decomposition and nitrification rates and reduced supply of water-soluble ions available for removal of drainage water. Growing vegetation also reduces nitrient losses by incorporating nutrients into developing biomass (Vitousek and Reiners,1975). This reduction of nutrient losses by developing plant biomass has important consequences for ecosystem stability. Ecosystems that recover nutrient cycling capability more rapidly (i.e. nutrient uptake equivalent to potential losses) can be considered more resilient and this more stable. Marks (1974) investigated functional role of a successional species such as pin cherry (Prunus pensylvanica) in disturbed areas of northern hardwood forests. Pin cherry is a rapidly growing species which often occurs in dense stands in disturbed sites. It appears to be effective in preventing nutrient loss by the rapid accretion of elements into its biomass. Marks concluded that pin cherry 'promotes ecosystem stability by biotic regulation of ecosystem functions. In another study Harcombe (1977a,b) experimentally analysed the role of successional vegetation in retaining nutrients within disturbed systems in a tropical forest ecosystem. Further, Foster et al.(1980)

studied the effect of ragweed (*Ambrosia artemissifolia*) on nutrient cycling in a 1st year old field and showed its conservatory role of nutrients. Similarly the early succession weeds under slash and burn agriculture system drastically check run-off and infiltration losses of nutrients and sediment losses in the very first year of the fallow phase after cropping (Toky and Ramakrishnan, 1981b; Mishra and Ramakrishnan, 1983a; Ramakrishnan *et al.*, 1981a).

Nutrient budget analysis under slash and burn agriculture:

The long term success of slash and burn agriculture depends upon the recovery and maintenance of soil fertility. If the nutrient lost or displaced during the short period of cultivation are approximately balanced by those replaced during the fallow period, the system could continue indefinetly. The maintenance of soil fertility in hot, humid and high rainfall area is a serious problem and is more severe in situations where the cycle becomes short, due to poor recovery of soil fertility and increased intensity of weed competition. This in turn resulted in reduced crop yield under short cycles(Nye and Greenland, 1960; Watters, 1971; Toky and Ramakrishnan, 1981a; Mishra and Ramakrishnan, 1981).

When the forests are cleared and the debris is burnt, all the cations are released on the surface soil as ash.

Heavey losses of carbon, nitrogen and sulphur occur due to volatilization during the burn (Nye and Greenland, 1960; De las Sales and Folster, 1976; Ramakrishnan and Toky, 1981b; Mishra and Ramakrishnan, 1983b; 1984). For phosphorus though, there are no obvious mechanisms of volatilization, losses are reported through convection via particulates to the atmosphere (Freedman, 1981). There are conflicting reports on addition of phosphorus through fire, (Nye and Greenland, 1960; Stark, 1971; Stromgaard, 1984) and others suggesting some losses from the system (Harwood and Jackson, 1975; Ashton, 1976; Mishra and Ramakrishnan, 1983). Llyod (1971) reported massive losses for phosphorus through fire.

Carbon and nitrogen losses occurred from the slash and burn agriculture system during and after a year of cropping period (Nye and Greenland, 1960; Zinke et al. 1978; Ramakrishnan and Toky, 1981; Mishra and Ramakrishnan, 1983b). Similar to carbon losses, there is also a net loss of nitrogen after cropping compared to that of the pre-burn soil pool. Nitrification after the burn is shown to be accelerated due to high microbial activity, due to rise in pH and temperature of the surface soil (Griffith, 1949; Moore and Jaiyebo, 1963; Ahlgren and Ahlgren, 1965). This increase is attributed partially to the removal of chemical inhibitors (Reed, 1951; Smith et al., 1968; Rice, 1974; Saxena and Ramakrishnan, 1986).

Deforestation for shifting agriculture or other needs has a major impact on both the amount and relative proportions of water, dissolved substances and particulate matter lost from the system. Moreover, the total concentration of cations in the soil solutions depends upon the concentration of anions. A high level of nitrate ion due to increased 'biological activity' (Ahlgren and Ahlgren, 1960; Weels, 1971) after burning balances ... corresponding concentration of cations in the soil solution and therefore heavy losses through water occurs (Bormann et al., 1968; Lewis Jr. 1974). The loss of water, nutrients and sediment gets reduced as crop and weed cover is establish (Toky and Ramakrishnan, 1981b; Mishra and Ramakrishnan, 1983a), with a transfer from soil to the plant biomass.

At the end of the cropping period during slash and burn agriculture at higher elevations of Meghalaya, Mishra and Ramakrishnan (1984) estimated nitrogen losses from the agroecosystems to be about 640 Kg ha^{-1}. Information on nutrient budgeting in agroecosystem also meagre. Agroecosystems are open systems in which biogeochemical functions consists of inputs from various sources, outputs to various sinks and a variable degree of internal cycling.

WEEDS UNDER SHIFTING AGRICULTURE

Weed potential:

Weeds are the major cause of declining yield under slash and burn agriculture in many parts of the world and include

Eupatorium odoratum in Thailand (Zinke *et al.*, 1978) and *Imperata cylindrica* in Sarwak (Freeman, 1955). Cutting *et al.* (1959) reported that the yield of maize in Nyasaland was 4284 Kg ha^{-1} when weeded four weeks after germination, but attained only 3217 Kg ha^{-1} when weeded six weeks after germination. Emerson (1953), describes the influence of weeds on the 'milpa' system in tropical America, in which successive crops of maize, mixed with beans, are grown. The second crop yielded less than the first, probably because it was more weedy and therefore farmers like to clear a fresh land than to continue cropping on the old plot. Toky and Ramakrishnan (1981) and Mishra and Ramakrishnan (1981) reported that under shorter jhum cycles the weed problem was severe due to arrested succession by exotic weeds in north-eastern India.

Conklin (1957) estimated that a Hanunoo farmer in the Philippines spends about 300 man-hours per hectare in weeding the first year land cleared from primary forest and about 600 man-hours on land cleared from secondary forest about 20 years old. Mishra and Ramakrishnan (1981) reported that weeding is one of the energy consuming tasks performed by women folk. They further indicated that this task is more energy consuming under shorter cycles under slash and burn agriculture in north-eastern India, also confirmed by Toky and Ramakrishnan (1982).

The non-weed concept:

Recently weeds have been viewed as an useful component in agroecosystems and may pay an important role in agricultural management of the future. Studies by Chacon and Gliessman (1982), Saxena and Ramakrishnan (1984), Mishra and Ramakrishnan (1984) suggested that the non-weed concept where, weeds have a useful role to play, is an essential ingredient of traditional agroecosystems in different parts of the world and in the north-eastern India. Tripathi (1977) analysed the possible consequences of a complete eradication of the weed flora from agroecosystems. Alteiri (1983) on the basis of a detailed review emphasized upon weed management as opposed to weed control.

Obviously, one of the important roles of the weeds in the cropland is related to reduction in soil erosion, protection of the soil surface from solar radiation and improved soil micro-climate (Moody, 1975; Tripathi, 1977; Chacon and Gliessman, 1982). Ramakrishnan and his co-workers (Toky and Ramakrishnan, 1981; Mishra and Ramakrishnan, 1983a) studied the reduction of soil erosion by weeds in jhum lands and observed considerable loss of nutrients before the plant cover is established. The role of weeds in checking run-off and infiltration losses becomes obvious in a 5-year old weed dominated jhum fallow, as compared to the losses during the cropping phase.

Another important positive role of the weed lies in the recycling of the nutrients, through organic manure. Mishra and Ramakrishnan (1984) studied nitrogen budget of three jhum cycles of 15-, 10-, and 5-years at higher elevation of Meghalaya, where nitrogen recycled through weeds was estimated to range from 4.8 to 20.8 Kg ha^{-1} of which about 1/6th is ploughed back into the soil and the rest is routed eventually via the manure pit of the village ecosystem (Mishra and Ramakrishnan, 1982).

Crop residues and weeded out biomass is used as a mulch by the farmers of Tanzania (Acland, 1971). Stigter argued that mulch used as shade by the traditional farmer of Tanzania is for the management of micro-climate in order to increase land productivity and yield capacity. De Schlippe (1956) indicated that weeds are useful elements in maintaining soil fertility in agroecosystems.

A variety of weeds are also used as food. The plants like Gnetum montanum and G. gnemon are important foods of the Naga tribe (Ramakrishnan, 1984). Leaves of Amaranthus sp., Chenopodium album, Portuluca olevacea, Celosia argentia, Euphorbia caducifolia are used as vegetables. Rhizomes of Typha when pulverized yield a sweet flour. Eichchornia crassipes has been recommended as a poultry feed. Weeds also have many other general uses. Dry bushes of Capparis decidua, Crotalaria burhia and Imperata cylindrica are used as thatching material. Thysanolaena maxima is used for brooms. Hedychium is used as a medicine for insect bite.

Natural weed management in slash and burn agriculture (jhum) is dependent upon the length of the fallow phase after the land is cropped. The weeds being the predominant component of the early successional communities upto 5 years of fallow regrowth (Toky and Ramakrishnan, 1983a), continuous imposition of short cycles of 5 years or less tends to exaggerate the weed potential in the cropping system.

Present study:

Slash and burn agriculture popularly called 'jhum' in India and variously termed locally in the country (Takenglu in Nagaland, Dawar or Dipa in Madhya Pradesh, Kumri in Western ghat region or podu in Orissa) is a common land use practice in the humid tropics throughout the world (known as Milpa in central America, Zande in Africa, Chena in Sri Lanka, Kaingin in Philippines and Tsembaga in Papua New Guinea). It involves slash and burn of the vegetation followed by mixed cropping for a year or two before the land is abandoned for natural regeneration for a few years, before coming back to the same site for cropping.This fallow period between two successive croppings at the same site, representing one cycle was fairly long in north-east India (20-30 years) in the past. However in the recent past, it has come down to 4-5 years due to increased population pressure and reduced ac age available for cropping. This has often resulted in an arrested succession at the weed stage (Saxena and Ramakrishnan, 1984b), which in turn has drastically degraded the quality of environment in terms of vegetational cover and soil fertility (Ramakrishnan and Toky, 1981). This was critically reviewed by Ramakrishnan (1985a) based on over a decades research experience by his group in this field of specialization. In an another review (1984) he also focussed upon the science behind shifting agriculture and its value for an integrated development of the tribal areas of the north-east India.

As a result of perturbation to the forest ecosystem by man or by natural means such as fire will drastically affect the environment in the tropics and sub-tropics due to their fragile nature, Considerable attention has been given to study the processes involved in the recovery pattern through a descriptive approach (Kenoyer, 1929; Budowsky, 1961), evolutionary approach (Gomez- Pompa, 1971), population approach (Sarukhan, 1964) an ecosystem approach (Franforth and Golley, 1974; Ramakrishnan *et al.*, 1983). However, our knowledge of the adaptive strategy of individual species under a varied environment after perturbation is more important for better understanding of the vegetation recovery process. The need for such studies has been emphasized by many workers (Gomez-Pompa and Vazquez-Yanes, 1974; Golley and Medina, 1975; Bazzaz, 1979; Toky and Ramakrishnan, 1982; Saxena and Ramakrishnan, 1984b).

Mikania genus with about 250 species of herbaceous or slightly woody vines belongs to the family compositae (Asteraceae). Most commonly known species are *M. cordata*, which is native to the old world *M. scandens*, which is confined to north-America and M. micrantha, which is a native of tropical America and Caribbean region. It is now reported to be in Asia and the south Pacific (Parker, 1972). Parker (1972) also reported this species from Assam and Kerala in India, Bangladesh, Sri Lanka, Malaysia and Indonesia and concluded that this may one of the most aggressive weed in the continent. Robinson (1934) stressed the need of more taxonomic work on *Mikania sp.* of the old world and Pacific islands.

Mikania propagates both through sexual and asexual means. It produces thousands of wind dispersed seeds. Thus hand weeding or cultivation without destruction or drying of stems may do little to control this weed (Holm *et al.*, 1978). Craig and Evans (1946) reproted an alarming rate of spread of *M. cordata*, due to the movement of stem materials by streams is an important means of dispersal. However, (Bamber, 1909; Burkill, 1935; King, 1966) its dispersal in the old world may be through its use as a ground cover, which is a recommended practice in Sri Lanka, Indonesia and Malaysia.

Mikania species occur in open and disturbed places. It is common in young secondary forests (Toky and Ramakrishnan, 1983a) in forest clearings and in plantation crops (Borthakur, 1977; Dutta, 1977) and Wastelands. *M. cordata* grows in partial shade but can not tolerate dense shade (Macalpine, 1959). Burkill (1935), and Craig and Evans (1946) stated that *M. cordata* takes up large quantities of potassium. According to Caum (1940) coconut and other tree crops in Malaysia were abandoned because of intrusion by *M. cordata*, Further, he described large bread fruit trees (*Artocarpus altilis*) being killed by this weed.

Due to its aggressive growth habit, this species competes with seedlings and mature crops (Dutta, 1965), but is also makes plucking difficult when it grows over the top of tea bushes (Kasasian, 1971). There is evidence from Malaysia and Indonesia that the effects of M. cordata on a crop cover may extend beyond the normal competition for nutrients, ligh and soil moisture (Mainstone and Wong, 1966; Wong, 1964; Wycherley and Chandapillai, 1969; Seth, 1971). Guha and Watson (1958) found lower rates of nitrification in soils mixed with leaves and stems of M. cordata. However, it did not affect ammonification. Wong (1964) found that M. cordata contains substances which inhibit the growth of rubber and tomato plants. Water ectracts (1 and 2%) of oven-dried stem and leaf materials significantly depressed dry weight and nitrogen and phosphorus content of tomato seedlings. However, M. cordata has been reported to be susceptible to parasitic attack by Cuscuta chinensis in Sri Lanka (King, 1966).

M. cordata is used as a cure for snake bite and scropion bites in South Africa (Watt and Breyerbrandwijk, 1962) as a remedy for itch in Malaysia and poultice for wounds in Java (Burkill, 1935).

Little is known about such an important species as M. micrantha on its growth, biology and ecology. The present study therefore, was undertaken to investigate the demographic, ecophysiological and adaptive strategies of Mikania micrantha, a perennial vine under varied environment after slash and burn agriculture. An attempt has also been made to study the ecological role of this weed in successional fallows after shifting agriculture, in north-east India. An analysis of different weed husbandary practices both from ecological and economic view points was analysed and the present study also considers nutrient budgeting and internal cycling in slash and burn agriculture system under 5- and 20-year jhum cycles under varied weeding regimes, at lower elevation of north-eastern part of India.

STUDY AREA AND CLIMATE

The study area (Fig. I) is located at Lailad which is about 70 Km towards the northern side of Shillong city, the capital of Meghalaya in the north-eastern region of India. It lies between 25°45" - 26°0" N latitude and 91°45" - 92°0" E longitude at an elevation of about 296 m. The pre-cambrian rocks are represented by gneiss, schists and granites. The soil is red, sandy loam and is of laterite origin. The pH ranges from 5.8 to 6.3. Angles of the slopes generally range from 20° to 60°. The climate is typically monsoonic with about 84% of the total annual rainfall occurring during May to September. April and October are also quite wet. The rest of the period is practically dry. The monsoon season is followed by a mild winter during mid-November to mid-February. March and early April represent a brief dry summer period (Fig. II).

Fig. I.   Location of study area.

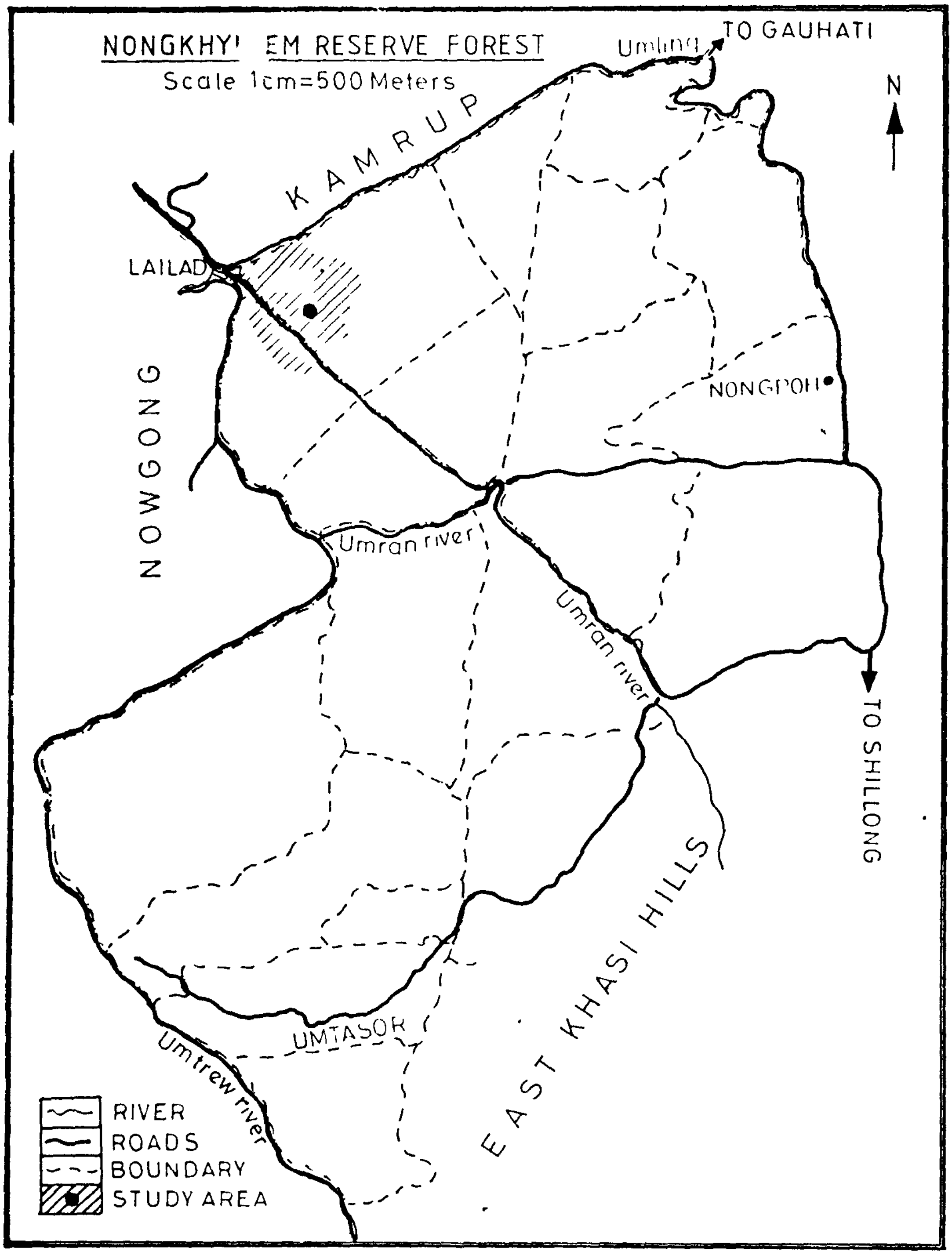
NONGKHYLLEM RESERVE FOREST
Scale 1cm=500 Meters
TO GAUHATI
N
KAMRUP
LAILAD
NOWGONG
NONGPOH
Umran river
Umran river
TO SHILLONG
EAST KHASI HILLS
UMTASOR
Umtrew river
RIVER
ROADS
BOUNDARY
STUDY AREA

Fig I

Fig. II. Ombrothermic diagram for the study area. Mean monthly maximum ( ) and minimum ( ) temperatures; monthly rainfall( )

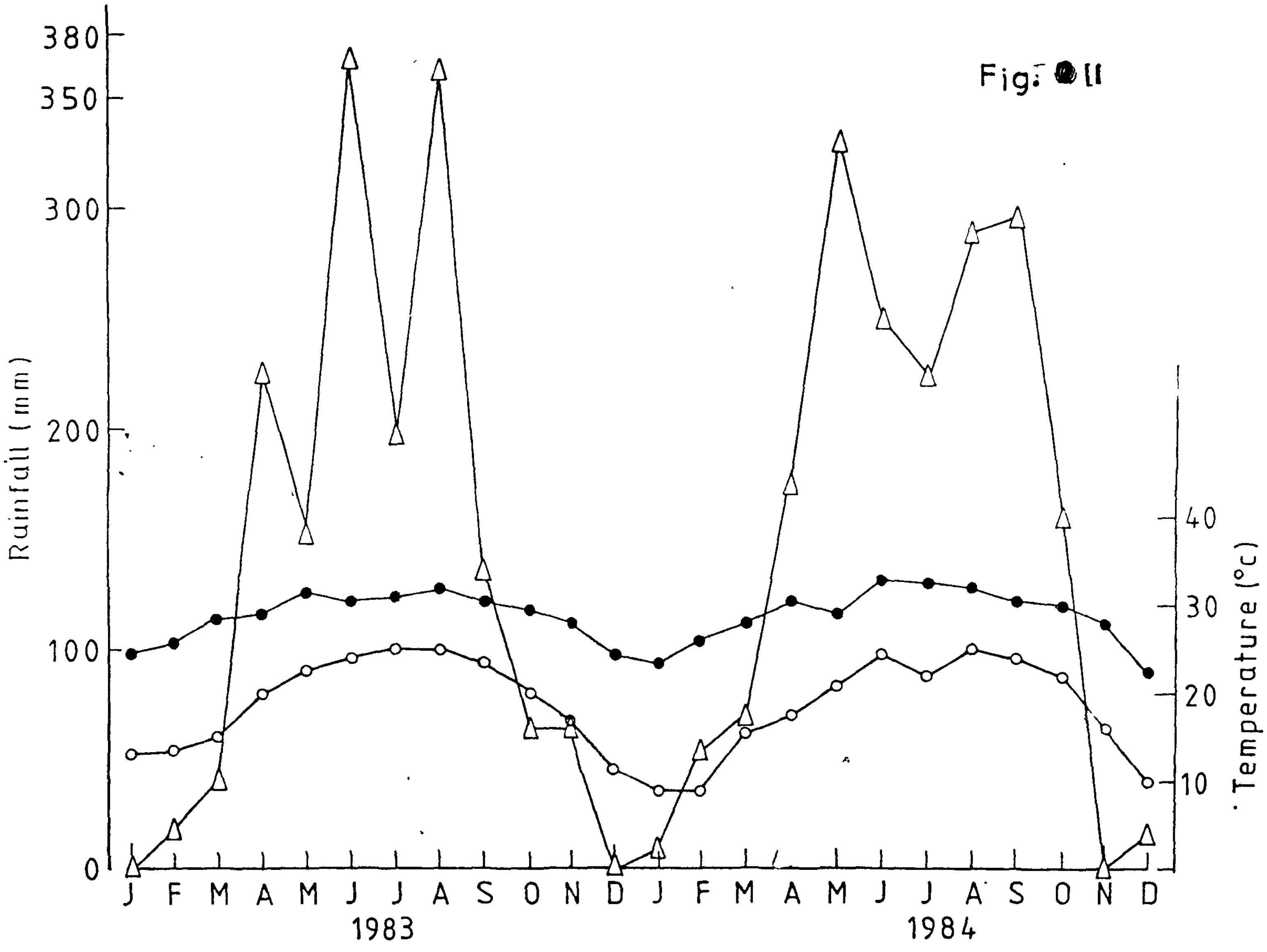
Rainfall (mm)
380
350
300
200
100
0
J F M A M J J A S O N D J F M A M J J A S O N D
1983
1984
Temperature (°c)
10
20
30
40

Fig. 11

****

CHAPTER 1

WEED POTENTIAL OF *MIKANIA MICRANTHA* H.B.K., AND ITS CONTROL IN FALLOWS AFTER SHIFTING AGRICULTURE (JHUM) IN NORTH-EAST INDIA.

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INTRODUCTION

Mikania micrantha Humboldt, Bonpland & Kunth, is an exotic perennial weed of the family Asteraceae and emerges as an early colonizer subsequent to slash and burn agriculture (Jhum) in north-east India (Toky and Ramakrishnan, 1983 a). The species was introduced as a non-legume ground cover for crops, but now seriously threatens various agricultural systems (Parker, 1972; Borthakur, 1977; Palit, 1981). It holds an advantage over many other weeds because of its vigorous vegetative and sexual reproduction. Research has been conducted on chemical (Dutta *et al.*, 1968; Dutta, 1977) and biological control (Cock, 1981) of *M. micrantha*, but no serious attempts have been made at understanding its growth and population biology under different ecological conditions. Such research is essential to devise effective control measures. The main purpose of the present investigation was to measure the relative performance of this species in terms of population size and reproductive behaviour in different successional communities developing after slash and burn agriculture (Jhum) in north-east India and their restriction and control during succession.

M. micrantha grows rapidly and has well defined ramets. The perennating caudex from the previous year produces an upright stem with 6-7 leaves in April and stolons arising from the axil of leaves. Each ramet has two expanded leaves on a node with a discrete root system. As the stolons extend, they often intermingle with the surrounding vegetation. Flowering occurs from October to late November. The plants die back to ground level during December-January.

METHODS

Five fallow plots of different ages (0,1,3,6 and 12 years) were identified around Lailad under similar topographic and exposure conditions, based on the records of the village headman. Age was calculated from the time the cropped plots were left fallow for natural regeneration of vegetation after slash and burn agriculture (land use with a 10-year jhum cycle). A 0-year-old fallow indicates first growing season of fallow following cropping.

Density, frequency and cover of the associated vegetation were studied using 1 X 1 m quadrats for herbaceous species and 10 X 10 m quadrats for shrubs and trees. The importance value index (IVI) was calculated using relative frequency, relative density and relative basal area of the species (Misra, 1968; Kershaw, 1973). The values were based on 20 quadrats at each site site with 2 to 2.5 hectares evaluated per site.

Demographic studies were carried out in randomly placed permanent quadrats of 0.5 X 0.5 m with ten replicates in each of the fallow plots. The fate of the ramets and the rosettes of established plants were followed from March 1982 to March 1983. Mapping of the vegetation was carried out at 2 week

Table 1.1. Importance indices of plant species associated with M. micrantha in different fallows.

Species	Age of fallow (Years) 0	1	3	6	12
Ageratum conyzoides L.	36.2	27.4	15.2	15.1	15.2
Borreria hispida K. Schum.	25.7	14.9	9.0	5.7	5.5
Desmodium triquitrum D.C.	5.0	5.5	8.0	12.5	18.6
Desmodium laxiflorum D.C.	3.5	3.9	4.7	8.3	11.6
Erigeron linifolius wild	16.1	10.1	6.0	2.7	-
Eupatorium odoratum Linn.	49.3	32.7	16.4	17.6	14.4
Imperata cylindrica Beaw.	-	3.2	8.8.	25.6	-
Hedychium cornonarium Koening	10.4	9.9	6.2	5.9	18.0
Ipomea pileata Roxb.	6.3	4.5	-	-	1.05
Mikania micrantha H.B.K.	16.4	46.5	60.5	32.7	20.1
Mucuna bracteata D.C.	4.9	5.8	6.9	6.4	-
Panicum maximum Munro	8.7	4.4.	4.6	4.9	4.7
Panicum khashianum Jav.	7.8	4.3	3.6	6.0	4.6
Thysanoleana maxima (Roxb.)O.Ktze	5.6	7.8	8.1	8.2	6.1
Clerodendrum colebrookianum Walp.	-	4.8	8.2	-	8.3
Litsaca assamica Hk.f.	3.5	9.1	11.5	9.8	7.5
Measa indica wall.	1.2	4.1	8.2	4.5	-
Melastoma malabathricum Linn.	6.9	8.0	8.7	10.4	12.0
Mussaenda roxiburghii Hk.f.	3.2	4.8	4.4	-	2.9
Anthocephalus cadamba Mev.	-	2.9	6.8	3.7	7.9
Cedrella toona Roxb.	4.6	-	3.9	-	4.0
Cinnamomum bejolghota (Buch.)Ham.	-	4.0	4.3	3.5	-
Calicarpa macrophylla Vahl	11.7	14.3	13.3.	6.7	14.4
Dendrocalamus hamiltonii Nees & Arn	32.9	20.5	29.1	55.6	82.9

...2/-

Sapium baccatum Roxb	7.9	12.8	7.1	11.3	11.1
Schima wallichii Choisy	5.7	6.0	2.6	7.4	10.6
Macaranga denticulata Muell	6.1	6.4	6.6	6.3	5.1
Sterculia villosa Roxb.	7.5	11.2	9.2	8.2	7.6
Hybiscus macrophyllus Roxb.	9.0	10.1	15.8	16.0	5.0
Duabanga sonneratioides Ham.	3.8	-	2.1	4.8	-

intervals. Ramet birth was recognized when a node bore two fully expanded leaves, and the death of the two expanded leaves was considered as the death of the ramet.

Biomass allocation studies were based on randomly selected rosettes, carefully removed from each plot, close to the permanent quadrats. A soil corer, 20 cm in diameter was centred on each plant and then pushed into the soil to a depth of 20-30 cm. This allowed harvesting of most of the root system which was then carefully cleaned. After separation the different components were dried at 60°C for 24 hours and weighed.

The average number of seeds per capitulum was based on 30 random observations per fallow. The number of capitula per unit area was based on 30, 0.5 X 0.5 m quadrats in each plot. These values were used for computing seeds per fertile ramet and seed output per m^2.

RESULTS

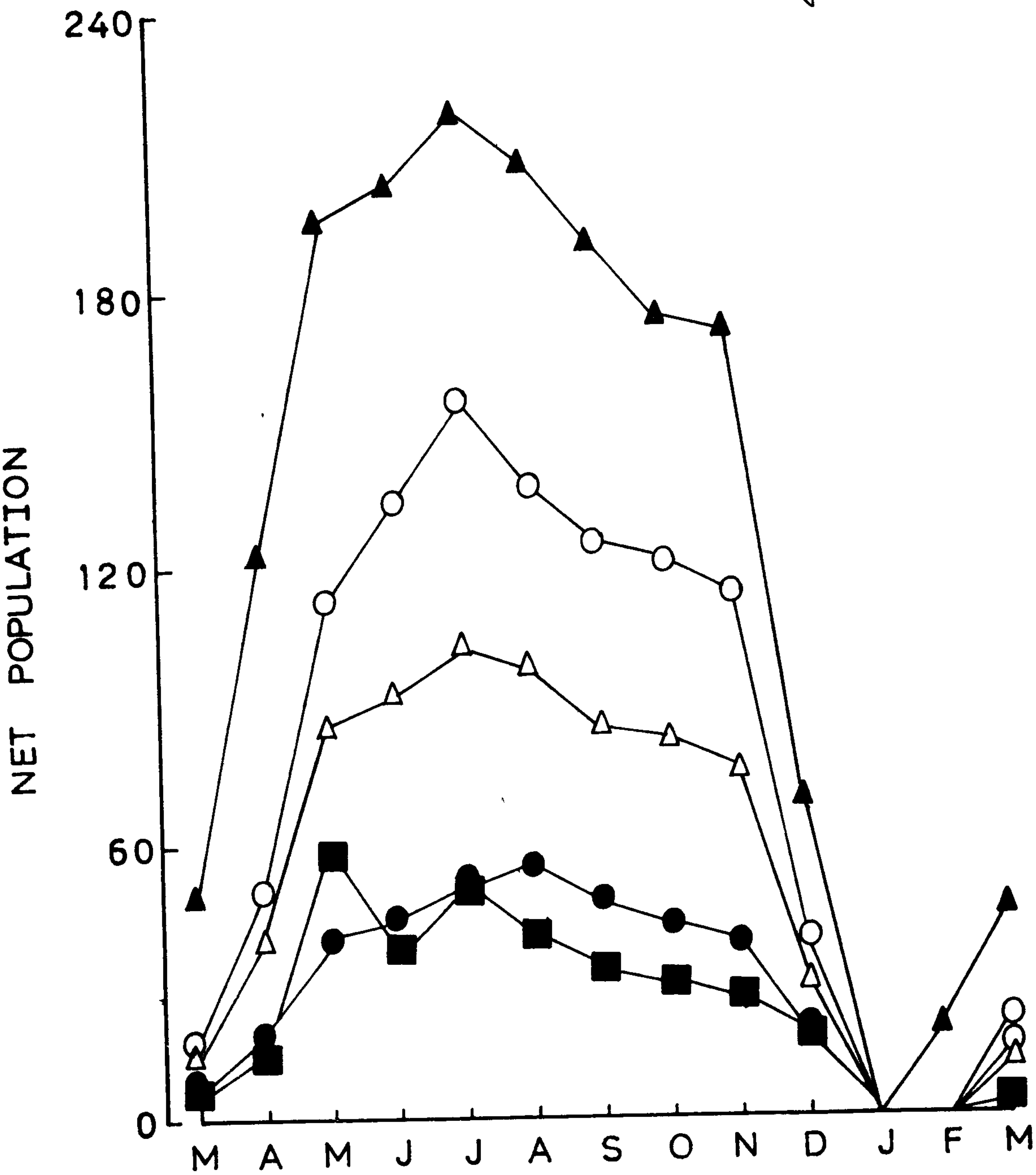
The early stages of secondary succession were dominated by a number of weedy species including Eupatorium odoratum, Ageratum conyzoides, Erigeron linifolius, Mikania micrantha and Imperata cylindrica (Table 1.1). Dendrocalamus hamiltonii was present in all plots, along with some tree species and a few shrub and vines. As the age of the fallow increased, the weedy stands were gradually replaced by D. hamiltonii, and various shrubs and trees.

Table 2 Fate of cohorts of seedlings of _M. micrantha_ in 6- and 12-year-old fallows

Cohort of the month	6-year-old fallow			12-year-old fallow		
	Seedlings recorded	Seedlings established before perennation	Rosettes produced after perennation	Seedlings recorded	Seedlings established before perennation	Rosettes produced after perennation
May	129	38	2	96	21	1
June	83	12	-	73	9	-
July	-	-	-	34	14	-

Fig. 1.1 : Net population size of <u>M. micrantha</u> in 0-year (●), 1-year (○), 3-year (▲), 6-year (△), and 12-year (■) old fallows.

Fig. 1.1



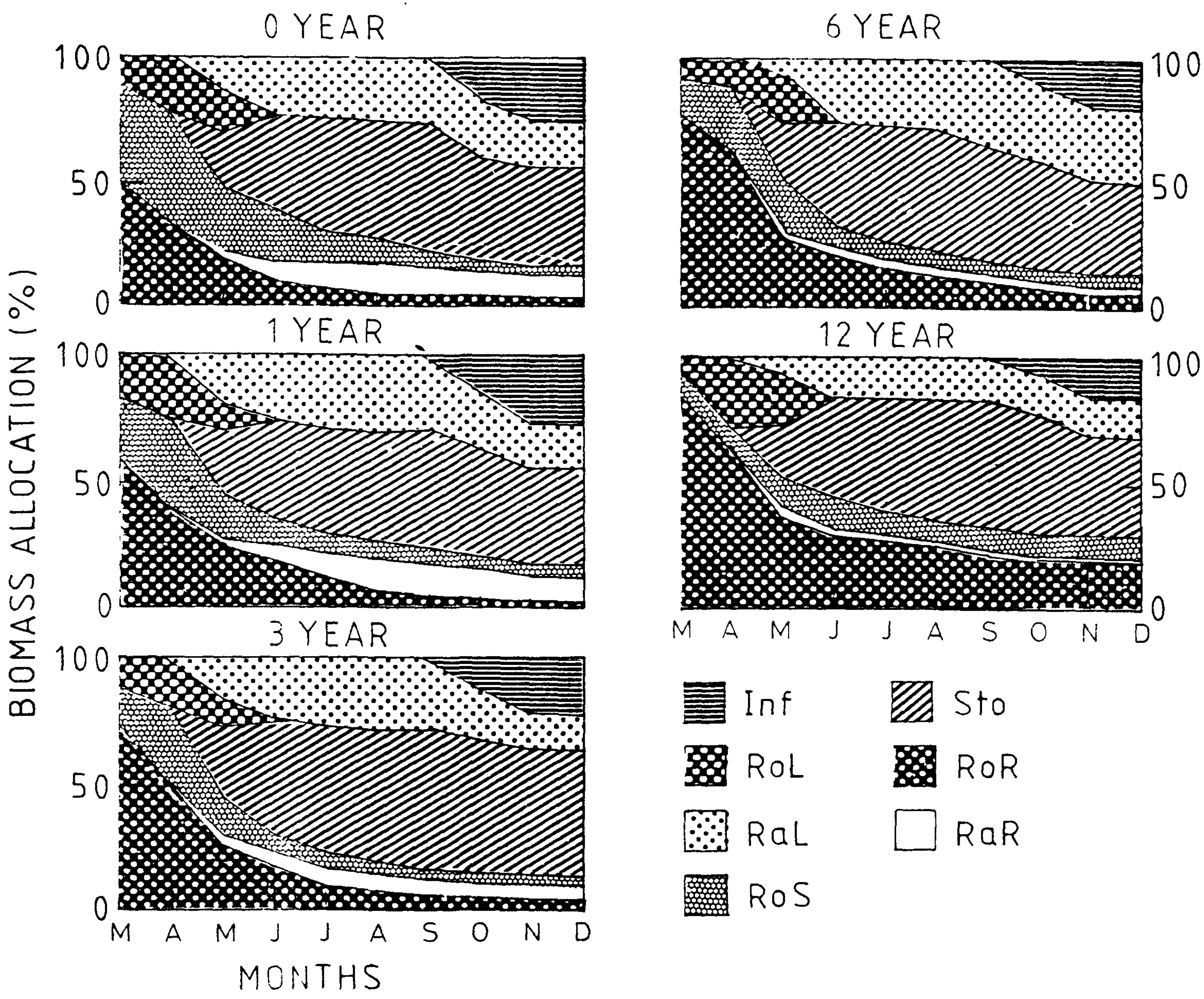
Population dynamics:

Birth and death rates of ramets were high during monsoon, reached a maximum during September and remained stable during winter. Of the total ramet population recorded during October, only 4 to 20% survived to produce new rosettes in the following rain season. This regeneration declined in older fallows. The net increase in the density of ramets was high during monsoon and declined gradually from September to November. The net population size of M. micrantha was initially low, increased sharply for the first 3 years of fallow, and then declined to extremely low numbers in a 12-year-old fallow (Fig.1.1).

Based on the time of birth of the new ramets, age specific survival curbes were drawn for specific cohorts in the populations. Death proportion was highest when birth rate was highest, i.e. during the peak growth period of June to September. All remaining ramets died during November to January. No seedling recruitment occurred in 0-, 1- and 3-year-old fallows. Survival of different seedling cohorts in 6- and 12-year-old fallows suggested that mortality rate was highest during the juvenile phase. The May cohort survived until January before perennation, the June cohort until November. The July cohort survived only until October. Seedling establishment in 6- and 12-year-old fallows was 24 to 27% based on observations in October, the regeneration of rosettes in the following year was very low (Table1.2).

Fig. 1.2 : Allocation of biomass (% of total biomass) to different organs: rosette leaves (RoL); inflorescence (Inf); ramet leaves (RaL); stlons (Sto); rosette stem (RoS); rosette roof (RoR); ramet roof (RaR) in <u>M.micrantha</u> in fallows of various ages.

Fig.1·2



0 YEAR
6 YEAR
1 YEAR
12 YEAR
3 YEAR
BIOMASS ALLOCATION (%)
100
50
0
M A M J J A S O N D
MONTHS
Inf
Sto
RoL
RoR
RaL
RaR
RoS

Table 3: Population flux of *M. micrantha* in fallows of various ages

	Age of fallow (years)				
	0[a]	1	3	6	12
a. Rosettes in March 1982	7	17	48	14	5
b. Rosettes in March 1983	15	22	45	11	2
c. Net change (b-a)	8	5	- 3	- 3	- 3
d. Net increase (b/a)	2.2	1.3	0.9	0.8	0.4
e. Ramets born between March 1982-March 83	690	1775	2914	1176	350
f. Ramets lost between March 82-March 83	675	1753	2850	1155	348
g. Rosettes surviving from March 82-March 83	4	9	27	6	2
h. Percentage of rosettes surviving (g/a x 100)	57.2	53	56.3	42.9	40
i. Expected turn over time in years ($\frac{1}{100-h}$ x100)	2.3	2.1	2.3	1.7	1.6
j. Total ramets recorded over the year	697	1792	2962	1190	355
k. Percentage annual mortality ($\frac{f}{j}$ x 100)	96.8	97.8	96.2	97	98

[a]Zero year fallow indicates first growing season of fallow

Table 14: Reproductive potential of *M. micrantha* in relation to the age of the fallow

	Age of fallow (years)				
	0	1	3	6	12
Ramets m^2	152	456	684	304	104
Non-reproductive ramets(%)	10	12	13	44	77
Reproductive remets(%)	90	88	87	56	23
Capitula per reproductive ramet	107	113	120	89	61
Seeds per capitulum	3.0	3.2	3.5	2.9	2.6
Seeds per reproductive ramet	321	362	420	258	159
Capitula m^2	14544	45652	71520	15308	1464
Seeds m^2	43632	146086	250320	44394	3806

An increase in population size occurred only in 0- and 1-year-old fallows (Table 1.3). The population size declined in older fallows, with the decline positively related to age of the fallow. Both the percentage survival as well as the expected turnover time were lower in 6- and 12-year-old fallows compared to others.

Biomass allocation strategy:

Biomass allocation pattern to different organs of *M. micrantha* were based on observation of the rosette, the attached ramets and their stolons jointly (Fig 1.2). In a given fallow, rosette root and stem biomass declined with time with least change in a 12-year-old fallow. Rosette leaves died by June in all fallows. Conversely, the allocation of biomass to the stolons increased with time.

While biomass allocation to the root system of the ramets was greater in fallows of 0- to 3-years-old, compared to 6 - and 12-year-old fallows, the reverse occurred with the rosette root system. Allocation of biomass to ramet leaves was maximum in a 6-year-old fallow. Reproductive allocation was the least in a 12-year-old fallow.

Reproductive potential:

The seed production potential of the ramets as indicated by the proportion which bore inflorescences, declined drastically with age of fallow (Table 1.4). While the number of seeds per capitulum was relatively stable the number of seeds per reproductive ramet and seed output per m^2 reached maximum in a 3-year-old fallow and declined sharply with fallow age.

DISCUSSION

When a forest is used for slash and burn agriculture not only is its original vegetation destroyed but the site is subjected to continuing perturbation due to fire, crop introduction, weeding, hoeing and disturbances to the soil during crop harvest. This results in a decreasing species diversity.

Mineral nutrients are initially depleted from the soil for the first few years of secondary succession due to rapid uptake by the developing communities (Ramakrishnan and Toky, 1981; Toky and Ramakrishnan, 1983 b), and soil moisture status may improve. As litter accumulates and decomposition occurs (Toky and Ramakrishnan, 1984) the soil pH is altered. As the community closure occurs, light progressively becomes limiting (Benett and Rao, 1968; Cruttwell, 1968; Kushwaha _et al._,1981; Ramakrishnan and Mishra, 1981). _M. micrantha_ is subjected to these drastic changes in the successional communities.

Reproduction of _M. micrantha_ through ramets arising from rosettes emerging in March far exceeded seedling regeneration, the latter being restricted to 6- and 12-year-old fallows only. Reproduction through ramets peaked in 3-year-old fallows. Regeneration of the rosettes was low in older fallows, as already observed for other weeds by Kushwaha et al. (1981) and Ramakrishnan and Misra (1981).

Lovett-Doust (1981) found that ramets from contrasting environments differed in the biomass allocated to their main organs. The ramet and the rosette were considered with parity for demographic analysis in the present study, but the allocation of biomass differed considerably between them. The rosette has a thick caudex and a strong tap root with six or seven leaves whereas a ramet has two leaves with a weakly developed root system at the node. The interdependency among ramets, the free flow of resources, and the ability to regulate position and density of shoots in a clone (Harnett and Bazzaz, 1985), may account for the great vegetative reproduction in *M. micrantha*.

Rosettes emerging in March are the chief resource for the developing ramets, nutrients being stored in the root system. Since rapid spread and establishment of the species through ramets is important in younger fallows, it is reasonable to find a higher allocation of biomass to the ramets in 0- to 3-year-old fallows as compared with older ones. Greater allocation to the rosette root system in older fallows ensures survival of the species population through late successional communities so that renewed population growth is possible during subsequent slash and burn operations. Similar observations of greater allocation to the root system of woodland populations of herbs compared with old field species was also noted by Abrahamson (1979) and Lovett-Doust (1981).

The larger allocation of biomass to the stolons as compared to other organs of *M. micrantha*, is to be expected as the species is able to spread rapidly in young fallows and place them at a high level in the canopy through rapid vertical growth. Thus, vegetative growth is adapted to horizontal spread under competitive conditions of the younger fallows and under stresses (chiefly reduced light) of the older fallows (Abrahamson, 1980). Greater allocation of biomass to the rosette root in the older fallows is advantageous for exploiting deeper soil layers of these fallows where the soil surface has been depleted of nutrients by the developing community (Ramakrishnan and Toky, 1981; Mishra and Ramakrishnan, 1983 b).

Seedling recruitment is particularly important in a species with emphasis on vegetative reproduction, in order to maintain population diversity. Seed numbers were high in younger fallows and declined drastically in a 12-year-old fallow. Interestingly seedling regeneration occurred only in 6- and 12-year-old fallows.

Population dynamics and reproductive strategy of *M. micrantha* indicate close correlation of population vigour with the successional environment. The species strives to survive in the late, light-limited successional communities through vertical growth and the climbing habit of the stolons. Where the jhum cycle was reduced to 4 or 5 years due to increased population pressure and reduced land availability (Ramakrishnan et al., 1981 a,b), the natural suppression of this species and other weeds becomes difficult. This results in arrested succession of weed communities (Saxena and Ramakrishnan, 1984 b) with weed problems and declining crop yields and productivity of the land.

SUMMARY

Mikania micrantha H.B.K. is an exotic, perennial weed which colonizes communities developing after slash and burn agriculture (Jhum) at lower elevations of north-east India. The population dynamics and reproductive potential of *M. micrantha* was studied. Reproduction through ramets arising from rosettes exceeded that from seeds. The ramet population growth was highest during the monsoon season as a consequence of high population birth and large-scale mortality. Net population increased as the age of the fallow increased for 3 years, and declined drastically in 6- and 12-year-old fallows. Biomass was allocated mainly to the ramet root system in younger fallows and to the rosette root system in older fallows. Seed reproduction potential peaked in a 3-year-old fallow and declined rapidly thereafter. The significance of the results in terms of natural elimination of the species through succession, and the increased weed potential leading to arrested succession under short jhum cycles is discussed.

CHAPTER 2

EFFECT OF FIRE ON POPULATION DYNAMICS OF *MIKANIA MICRANTHA* H.B.K., UNDER SUCCESSIOANL ENVIRONMENT

INTRODUCTION

Frequent disturbances in a forest ecosystem as for slash and burn agriculture is often responsible for rapid colonization and spread of many weeds such as Eupatorium odoratum (Kushwaha et al., 1981), E. adenophorum (Ramakrishnan and Mishra, 1981), Imperata cylindrica (Eussen and Wirjahardja, 1973; Kushwaha et al., 1982). Mikania micrantha Humboldt, Bonpland and Kunth, is one such noxious weed (Parker, 1975) which has spread extensively in the north-eastern hill region of India forming part of early successional weed communities developing after slash and burn agriculture (locally called jhum). The length of the jhum cycle (The intervening fallow phase between two successive croppings at the same site) is an important factor affecting weed potential of M. micrantha (Chapter I) and many others (Saxena and Ramakrishnan, 1984 b).

Fire used in the jhum is another important factor determining the population dynamics of many early successional weeds through its potential effects on the physical and biological properties of the soil (Uhl, 1982). Apart from the scorching effects of fire on the surface and sub-surface soil resulting in reduction in propagule bank in the soil system, it alters the micro-environment through increased insolation, higher soil fertility status and release from inhibitory allelochemics (Smith et al., 1968; Rice, 1974). The present study therefore compares the population dynamics of M. micrantha through the early phases of succession after slash and burn agriculture in north-east India with emphasis on fire effects.

METHODS OF STUDY

Three fallow plots of about 2 ha. each of different ages (2, 4 and 8 year) with three replications were identified at Lailad taking care to ensure similar topographic and exposure conditions. The age of the fallows and the similarity in land use with a 10-year jhum cycle (the intervening fallow phase between two successive croppings at the same site) were based on the records available with the village headman. Age was calculated from the time the cropped plots were left a fallow for natural regeneration of vegetation after slash and burn agriculture. Half of each fallow plot was slashed in February and the dried slash was burnt in March to study the effect of fire; the other half was maintained as an undisturbed control. A fire line separated the two halves in each plot

Density, frequency and cover of the vegetation were studied using 1 X 1 m quadrats for herbaceous species and 10 X 10 m quadrats for shrubs and trees. The importance value index (IVI) was calculated using relative frequency, relative density and relative basal area of the species (Misra, 1968; Kershaw, 1973). The values are based on twenty quadrats for each treatment.

Demographic studies were carried out on ten randomly placed permanent quadrats of 0.5 X 0.5 m for each treatment. The fate of the ramets, seedlings and the rosettes of established plants were followed from March 1982 to May 1983 by mapping the vegetation at two weekly intervals. Ramet birth was recognized when a rooted node bore two fully expanded leaves, and the death of the two expanded leaves was considered as the death of the ramet.

The average number of seeds per capitulum was based on thirty random observations under each treatment. The number of capitula per unit area was based on thirty 0.5 X 0.5 m quadrats in each treatment. This was then used for computing seeds per fertile ramet and seed output per m^2.

RESULTS

Vegetation analysis:

Burning increased the intensity of weeds like *Ageratum conyzoides*, *Borreria hispida*, and *Eupatorium odoratum* in an

Table 2.1 Importance indices of plant species associated with M. Micrantha in different fallows.

Species	Burnt			Unburnt		
	Age of fallow (years)					
Herbs:	2	4	8	2	4	8
Ageratum conyzoides L.	41.8	20.6	31.3	44.1	20.4	19.7
Borreria hispida K. Schum.	23.1	7.9	13.3	27.8	13.4	8.7
Desmodium triquitrum D.C.	6.2	5.4	3.5	7.1	4.9	2.2
Desmodium laxiflorum D.C.	-	7.0	7.1	--	5.5	-
Digitoria adscendens H.B.K.	9.98	8.9	6.2	3.5	4.6	-
Erigeron linifolius Wild	13.3	4.8	4.0	15.1	-	11.7
Eupatorium odoratum Linn.	56.2	42.9	46.5	51.9	43.5	27.8
Imperata cylindrica Beaw.	-	14.9	28.3	-	9.2	-
Ipomea pileata Roxb.	-	-	-	8.0	5.2	20.2
Mikania micrantha H.B.K.	66.1	51.3	28.2	37.4	44.7	4.7
Muccuna bracteata D.C.	14.8	13.2	5.1	9.8	10.3	-

Continued...

Panicum khashianum Jav.	12.1	11.4	8.3	6.1	5.4	10.0
Panicum maximum Munro.	11.5	13.6	8.1	6.8	8.3	-
Seteria gluca (Beauv)	5.9	2.4	3.4	-	5.8	-
Thysanoleana maxima (Roxb.) O.Ktze	-	10.5	-	-	11.0	-
Shrubs:						
Clerodendrum colebrookianum Walp.	-	-	2.0	4.6	-	-
Litsaea assamica Hk.f	-	1.8	5.0	-	10.2	14.0
Lea Sp	4.5	-	2.7	18.2	-	10.0
Melastoma malabathricum Linn.	-	7.3	11.0	3.6	11.9	10.4
Mussaenda roxiburghii Hk.f	-	14.5	4.1	-	15.1	13.9
Trees:						
Calicarpa macrophylla	-	-	4.0	-	-	17.5
Cedrella toona Roxb.	-	9.9	-	-	7.4	-
Dendrocalamus hamiltonii Nees & Arn.	13.8	19.7	26.9	17.6	20.7	44.2
Duabanga sonneratioides Ham.	7.5	-	5.6	5.4	-	5.6
Macaranga denticulata Muell	-	8.5	6.1	-	18.2	20.7

Sapium baccatum Roxb.	-	5.0	3.9	-	4.4	14.3
Schima wallachii Choisy.	4.5	-	14.6	-	-	32.1
Shorea robusta Gaertn.	-	6.3	-	8.7	16.0	-
Sterculia villosa Roxb.	0.6	-	11.4	-	-	-
Vitex glabrata Br.	-	7.5	9.0	13.4	6.2	11.8

Fig. 2.19. Cummulative births and deaths of M. micrantha populations in 2-year (circles) 4-year (triangles) and 8-year (squares) old fallows after slash and burn agriculture. Closed symbols, burnt; open symbols, unburnt sites.

Fig. 2.1a

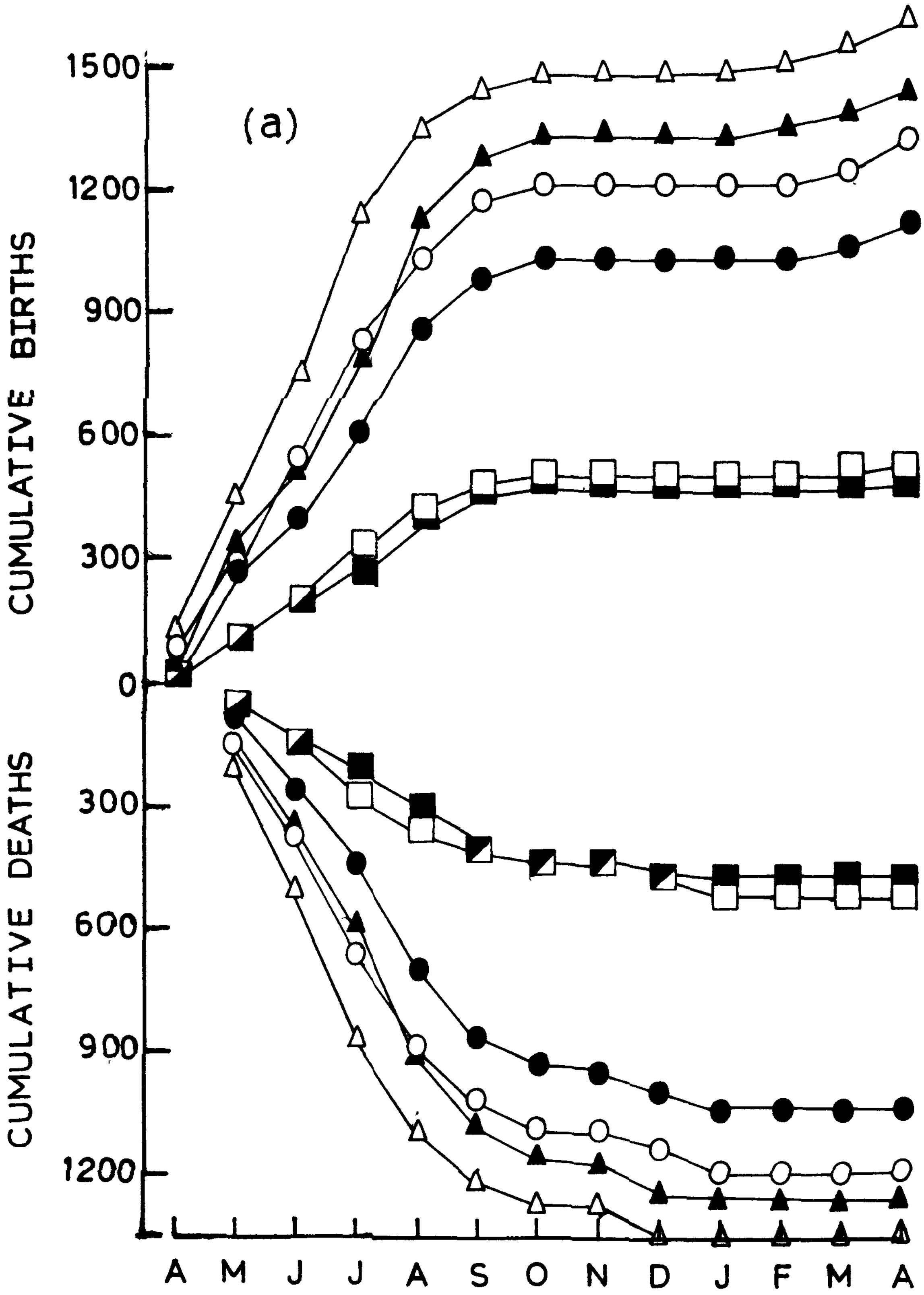

(a)
1500
1200
900
600
300
0
300
600
900
1200
CUMULATIVE BIRTHS
CUMULATIVE DEATHS
A M J J A S O N D J F M A

Fig.2.16. Net population size of *M. micrantha* in 2-year (circles), 4-year (triangles), and 8-year (squares) old fallows after slash and burn agriculture. Closed symbols, burnt; open symbols, unburnt sites.

Fig. 2.1b

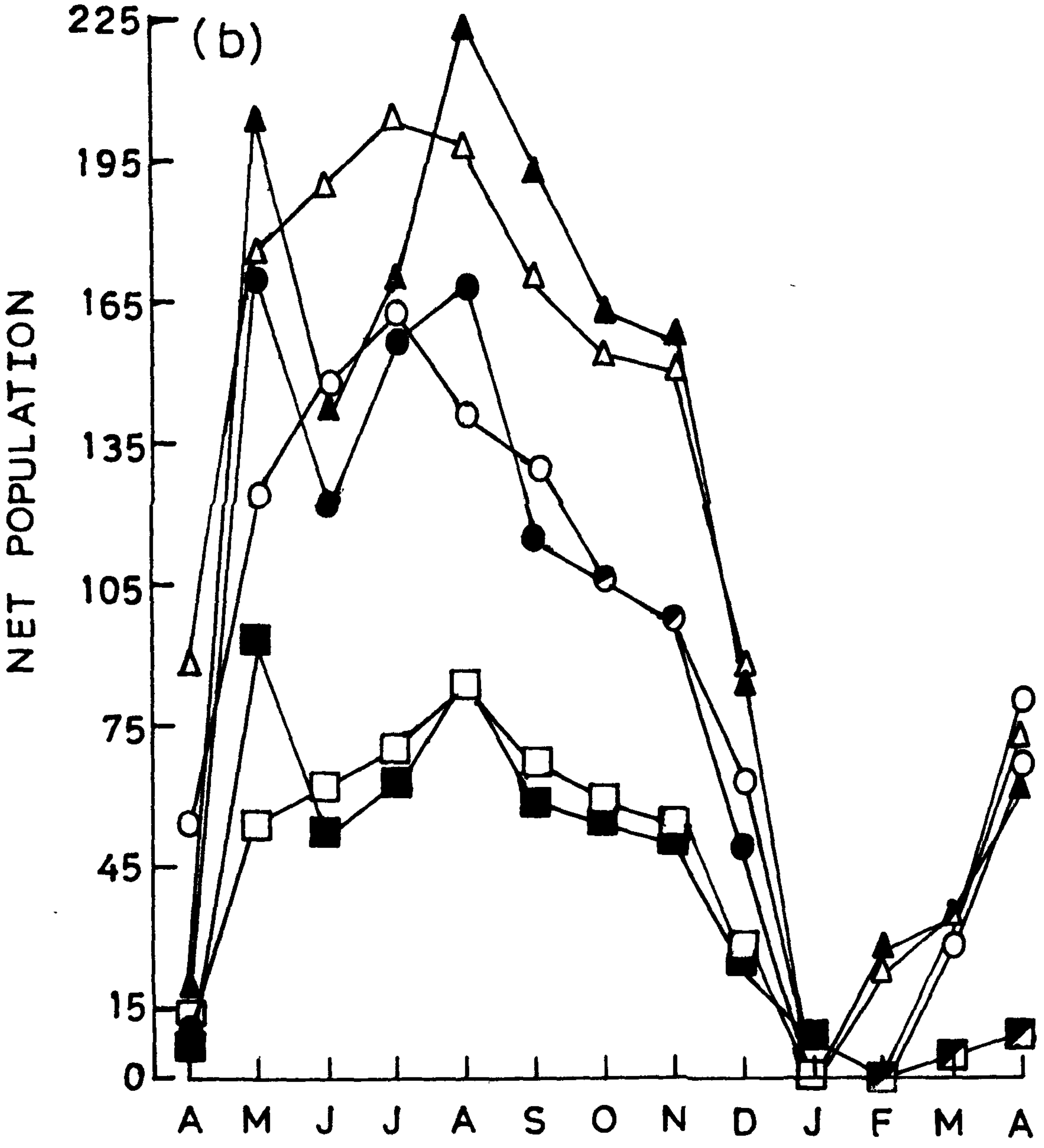
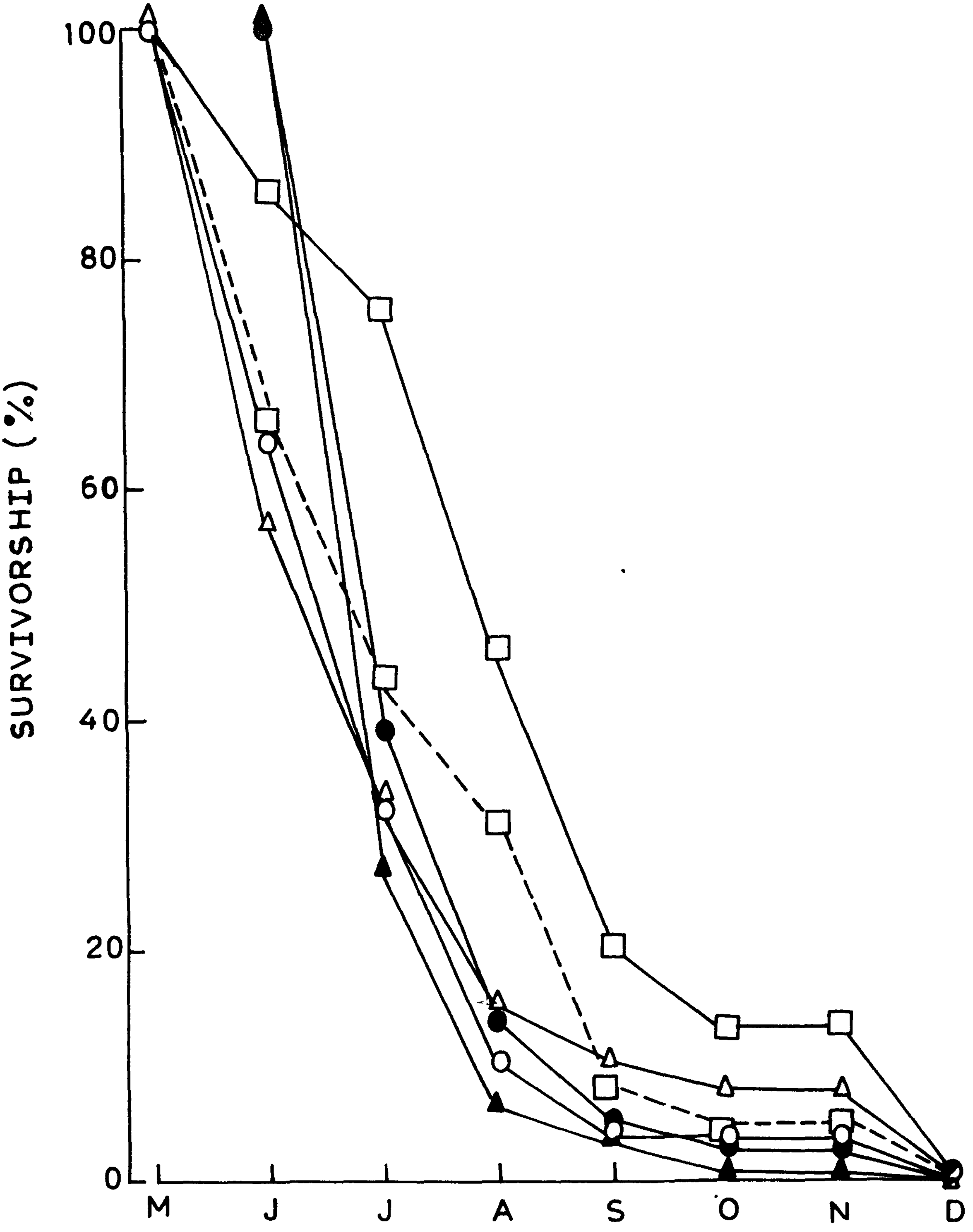


Fig. 2.3. Survivorship curves of two cohorts of seedlings of *M. micrantha* in burnt 2-year (circle) 4-year (triangles) and 8-year (squares) old fallows after slash and burn agriculture. Open symbols, 1st cohort; closed symbols; 2nd cohorts; solid line, burnt site; broken line, unburnt site.

Fig. 2.3



8-year-old fallow only (Table 2.1). Mikania micrantha population increased after the burn in all the fallows but more markedly in 8-year-old fallow. In general, shrubs and trees declined after the burn, in all the fallows. Weed intensity in younger fallows increased whilst the shrubs, trees saplings and sprouts declined.

Population dynamics:

M. micrantha responded to burning through increased birth and death rates of the total (Seedling and ramet) population, more markedly so in 2-and 4-year-old fallows (Fig.2.1a). The rates were high during the monsoon period, reached a maximum in October and levelled off subsequently. The net population size in the burnt sites had two distinct peaks, one in May and the other in August, where as the unburnt sites had one peaking in July-August (Fig.2.2b). In January and February the senescence occurred and the population died in all treatments. Age-specific survival curves drawn for specific seedling cohorts of the population of M. micrantha (Fig.2.3), showed that the greatest risk of death occurred during the peak growth period of June-September. During November and December the plants that flowered in October died due to senescence. In 2-and 4-year-old fallows, seedling recruitment occurred only in burnt sites whereas in an 8-year-old fallow both burnt and unburnt sites had seedling recruit-

Table 2.2 Fate of cohorts of seedlings of *M. micrantha* in fallows of various ages. Values in parentheses are given for unburnt fallows.

Fallow age	Seedlings recorded	Seedlings established before perennation	Rosettes produced after perennation
2	988	59	59
	(-)	(-)	(-)
4	1752	41	41
	(-)	(-)	(-)
8	24	3	3
	(307)	(15)	(-)

Table 2.3 Population flux of *M. micrantha* in fallows of various ages.

		BURNT			UNBURNT	
	Age of fallow (years)					
	2 Yr	4 Yr	8 Yr	2 Yr	4 Yr	8 Yr
(a). No. of rosettes in April 1982	11	19	5	54	87	13
(b). No. of rosettes in April 1983	67	63	8	81	72	8
(c). Net change (b-a)	56	44	3	27	-15	-7
(d). Net increase (b/a)	6.1	3.3	1.6	1.5	0.8	0.6
(e). Ramets born between April 1982 to April 1983.	1117	1437	483	1255	1417	488
(f). Ramets lost between April 1982 to April 1983	1033	1245	469	1196	1347	493
(g). Rosettes surviving from April 1982 to April 1983	3	6	3	31	43	5
(h). Percentage of rosettes surviving (g/a x 100)	27.3	31.5	60	57.4	49.4	38.4
(i). Expected turnover rate $\left(\frac{I \times 100}{100-h}\right)$	1.4	1.5	2.5	2.3	2.0	1.6
(j). Total plants (ramets + rosettes) recorded over the year	1128	1456	488	1330	1572	508
(k). Percentage annual mortality of ramets (f/j x 100)	99.0	98.7	99.0	94.4	90.1	96.1

ment. In an 8-year-old fallow survivorship was lower in the burnt site compared to the unburnt one.

The plants established through seedlings of M. micrantha arising out of May-October 1982 recruitment were followed upto March 1983 for their ability for rosette formation (Table 2.2). In all the burnt fallows, the established plants of the previous year developed into rosettes during the subsequent growing season. In the unburnt 8-year-old fallow plot none of the established plants of the previous year developed into rosettes subsequently. The seedling recruitment in a given year itself was maximum in a 4-year burnt fallow followed by a 2-year-old burnt fallow and least in an 8-year-old burnt fallow. Seedling recruitment under unburnt situation occurred only in an 8-year-old fallow. The population flux for M. micrantha (Table 2.3) shows that the net increase in rosette population was generally higher in the burnt sites compared to unburnt sites. However, this net increase declined with the age of the fallow. The percentage of surviving rosettes and the expected turnover rates increased with the fallow age in burnt sites whilst it declined with the fallow age in unburnt sites. The ramet mortality was generally higher in burnt sites than in unburnt sites.

Table 2.4 Reproductive potential of <u>M. micrantha</u> in relation to the age of the fallow.

	Burnt			Unburnt		
	Age of fallow (years)					
	2 Yr	4 Yr	8 Yr	2 Yr	4 Yr	8 Yr
No. of ramets m^2	392	624	200	388	600	216
Non reproductive ramets (%)	12	18	15	17	29	68
Reproductive ramets(%)	88	82	85	83	71	32
Capitula per reproductive ramet	113	109	118	120	108	72
Seeds per capitula	3.3	3.0	3.5	3.3	3.1	2.8
Seeds per reporductive ramet	373	327	413	396	335	202
Capitula per m^2	38985	48941	20060	38640	46008	4968
Seeds per m^2	128650	146823	70210	127512	142624	13910.

Reproductive potential:

Burning resulted in an increase in the percentage of sexual reproductive ramets, more markedly so in an 8-year-old fallow. Seed output per m^2 was maximum in a 4-year-old fallow declining drastically in an 8-year-old fallow. Unburnt 8-year-old fallow had the lowest seed output (Table24).

DISCUSSION

The total population size is determined partly by the age of the fallow after the slash and burn agriculture operation as discussed earlier (Chapter I) and as also reported for other weedy species under similar land use in north-east India (Kushwaha et al., 1981; Ramakrishnan and Mishra, 1981). The results presented here clearly shows as to how the density of this species, determined through both vegetatively regenerating ramets and seedlings, is altered after fire, as also observed during the post-fire cycle of succession in Chamise chapparal (Christensen and Muller, 1975). The higher density of *Mikania micrantha* in burnt sites compared to unburnt sites of the same fallow could partly be related to increased insolation (Bennett and Rao, 1968; Cruttwell, 1968), enriched soil through ash deposit (Ramakrishnan and Toky, 1981) and possible release from allelopathic effects from its own individuals (Wong, 1964) and from other species such as *Eupatorium odoratum*

(Yadav and Tripathi, 1981). Competition may not be a factor for increase of M. micrantha density in burnt sites as the density of most of the associated species is either unaffected by fire or even increased due to burn in an 8-year-old fallow.

Recruitment of individuals into a given site is often density-dependent (Ramakrishnan and Kumar, 1972). High population birth is often accompanied by large scale mortality. Such a density-dependent mortality preceeded by heavy recruitment is a common phenomenon (Sarukhan and Harper, 1973; Lovett-Doust, 1981; Noble et al., 1877). Heavy mortality and the consequent reduced density may result in another wave of heavy recruitment. The double peaking in net population size in burnt sites during May and August may be explained on this basis. Relatively slower recruitment rate in unburnt sites may result in slow increment in net population size and one peak attained during July-August.

In a species such as M. micrantha where vegetative reproduction is predominant sexual reproduction through seedling regeneration is important in maintaining genetic diversity (Harper, 1978). That this exotic weed is a ruderal species with greater vigour under disturbed sites is evident from the fact that seedling recruitment occurs exclusively in burnt sites in 2-and 4-year-old fallows. The total absence of seedling recruitment in unburnt sites of 2- and 4-year-old fallows may partly be because of rapid vegetative regeneration of *M. micrantha.* Vigourous and quicker in vegetative multiplication from a larger rosette population reduces free space available with sufficient light penetration at ground level for seed germination and seedling establishment in there fallows. In these burnt sites of 2-and 4-year-old fallows, though ramet population size is not very different from the unburnt sites, these ramets are largely derived from current seedling recruitment itself, rather than from an already well established rosette population. Thus there is a qualitative difference in the ramet population of burnt and unburnt sites. That would explain seedling recruitment occurring in an 8-year-old unburnt fallow where *M. micrantha* population density is very reduced, to start with.

Seedling mortality in its severest form often expresses itself during the first few weeks of the growth of a plant (Ramakrishnan and Kumar, 1971) as also observed in the present study. High intensity of intraspecific competition (Ramakrishnan and Jeet, 1972) and high density of other species emerging during the monsoon (Kushwaha *et al.*, 1981; Ramakrishnan and Mishra, 1981) would account for such a mortality pattern, a conclusion further supported by lack of seedling regeneration in unburnt 2-and 4-year-old fallows. In contrast to this, in an 8-year-old fallow seedling recruitment is higher in unburnt sites. Here burning would result in a larger population of herbaceous weeds resulting in greater competition whilst unburnt sites largely have shrubs, tree saplings and fewer herbaceous ground flora species. It may be noted here that some seedling recruitment occurring in unburnt 8-year-old fallow is perhaps because of tolerance to partial shade (Macalpine, 1959) from shrubs and tree saplings.

In M. micrantha, we have three recruitment strategies: (i) through seedlings, (ii) through ramet formation (iii) through perennating rosettes derived from rosette caudex or ramet caudex. Ramet recruitment pattern is essentially a function of the successional development of the fallow phase after slash and burn agriculture (Chapter I; Kushwaha et al., 1981; Ramakrishnan and Mishra, 1981) the population declining in older fallows, being shaded out by larger shrubs and tree saplings (Kushwaha and Ramakrishnan, 1982; Macalpine, 1959). However, rosette perennation and seedling recruitment are chiefly determined by fire. Thus damage to rosette caudex due to fire may explain reduced regeneration of these in the post-burn phase in all the fallows. Further, seedling recruitment in younger fallows is promoted by fire, while inhibited by it in the 8- year-old fallow. Fire also has a general promoting effect on seed reproductive potential of this species. However, this potential declines drastically in older fallows. Thus, frequent disturbance of the site for slash and burn agriculture with a short cycle of 4-5 years results in larger recruitment of a weedy species such as this both through ramets and seedlings. Consequently the weed potential increases drastically (Saxena and Ramakrishnan, 1984b) and results in an arrested succession (Toky and Ramakrishnan, 1983a). The success of this weed, therefore, is related to frequent disturbances such as fire and its best control seems to be biological through a long secondary successional fallow phase as under a long jhum cycle.

SUMMARY

Mikania micrantha H.B.K. population size is considerably enhanced by fire in 2-, 4-and 8-year-old fallows developing after slash and burn agriculture (Jhum) in north-east India. The recruitment pattern in burnt and unburnt sites in each fallow differed. Seedling recruitment was restricted only to burnt sites in 2-and 4-year-old fallows, whereas it occurred in both burnt and unburnt sites in an 8-year-old fallow. Sexual reproductive potential of the species was affected both by the age of the fallow and as a consequence of the effect of fire in each fallow plot. These results are related to micro-environmental changes of the habitat as a consequence of fire in different fallow plots.

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CHAPTER 3

GROWTH STRATEGY AND ALLOCATION PATTERN OF *MIKANIA MICRANTHA* H.B.K., UNDER SUCCESSIONAL ENVIRONMENT AFTER SLASH AND BURN AGRICULTURE

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INTRODUCTION

Mikania micrantha Humboldt, Bonplad and Kunth is an early successional exotic weed introduced to north-east India from tropical America as a ground cover in tea plantations. Now it is a very vigorous weed of agricultural systems, difficult to control because of its perennial habit and its ability to spread vegetatively even through tiny stem fragments.

Rapid growth and multiplication are two important features of a colonizing species (Gomez-Pompa and Vazquez-Yanes, 1974; Grime, 1979) apart from their ability to make efficient growth under high light and warmer temperature regimes of an open environment. During succession, ruderal species flourish under relatively nutrient rich and non-competitive environment for a period of time to be gradually replaced due to more competitive stressful conditions.

The success of an organism in a given environment is often through a favourable allocation of the limited available resources to diverse life purposes such as maintenance,growth and reproduction (Abrahamson and Gadgil, 1973). It is to be expected that a ruderal species such as M. micrantha would show changing patterns in its allocation strategies through the successional environments (Saxena and Ramakrishnan, 1984a).

It is part of the shifting agricultural system (Ramakrishnan *et al.*, 1981; Toky and Ramakrishnan, 1983a) during the cropping phase and during the early secondary successional fallow phase. Short shifting agricultural cycles (the intervening fallow phase between two successive croppings at the same site) increase the weed potential of this and a large number of other species often resulting in an arrested weedy stage in succession (Toky and Ramakrishnan, 1983a; Saxena and Ramakrishnan, 1984b). An understanding of the growth and allocation strategies of this species is therefore, important for its control, possibly biological.

METHODS OF STUDY

Five fallow plots of different ages (0,1,3,6,and 12 year) were identified at Lailad taking care to ensure similar topographic and exposure conditions. The age of the fallows and the similarity in land use with a 10 year jhum cycle were based on the records of the village headman. Age was calculated from the time the cropped plots were left a fallow for natural regeneration of vegetation, after slash and burn agriculture.

Fifty plants (a rosette with clear caudex and stem base) of *M. micrantha* were selected and tagged randomly in each fallow plot at the initiation of vegetative growth in early March.

Five replicate plants with attached ramets were harvested at monthly intervals during the growing season from April to December 1983, taking care not to damage any plant part. Belowground parts were carefully washed and separated into different component organs. The fallen leaves and seeds were also included following Hickman (1975). Fruits of *M. micrantha* are achenes, which are ecological equivalents of seeds. Fruit biomass, thus equals seed biomass (Harper, Lovell and Moore, 1970). The different components were dried at 80 ± 5°c for 48 hours and weighed. Leaf area estimations using a planimeter and leaf dry weight per unit area were based on three replicates and the average of 50 leaves per replicate. Total leaf area per plant was computed using leaf biomass and leaf dry weight per unit area.

The growth functions: relative growth rate (RGR), net assimilation rate (NAR) and leaf area ratio (LAR) (Hughes and Freeman, 1967; Radford, 1967) were calculated as:

$$\mathrm{RGR} = \frac{\mathrm{In}\ W_2 - \mathrm{In}\ W_1}{t_2 - t_1}$$

$$\mathrm{NAR} = \frac{(W_2 - W_1)(\mathrm{In}\ A_2 - \mathrm{In}\ A_1)}{(A_2 - A_1)(t_2 - t_1)}$$

$$\mathrm{LAR} = \frac{(A_2 - A_1)(\mathrm{In}\ W_2 - \mathrm{In}\ A_1)}{(\mathrm{In}\ A_2 - \mathrm{In}\ A_1)(t_2 - t_1)}$$

Table 3.1 Mean values ± S.E.M of growth functions of *M. micrantha* in successional fallows after slash and burn agriculture.

Growth functions	Age of fallow (years)				
	0	1	3	6	12
RGR	0.014	0.017	0.018	0.008	0.005
mg mg^{-1} d^{-1}	± 0.004	± 0.005	±0.006	±0.002	±0.001
NAR	0.18	0.27	0.21	0.11	0.05
mg $cm^{2^{-1}}$ d^{-1}	±0.06	±0.09	±0.05	±0.04	±0.001
LAR	0.04	0.13	0.25	0.02	0.01
cm^2 mg^{-1}	±0.01	±0.03	±0.05	±0.004	±0.002

3.1. Biomass (a) and leaf area (b) changes of *M. micrantha* in 0-year(●), 1-year (○), 3-year (▲), 6-year (△) and 12-year (■) old fallows after slash and burn agriculture.

Fig. 3.1

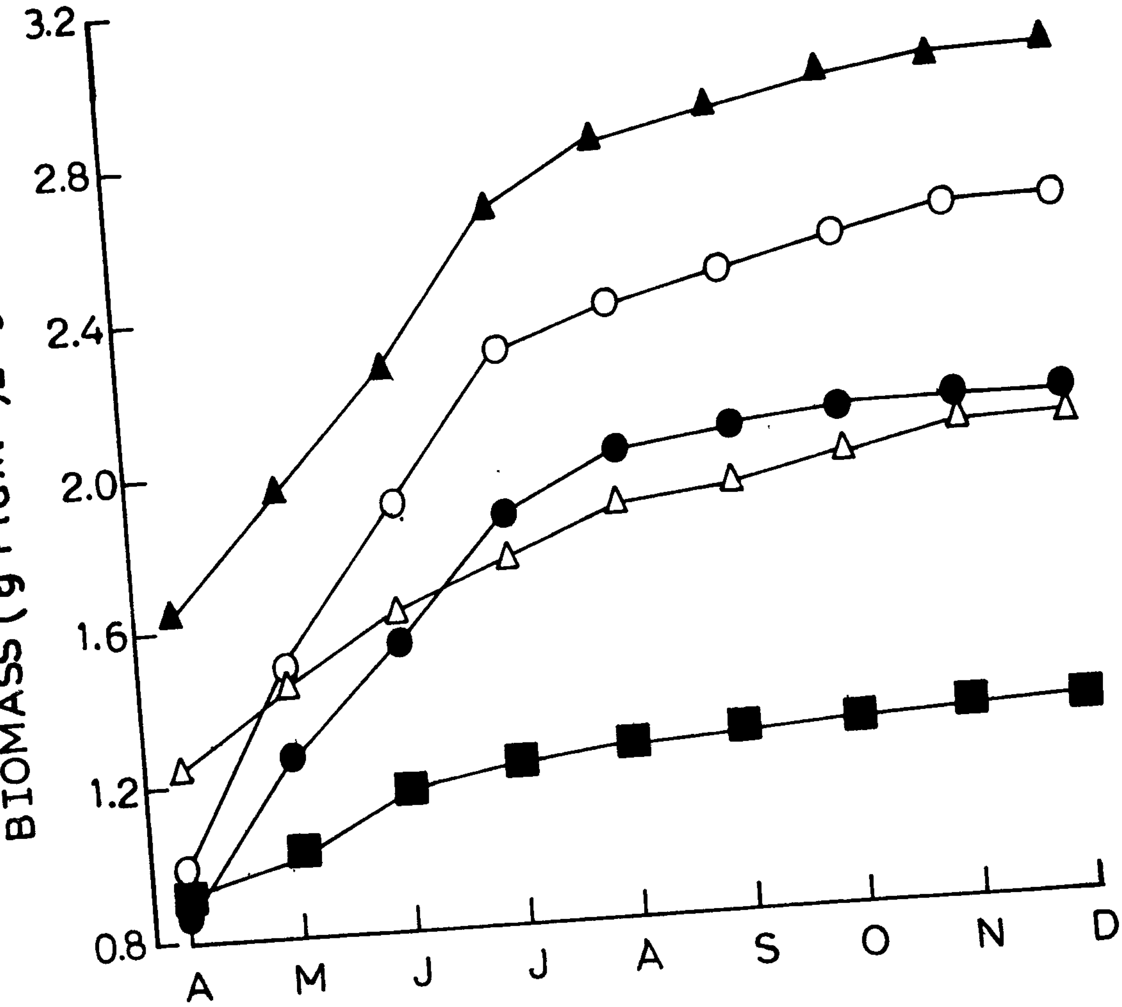
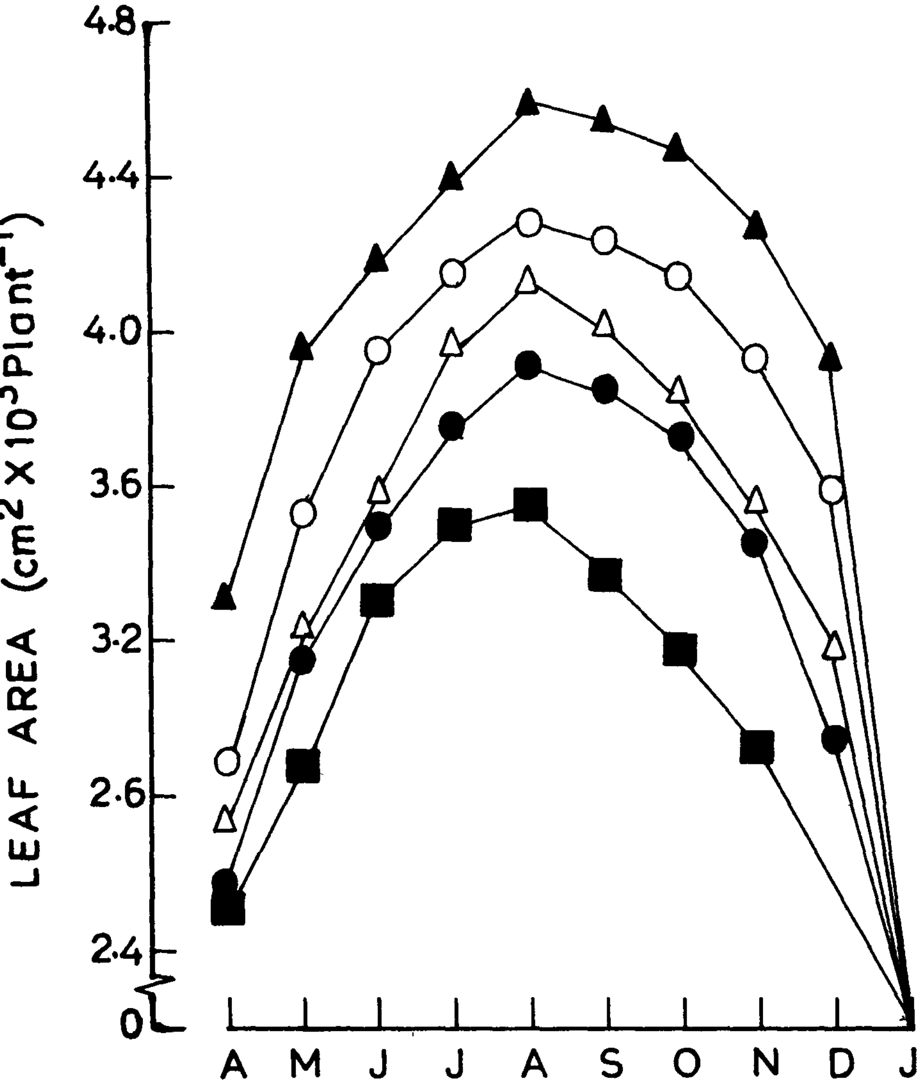


Fig. 3.1b



Where W_1 and A_1 are the biomass per plant and leaf area per plant respectively at time t_1 and W_2, A_2 are the same at time t_2.

The concentration of nutrients in different plant parts were determined following standard methods (Allen et al., 1974). Thus, nitrogen was analysed by micro-kjeldahl method; phosphorus by molybdenum-blue method and potassium by flame photometry, after wet digestion with triple acid (perchloric, nitric and sulphuric acids).

Nutrient uptake efficiency was calculated as mg nutrient absorbed per mg root biomass following Blair and Cordero, 1978). Nutrient use efficiency was calculated as mg dry matter production per g nutrient absorbed (Brown, 1978).

RESULTS

The biomass increment in all the fallows occurred with a steap increase upto July, more so in younger fallows upto 3-year-old fallow (Fig.3.1a). Leaf area increase during the season occurred upto August, declining in subsequent months due to leaf fall, and subsequent death of aboveground plant parts in January (Fig.3.1b). Leaf area per plant in different fallows increased with fallow age upto 3-years and declined subsequently with fallow age. All growth functions reached a maximum in a 1-year or 3-year-old fallow followed by a sharp decline in 6- and 12-year-old fallows (Table3.1).

Fig. 32a,b,c,d. Allocation of biomass and nutrients (% of total capital) to different organs: rosette leaves ( ); inflorescence ( ); ramet leaves( ); stolons ( ); rosette stem ( ); rosette roof ( ); ramet root ( ) in M. micrantha in fallows of various ages.after slash and burn agriculture.

Fig. 3.2a

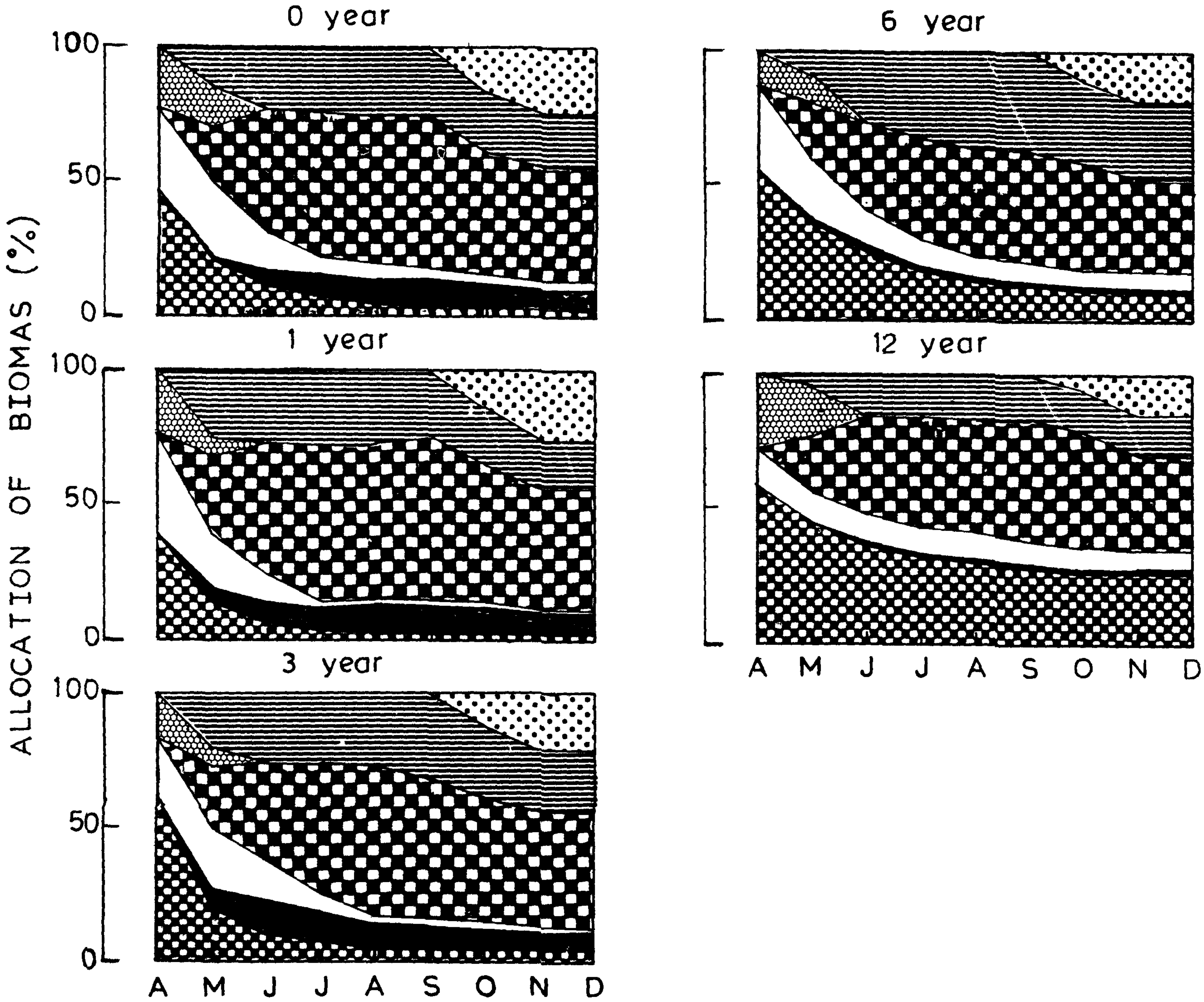

ALLOCATION OF BIOMAS (%)
0 year
1 year
3 year
6 year
12 year
100
50
0
A M J J A S O N D

Fig. 3.2 b

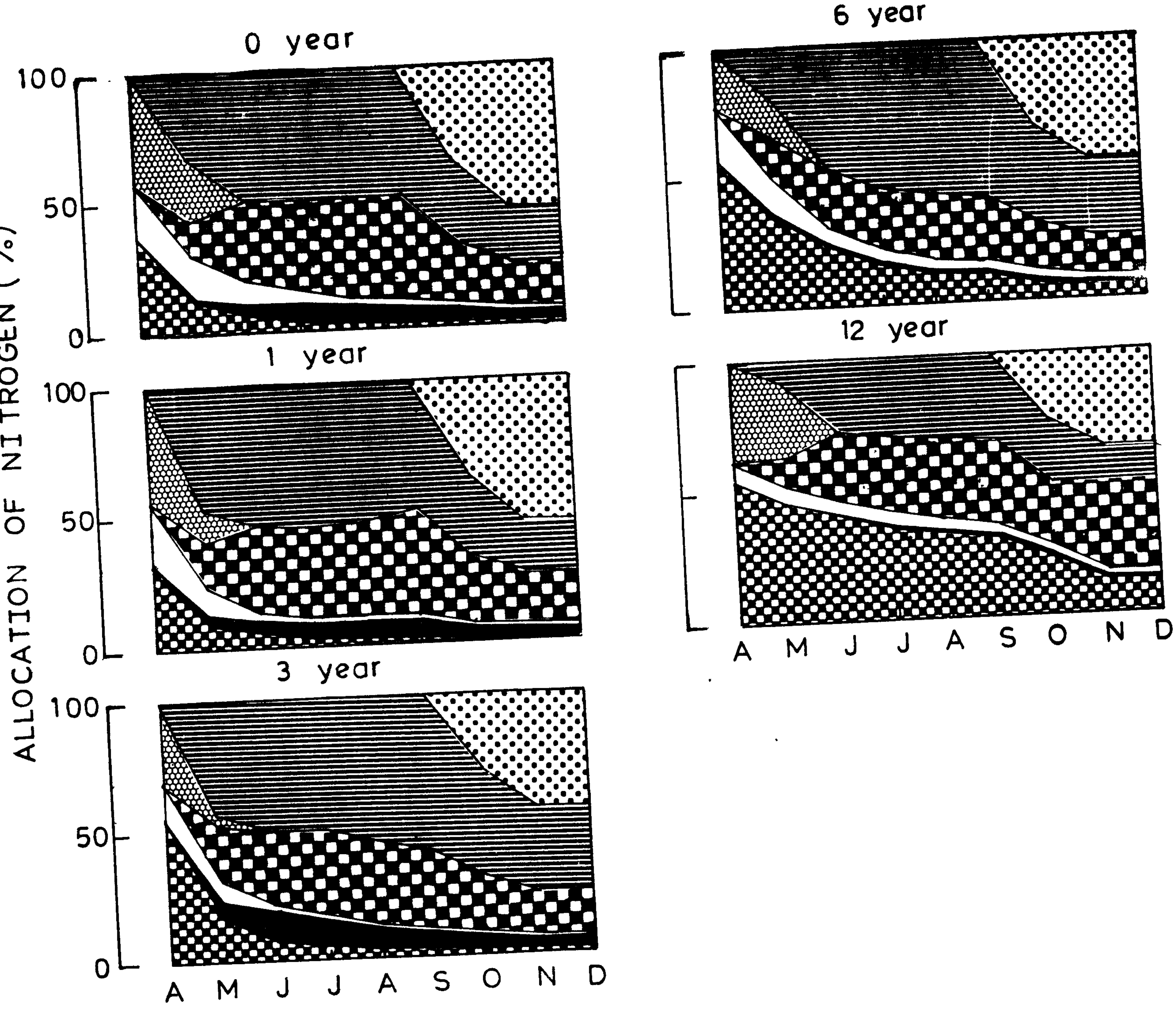

0 year
1 year
3 year
6 year
12 year
ALLOCATION OF NITROGEN (%)
100
50
0
A M J J A S O N D

Fig. 3.2c

ALLOCATION OF PHOSPHORUS (%)

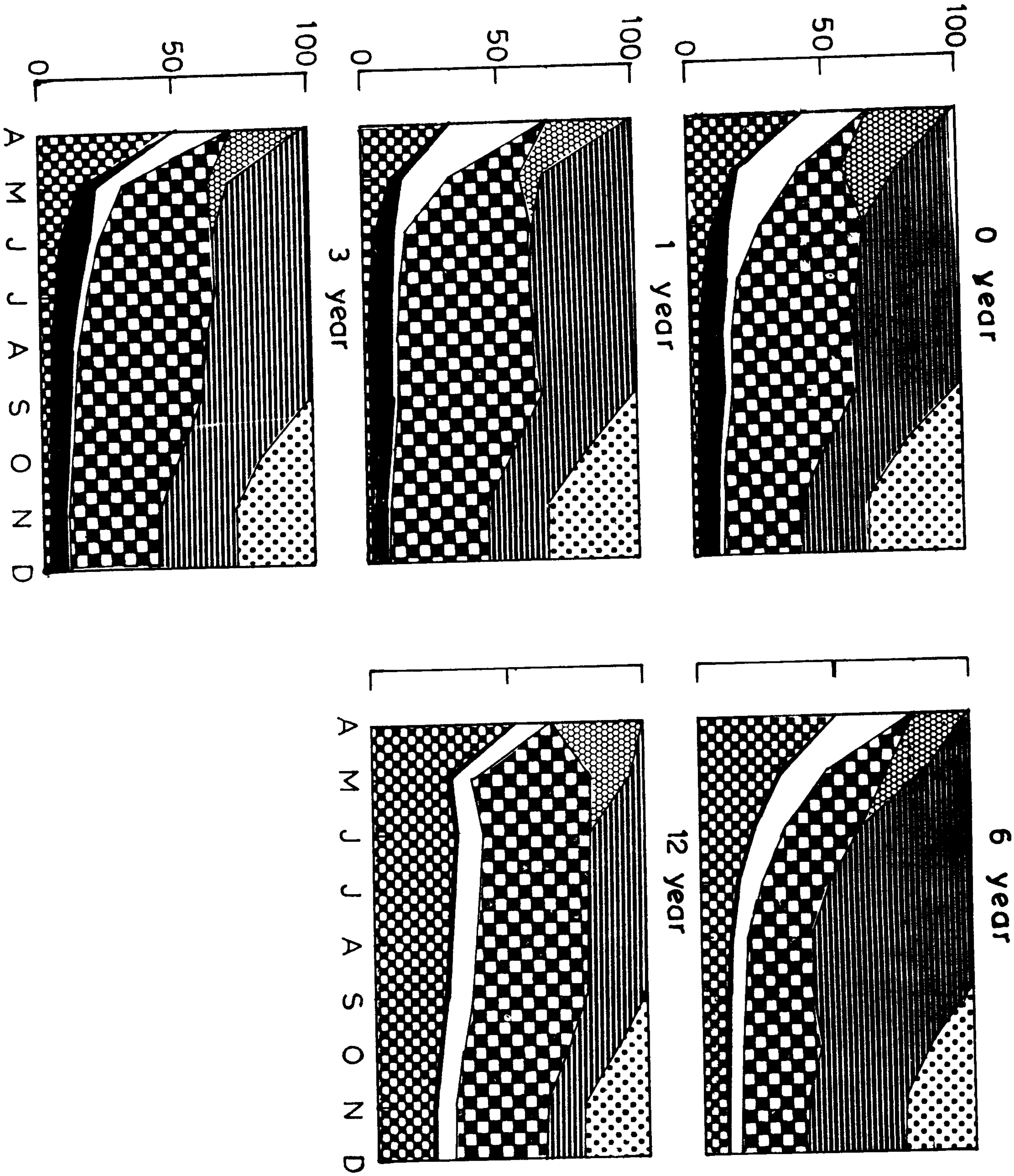


Fig. 3.2d

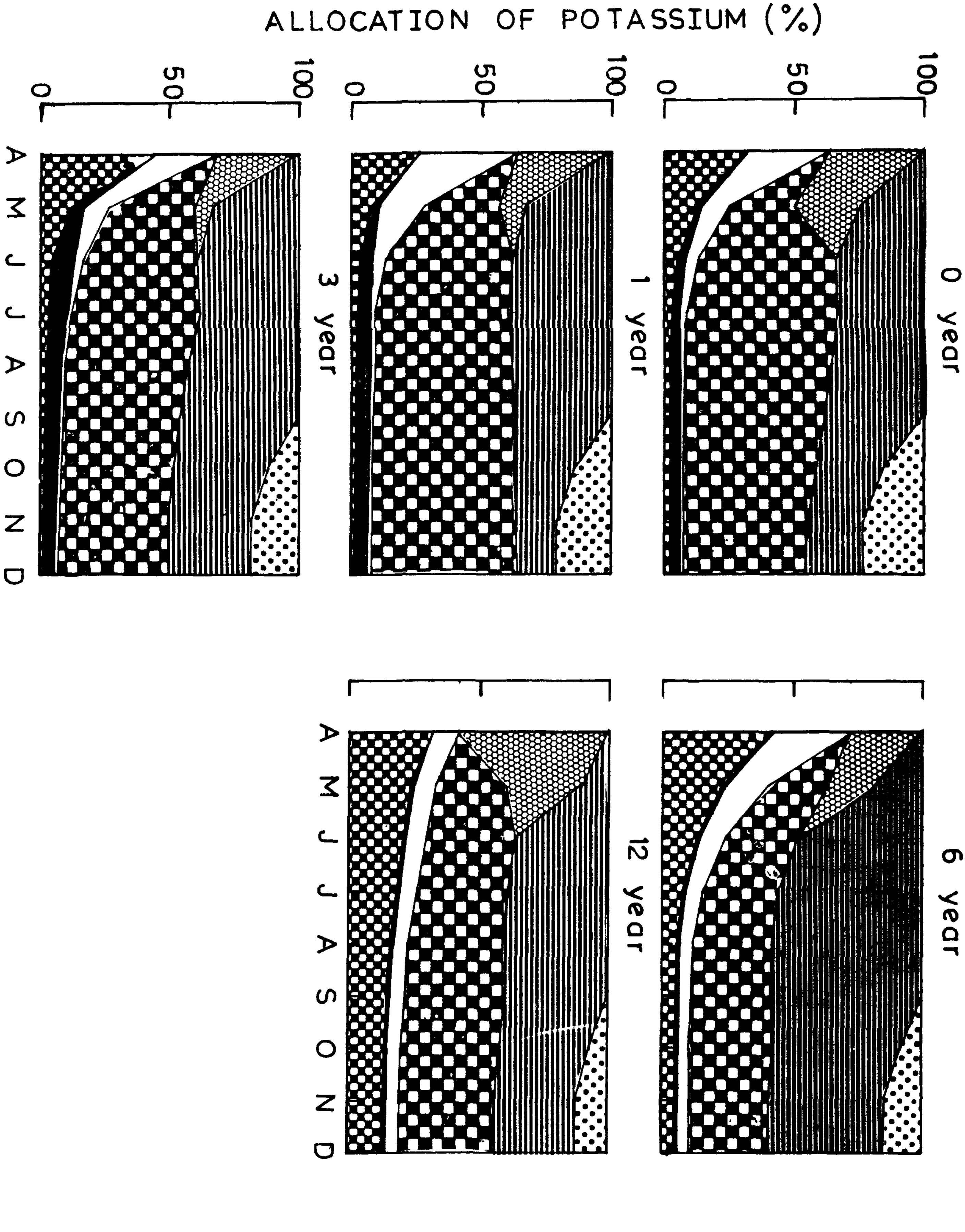

ALLOCATION OF POTASSIUM (%)
0
50
100
0 year
1 year
3 year
6 year
12 year
A M J J A S O N D

Figure3.2a shows the allocation pattern of biomass to different component organs, expressed as a percentage of the total capital. In a given fallow, rosette root and stem biomass declined with time and this decline was least in a 12-year-old fallow. Rosette leaves died off by June in all the fallows. Conversely, the allocation of biomass to the stolons increased with time. While the allocation to the root system of the ramets was more in the younger fallows, the reverse was the case for the rosette root system. Allocation of biomass to leaves of the ramets was maximum in a 6-year-old fallow. Reproductive allocation was least in a 12-year-old fallow.

Unlike biomass, higher fraction of nitrogen was allocated to the leaf and seed component while the reverse was true for stem, stolon and root component in all the fallows (Fig.3.2b). While the allocation of nitrogen to rosette root component increased with increase in age of the fallow that to the leaf and seed component was least in a 12-year-old fallow. Phosphorus also showed a similar pattern as nitrogen (Fig.3.2c). In contrast, a smaller fraction of potassium was allocated to the seed and root component in all the fallows (Fig.3.2d). Allocation of potassium to the stolon component was, however higher in all the fallows. The allocation of potassium to the leaf component reached its maximum in a 6-year old fallow and declined subsequently.

Table 3.2 Nutrient uptake efficiency (mg nutrient absorbed per g root biomass) of *M. micrantha* in successional fallows after slash and burn africulture.

Nutrient uptake efficiency	Age of fallow (years)					
	0	1	3	6	12	LSD (P=0.01)
Nitrogen	101.3	114.1	118.5	77.4	26.2	4.[illegible]
Phosphorus	10.2	12.8	13.3	7.1	2.8	0.4
Potassium	124.2	149.3	156.5	80.1	31.0	4.2

Table 3.3 Nutrient use efficiency (mg dry matter produced per mg nutrient absorbed) of *M. micrantha* in successional fallows after slash and burn agriculture.

Nutrient use efficiency	Age of fallow					
	0	1	3	6	12	LSD (P=0.0
Nitrogen	100.6	93.5	80.0	115.0	154.6	4.1
Phosphorus	1000.1	833.4	714.3	1250.5	1461.2	37.3
Potassium	82.0	71.4	60.6	111.1	130.9	3.3

Table 3.4 Reproductive effort (calculated as allocation to propagules as the percentage of net primary production or nutrient uptake during current growing season) of *M. micrantha* in successional fallows after slash and burn agriculture.

Reproductive effort		Age of Fallow (years) 0	1	3	6	12	LSD (P=0.01)
Biomass	Sexual	30.9	28.4	22.8	21.4	20.5	1.4
	Vegetative	40.9	50.1	50.0	55.0	59.7	4.8
Nitrogen	Sexual	64.2	59.4	45.5	54.9	10.6	4.0
	Vegetative	20.9	25.2	29.3	32.3	66.2	4.2
Phosphorus	Sexual	40.9	31.3	31.6	36.7	74.4	3.6
	Vegetative	31.3	40.4	40.0	44.9	116.0	7.3
Potassium	Sexual	34.7	30.8	23.9	33.7	386.9	39.32
	Vegetative	50.0	52.8	56.0	66.8	1835.6	49.60

Nutrient uptake efficiency increased with the age reaching a maximum in a 3-year-old fallow followed by a short decline in 6- and 12-year-old fallows (Table3.2). Nutrient use efficiency was generally low in younger fallows upt 3 years compared with 6- and 12-year-old fallows. The least efficiency was observed in a 3-year-old fallow (Table3.3).

Reproductive effort was calculated as a percentage of net primary procution or nutrient absorbed during the current season and allocated to reproductive units. Net primary production or increment in nutrient capital was obtained by substracting the resource capital existing before the initiation of growth from that at the end of the growing season. Such a quantification showed some difference (Table3.4) from the reproductive effort expressed as the proportion of the total available resource allocated to reproduction represented in Fig. 2a. Sexual reproductive effort in terms of biomass showed a gradual decline with the age of the fallow upto 12-years where as N,P,K showed a gradual decline upt 3 years followed by an increase in 6- and 12-year old fallows. Vegetative reproductive effort in terms of biomass and N,P,K showed increase with increase in age of the fallow.

DISCUSSION

For weedy colonizers coming up after slash and burn agriculture, as in nort-east India a useful strategy is to capitalize upon the nutrient resources of an enriched substratum (Saxena and Ramakrishnan, 1984b), and to rapidly colonize the site so that they are able to effectively compete with a number of other weedy species of this early successional environment (Toky and Ramakrishnan, 1983a; Saxena and Ramakrishnan, 1984b). This is reflected in the growth and biomass production pattern of Mikania micrantha established in early successional fallows.

Starting with a 0-year-old fallow where this species establish either from seed or from a ramet, in a short period of 2-3 weeks it gets established as a rosette with a tap root system which subsequently produces stolons rooting at nodes (ramet with a pair of leaves). The peak growth of this species is attained in early successional fallows upto 3 years after which the vigour declines. Such a decline in vigour in older fallows may be due to decreasing light availability due to larger shrubs and trees which limit growth of this light demander, as observations also made for other species such as Eupatorium odoratum in successional environments (Saxena and Ramakrishnan, 1984a).

The allocation strategy of *M. micrantha* both in terms of biomass and nutrients also supported the ruderal strategy of this species. Thus in younger successional fallows the allocation of resources to vegetatively reproducing stolons and seeds involved in sexual reproduction was proportionally higher than in older fallows. The higher allocation to the rosette root system in older fallows is indicative of the rapid transfer of resources as the plant ages to the perennating organ so that after perturbation the chances of establishment of this species through sprouts is considerably enhanced. Such shifts in allocation pattern in successional environment has also been shown by others (Abrahamson and Gadgil, 1973; Gaines et al., 1974; Roos and Quinn, 1977). However, many of these studies (Newell and Tramer, 1978; Abrahamson, 1979; Saxena and Ramakrishnan, 1982) suggest that the shift in allocation strategy is chiefly confined only to vegetative reporduction and sexual reproduction tends to remain more or less fixed under varied environments. Our studies on *M. micrantha* presented here and similar studies done for *Eupatorium odoratum* suggests that sexual reproductive allocation is equally variable as vegetative reproduction through ramets as observed in the allocation to the stolons.

Differences also occurred in the allocation strategy of the three nutrients considered here. While nitrogen and phosphorus tend to follow a similar pattern with more proportionate allocation to seed reproduction, potassium allocation was lesser to seed reproduction and more to stolons which are directly involved in vegetative reproduction. The allocation of all the three nutrients to leaf component was higher. This is to be expected because leaf is the chief photosynthetic organ that determines both seed and vegetative reproductive potential of the species. This is an agreement with the findings of van Andel and Vera (1977), Benzing and Davidson (1979), Williams and Bell (1981) and Abrahamson and Caswell (1982) emphasizes the importance of considering nutrients in allocation studies.

The sexual reproductive effort in the case of perennials to be more accurate should be on the basis of the current increment in the available resources devoted to reproductive units as suggested by Harper and Ogden (1970). Such a measure of sexual reproductive allocation of biomass (net reproductive effort of Harper and Ogden, 1970, expressed as the ratio of reproductive biomass to net primary production) was lower in 6- and 12-year-old fallows. However, this was higher in older fallows when nutrient cost was considered. Thus the reproductive development in this species is favoured in a ruderal open environment than when the species is under stress in older fallows, competing with others both for light and soil nutrients which are depleted during initial fallow growth (Ramakrishnan and Toky, 1981; Mishra and Ramakrishnan, 1983). This is in agreement with the results obtained for Eupatorium odoratum under similar situations (Saxena and Ramakrishnan, 1984a). The higher values for vegetative reproductive effort both in terms of biomass and nutrients in older fallows is perhaps a mechanism for survival under competitive stress (Grime, 1977; Chapin, 1981).

Though sexual reproductive effort is higher in younger fallows, seedling regeneration does not occur here but is noted only in a 12-year-old fallow where propagation through vegetative reproduction is less and therefore the seedlings can establish on the ground under the shade of larger shrubs and trees (Chapter I). In younger fallows seedling regeneration can occur only after a fire confirming the ruderal habit of the species with a preference for open and nutrient rich sites. The higher nutrient use efficiency in 6- and 12-year-old fallows may be an adaptation to survive and make adequate growth in a low nutrient environment.

After slash and burn agriculture the nutrient capital in the soil is gradually depleted because of the rapid transfer from soil to the vegetation and this continues upto about 10-years. M. micrantha which is a component of the weed community during this fallow phase shows greatest vigour upto about 3-years, after which it declines. This decline may be partly related to nutrient depletion in the soil, reduced light availability for this light demanding species and increased competition. This ruderal species therefore, has an exploitative growth strategy characteristic of a ruderal species (Chapin, 1981), with natural elemination of it under a more competitive stress environment of the older fallow phase.

SUMMARY

The growth and allocation of biomass and nutrients in *Mikania micrantha* H.B.K., an exotic early successional perennial weed was studied in seral stages after slash and burn agriculture. The peak vigour of the species was reached in a 3-year-old fallow with decline in older fallows. Allocation of biomass, nitrogen and phosphorus for reproduction was the least in a 12-year-old fallow. Allocation of biomass and nutrients to the leaf component was also very low in a 12-year-old fallow. On the other hand, allocation to the rosette root which is the perennating organ increased in older fallows, a strategy for survival and regeneration after a subsequent perturbation. Lower nutrient uptake efficiency and higher nutrient use efficiency in 6- and 12-year-old fallows are adaptations for survival in a nutrient poor competitive environment. This ruderal species has an exploitative growth strategy with biological control operating in older successional fallows.

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CHAPTER 4

EFFECT OF FIRE ON GROWTH AND ALLOCATION STRATEGY OF *MIKANIA MICRANTHA* H.B.K., UNDER SUCCESSIONAL ENVIRONMENT AFTER SLASH AND BURN AGRICULTURE

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INTRODUCTION

Fire is a tool used by the tribal population of the north-eastern hill region of India for shifting agriculture (locally called jhum) (Ramakrishnan *et al.*, 1981a,b). During the early fallow phase of 5-6 years, weeds form an important component of the ecosystem, and an exotic weed such as *Mikania micrantha* Humboldt, Bonpland and Kunth, is one of the important species. Unless the jhum cycle (the length of the fallow phase between two successive croppings at the same site) is a longer 10 year cycle or more, the weed potential increases (Saxena and Ramakrishnan, 1984b) and results in an arrested succession at the weed stage (Toky and Ramakrishnan, 1983a). Frequent disturbances through fire followed by cropping contribute to increased weed potential.

Many species that are fire adapted respond partly through increased reproductive effort, both sexual and or vegetative (Gill, 1981; Newell and Tramer, 1979) or through adjustments in the allocation strategies both of biomass (Keeley and Keeley, 1977; Saxena and Ramakrishnan, 1983a,b) and of nutrients (Saxena and Ramakrishnan, 1983a,b). The present study on *M. micrantha* is, therefore, an attempt to understand the adaptive strategy of this early successional weed as a response to fire, through early successional environment.

METHODS OF STUDY

Three replicate fallow plots each of about 2 ha. of different ages (2,4 and 8 year) were identified at Lailad taking care to ensure similar topographic and expsure conditions. The age of the fallows and the similarity in land use with a 10-year-jhum cycle were based on our own observations and the records available with the village headman. Age was calculated from the time the cropped plots were left a fallow for natural regeneration of vegetation after slash and burn agriculture. Half of each fallow plot was slashed in February and the dried slash was burnt in March to sutudy the effect of fire; the other half was maintained as an undisturbed control. A fire line separated the two halves in each plot.

Fifty plants coming up through seedlings in burnt sites (mostly seedling regeneration occurred here, vegetative propagation was rare) and the same number in unburnt sites (coming up through ramets) were selected and tagged randomly in each fallow plot in April 1983. Five replicate plants with attached ramets were harvested at monthly intervals during the growing season from May to December 1983, taking care not to damage any plant part. Belowground parts were carefully washed and separated into different component organs. The fallen leaves and seeds were also included following

Hickman (1975). Fruits of M. micrantha are achenes, which are ecological equivalents of seeds. Fruit biomass, thus equals seed biomass (Harper, Lovell and Moore, 1970). The different components were dried at 80 ± 5°c for 48 hours and weighed. Leaf area estimations using a planimeter and leaf dryweight per unit area were based on three replicates and the average of 50 leaves per replicate. Total leaf area per plant was computed using leaf biomass and leaf dry weight per unit area.

The growth functions: relative growth rate (RGR), net assimilation rate (NAR) and leaf area ratio (LAR) (Huges & Freeman, 1967; Radford, 1967) were calculated as:

$$RGR = \frac{\text{In } W_2 - \text{In } W_1}{t_2 - t_1}$$

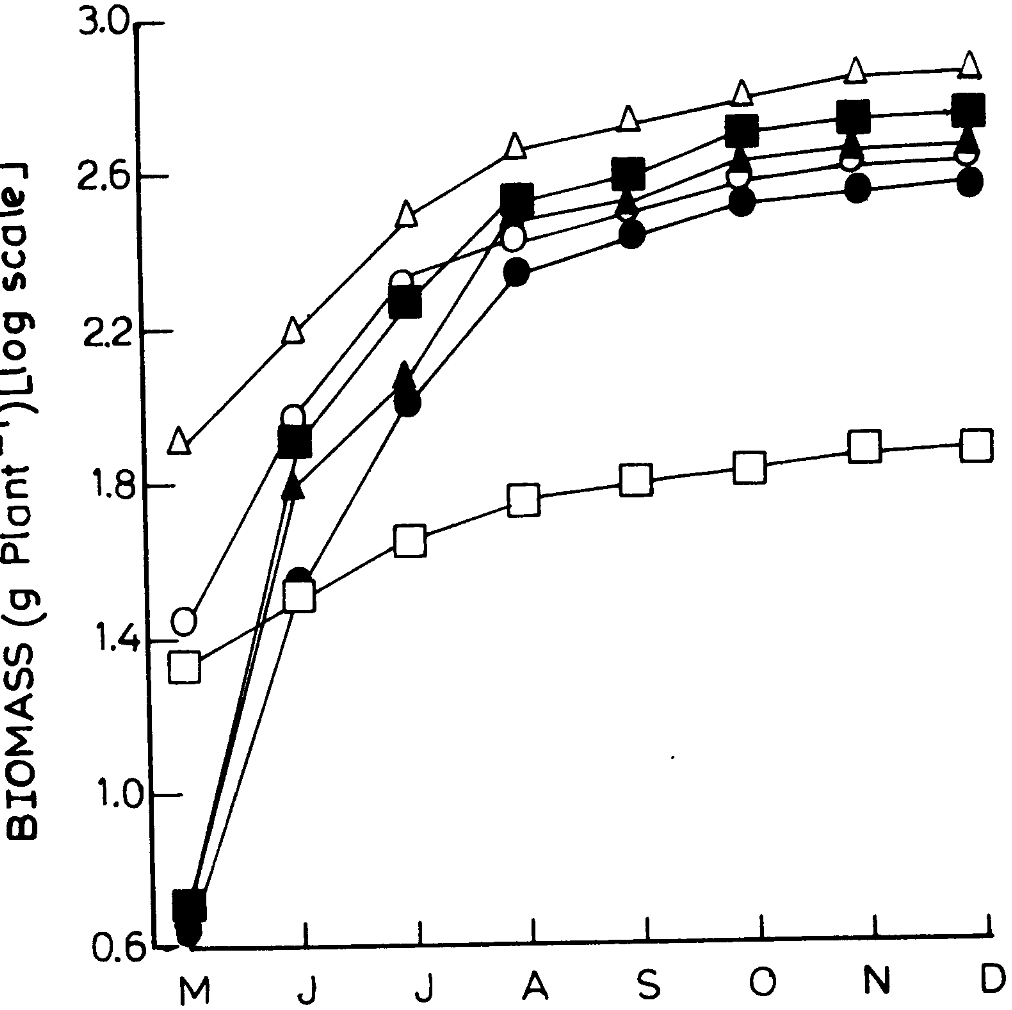
$$NAR = \frac{(W_2 - W_1)\ (\text{In } A_2 - \text{In } A_1)}{(A_2 - A_1)\ (t_2 - t_1)}$$

$$LAR = \frac{(A_2 - A_1)\ (\text{In } W_2 - \text{In } W_1)}{(\text{In } A_2 - \text{In } A_1)\ (t_2 - t_1)}$$

Where W_1 and A_1 are the biomass per plant and leaf area pet plant respectively at time t_1 and W_2 , A_2 are the same the time t_2.

Fig. 4.1 Biomass (a) and leaf area (b) changes of <u>M. micrantha</u> in 2-year (○), 4-year (△), and 8-year (□),old fallows after slash and burn agriculture. Closed symbols, burnt sites; Open symbols unburnt sites.

Fig. 4.1a



The concentration of nutrients in different plant parts were determined following standard methods (Allen, et. al., 1974). Thus, nitrogen was analysed by micro-kjeldahl method, phosphorus by molybdenum-blue method and potassium by flame photometry, after wet digestion with triple adid (perchloric, nitric and sulphuric acid).

Nutrient uptake efficiency was calculated as mg nutrient absorbed per g root biomass following Blair and Cordero (1978). Nutrient use efficiency was calculated as mg dry matter production per mg nutrient absorbed (Brown, 1978).

RESULTS

Growth in unburnt sites started in March through the perennating rosette stock, whilst in burnt sites it started through seedling in May. Biomass increased with time in both burnt and unburnt sites of all the fallows (Fig.4.1a). This increment was steeper upto August in all the burnt sites compared to the unburnt sites. A comparision of unburnt sites indicate that the initial increment was sharper in younger fallows compared to an 8-year-old fallow. The values at final harvest in unburnt sites was maximum in a 4-year-old fallow but low in an 8-year-old fallow ($P<0.01$). A gradual but significant increase ($P<0.05$) occurred in the biomass in burnt sites, with the age of the fallow.

Table 4.1 Mean values ± S.E.M. of growth functions of *M. micrantha* in successional fallow plots after slash and burn agriculture.

Growth functions	Age of fallow (years)	Burnt	Unburnt
Relative growth rate (mg $mg^{-1} d^{-1}$)	2	0.0235±0.0005	0.0148±0.0003
	4	0.0247±0.0004	0.0153±0.0002
	8	0.0257±0.0004	0.0070±0.0004
Net assimilation rate (mg $cm^{-2} d^{-1}$)	2	0.171±0.003	0.154±0.004
	4	0.184±0.003	0.163±0.003
	8	0.197±0.006	0.088±0.001
Leaf area ratio ($cm^{2} mg^{-1}$)	2	0.195±0.006	0.139±0.005
	4	0.254±0.008	0.214±0.005
	8	0.293±0.009	0.019±0.0005

Fig. 4.1b

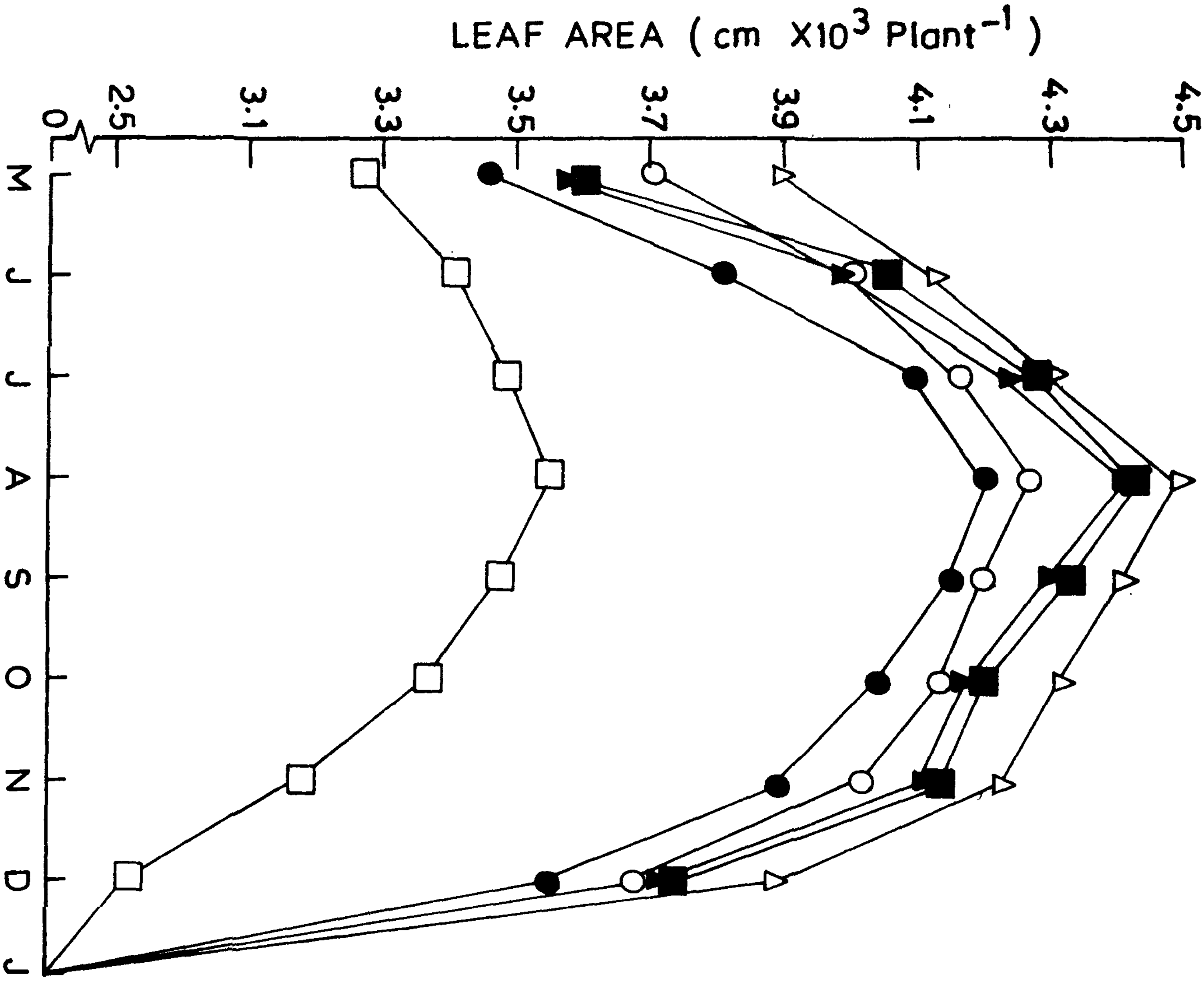


Fig. 4.2a,b,c,d. Allocation of biomass and nutrients (% of total capital) to different organs: rosette leaves ( ); inflorescence ( ); ramet leaves ( ); stolons ( ); rosette stem ( ); rosette roof ( ); ramet root ( ) in M. micrantha in fallows of various ages after slash and burn agriculture.

Fig. 4.2a

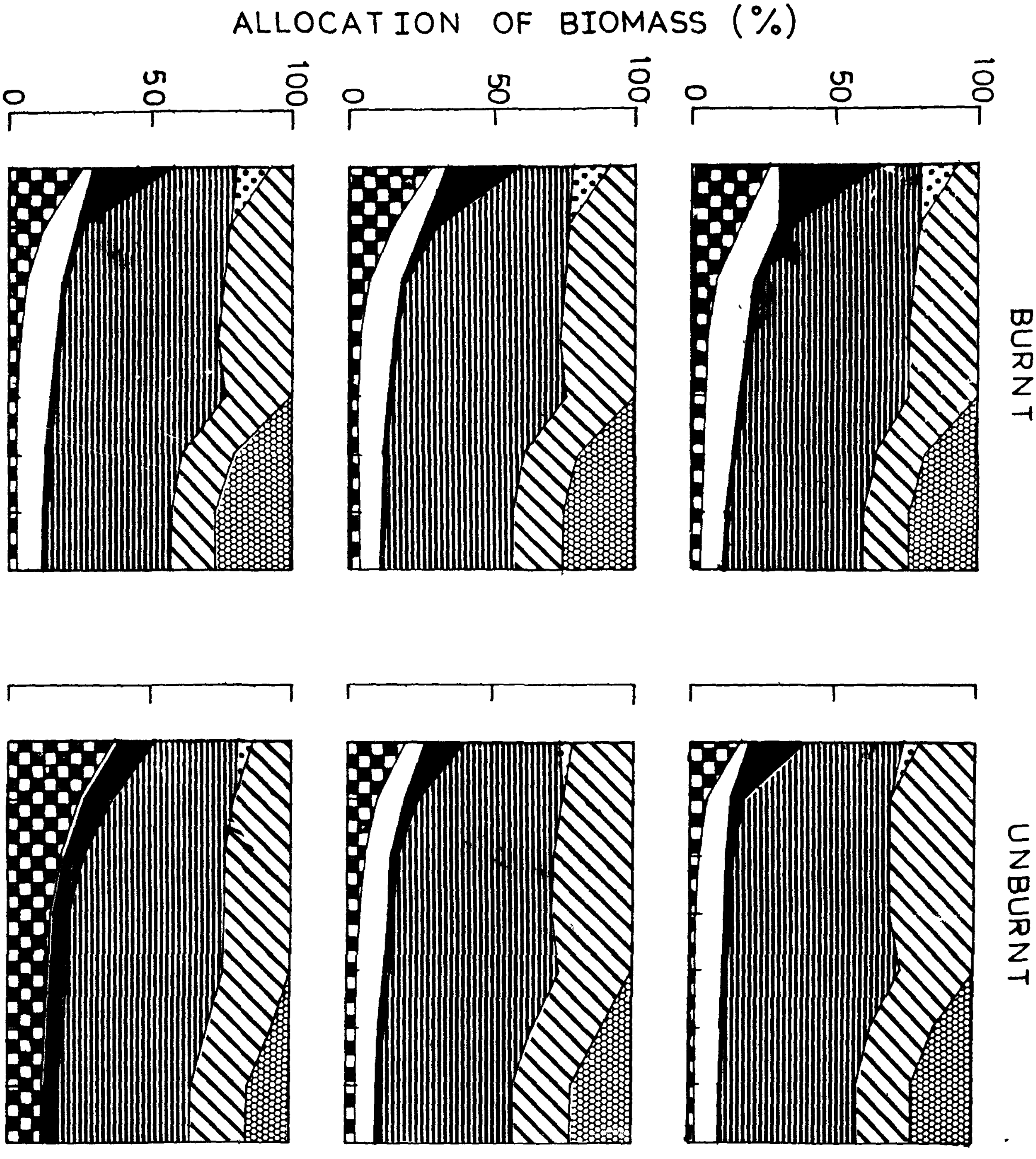


Fig. 4.2b

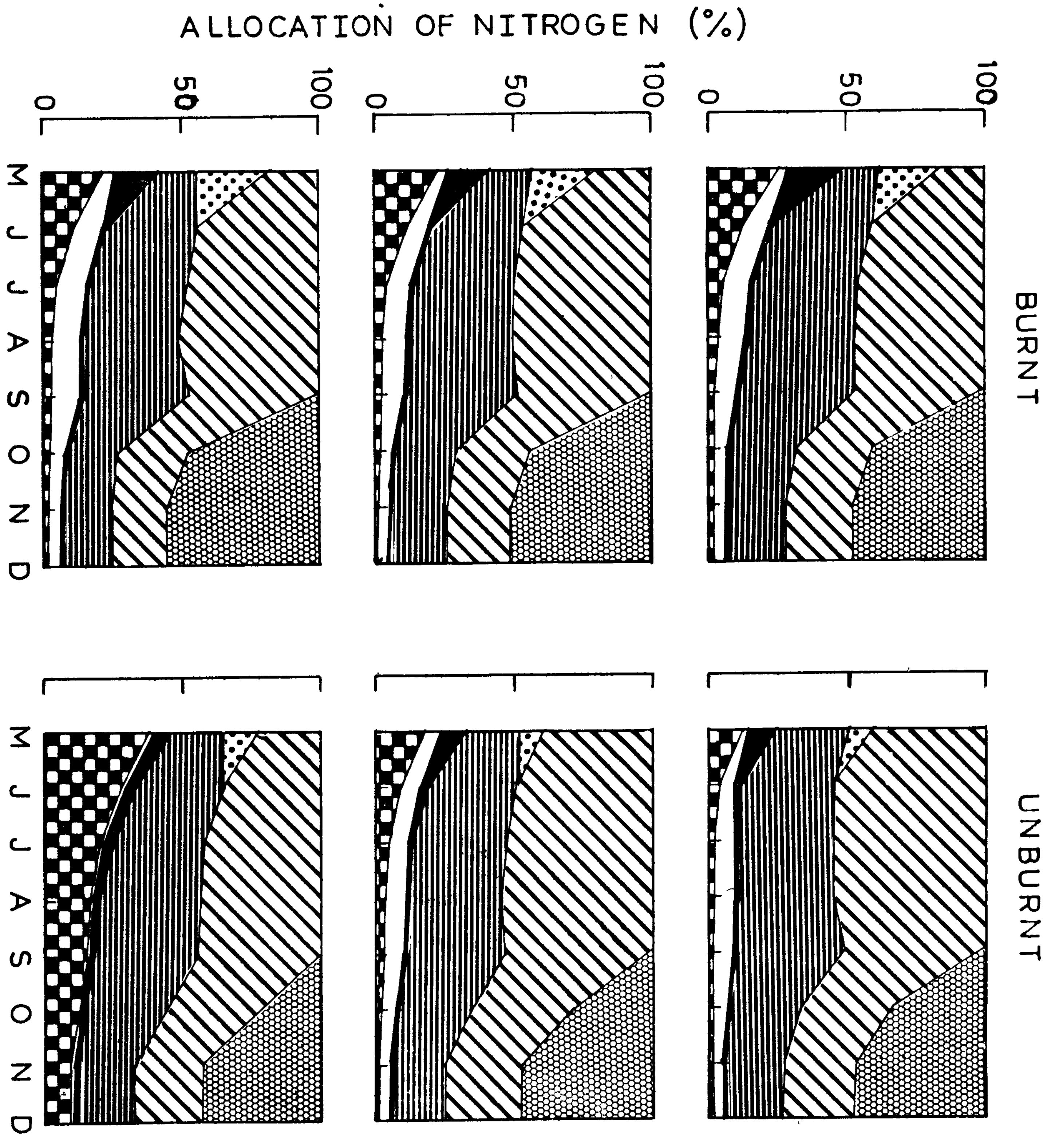


Fig. 4.2c

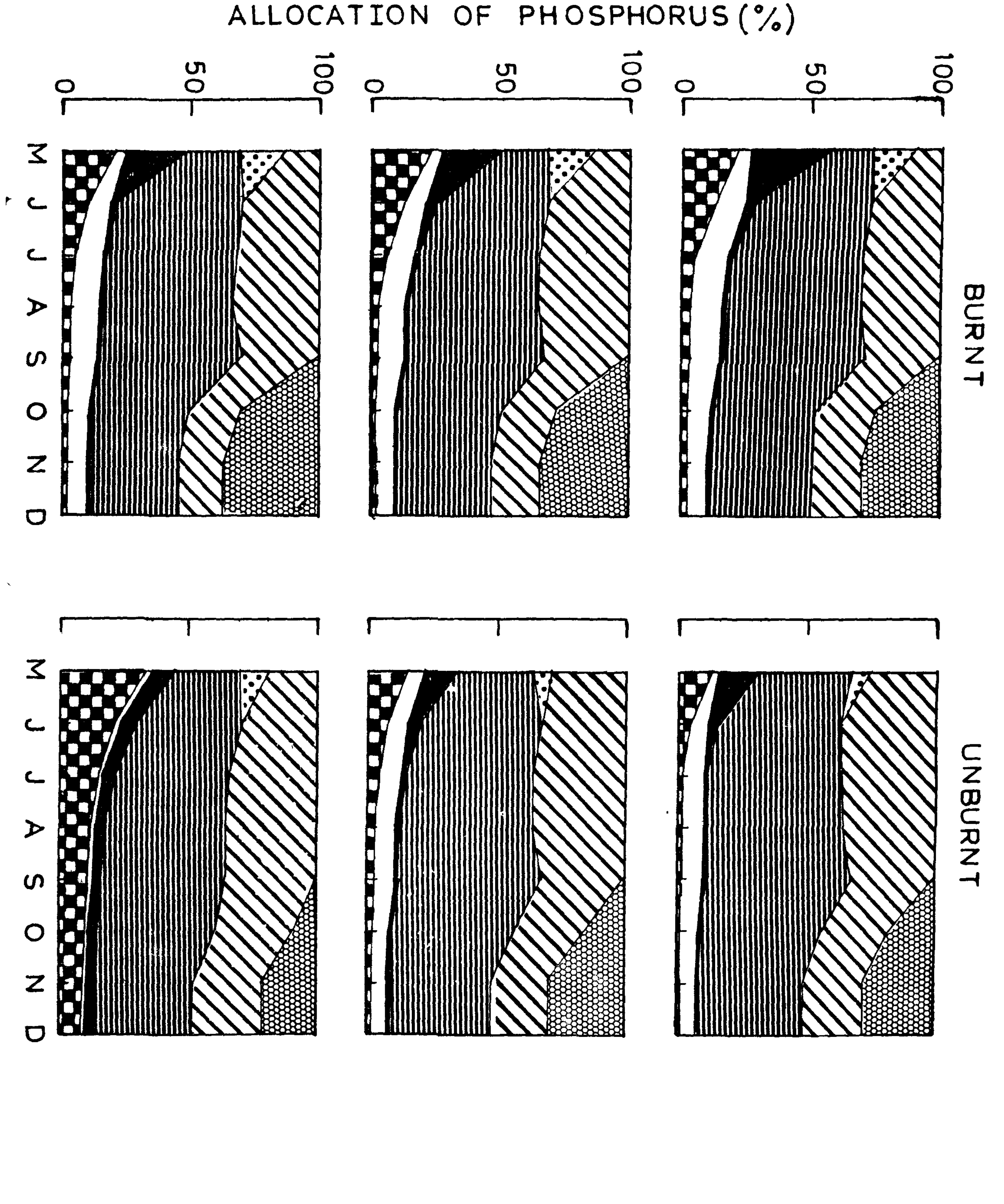
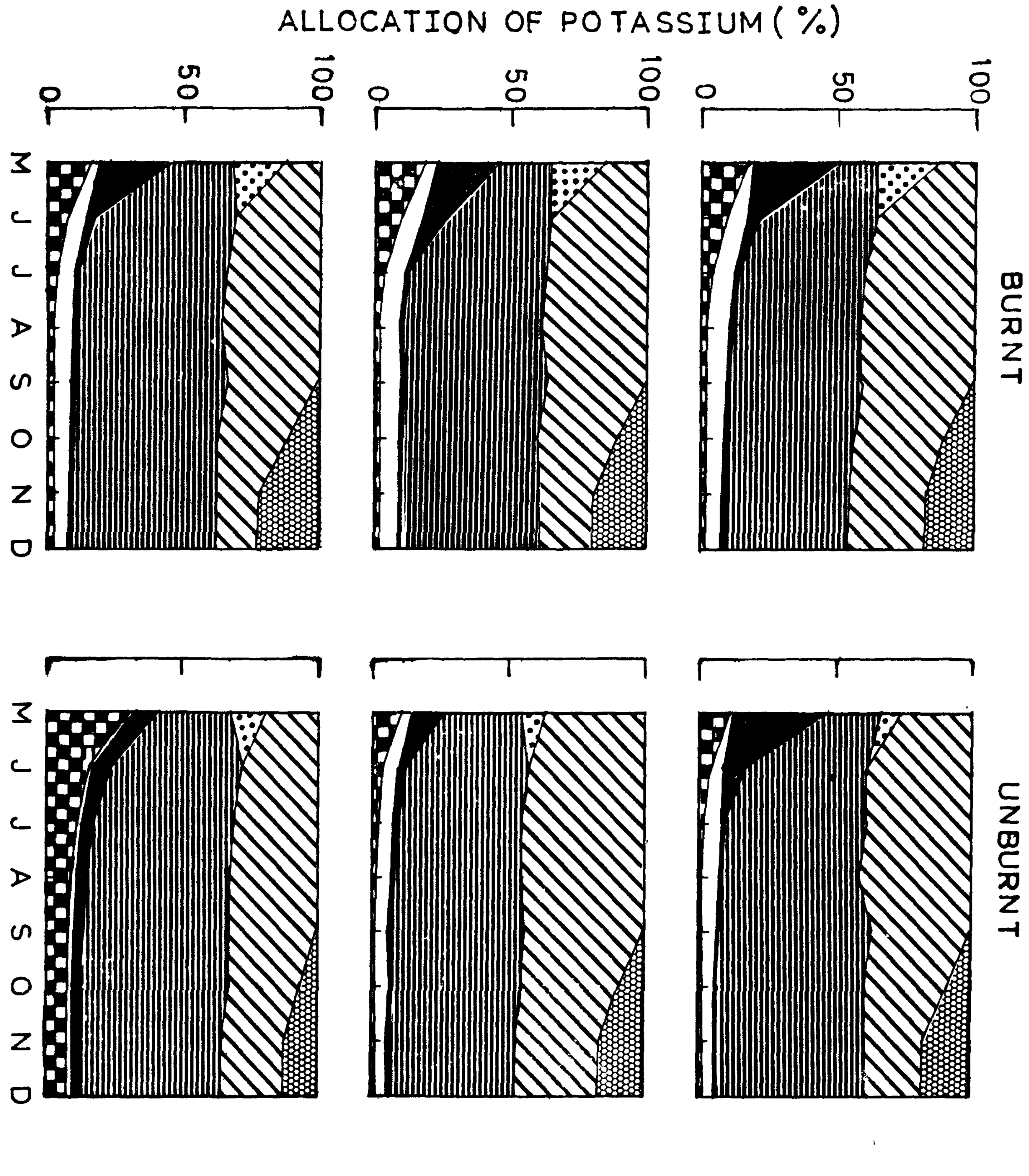


Fig.4.2d



Leaf area also followed a similar pattern as biomass in different treatments (Fig.4.1b). However, leaf area reached a maximum in August after which it declined to zero value in January when the death of the aerial parts occurred.

Growth functions (RGR, NAR and LAR) increased significantly ($P = < 0.01$) between 2-and 8-year-old fallows, in burnt sites (Table 4.1). In unburnt sites growth functions significantly decreased ($P < 0.01$) in an 8-year-old fallow. A significant increase ($P < 0.01$) due to burn was observed in all the fallow plots.

Allocation of biomass to the seed component increased in burnt sites of the older fallows, whereas in declined in unburnt sites (Fig.4.2a). Generally speaking, allocation of biomass to seed reproduction was lower in unburnt sites than in burnt sites of all fallows, more markedly so in an 8-year-old fallow. Rosette root allocation and that to the stolon in an 8-year-old fallow was initially higher in the unburnt site compared to the burnt site. Allocation to the leaf component declined gradually with the age of the fallow in unburnt sites only.

Allocation of nitrogen, phosphorus and potassium followed a similar pattern as allocation of biomass in different treatments (Fig.4.2b,c,d). However, allocation of potassium to the

Table 4.2 Nutrient uptake efficiency (mg nutrient absorbed per g root biomass) of *M. micrantha* in successional fallow plots after slash and burn agriculture.

Nutrient uptake efficiency	Age of fallow (years)	Burnt	Unburnt
Nitrogen	2	108.1	85.2
	4	120.7	92.7
	8	128.0	45.1
LSD (P=0.05)		10.6	7.3
Phosphorus	2	11.5	9.5
	4	13.6	9.3
	8	14.5	4.4
LSD (P=0.05)		1.3	1.2
Potassium	2	133.8	114.6
	4	154.8	120.9
	8	166.1	81.2
LSD (P=0.05)		14.6	11.00

Table 4.3 Nutrient use efficiency (mg drymatter produced per mg nutrient absorbed) of *M. micrantha* in successional fallow plots after slash and burn agriculture.

Nutrient use efficiency	Age of fallow (years)	Burnt	Unburnt
Nitrogen	2	78.1	98.3
	4	75.6	100.4
	8	69.3	175.0
LSD (P=0.05)		7.6	7.6
Phosphorus	2	699.3	895.7
	4	672.1	1005.8
	8	583.4	2029.9
LSD (P=0.05)		24.9	157.0
Potassium	2	60.3	73.7
	4	56.5	77.1
	8	50.7	97.9
LSD (P=0.05)		6.0	5.2

Table 4.4 Reproductive effort (calculated as allocation to the seed as the percentage of net primary production or nutrient uptake during current growing season) of *M. micrantha* in successional fallow plots after slash and burn agriculture.

Reproductive effort	Age of fallow (years)	Burnt	Unburnt
	2	24.1	22.6
Biomass	4	24.8	21.8
	8	26.9	22.3
	2	57.3	53.2
Nitrogen	4	59.7	60.8
	8	63.8	87.5
	2	50.6	46.3
Phosphorus	4	53.2	48.8
	8	55.8	79.6
	2	30.8	33.2
Potassium	4	31.2	39.1
	8	32.9	83.0

seed reproduction was generally lower compared to nitrogen and phosphorus allocation. Allocation of potassium to stolon was generally higher compared to nitrogen. Conversely, allocation of nitrogen to the leaf component was higher compared to potassium.

Nutrient uptake efficiency increased significantly ($P < 0.01$) with age in burnt sites. In unburnt sites it decreased sharply ($P < 0.01$) in an 8-year-old fallow as compared with younger fallows (Table4.2). While nutrient use efficiency decreased significantly ($P < 0.01$) with the age of the fallow in burnt sites, reverse was the case in unburnt sites (Table4.3). Burnt fallows showed significantly lower values ($P < 0.01$) for all the nutrients.

Reproductive effort in terms of biomass and nutrients were not significantly ($P > 0.05$) different in the different fallow plots, that were burnt or unburnt (Table 4.4). However, the reproductive effort in terms of nutrients was significantly higher ($P < 0.05$) in an 8-year-old fallow compared to younger ones, in unburnt sites only.

DISCUSSION

A number of changes in the micro-environment of the site would occur soon after slash and burn. The release of nutrients through ash is regulated by the fuel load (Toky and Ramakrishnan, 1981b; Mishra and Ramakrishnan, 1983b) which would depend upon the fallow age. Thus slash and burn of an 8-year-old fallow, in the present case, would release more nutrients compared to a 2-year-old fallow. Apart from this changes in the micro-environmental conditions also occur due to increased insolation and the subsequent changes in soil moisture and atmospheric humidity in the site. After slash and burn the competition from other species is also drastically reduced. All these changes would influence the growth strategy of an early successional weed such as Mikania micrantha.

An important consequence of fire, in terms of the establishment strategy of M. micrantha, is that in the burnt site, it is chiefly through seed as the perennating rosette stock is killed due to the burn and the species largely resorts to seed reproduction. On the other hand, in unburnt sites, even though seed source is available the seedlings are unable to germinate/establish in any of the fallows. While in unburnt younger fallows seed germination does not occur at all, in an 8-year-old fallow few seedlings that come up fail to establish.

The fire dependence of M. micrantha is obvious from the growth pattern of the species in different fallows with or without burn. While in all the burnt fallow plots growth was generally high irrespective of fallow age, in the unburnt sites the growth got drastically reduced in an 8-year-old fallow. Since the plants in burnt plots come up and establish through seedlings with less resource stock, the promotion of growth here apparently is due to changes brought about in the micro-environment by fire, rather than due to a direct promotary effect suggested in some of the other studies (Keeley and Zedler, 1978; Kilgore, 1979; Christensen, 1979; Gill, 1981). Thus whilst growth functions such as RGR, NAR and LAR all decline in an 8-year-old fallow plot not subjected to burn, the reverse condition where there is an increase in growth functions in older fallows subjected to burn could be related to increased soil fertility through ash because of the higher fuel load in older fallows (Ramakrishnan and Toky 1981).

The ruderal nature and the fire dependence of M. micrantha is further supported by the allocation strategy changes. Increased biomass allocation to seed component in burnt sites supports the shift towards seedling regeneration and establishment promoted through fire, discussed earlier. Thus in unburnt sites, allocation to the seed component declines with fallow age unlike in the burnt sites. The decline in the weed vigour in older unburnt fallows is also reflected in reduced allocation to the leaf component with fallow age.

Though nutrient allocation pattern generally tended to fallow the biomass allocation pattern, allocation of potassium to the leaf and seed components was generally lower than that of nitrogen, an observation also made by others (van Andel and Vera, 1977; Benzing and Davidson, 1979; William and Bell, 1981). Similarly, generally higher allocation of nitrogen compared to phosphorus and potassium to the leaf component was noted, an observation similar to that of Saxena and Ramakrishnan(1984a). Since nitrogen is closely associated with photosynthetic components especially chlorophyll and carboxylase enzymes and since phosphorus and potassium are less critical in this respect (Terry and Ulrich, 1973; Natr, 1975). Such an allocation pattern is understandable.

During cropping under slash and burn agriculture nutrient losses that occur through ash blow-off and through hydrology (Toky & Ramakrishnan, 1981b) are very high, In the early fallow phase, a rapid depletion of nutrients from the soil occur, so that in the younger fallows nutrient availability is limited (Ramakrishnan and Toky, 1981; Toky and Ramakrishnan, 1983b). This depletion from the soil would, however, increase with fallow age. This would explain the higher nutrient uptake efficiency of M. micrantha from younger unburnt fallow plots compared to the older ones. However, the low nutrient uptake efficiency in younger unburnt fallow plots is compensated to some extent by a high nutrient use efficiency, which declines in older fallows. The low nutrient use efficiency in older fallows is also reflected in the high nutrient cost for seed reproduction in an 8-year-old fallow that was unburnt, when compared to the burnt site.

In burnt fallow plots, the nutrient uptake efficiency, however, was generally higher than in unburnt plots and this increased with fallow age. This is related to increased fertility because of increased fuel load in older fallows. Consequently here the nutrient use efficiency declined with fallow age. This early successional exotic weed, thus, is adapted to a ruderal environment subjected to constant perturbation. In the present case, fire seems to be an important component at various stages in its life cycle right from the stage of its establishment through growth and reproduction.

SUMMARY

Effect of fire on growth and allocation of biomass and nutrients in Mikania micrantha H.B.K., an exotic early successional perennial weed studied in seral stages after slash and burn agriculture. In burnt sites establishment of M. micrantha was chiefly through seeds, whereas in unburnt sites vegetative reproduction alone occurred. While growth in the burnt sites was less affected through fallow age, the plant vigour declined sharply in an 8-year-old unburnt fallow plot. In burnt sites both biomass and nutrient allocation to the seed component was generally higher compared to unburnt sites of all fallow ages. The biomass and nutrient allocation strategies of this species followed different patterns suggesting that both the currencies are important. Generally higher nutrient uptake efficiency which increased with fallow age in burnt sites are related to soil nutrient level. The high nutrient uptake efficiency in younger fallows and low nutrient uptake efficiency in older fallows that are unburnt plots are also similarly related. However, the reverse pattern for nutrient use efficiency may be a compensatory plasticity mechanism for survival in successional environments. It is concluded that perturbation such as fire plays an important role at various stages of the life cycle of this species.

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CHAPTER 5

CONTRIBUTION OF *MIKANIA MICRANTHA* H.B.K., DURING SECONDARY SUCCESSION FOLLOWING SLASH AND BURN AGRICULTURE (JHUM) IN NORTH-EAST INDIA. I. BIOMASS, LITTER-FALL AND PRODUCTIVITY

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INTRODUCTION

Slash and burn agriculture is a predominant land use system in the humid tropics of the north-east India (Ramakrishnan, 1985a). Partly due to increase in population pressure and partly to reduced land availability as related to desertification (Ramakrishnan, 1985b,c), the slash and burn agriculture cycle (the intervening fallow phase between two successive croppings at the same site) has come down from a more reasonable length of 10 years or more to less than 5 years. This has aggravated the weed potential under this land use (Saxena and Ramakrishnan, 1984). *Mikania micrantha* Humboldt, Bonpland and Kunth, is one such exotic weed that was introduced into this region a few decades ago (Parker, 1972; Dutta, 1977) as a ground cover for tea plantations, but has now become difficult to control, this and many other weeds, however, have a conservation role in terms of restoring a disturbed ecosystem after slash and burn agriculture (Ramakrishnan, 1984). The present paper, therefore, deals with the biomass, litter production and aboveground net primary productivity of early successional plant communities developed after slash and burn agriculture, but with particular emphasis on *M. micrantha* dominated fallows (Toky and Ramakrishnan, 1983a). The contribution by *M. micrantha* in the early successional ecosystem function is emphasized.

METHODS

Site characteristics and phytosociology:

Vegetation analysis, biomass and litter fall studies were done in M. micrantha dominated 1-,2-,4-,8-and 12-year-old fallows (three replicates) identified at Lailad, taking care to ensure similar topographic and exposure conditions. The age of the fallows and the similarity in land use with a 10-year jhum cycle (the intervening fallow phase between two successive croppings at the same site) were based on our own observations and also on the records of the village headman. Age was calculated from the time the cropped plots were left fallow for natural regeneration.

Density, frequency and cover of the associated vegetation were studied using 1 m^2 quadrats for herbaceous species and 100 m^2 quadrats for shrubs and trees. The importance value index (IVI) was calculated using relative frequency, relative density and relative basal area of the species (Misra, 1968; Kershaw, 1973). The values are based on 20 randomly placed quadrats at each fallow plot with 2 to 2.5 ha. evaluated per site (left-over tree species during slash and burn operation were excluded from the study).

Litter:

In 8-and 12-year-old fallows 15 litter traps of 100 X 100 X 15 cm size were placed at random in each fallow plot.

However, in 1-2-and 4-year-old fallows, where herbaceous vegetation was dense, the litter was carefully collected from 15 randomly placed 1 m^2 permanent quadrats. Litter sampling was done for a one year period, at monthly intervals, except during rainy season, (May-August), when 2 weekly collections were made. Litter was classified into different components and categories. Litter was dried at 80°c for 24 hours and weighed.

Biomass and productivity:

The biomass of vegetation less than 2 m tall was estimated by harvest method when most of the species were at their peak biomass (October, 1983). 20, 1 m^2 quadrats placed 40 m apart along a transect in each fallow plot were clipped at ground level and sorted out into different categories and components. They were oven dried at 80°c for 24 hours and weighed.

Biomass of individuals taller than 2 m in 4-,8-and 12-year-old fallows were estimated on the basis of individual harvests of different size classes of a given species. Thus, the bamboo shoots were divided into five diameter classes at 2 cm intervals from 3 to 11 cm. Five random replicates of each diameter class were cut at ground level and the fresh weight biomass was obtained separately for different components. Dry weight was calculated on the basis of weighed samples dried at 80^{o}c, as above, The average shoot density of each diameter class was then used to calculate total biomass. For all other shrubs and trees linear regressions between diameter at breast height (dbh) and various biomass components were calculated (Newbould, 1967) based on the harvest of 20 individuals of each dbh class.

The community biomass accumulation rates in different fallows was determined from the difference between the standing biomass at peak growth of two consecutive fallow ages. The annual litter production was added to this value to give aboveground net community primary productivity. The biomass accumulation rate in M. micrantha in different fallows was the difference between the initial biomass in March just before current year's growth was initiated and the peak biomass obtained in October. Aboveground net production for this species included biomass losses during the growth period. Herbivory was not determined.

RESULTS

In younger successional fallows upto about 8 years, weedy species such as Mikania micrantha, Eupatorium odoratum, Ageratum conyzoides, Erigeron linifolius and Imperata cylindrica form important components of the community. Dendrocalamus

Table 5.1 Importance value indices of plant species associated with M. micrantha in successional fallows after slash and burn agriculture.

Species	Age of Fallow (years) 1	2	4	8	12
Herbs:					
Ageratum conyzoides L.	70.0	50.4	27.4	22.3	15.0
Borreria hispida K. Schum.	33.3	22.0	-	-	-
Desmodium triquitrum D.C.	11.2	-	-	21.0	-
Desmodium Laxiflorum D.C.	-	-	14.2	-	21.8
Erigeron linifolius Wild.	27.0	16.6	5.93	-	-
Eupatorium odoratum Linn.	51.2	66.8	51.0	35.4	23.7
Imperata cylindrica Beaw.	12.8	22.0	28.6	22.2	-
Hedychium cornonarium Koeing	-	7.5	-	27.9	19.3
Ipomea pileata Roxb.	10.0	-	-	-	-
Mikania micrantha H.B.K.	40.4	84.7	111.6	44.3	28.4
Muccuna bracteata D.C.	9.0	-	20.6	-	-
Panicum maximum Munro	15.3	9.8	18.9	-	21.6
Panicum khashianum Jav.	13.0	-	-	15.5	-
Thysanoleana maxima (Roxb.)O.ktze	-	11.76	-	27.9	34.5

Shrubs:					
<u>Clerodendrum</u> <u>colebrokianum</u> Walp	-	-	0.2	2.8	-
<u>Litsaea</u> <u>assamica</u> Hk.f	0.2	-	0.2	4.7	3.6
<u>Measa</u> <u>indica</u> Wall.	-	0.2	0.1	4.6	5.9
<u>Melastoma</u> <u>malabathricum</u> Linn.	-	-	0.2	9.2	6.8
<u>Mussaenda</u> <u>roxiburghii</u> Hk.f	-	0.2	0.2	3.5	1.6
Trees:					
<u>Anthocephalus</u> <u>cadamba</u> Mev.	0.2	-	0.1	-	3.2
<u>Cedrella</u> <u>toona</u> Roxb.	-	0.2	0.2	3.7	5.3
<u>Cinnamomum</u> <u>bejolghota</u> (Buch.)Ham.	-	-	2.1	2.2	9.9
<u>Cálicarpa</u> <u>macrophylla</u> Vahl.	-	-	-	-	4.7
<u>Dendrocalamus</u> <u>hamiltonii</u> nees & Arn.	3.4	7.9	12.9	28.7	47.8
<u>Sapium</u> <u>baccatum</u> Roxb.	0.2	-	0.1	2.1	5.1
<u>Schima</u> <u>wallichii</u> Choisy.	-	0.2	0.1	1.1	4.3
<u>Macaranga</u> <u>denticulata</u> Muell.	0.2	-	-	1.5	4.3
<u>Sterculia</u> <u>villosa</u> Roxb.	0.1	1.0	0.2	0.8	6.0
<u>Hybiscus</u> <u>macrophyllus</u> Roxb.	0.2	0.2	0.3	-	4.9
<u>Duabanga</u> <u>sonneratioides</u> Ham.	-	0.2	0.1	0.8	5.8

Table 5.2 Annual litter production ± 95% confidential limits ($g\ m^{-2}\ yr^{-1}$) of successional communities developed after slash and burn agriculture. Percentages out of total litter as given in parentheses.

Litter component	Age of Fallow (years)				
	1	2	4	8	12
M. Micrantha	76±10	190±22	360±70	56±8	3±0.39
	(70%)	(58%)	(63%)	(8%)	(0.4%)
Other herbs	33±4	109±26	110±19	20±2	10±1
	(30%)	(33%)	(19%)	(3%)	(1.4%)
Shrubs and trees (including bamboo)	-	30±5	100±16	600±110	720±140
		(9%)	(18%)	(89%)	(98%)
Total	109±14	329±56	570±110	676±120	733±140

Table 5.3 Above ground standing biomass ± 95% confidential limits (g m^{-2} yr^{-2}) of different components in successional communities developed after slash and burn agriculture. Percentages out of total biomass are given in parentheses.

	Age of Fallow (years)				
Vegetation components	1	2 2	4 4	8	12
M. micrantha	210±50 (35%)	584±90 (54%)	848±180 (42%)	91±20 (2%)	6.0±0.98 (0.07%)
Other herbs	353±80 (58%)	339±70 (31%)	387±76 (19%)	86±19 (2%)	24±5 (0.29%)
Shrubs and trees (including bamboo)	41±10 (7%)	158±13 (15%)	778±160 (39%)	4790±1000 (96%)	8340±1700 (99.6%)
Total biomass	604±140	1081±200	2013±370	4967±1100	8370±1700

hamiltonii, a bamboo which comes as sprouts in younger fallows become more dominant in 8-and 12-year-old fallows. A few trees and shrubs come up as seedlings, stem and root sprouts (Table5.1).

Litter production:

The total annual production of litter increased ($P < 0.05$) with fallow age and reached 732 g m^{-2} $year^{-1}$ in a 12-year-old fallow (Table5.2). M. micrantha alone contributed 69, 58 and 63 percent respectively in 1-, 2-and 4-year-old fallows, 8 and 0.4 percent respectively in 8-and 12-year-old fallows. Whereas in fallows upto 4 years the herbaceous species contributed anywhere between 82 to 100 percent of the total litter production, their contribution to the total litter production in 8-and 12-year-old fallows was very low but with shrubs and trees contributing 91 to 99 percent.

Biomass and productivity:

The standing aboveground biomass in successional fallows increased significantly ($P < 0.01$) with fallow age with a maximum of 8.37 Kg m^{-2} in a 12-year-old fallow (Table5.3). The biomass contribution by M. micrantha and other herbs increased with increase in fallow age upto 4 years, beyond which it declined drastically. The contribution of biomass by M. micrantha to the herb biomass total was significantly

Table 5.4 Changes in rates of biomass accumulation, litterfall and net primary production in successional communities developed after slash and burn agriculture.

	Age of fallow (years)				
	1	2	4	8	12
Standing biomass (g m^{-2})	604	1081	2013	4967	8370
Rate of biomass accumulation	454	477	466	738	851
Total litter fall (g m^{-2} yr^{-1})	109	329	570	680	732
Net primary production	563	806	1036	1418	1583
Biomass accumulation quotient	1.07	1.34	1.94	3.50	5.28

(Standing biomass/net primary production).

Table 5.5 Changes in rates of biomass accumulation, litter fall and net production of _M. micrantha_ in successional communities developed after slash and burn agriculture.

	Age of fallow (years)				
	1	2	4	8	12
Standing living biomass at the beginning of the growth period (g m^2)	9	98	296	56	3.8
Standing living biomass at the end of the growth period (g m^2)	210	584	848	91	6.0
Biomass accumulation	201	486	552	34	2.2
Losses during the growth period	23	48	76	2	-
Net primary production	224	534	628	36	2.2
Biomass accumulation quotient	0.9	1.09	1.35	2.5	2.72

Table 5.6 Changes in rates of biomass accumulation, litter fall and net production of *M. micrantha* in successional communities developed after slash and burn agriculture.

	Age of fallow (years)				
	1	2	4	8	12
Standing living biomass at the beginning of the growth period (g m^2)	9	98	296	56	3.8
Standing living biomass at the end of the growth period (g m^2)	210	584	848	91	6.0
Biomass accumulation	201	486	552	34	2.2
Losses during the growth period	23	48	76	2	-
Net primary production	224	534	628	36	2.2
Biomass accumulation quotient	0.9	1.09	1.35	2.5	2.72

higher (P 0.05) in 2-and 4-year-old fallows. The biomass of shrubs and trees of which *Dendrocalamus hamiltonii* was the dominant species increased with fallow age, more sharply in 8-and 12-year-old fallows. Biomass accumulation rate was not significantly different in 1- to 4-year-old fallows but improved markedly in 8-and 12-year-old ones. The net primary productivity, however, increased significantly with fallow age (Table 5.4). Biomass accumulation quotient which is a ratio of standing biomass divided by net primary productivity also showed a similar increase with fallow age, but more markedly in 8-and 12-year-old fallows.

Standing biomass, biomass increment and net primary productivity of *M. micrantha* all increased with the fallow age up to 4 years, beyond which they declined sharply (Table 5.5). Biomass accumulation quotient, however, increased with increase in fallow age up to 12 years.

DISCUSSION

The early stages of secondary succession is largely determined by the degree of destruction of the pre-forming vegetation and its propagules in the soil. During the first few years, when weed species predominate, there is considerable variation in species composition according to the agricultural cycle, weeding intensity and available seed source. Thus four different types of early successional weed communities were recognized at lower elevations in Meghalaya (Toky & Ramakrishnan, 1983a), of which M. micrantha dominated fallow is one, which is emphasized in this study.

The aboveground parts of this vigorously growing species, that is largely clonal with extensive rooting at nodes and forming a thick mat on the ground and smothering over other herbs and shrubs, die out during December-January, after a growth phase between March to November. Such a pattern of litter production where the entire aboveground parts contribute may explain the 'overshoot' in the early phases of succession, noted also by Ewel (1976) in tropical successional environments in Gautemala. The rapid decline in biomass and litter production by herbs including M. micrantha in 8-and 12-year-old fallows is related to biological suppression (Chapter I) of these due to reduced light availability in communities dominated by bamboos, shrubs and trees. The values for litter production obtained during this study are similar to that shown for early successional communities in Izabel, Gautemala (Ewel, 1976) and our earlier observations in north-east India (Toky and Ramakrishnan, 1983a). Much of the litter fall occurred during the dry season, with high rate of decomposition during the subsequent monsoon season, so that the nutrients released through mineralization during this period caused an annual pulse in production as also observed in Amazonian early successional forests (Uhl and Jordan, 1984).

Rapid increment in biomass in early successional fallows could be related to the exploitative nature of the species that capitalize upon a nutrient rich environment after slash and burn, high light availability and rapid cycling of nutrients through high litter fall and quick decomposition. The values reported here are comparable to the range of values reported by others from elsewhere in the tropics (Snedaker, 1970; Ewel, 1971). Whilst the net primary productivity showed a gradual increment from 1- to 12-year-old fallows, there was a rapid upward shift in standing biomass in 8-and 12-year-old fallows due to a shift in community structure from herbs to shrubs and trees including bamboo. Biomass accumulation quotient increased with fallow age more drastically in 8-and 12-year-old fallows suggesting that though standing biomass increased the net primary productivity in relation to biomass actually declined. The net primary production of M. micrantha drastically declined in 8-and 12-year-old fallows due to extremly reduced vigour of this species in these fallows. Thus, under longer shifting agriculture cycles, M. micrantha is suppressed during successional devèlopment of the plant community but is arrested at the weedy stage under shorter cycles of upt about 5 years (Saxena and Ramakrishnan, 1984b). An early successional exotic weed such as M. micrantha would thus contribute to restoration of the disturbed ecosystem under longer shifting agriculture cycles which it would pose problems related to weed control under shorter slash and burn agriculture cycles as is prevalent in the region now.

SUMMARY

Biomass, litter production and aboveground net primary productivity of the plant communities during secondary succession upto 12 years of slash and burn agriculture increased but the contribution by *Mikania micrantha* H.B.K., reached its maximum in a 4-year-old fallow after which there was a drastic decline. During the first four years of secondary succession the total aboveground biomass of *M. micrantha* produced during the growing season between March to November was converted to litter due to total death of the aboveground parts of this species resulting in an 'overshoot' of litter production during this phase.

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CHAPTER 6

CONTRIBUTION OF *MIKANIA MICRANTHA* H.B.K., DURING SECONDARY SUCCESSION FOLLOWING SLASH AND BURN AGRICULTURE (JHUM) IN NORTH-EAST INDIA. II. NUTRIENT CYCLING

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INTRODUCTION

The pattern of secondary succession and the rapidity with which the system recovers after slash and burn agriculture depend upon the degree of destruction of the pre-forming vegetation and its propagules in the soil. The pattern during the first few years vary according to the agricultural cycle, weeding intensity and available seed source (Toky and Ramakrishnan, 1983a; Chapter 5). A knowledge of the cycling of nutrients is essential to understand the way in which soil fertility lost during the cropping phase is restored during the fallow period. The patterns and processes involved during the first few years, of secondary succession not only vary depending upon the vegetation structure, but are important for a better appreciation of nutrient conservation mechanisms operating after perturbation of the system. Further, little is known of nutrient cycling in tropical and subtropical forests (Greenland and Kowal, 1961; Nye, 1961; Jordan and Klinge, 1972; Golley _et al._, 1975; Grubb and Edwards, 1982) and much less about the pattern of nutrient cycling in tropical secondary successional fallows (Bartholomew, Meyer and Laudelout, 1953; Toky and Ramakrishnan, 1983b).

The present study deals with nutrient cycling in early successional fallows that are dominated by *Mikania micrantha* Humboldt, Bonplad and Kunth, developed after slash and burn agriculture (jhum) in north-east India. The contribution by *M. micrantha* in these plant communities is emphasized.

METHODS

1-,2-,4-,8- and 12-year-old fallows after slash and burn agriculture (three replicates) were identified at Lailad, taking care to ensure similar topographic and exposure conditions. The age of the fallows and similarity in land use with a 10-year-jhum cycle (the intervening fallow phase between two successive croppings at the same site) were based on our own observations and also on the records of the village headman. Age was calculated from the time the cropped plots were left fallow for natural regeneration.

Ten soil samples from each fallow were collected in October 1983, along a transect, at regular intervals of 40 m. sampling was done upto a depth of 40 cm at intervals of 0-7, 7-14, 14-28 and 28-40 cm. A composite sample for each depth was prepared by thoroughly mixing the ten soil samples of a given replicate fallow.

Available phosphorus was measured in the fresh soil sample, colorometrically, by ammonium-molybdate method after extraction with Bray and Krutz's solution (1947). The soil was air dried, ground and passed through 2 mm sieve and stored in polythene jars for subsequent analysis. Elemental analyses were done following standard procedures (Allen _et al._, 1974). Nitrogen was estimated by micro-kjeldhal method. Cations were extracted with 1 M ammonium acetate solution at pH 7. Potassium was estimated with flame-emession method and calcium and magnesium by EDTA titration.

The weight of each element (m^2) in the soil was calculated using bulk density (the quotient of the dry weight of soil to the total volume it occupies in the field) estimates calculated for each relicate fallow and depth separately using a 10 X 10 cm core sampler.

For the elemental analysis of the vegetation, samples of predominant species in each category were analysed separately; the minor species were combined into a composite sample. In all the cases, leaves, branches and main stem were analysed separately. Litter samples were similarly categorized before analysis. Oven dried plant and litter samples were ground to powder and passed through a 0.5 mm sieve. After wet digestion with triple acid (Allen _et al._, 1974) nitrogen, phosphorus, potassium, calcium and magnesium were analysed as above.

Table 6.1 Nutrient content (g m^{-2}) of aboveground vegetation in successional fallows developed after slash and burn agriculture.

Species	Nutrient	Age of fallow (years) 1	2	4	8	12
	N	1.84	5.13	7.94	0.85	0.058
	P	0.30	0.73	1.24	0.14	0.009
M. micrantha	K	3.01	7.77	10.46	1.35	0.09
	Ca	1.22	3.23	4.48	0.55	0.37
	Mg	0.97	3.01	4.64	0.46	0.032
	N	2.86	2.86	3.17	0.87	0.23
	P	0.43	0.43	0.47	0.12	0.053
Other herbs	K	2.92	2.90	3.62	0.99	0.20
	Ca	1.70	1.67	1.88	0.49	0.12
	Mg	1.11	1.35	1.59	0.39	0.092
	N	0.32	0.83	3.93	16.86	29.24
	P	0.05	0.18	0.80	2.41	4.57
Shrubs and trees (including bamboo	K	0.36	1.44	6.75	40.18	67.40
	Ca	0.26	0.93	4.08	15.85	25.49
	Mg	0.15	0.56	2.49	8.08	13.36

In the present study the cycling of elements between the soil and vegetation only was considered. The fractional annual turnover of each element was calculated by dividing the weight that left the compartment by the weight held in that compartment and expressed as a percentage (Reiners and Reiners, 1970). Thus for the vegetation, the weight lost through litter fall was divided by the weight in the vegetation and for the soil, the weight taken up by the vegetation was divided by the weight in the soil. In order to compare the rates at which elements are incorporated into the vegetation, the enrichment quotient was calculated for each stand as the quotient of the weight of a given element in the vegetation divided by its rate of uptake by the vegetation (increase in the aboveground living biomass + litter fall) (Woodwell, wittaker and Houghton, 1975).

RESULTS

In Mikania micrantha, the amount of nutrients stored in the biomass increased upto a 4-year-old fallow followed by a drastic decline in 8- and 12-year-old fallows (Table6.1). The other herb species also followed a similar pattern except that the nutrient content in 8- and 12-year-old fallows declined less drastically. On the other hand, the nutrient content in shrubs and trees increased gradually upto 2 years, but sharply in 8- and 12-year-old fallows.

Table 6.2 Total inventory of nutrients (g m^{-2} yr^{-1}) for successional fallows developed after slash and burn agriculture.

	Nutrient	Age of fallow (years) 1	2	4	8	12
	N	5.02	8.82	15.04	18.62	29.53
	P	0.78	1.34	2.51	2.64	4.64
Standing biomass	K	6.29	12.11	20.83	42.28	67.69
	Ca	3.18	5.83	10.44	16.79	25.65
	Mg	2.23	4.92	8.72	8.89	13.48
	N	916	949	1070	1125	1101
	P	1.02	1.02	0.95	1.54	2.29
Soil pool to a depth of 0-40 cm	K	138	94.12	68.80	84.67	115.20
	Ca	150	125.65	83.63	91.32	112.73
	Mg	99.52	109.70	79.16	63.13	96.12
	N	0.38	0.67	1.07	1.56	1.92
	P	0.03	0.05	0.08	0.12	0.14
Litter on the ground	K	0.19	0.32	0.52	0.75	0.93
	Ca	0.25	0.44	0.69	1.01	1.25
	Mg	0.18	0.31	0.50	0.73	0.90
	N	921.40	958.49	1086.11	1145.18	1132.45
	P	1.84	2.41	3.54	4.31	7.07
Total	K	144.48	108.96	90.25	127.70	183.82
	Ca	153.43	131.92	94.76	109.12	139.63
	Mg	101.93	114.92	88.38	72.75	110.50

Table 6.3 Annual nutrient return through litter ($g\ m^{-2}\ yr^{-1}$) in successional fallows developed after slash and burn agriculture.

	Nutrient	Age of fallow (years) 1	2	4	8	12
	N	0.55	1.08	2.36	0.39	0.013
	P	0.04	0.12	0.33	0.05	0.0014
M. micrantha	K	0.36	0.77	1.94	0.26	0.0098
	Ca	0.46	0.95	2.02	0.34	0.013
	Mg	0.31	0.62	1.20	0.24	0.007
	N	0.26	1.00	0.79	0.14	0.080
	P	0.02	0.07	0.06	0.01	0.0074
Other herbs	K	0.13	0.73	0.61	0.10	0.0056
	Ca	0.14	0.55	0.51	0.09	0.0049
	Mg	0.13	0.38	0.34	0.06	0.029
	N	-	0.32	0.83	5.74	6.77
	P	-	0.02	0.08	0.50	0.598
Shrubs and trees (including bamboo)	K	-	0.25	0.68	4.82	5.84
	Ca	-	0.23	0.66	4.35	4.89
	Mg	-	0.13	0.18	4.78	2.86
	N	0.81	2.40	3.98	6.27	6.86
	P	0.06	0.21	0.47	0.56	0.60
Total	K	0.49	1.75	3.23	5.18	5.85
	Ca	0.60	1.73	3.19	4.78	4.95
	Mg	0.44	1.13	1.72	2.74	2.89

Table 6.4 Rate of nutrient uptake (g m^{-2} yr^{-1}) by M. *micrantha* and the vegetation in successional fallows developed after slash and burn agriculture. Values in parentheses are for the total vegetation.

Nutrient	Age of fallow (years)				
	1	2	4	8	12
Nitrogen	2.05 (3.99)	4.98 (6.20)	6.63 (7.09)	0.46 (7.17)	0.03 (9.59)
Phosphorus	0.31 (0.63)	0.65 (0.77)	0.95 (1.05)	0.072 (0.70)	0.0042 (1.10)
Potassium	3.01 (4.73)	6.59 (7.57)	6.49 (7.59)	0.53 (10.54)	0.032 (12.20)
Calcium	1.44 (2.93)	3.13 (4.39)	3.66 (5.49)	0.46 (6.37)	0.015 (7.16)
Magnesium	1.11 (1.90)	3.07 (3.81)	4.32 (3.62)	0.31 (2.78)	0.021 (4.04)

Nutrients stored in the aboveground standing biomass increased with age of the fallow upto 12 years, with maximal accumulation for potassium, nitrogen and calcium (Table62). The amount of nitrogen in the soil pool to a depth of 40 cm increased upto 8 years and more or less stabilized in a 12-year-old fallow. Available phosphorus increased with fallow age. Exchangeable cations initially declined with fallow age but improved in a 12-year-old fallow. Nutrient content in the standing litter improved with fallow age upto 12 years. Whilst the total nitrogen and phosphorus budget for the ecosystem improved with fallow age, cations declined upto 4 years with improvement in older fallows.

The annual nutrient return through M. micrantha increased upto a 4-year-old fallow followed by a sharp decline in older fallows; the other herbs also showed a similar trend (Table63). The return through shrubs and trees improved with fallow age, more markedly so in 8- and 12-year-old ones. The total nutrient return through litter fall also increased with the age of the fallow.

Rate of nutrient uptake by M. micrantha increased upto 4-year-old fallow with a sharp decline in 8- and 12-year-old ones, in contrast to the total uptake by the vegetation as a whole which increased steadily (Table64).

Table 6.5 Enrichment ratios, which are elemental stock/elemental uptake (Woodwell, Whittaker and Houghton 1975), for M. *micrantha* and for the vegetation in successional fallows developed after slash and burn agriculture. Values in parentheses are for total vegetation.

Nutrient	Age of fallow (years) 1	2	4	8	12
Nitrogen	0.85 (1.14)	1.03 (1.42)	1.19 (2.12)	1.85 (2.63)	1.93 (3.08)
Phosphorus	0.97 (1.25)	1.12 (1.74)	1.30 (2.67)	1.94 (5.62)	2.19 (4.64)
Potassium	1.00 (1.32)	1.18 (1.60)	1.61 (2.74)	2.55 (4.01)	2.81 (6.15)
Calcium	0.85 (1.08)	1.03 (1.33)	1.22 (1.90)	2.44 (2.64)	2.47 (3.58)
Magnesium	0.88 (1.17)	0.98 (1.29)	1.07 (2.41)	1.46 (3.20)	1.52 (3.34)

Table 6.6 The quotients of the annual return of elements through litterfall to the annual uptake by M. micrantha and vegetation, expressed as percentage in successional fallows developed after slash and burn agriculture. Values in the parentheses are for total vegetation.

Nutrient	Age of fallow (years)				
	1	2	4	8	12
Nitrogen	26.83 (18.40)	34.28 (38.70)	35.43 (56.14)	84.78 (88.81)	106.89 (71.53)
Phosphorus	12.90 (9.52)	34.28 (27.27)	34.93 (44.76)	69.44 (80.00)	75.00 (55.00)
Potassium	11.96 (10.36)	21.50 (23.12)	29.84 (42.56)	49.05 (49.14)	70.00 (47.95)
Calcium	33.57 (20.48)	48.46 (39.41)	58.89 (58.11)	113.33 (75.04)	135.00 (69.13)
Magnesium	28.18 (23.16)	29.52 (29.66)	27.71 (47.51)	77.41 (98.56)	85.71 (71.53)

Table 6.7 Fractional annual turnover (%) of various elements in soil and vegetation compartment in successional fallows developed after slash and burn agriculture. Values in parentheses are for total vegetation.

Age of fallow (years)	N		P		K		Ca		Mg	
	Soil	Veg.	Soil	Veg.	Soil	Veg.	Soil	Veg.	Soil	Veg.
1	0.48	29.30 (16.14)	61.76	14.33 (7.59)	3.43	11.96 (7.79)	1.95	37.70 (18.86)	1.90	31.63 (19.73)
2	0.65	21.05 (27.21)	75.49	16.43 (15.67)	8.04	9.90 (14.45)	3.49	29.41 (29.67)	3.47	20.59 (23.01)
4	0.60	29.72 (26.46)	99.89	26.61 (18.72)	15.81	18.55 (15.50)	6.56	45.08 (30.55)	3.14	23.75 (19.72)
8	0.63	45.88 (33.67)	50.00	35.71 (21.21)	16.09	19.26 (12.25)	6.98	61.81 (28.46)	2.46	43.47 (30.82)
12	0.87	54.38 (23.23)	44.98	33.33 (12.93)	10.62	23.33 (8.64)	6.35	67.50 (19.29)	4.20	56.25 (21.43)

Enrichment ratio for *M. micrantha* as well as for the total vegetation increased with the age of the fallow for all the elements (Table 65). The exception to this was phosphorus in the vegetation; in which case the ratio decreased in a 12-year-old fallow.

The quotients of the annual return of elements through litter fall to the annual uptake by *M. micrantha* increased with the age of the fallow (Table 66). In general calcium had higher values whilst potassium and phosphorus had least values. The quotients for the vegetation reached maximal values in an 8-year-old fallow followed by a decline in a 12-year-old one except for potassium, where 8- and 12-year-old fallows had similar values.

The fractional annual turnover of nutrients for soil and vegetation is given in Table 67. Those for phosphorus and potassium of the soil gave maximum values in 4- and 8-year-old fallows respectively, whereas for other elements improved in older fallows. The nutrient turnover through *M. micrantha* generally increased with the age of the fallow where as the turnover rate in the total vegetation reached a maximum in an 8-year-old fallow followed by a sharp decline in a 12-year-old fallow.

DISCUSSION

Mikania micrantha is an early successional weed dominant in fallows upto about 4 years only (Chapter I). The nutrient content in the living aboveground biomass of this weed and its release through litter fall increased upto 4 years of fallow regrowth with a drastic decline in subsequent years due to its natural suppression by fast growing shrubs and trees (Chapter 5). The nutrient content in the living biomass of the total vegetation and its return through litter drastically increased beyond 8 years. Such a shift in nutrient cycling pattern due to a shift in community structure was also reported in another study on secondary succession from north-east India (Toky and Ramakrishnan, 1983a,b). Steady increase in total biomass upto 12 years resulted in nutrient build up in the vegetation and the amount present in the litter on the ground.

A higher initial pool of nutrients in the soil derived after slash and burn is rapidly depleted by fast growing early successional vegetation of upto 8 years of fallow regrowth (Toky and Ramakrishnan, 1983a; Mishra and Ramakrishnan, 1983c). The only exception to this was nitrogen where the recovery occurred right through the 12 year period. This may be related to increased mineralization due to higher microbial activity

(Ewel, 1976). Higher microbial activity may partly be due to rise in soil pH after the burn (Ahlgren and Ahlgren, 1965; Griffith, 1949; Moore and Jaiyebo, 1963) and partly to removal of allelo-chemical effects after clear cutting of vegetation (Rice, 1974).

A high rate of uptake of nutrients for *M. micrantha*, only upto a 4-year-old fallow; subsequent drastic decline in uptake is related to decline in the population vigour of this species. This is also reflected in the sharp increase in the quotient of the annual return of nutrients through litter to the annual uptake, in 8- and 12-year-old fallows. Such a conservatory role of potassium in fallows derived after shifting agriculture was also recorded for the bamboo species, *Dendrocalamus hamiltonii* (Toky and Ramakrishnan, 1982) and for *M. scandens* (Burkill, 1935; Craig and Evans, 1946). Conservation of potassium is important in tropical environment, as this element is shown to be highly mobile and susceptible to leaching (Nye and Greenland, 1960).

The uptake of nutrients by the total vegetation generally increased with fallow age. However such a rapid transfer of nutrients from soil to the living biomass is reflected in nutrient pool depletion of the soil, to a certain extent only with respect to the cations. Phosphorus in the soil pool improved sharply in 8- and 12-year-old fallows and this could be related to the release from the rapidly declining *M. micrantha* and other herbaceous weeds that take up phosphorus (Toky and Ramakrishnan, 1983b) after 4 years. The gradual increase in nitrogen of the soil pool with fallow age inspite of rapid uptake by the developing vegetation could be due to rapid nitrification in the soil, discussed above. The increasing enrichment ratio, for different nutrients in M. micrantha and the total vegetation, with fallow age also suggests of greater elemental storage in the living biomass as compared to uptake by the vegetation.

The quotient of the annual return of elements through litter fall to the annual uptake for the total vegetation increased upto 8 years followed by a sharp decline, suggesting that during the herbaceous community phase nutrient retransfer from the living biomass to the soil increased. The exception to the above pattern was potassium. Toky and Ramakrishnan, (1983b) have shown in an earlier study that between 10-20 years of fallow regrowth, this quotient stabilized at a lower level. Such a trend, perhaps, would have become evident if this tudy was extended to older fallows. This is explainable because both M. micrantha during the early phases of secondary succession and Dendrocalamus hamiltonii that come up after about 8 years (Toky and Ramakrishnan, 1983a,b) both conserve potassium in the plant biomass.

Increase in uptake of nutrients by the vegetation in the early stages of secondary succession is reflected in the increase in annual fractional turnover rate in the soil upto 12 years for nitrogen and magnesium and 4-8 years for other elements. Greater release through the litter of M. micrantha is reflected in the increase in annual turnover through this species with fallow age. Such a trend was observed for the total vegetation too, except that, there was a decline in turnover rate particularly in a 12-year-old fallow. This may be related to the nutrients released through herbaceous species being taken up and transferred rapidly to the living biomass of developing shrubs and trees.

During the early phases of secondary succession upto 4 years M. micrantha maintains a high rate of nutrient cycling through its rapid growth, total death of aboveground parts during the winter months and the consequent high litter production. Thus the nutrient cycling pattern in M. micrantha-dominated early successional fallows such as these are some what different from that observed in others where this species was not present (Toky and Ramakrishnan, 1983b). Only with the shift in community structure from herbs to shrubs and trees which have a large storage capacity in the living biomass, after 8 years of fallow regrowth, stability in nutrient cycling is achieved over a period of time.

SUMMARY

During the herbaceous phase of secondary succession after slash and burn agriculture, *Mikania micrantha* H.B.K., plays an important role in nutrient cycling in the present system. *M. micrantha* conserves considerable quantities of potassium in its biomass. During the herbaceous community phase of secondary succession, though there was an increment in nutrient uptake by the developing vegetation, the re-transfer through litter fall increased at a greater rate. The shift in nutrient cycling properties of the developing vegetation because of changes in community structure from a pre-dominantly herbaceous type to shrubs and trees pre-dominating is reflected in various parameters observed in older fallows.

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CHAPTER 7

ECOLOGICAL IMPLICATIONS OF TRADITIONAL WEEDING AND OTHER IMPOSED WEEDING REGIMES UNDER SLASH AND BURN AGRICULTURE (JHUM) IN NORTH-EAST INDIA

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INTRODUCTION

Natural weed management in slash and burn agriculture (jhum) system being based on the length of the fallow phase after the land is left fallow for vegetation regrowth, the length of the fallow phase plays a critical role in weed control. The weeds being the predominant component of the early successional communities upto 5 years of fallow re-growth (Toky and Ramakrishnan, 1983a), continuous imposition of a short cycle of 5 years or less tends to exaggerate the weed potential in the cropping system (Saxena and Ramakrishnan, 1984b). As the perennial vegetation gets re-established with long fallow periods, weeds are suppressed to a large degree which is reflected in the reduced weed potential during the cropping phase. Our preliminary observations (Ramakrishnan, 1984) and those of others (Chacon and Gliessman, 1982; De Schiope, 1956; Altieri, 1983; Moody, 1975) suggest that weeds have a positive role to play in these traditional agricultural systems. The present study, therefore, aims at an evaluation of the traditional weeding practices of the jhum farmer and an assessment of the resedual weed population as an integral component of the agroecosystem.

METHODS

Cropping and yield measurements:

Agroecosystems under two slash and burn agriculture (jhum) cycles of 20- and 5-years were identified at Lailad taking care to ensure similar topographic and soil conditions. Each jhum cycle (intervening fallow phase between two successive croppings at the same site) with three replicate fields of 2 ha each were selected. Each replicate field was divided into three sub-plots of 50 X 50 m each with a given weeding regime; i.e., traditional weeding (Trw) which is a partial weeding as practiced by the farmer, total weeding (Tow), and unweeded (Unw). Both partial and total weeding regimes involved weeding through hand hoeing four times during the cropping period except that in the former case part of the weed population (about 20% weed biomass) was left undisturbed.

Phytosociological analysis of the crop plants under different treatments were done before the harvest of early maturing crops (Zea mays and Seteria italica) of the mixed cropping system, where sequential harvesting was done as and when crops matured starting from mid-July to November. Phytosociological analysis of weeds was done just before the first weeding in mid-May and before the fourth weeding in September. Frequency, density and basal area measurements are based on 20 randomly placed 1 m^2 quadrats. Important value indices were calculated following the procedure given by Kershaw (1973).

The biomass (including fallen leaves) and economic yield measurements are based on an average of 15 individuals of each crop species, under each treatment. Economic yield per unit area was then computed using the density values obtained for each crop species. Weed biomass measurements are based on the weeds removed from a 100 m^2 quadrat (three replicates) during each of the four weedings under the two weeding regimes. In the unweeded plot, weed biomass was similarly measured but during the peak growing period in October.

Cost-benefit analysis:

The monetary input/output analysis was done on the basis of the prevailing rates of wages for labour at the rate of Rs. 8/-. The total economic yield was converted into Rupees on the basis of prevailing market prices. Economic efficiency was evaluated as output/input ratio.

Energy measurements:

Labour input in man hours was recorded for cropping under different treatments. Total food energy consumed was apportioned to each activity (leach, 1976) according to relative duration on the basis of grouping involving either sedentary, moderate or heavy work. Per hour energy expenditures of 0.418 MJ for sedentary work, 0.488 MJ for moderate work and 0.679 MJ for heavy work for an adult male, and 0.331 MJ for sedentary work, 0.383 for moderate work and 0.523 MJ for heavy work for an adult woman, were used to calculate the labour energy input

Table 7.1 Energy value for different component considered in the agro-ecosystem (after Gopalan et al. 1982) (Values expressed as dry weight megajoule equivalent).

Category	Average energy value ($M J kg^{-1}$)
Grains	16.29
Pulses	16.24
Seasamum	26.60
Castor	25.96
Leafy vegetables	13.75
Roots and tubers	13.76

into the system (Gopalan et al., 1978). The input of energy through seeds was calculated on the basis of total energy expended to produce that graction of crop yield. For calculating the output of energy under different treatments, the total economic yield of the various crops was converted into megajoules of energy by multiplaying with standard values of various edible parts of crops as given in Table7.1. The energy efficiency was calculated as the output/input ratio.

Losses through water:

For studies pertaining to run-off and sediment, the loss from a confined area of 1 X 10 m along the slope was collected in large collectors and periodically removed for analysis. Percolation studies were made with the help of a simple lysimeter of the Russian type (Buckman and Brady, 1960). The soil was cut into vertically, to expose the profile. A tunnel was then excavated at a depth of 40 cm (this is the depth to which most of the root system penetrate) and a collector of 30 X 30 X 15 cm was placed in the tunnel. By pressing from below, the rim of the collector was firmly inserted into the indisturbed soil above. The water percolating through the soil was tapped from the collector into receptacles from time to time for analyses. Formaldehyde (40%) was used to stop biological activity immediately after collection.

Table 7.2 Important value indices of crop species under different weed regimes under 20 - and 5 - year jhum cycles. Values in parentheses are density m^{-2}.

Crop species	Jhum cycle (years) 20 Trw	20 Tow	20 Unw	5 Trw	5 Tow	5 Unw
Grain and seed:						
Oryza sativa	169.1(10.2)	166.0(10.8)	170.7(7.2)	189.3(12.9)	189.4(13.2)	174.8(5.3)
Seasamum indicum	18.0(0.5)	17.7(0.5)	13.9(0.3)	-	-	-
Zea mays	32.4(1.5)	33.9(1.8)	34.0(1.2)	42.0(2.0)	41.5(2.0)	48.7(1.3)
Seteria italica	42.9(3.8)	41.8((3.92)	33.9(2.0)	52.2(4.0)	52.7(4.2)	50.1(1.6)
Phaseolus mungo	3.6(0.2)	6.4(0.3)	3.9(0.1)	-	-	-
Ricinus communis	5.9(0.2)	5.8(0.2)	11.2(0.2)	-	-	-
Leaf and fruit vegetables:						
Hybiscus sabdariffa	4.2(0.1)	4.7(0.2)	4.8(0.1)	2.7(0.1)	2.6(0.1)	4.3(0.1)
Capsicum frutesence	1.8(0.1)	1.7(0.1)	2.4(0.1)	-	-	-
Cucurbita maxima	2.4(0.1)	2.5(0.2)	2.6(0.1)	(2.3(0.1)	2.3(0.1)	3.6(0.1)
Cucumis sativa	2.6(0.2)	2.5(0.2)	3.8(0.2)	2.4(0.1)	2.4(0.1)	3.9(0.1)
Memordica charantia	5.9(0.5)	6.3(0.6)	4.1(0.1)	-	-	-
Tubor crops:						
Manihot esculentus	5.1(0.01)	4.9(0.01)	6.5(0.01)	3.6(0.01)	3.6(0.01)	4.9(0.01)
Colocassia antiquorum	6.2(0.02)	5.8(0.02)	8.2(0.02)	2.0(0.02)	3.8(0.02)	7.1(0.02)
Xanthosoma sp	-	-	-	1.9(0.02)	1.9(0.02)	2.6(0.02)

Table 7.3 Important value indices of weeds before first and final weeding under 20 - and 5 - year jhum cycles.

Species	Jhum cycle (years) 20		5	
	First weeding	Final(forth) weeding	First weeding	Final(forth) weeding
Herbs:				
Ageratum conyzoides L.	29.2	69.4	57.5	54.3
Boreria hispida K.Schum	-	24.2	-	-
Carex crucinata Vahl	9.9	-	14.4	-
Desmodium triquitrum D.C.	4.9	-	-	-
Erigeron linifolius Wild	-	30.0	28.0	39.7
Eupatorium odoratum Linn	9.3	41.6	41.6	71.6
Imperata cylindrica Beaw	-	-	19.7	28.6
Hedychium cornonarium Koening	15.1	-	-	-
Ipomea crinata Roxb.	-	13.1	15.7	-
Mikania micrantha H.B.K.	-	17.3	-	25.5
Muccuna brachteata D.C.	10.7	-	-	25.8
Panicum maximum Munro	-	22.8	26.5	19.5
Panicum khashianum Jav.	-	13.0	7.7	-
Thysanolena maxima (Roxb.)O.ktze.	-	-	5.6	8.2
Others	25.7	39.1	15.7	-

Shrubs:				
Clerodendrum colebrookianum Walp.	2.3	4.9	-	-
Leea assamica L.	4.7	-	5.7	5.1
Osbeckia crinata Benth	7.0	-	3.2	-
Others	2.5	-	5.2	5.07
Trees:				
Anthocephalus cadamba Mev.	12.4	-	-	-
Cedrella toona Roxb.	13.9	-	-	-
Dendrocalamus hamiltonii Nees & Arn	59.6	8.4	25.4	13.4
Macaranga denticulata Muell	16.7	-	6.9	-
Sapium baccatum Roxb.	7.9	-	3.8	-
Schima wallachii Choisy	9.8	4.9	7.2	-
Sterculia villosa Roxb.	-	4.7	-	-
Others.	43.4	6.6	12.9	3.2

The analyses of water samples were done following the methods given by Allen et al. (1974). Thus NO_3-N was estimated by the phenol-disulphonic acid method, and PO_4-P was estimated by the molybdenum-blue method. Potassium was estimated by the flame-emission method, while calcium and magnesium were analysed by EDTA titration method.

RESULTS

While in a 20-year jhum cycle there were 13 crop species in the mixture, a 5-year cycle had only 9 (Table7.2). Under the two jhum cycles, the emphasis was more on grain and seed crops, particularly on rice. Under different weeding regimes, the density of the individual species differed only with respect to grain and seed crops. The density generally was lower in the unweeded plots, under both the cycles; IVI values, however, were not very different.

A 20-year jhum cycle had more of shrub and tree sprouts including bamboo in the initial phases of cropping compared to a 5-year cycle (Table7.3). By the end of the cropping phase, during fourth (final) weeding shrubs and the trees generally declined and herbaceous weeds increased under a 20-year jhum cycle. On the other hand, under a 5-year cycle, herbaceous weed were dominant over shrubs and trees.

Table 7.4 Total biomass (10^3 kg ha^{-1}) of crop and weed plants under different weeding regimes in 20 - and 5 - year jhum cycles. Values in parentheses are biomass retained *in situ*.

Biomass	Jhum cycle (years) 20			5		
	Trw	Tow	Unw	Trw	Tow	Unw
Crop	16.8±1.1	19.3±1.2	8.7±0.7	10.0±0.9	10.2±0.9	3.6±0.2
Weed	2.0±0.1 (0.4)	2.0±0.2	10.20±1.0	1.2±0.1 (0.3)	2.0±0.2	5.8±0.4
Total	18.8±1.2	21.3±1.4	18.9±1.6	11.1±1.0	12.2±1.1	9.4±0.6

*Mean values ± standard error.

Table 7.5 Mean economic yield ($Kg\ ha^{-1}$) of crop species under different weeding regimes under 20 - and 5 - years jhum cycles. Values in parentheses are yield-$plant^{-1}$ (g).

Crop species	Jhum cycle (years) 20 Trw	20 Tow	20 Unw	5 Trw	5 Tow	5 Unw
Grain and seed:						
Oryza sativa	1305.6(12.8)	1404.0(13.0)	158.4(2.2)	670.8(5.2)	792.0(6.0)	47.7(0.9)
Seasamum indicum	193.0(38.6)	195.5(39.1)	73.8(24.6)	-	-	-
Zea mays	600.4(40.0)	813.6(45.2)	352.0(29.[illegible])	460.0(23.0)	480.0(24.0)	143.0(14.3)
Seteria italica	338.2(8.9)	360.6(9.2)	78.0(3.9)	160.0(4.0)	172.2(4.1)	33.6(2.1)
Phaseolus mungo	19.6(9.8)	30.6(10.2)	4.2(4.2)	-	-	-
Ricinus communis	7.2(3.6)	7.4(3.7)	5.6(2.8)	-	-	-
Total (with S.E. values)	2464.0±139	2811.7±156	355.2±21	1290.8±83	1444.2±91	224.3±17
Leaf and fruit vegetables:						
Hybiscus sabdariffa	36.3(36.3)	74.2(37.1)	30.0(30.0)	49.0(49.0)	49.5(49.5)	28.0(28.0)
Capsicum frutesence	1.2(1.2)	1.3(1.3)	0.2(0.2)	-	-	-
Cucurbita maxima	2.1(2.1)	4.4(2.2)	0.8(0.8)	2.4(2.4)	2.6(2.6)	1.3(1.3)
Cucumis sativa	253.2(126.6)	254.4(127.2)	138.0(69.0)	120.6(120.6)	122.0(122.0)	106.0(106.0)
Memordica charantia	15.5(3.1)	19.2(3.2)	3.1(3.1)	-	-	-
Total (with S.E. values)	308.3±16	353.5±18	172.1±11	172.0±8	174.1±14	135.3±6
Tuber crops:						
Manihot esculentus	98.0(998.0)	102.0(1020.0)	76.0(760.0)	72.0(720.0)	74.0(740.0)	59.0(590.0)
Colocassia anticuorum	146.2(73.1)	149.0(74.5)	80.2(40.1)	17.4(87.0)	17.8(89.0)	16.4(82.0)
Xanthosoma sp.	-	-	-	32.0(160.0)	33.0(166.0)	28.0(140.0)
Total (with S.E. values)	244.2±12	251.0±15	156.2±11	121.4±8	124.8±6	103.4±4
Grand total (with S.E. values)	3016.2±198	3416.2±210	683.5±37	1584.2±94	1743.1±110	463.0±23

Table 7.6 Cost-benefit analysis (Rs ha^{-1} yr^{-1}) of different weeding regimes under 20 - and 5 - year jhum cycles.

	Jhum cycle (years)					
	20			5		
	Trw	Tow	Unw	Trw	Tow	Unw
A. Input:						
(1) Labour (excluding weeding)	1162	1162	1162	530	530	530
(2) Weeding only	184	304	-	264	288	-
(3) Seed input	38	38	38	23	23	23
Total	1384	1504	1200	817	841	553
B. Output:						
(1) Grain and seed	5753	6501	1203	2272	2562	360
(2) Leaf and vegetables	124	190	67	109	122	77
(3) Tuber crops	317	402	216	170	176	117
Total	6318	7093	1487	2551	2860	554
C. Net gain	4934	5589	287	1734	2019	1
D. Output/Input ratio	4.6	4.7	1.2	3.1	3.4	1

Under a given treatment crop biomass declined sharply under a 5-year cycle compared to a 20-year cycle (Table7.4). Within a given cycle, unweeded plots showed a drastic reduction in crop biomass. Weed biomass (both standing and that weeded out) declined drastically under total and traditional weeding regimes as compared to unweeded plots. In traditionally weeded plots about 20% of the total weed biomass is retained in the cropping system.

Grain and seed crops accounted for a major proportion of the total yield followed by leaf and fruit vegetables and least for tubers (Table7.5). Between the two jhum cycles, the yield per plant and per hectare was drastically reduced under a 5-year jhum cycle compared to a 20-year cycle. The yield per plant and per hectare under the two jhum cycles improved marginally only under total weeding as compared with traditionally weeded plots. However, the yield in the unweeded plots was markedly reduced, compared to other two treatments.

Much of the labour cost is for slash and burn, but construction and harvesting operations (Table7.6). This cost was lesses than half under a 5-year jhum cycle compared with a 20-year cycle. Labour input for total weeding was more or less the same under the two jhum cycles, except that traditional weeding under a 5-year jhum cycle was contlier than that under a 20-year cycle.

Table 7.7 Energy budget analysis (MJ ha^{-1} yr^{-1}) under different weeding regimes under 20 - and 5 - year jhum cycles.

	Jhum cycle (years)					
	20			5		
	Trw	Tow	Unw	Trw	Tow	Unw
A. Input:						
(1) Labour (excluding weeding)	853	853	853	337	337	337
(2) Weeding only	87	145	Ni-	123	136	-
(3) Seed	30	30	30	26	26	26
Total	971	1028	883	487	499	363
B. Output:						
(1) Grain and seed	42197	47872	6601	21027	23526	3980
(2) Leaf and vegetables	4390	4861	2366	2365	2394	1860
(3) Tuber crops	3360	3454	1874	1671	1717	1010
Total	49948	56186	10842	25063	27637	6850
C. Output/Input ratio	51	55	12	52	55	19

Economic outout under a 5-year jhum cycle, under a given weeding regime, was drastically reduced when compared to a 20-year cycle (Table7.6). This reduction was more obvious with respect to grain and seed crops compared to others. While there was only a marginal reduction in economic outnut under traditional weeding when compared with total weeding, the reduction was very pronounced in unweeded plots. Again, this adverse effect of no weeding was more prounounced with respect to economic output through grain and seed crops.

Net gain was generally higher under a 20-year jhum cycle than under a 5-year cycle (Table7.6). Further drastic reduction in net gain was obvious only in unweeded plots, so much so that under a 5-year cycle with no weeding the input equalled the output from the system. This pattern was reflected in the output/input ratio too.

The energy inout and output patterns broadly correspond with the monetary input/output patterns discussed earlier, with drastic reduction in outout with shortening of the jhum cycle, and in unweeded plots under a given cycle (Table7.7). The outout/input ratio was well above 50 under all treatments except where no weeding was done under the two jhum cycles, where the ratios were a low 12.3 and 18.8 .

Table 7.8 Soil and water loss from 20 and 5 - year jhum cycles under differenct weeding regimes during the monsoon period. (Total rain fall received 183 cm).

Category of loss	Jhum cycle (years)					
	20			5		
	Trw	Tow	Unw	Trw	Tow	Unw
Run-off water (cm)	30.4 ±1.8	34.3 ±1.4	22.1 ±1.0	36.4 ±2.2	41.5 ±2.9	26.4 ±2.0
Percolation water (cm)	11.6 ±0.8	15.4 ±1.0	8.8 ±0.6	15.8 ±1.0	20.2 ±1.5	11.8 ±0.9
Sediment (t ha^{-1})	16.4 ±1.1	21.1 ±1.4	7.2 ±0.7	22.6 ±1.0	27.8 ±1.8	10.2 ±0.8

* Mean values with ± standard error.

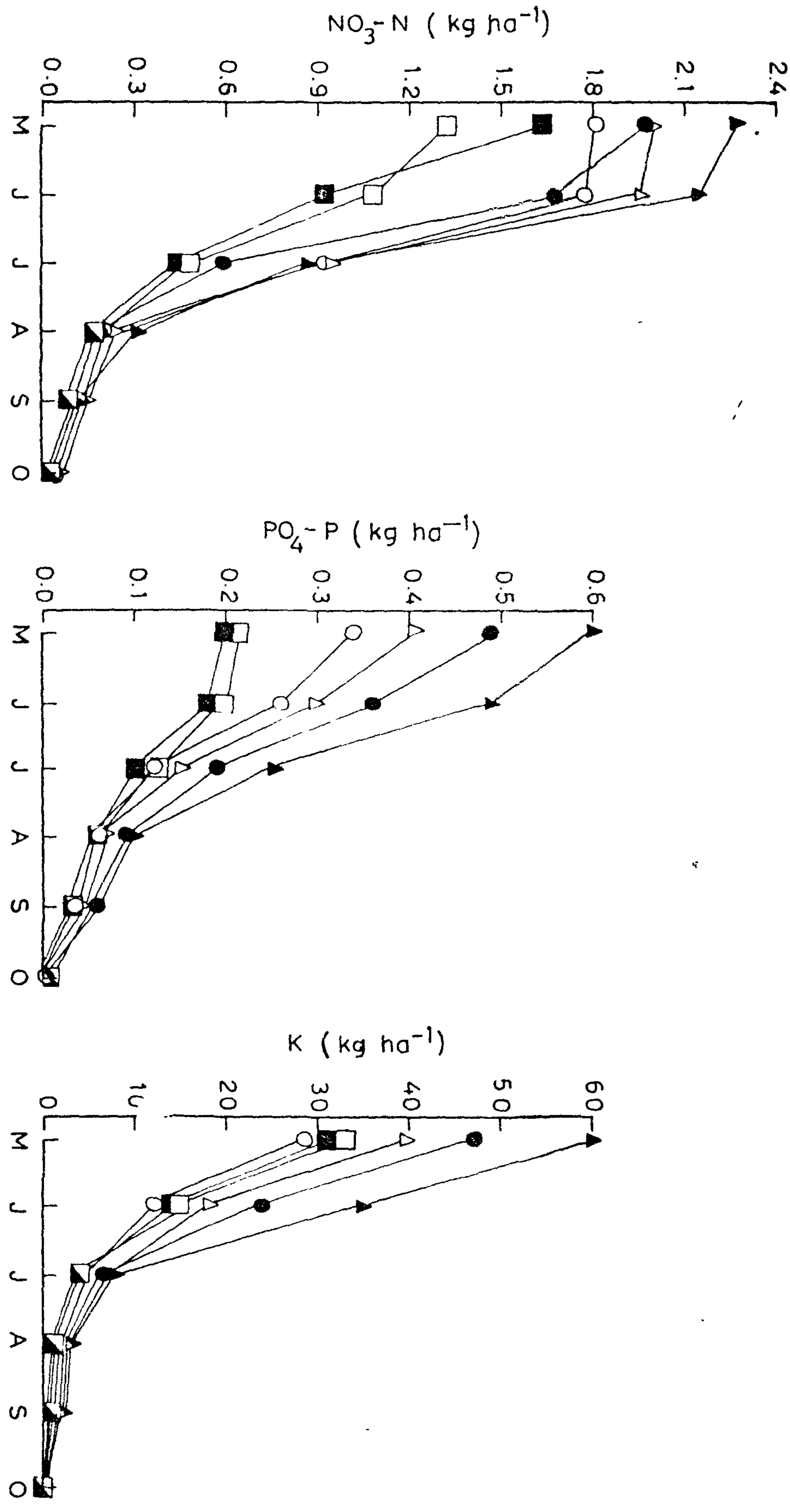
Table 7.9 Total loss of nutrients (Kg ha^{-1} yr^{-1}) in run-off water under different weeding regimes in 20 - and 5 - year jhum cycles.

Nutrients	Jhum cycle (years)					
	20			5		
	Trw	Tow	Unw	Trw	Tow	Unw
No_3-N	4.3±(0.2)	5.3±0.2	2.8±0.08	4.8±0.2	5.3±0.3	3.1±0.1
Po_4-P	1.2±0.06	1.6±0.05	0.6±0.003	0.8±0.004	0.10±0.004	0.6±0.002
K^+	81.4±5.6	106.2±8.1	51.3±3.1	49.3±2.7	69.7±3.6	55.8±3.3
Ca^{++}	23.7±2.0	31.5±2.4	14.6±0.9	12.9±0.6	15.7±0.7	16.1±0.5
Mg^{++}	10.6±0.7	15.3±1.0	9.0±0.6	10.1±0.5	12.5±0.6	9.9±0.5

*Mean values ± standard error.

Fig. 7.1. Monthly loss of No_3^{-N} (A), Po_4^{-P} (B), and potassium (C) in run-off water during the monsoon under Trw (circles), Tow (triangles) and Unw (squares) regimes under slash and burn agriculture. Closed symbols, for 20 year; open symbol for 5 year jhum cycles.

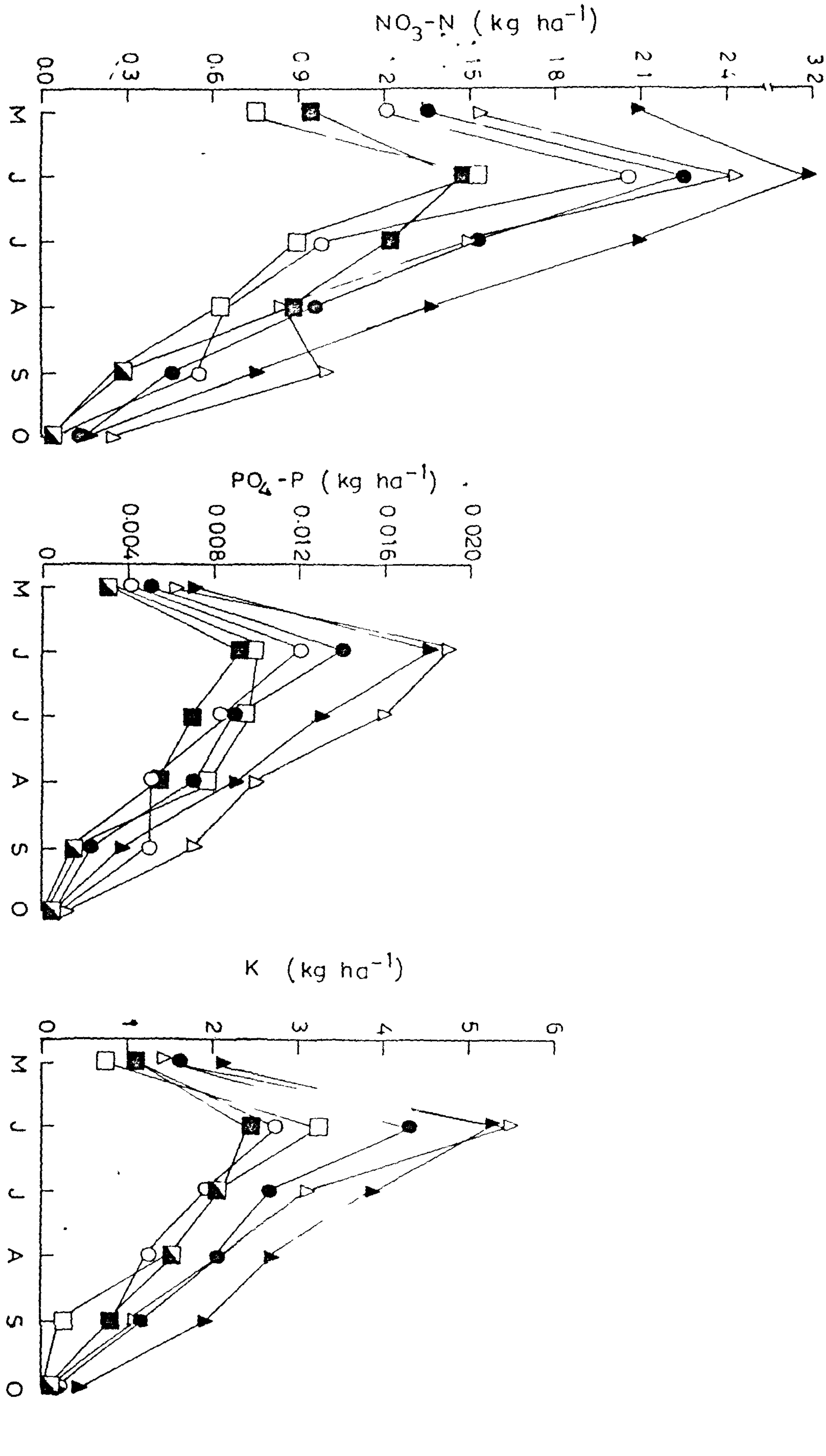
Fig. 7.1



NO3- N (kg ha-1)
0.0 0.3 0.6 0.9 1.2 1.5 1.8 2.1 2.4
M J J A S O
PO4- P (kg ha-1)
0.0 0.1 0.2 0.3 0.4 0.5 0.6
M J J A S O
K (kg ha-1)
0 10 20 30 40 50 60
M J J A S O

Fig. 7·2. Monthly loss of NO_3^--N (A), PO_4^--P (B), and potassium (C) in percolated water during the monsoon under Trw (Circles), Tow (triangles) and Unw (squares) regimes under slash and burn agriculture. Closed symbols, for 20 year; open symbol for 5 year jhum cycles.

Fig. 7.2



Losses through water:

Run-off loss of water was generally higher than that of through percolation (Table7.8). Water loss through run-off and sediment had consistently higher under a 5-year cycle than under a 20-year cycle. Under traditional weeding the losses were significantly lower ($P < 0.05$) than under total weeding; losses were least in unweeded plots.

Losses of nutrients generally were higher under a 20-year cycle than under a 5-year cycle, other than a few exceptions related to nitrate and phosphate losses (Table7.9). This difference was more pronounced for cations, potassium losses were heavier than calcium and magnesium. Under a given cycle, the losses were maximum under total weeding and least under no weeding, the traditional weeding being intermediate between the other two.

Run-off losses of all elements was maximum in May followed by a decline in subsequent months (Fig.7.1). The difference between jhum cycles and between weeding regimes were most pronounced in May-June, as compared with three subsequent months.

Percolation losses of all elements peaked in June followed by a decline on either side (Fig.7.2). The difference between the treatments was also more pronounced at this peaking in June.

Table 8.0 Total loss of nutrients (Kg ha^{-1} yr^{-1}) in percolated water under different weeding regimes in 20 - and 5 - year jhum cycles.

Nutrients	Jhum cycle (years) 20 Trw	20 Tow	20 Unw	5 Trw	5 Tow	5 Unw
No_3 -N	6.92±0.4	9.61±0.7	4.85±0.2	5.47±0.2	7.86±0.3	4.14±0.2
Po_4-P	0.04±0.002	0.05±0.003	0.213±0.01	0.035±0.001	0.059±0.002	0.03±0.00
K^+	12.22±0.9	16.25±1.1	8.15±0.04	7.91±0.04	13.62±0.5	8.25±0.4
Ca^{++}	5.03±0.2	6.36±0.3	3.03±0.1	3.06±0.1	4.51±0.2	2.44±0.0[illegible]
Mg^{++}	2.33+0.01	3.10+0.01	1.54+0.008	1.47+0.006	2.08+0.08	1.27+0.0[illegible]

* Mean values ± standard error.

Total loss of nutrients through percolation under a given treatment was generally higher under a 20-year jhum cycle than under a 5-year cycle (Table 80). Further, within a given cycle the losses through percolation was maximum under total weeding and least in unweeded plots being intermediate between the other two. Among the cations potassium losses were heavier.

DISCUSSION

Cropping and yield patterns:

Under the three weeding regimes the two jhum cycles of 20- and 5-years, density of the grain and seed crops alone declined in the unweeded plots, but with little difference between the other two weeding regimes. Lack of difference in IVI of the crops under different weeding regimes may be because of compensation through frequency and basal area.

The chief difference between traditional and total weeding in the present study is related to the intensity of the weeding done, since both the treatments had four weeding regimes imposed on them; the traditional weeding retained about 20% of the weed biomass as part of the agroecosystem. Such a retention of weeds during traditional weeding does not seem to have much adverse effect; crop yield is only marginally affected. On the other hand, as is to be expected, the yield in unweeded plots was drastically reduced. This reduction in yield due to weed intensity was more pronounced for grain and seed crops than for others, suggesting that these species are more susceptible. The drastic decline in yield under a short jhum cycle of 5 years may partly be due to reduced soil fertility status (Ramakrishnan and Toky, 1981) and partly to increased weed potential, particularly of the herbaceous kind as shown by us (cf. Table 3) and through an earlier study (Saxena and Ramakrishnan, 1984b).

An important aspect that emerges out of the economic and energy analyses is that the cost of traditional weeding is considerably reduced only under a 20-year cycle but not under a 5-year cycle. With lesser potential for herbaceous weeds under a longer cycle, the initial slashing of the shrubs and tree sprouts keep them under check until after the cropping at the same time contributing to the standing weed biomass left *in situ*. under traditional weeding. Therefore, the farmer during traditional weeding tends to remove the herbaceous weeds alone. On the other hand, total weeding would involve frequent slashing of the shrubs and tree sprouts along with removal of herbaceous weeds. This would explain the difference in the cost for weeding under a 20-year cycle. Under a 5-year cycle, 20% weeds retained are chiefly part of the herbaceous weed component and therefore, the cost for traditional and total weeding tend to be the same. With a drastic decline in monetary and energy output in unweeded plots, the economic and ecological efficiency of the system is drastically affected but was not different in traditionally weeded plots from that of totally weeded plots.

Weeds are traditionally considered to be undesirable (Baker, 1965) adversely affecting crop yield in agroecosystems. Under slash and burn agriculture, they are considered to be an important yield depressing factor (Zinke et al., 1978; Freeman, 1955). However, yield reduction of crops need to consider a variety of complex factors (Snaydon, 1982) of which weed species and density are important. The 'non-weed' concept in traditional agricultural systems such as the present one is based on the assumption that weeds below a particular density level has useful functions to perform in the agroecosystem (Chacon and Gliessman, 1982; Ramakrishnan, 1984). There are many suggestions to the effect that weeds contribute to maintenance of soil fertility (De Schippe 1956), reduction in soil erosion (Moody, 1976) and in pest control (Altieri, 1983). Many of these suggestion, however, need rigorous experimental verification. In our earlier studies on nitrogen budget analysis of slash and burn agricultural system (Mishra and Ramakrishnan, 1984), we have shown the role played by weeds in nitrogen economy.

Losses through water:

Subsequent to slash and burn operation and during the cropping phase the ecosystem losses the ability to hold the nutrients in the soil and much losses occur (Toky and Ramakrishnan, 1981b; Mishra and Ramakrishnan, 1983a). Though the total nutrient losses from the system under a 5-year jhum cycle is generally low compared to a 20-year cycle, the losses, obviously, are more frequent. Further, more frequent slash and burn operations would adversely affect soil physical properties (Pophenoe, 1957) and this would explain the increased sediment load through run-off under a 5-year jhum cycle.

As also observed through our earlier studies (Toky and Ramakrishnan, 1981b; Mishra and Ramakrishnan, 1983a), the losses are maximum in the early cropping phase. This is partly related to lack of plant cover over the soil, both through crops and weeds and partly due to changed chemical characteristics of the soil through increased pH after the burn. Increased pH may promote nitrification (Granhall and Hendrikson, 1969) and this along with increased concentration of bicarbonates may result in an increase in anions that are balanced by free cations, with consequent increases in losses from the system (Bormann _et al._ 1968) at the intial phase. Heavy losses of potassium is perhaps related to greater solubility of this element compared to calcium and magnesium (Allen 1964; Lloyd, 1971). However, heavier losses of potassium occurring under a 20-year cycle could be related to the greater release of this element during slash and burn of a predominently bamboo (Dendrocalamus hamiltonii) forest that accumulates potassium in greater quantities (Ramakrishnan and Toky, 1981; Toky and Ramakrishnan, 1982).

An important outcome of this study is related to the role of weeds under traditional weeding practices of the jhum farmer. With retention of about 20% the weed population in the cropping system, the loss of sediment and an element such as potassium through run-off is reduced by 20% as compared to total weeding. Similar reductions in losses of other elements are also observed. Conservation of resources of the soil even to this extent is significant because of the heavy losses that occur under slash and burn agriculture which under a 5-year jhum cycle, eventually would lead to site desertification (Ramakrishnan, 1980; 1985c).

The results presented here on the 'non-weed' concept of the jhum farmer suggest that the economic and ecological efficiency of the system is not adversely affected by retention of part of the weed biomass. With the harvested weed biomass traditionally being put back into the system, even this component is recycled into the agroecosystem (Mishra and Ramakrishnan, 1984). As shown here, a residual weed population as part of the cropping system not only does not interfere significantly with crop yield but could contribute to conservation of soil and nutrients. We believe that a deeper understanding of the non-weed concept offers possibilities in terms of better weed management of temperate (Mutchler et al. 1984) and of tropical and sub-tropical (Chacon and Gliessman, 1982; Ramakrishnan, 1984) agroecosystems that needs to be further explored.

SUMMARY

Traditional weeding in slash and burn agriculture (Jhum) in north-east India involves retention of a certain proportion of weed biomass *in situ*. Comparing this weed management practice with total weeding and no weeding, the economic and ecological efficiency of this agroecosystem has been assessed. It is concluded that the traditional weeding has little effect on the yield potential of the crop mixture. On the other hand it could contribute to conservation of soil resources upto about 20% as compared to a total weeding regime. Indeed, harvested weed biomass put back into the system is an efficient way of recycling of resources under stress.

CHAPTER 8

NUTRIENT BUDGET UNDER SLASH AND BURN AGRICULTURE (JHUM) AT LOWER ELEVATIONS OF MEGHALAYA IN NORTH-EASTERN INDIA.

I. NITROGEN AND PHOSPHORUS.

INTRODUCTION

The ecosystem concept as an approach to the study of agriculture is of relatively recent origin (Spedding, 1975; Hart, 1980; Gliessman *et al.*, 1981; Ramakrishnan *et al.*, 1981b). Traditional agricultural systems of the slash and burn type not only offer scope for such an analysis but also offer possibilities for studying perturbation effects on nutrient retention and losses (Loucks, 1977; Ramakrishnan and Toky, 1981; Toky and Ramakrishnan, 1981b; Mishra and Ramakrishnan, 1983a,b). Such an approach for nitrogen budgeting of agroecosystem (Mishra and Ramakrishnan, 1984) have yielded valuable information on internal cycling of nutrients. Since the low elevation slash and burn agriculture involves total slashing of vegetation followed by uncontrolled burn before cropping, it was suspected that nitrogen and phosphorus budget analyses may yield useful information of value for understanding this agroecosystem function. Unlike the slash and burn system of higher elevation with controlled burning (Mishra and Ramakrishnan, 1983b; 1984). Therefore, the present study deals with nitrogen and phosphorus budgeting and cycling under two slash and burn agricultural cycles (intervening fallow phase between two successive croppings at the same site), at lower elevations of Meghalaya in north-east India. Three weeding regimes have been also incorporated into this study because of the fact that the traditional slash and burn farmer emphasizes on the 'non-weed' concept, considering that the weeds have a useful role to play in his agroecosystem (Ramakrishnan, 1984) and resorts only to a partial weeding regime.

METHODS

Agroecosystems under two slash and burn agriculture (Jhum) cycles of 20- and 5-years were identified at Lailad, taking care to ensure similar topographic and soil conditions. Each jhum cycle with three replicate fields of 2 ha. each were selected. Each replicate field was divided into three sub-plots of 50 X 50 m and in each of these sub-plots three weeding regimes were imposed, i.e., traditional weeding (Trw) which is partial as practised by the farmer, total weeding (Tow and unweeded plots (Unw). Both partial and total weeding regimes involved weeding through hand-hoeing, four times during the cropping period except that in the former case part of the weed biomass (20% of the total) was left *in situ*.

Direct fall through precipitation was collected from ten random points of each field. Soil was sampled at ten random points at each sub-plot, upto a depth of 40 cm. Soil sampling was done on three different occasions: (i) a day before burning the slash in March, (ii) a day after the burn in March and (iii) at the end of cropping period in December.

Calculations of the amount of slash burnt and the materials removed from the agroecosystem as economic yield through crop, crop byproducts and weeds or last two components ploughed back into the system under different treatments are based on three 100 m^2 quadrat samples from each sub-plot.

For studies pertaining to loss of nitrogen and phosphorus through sediment and run-off water, the loss from a confined area of 1 X 10 m along the slope was collected in large collectors and periodically removed for analysis. Percolation studies were made with the help of a simple lysimeter of the Tussian type (Buckman and Brady, 1960). The soil was cut into vertically, to expose the profile. A tunnel was then excavated at a depth of 40 cm (this is the depth to which most of the root system penetrate) and a collector of 30 X 30 X 15 cm was placed in the tunnel. By pressing from below, the rim of the collector was firmly inserted into the undisturbed soil above. The water percolating through the soil was tapped from the collector into receptacles from time to time for analysis. Formaldehyde (40%) was used to stop biological activity immediately after collection. After analysing the fresh soil/water samples for NO_3-N and PO_4-P soon after collection the water samples were preserved in plythene jars, for subsequent analysis.

The soil sampling was done using a core sampler of 10 cm diameter. The amount of nutrients present in the soil pool (Kg ha^{-1}) was calculated to a depth of 40 cm using soil bulk

Table 8.1 Loss of total nitrogen and available phosphorus (Kg ha^{-1}) through fire (with mean $\pm$ S.E.) under 20 - and 5 - year jhum cycles.

	Jhum cycle (years)			
	20		5	
	Nitrogen	Phosphorus	Nitrogen	Phosphorus
Pre-burn soil pool (a) ($x10^3$)	10.9±0.12	0.024±0.001	10.45±0.15	0.007±0.0002
Addition through slash (b)	489±13	64±3	26±2	6±0.01
Total in soil pool before burning(a+b) ($x10^3$)	11.43±0.16	0.088±0.01	10.48±0.16	0.013±0.006
Post-burn soil pool (c)($x10^3$)	9.77±0.11	0.023±0.001	9.93±0.12	0.006±0.002
Loss (a+b) - (c)	1660±52	65±3	550±27	7.2±0.001

density estimates calculated for each site, at depths of 0-7, 7-14, 14-28 and 28-40 cm, considered separately. Bulk density or volume weight (the quotient of the air dry mass weight of soil to the total volume it occupies in the field) was determined from the air dry mass of a known field volume of soil. The samples were analysed by standard procedures given by Allen et al., (1974). Thus nitrate nitrogen was estimated colorimetrically by phenoldisulphonic acid method, total nitrogen by micro-kjeldahl method and phosphorus by molybdenum blue method.

Calculations of the amount of nutrients lost due to fire are based on the difference on that present in the soil upto a depth of 40 cm between the pre-burn (a day before the burn) and post-burn (a day after the burn) stages: (nutrients in pre-burn soil pool + addition through slash) - (nutrients in the post-burn soil pool) = loss of nutrients due to fire.

Input and output of total nitrogen and phosphorus for each of the sub-plot were calculated on the basis of amount of that particular input/output and the concentration of the element in it.

RESULTS

Nitrogen and phosphorus losses due to slash and burn are given in Table 8.1. A significantly higher ($P<0.05$) nitrogen level in the soil pool under a 20-year cycle, when compared with a 5-year one was observed only at the pre-burn stage but not in

Table 8.2 Nitrogen output (Kg ha^{-1}) through non-edible and edible (within parentheses) crop biomass under different weeding regimes under 20 - and 5 - year jhum cycles. Mean ± S.E. values are given for total.

Crop species	Jhum cycle (years) 20			5		
	Trw	Tow	Unw	Trw	Tow	Unw
Grain and seed:						
Oriza sativa	68.3(22.4)	74.5(23.8)	33.1(2.9)	36.1(1.16)	39.6(13.2)	6.4(0.80)
Seasamum indicum	4.7(4.8)	5.3(2.1)	2.9(1.8)	-	-	-
Zea mays	24.6(10.5)	29.5(14.2)	19.8(4.3)	15.2(8.0)	15.4(8.2)	9.5(0.33)
Setaria italica	12.2(6.5)	16.5(6.7)	.8(1.4)	10.8(3.2)	12.2(3.4)	3.2(0.[illegible]
Phaseolus mungo	0.8(0.4)	1.3(0.6)	0.4(0.08)	-	-	-
Ricinus communis	0.8(0.1)	8.4(0.08)	7.7(0.06)	-	-	-
Total	114.4(44.7)	135.5(47.48)	70.7(10.5)	62.1(22.81)	67.2(24.8)	19.1(4.68)
Leaf and fruit vegetables:						
Hibiscus sabdariffa	3.5(0.10)	7.1(2.10)	2.0(0.86)	5.6(1.4)	5.7(1.42)	4.8(0.8)
Capsicum fructesence	0.2(0.003)	0.2(0.003)	0.1(0.0005)	-	-	-
Cucurbita maxima	0.6(0.08)	1.2(0.152)	0.1(0.04)	0.3(0.001)	0.4(0.002)	0.2(0.0008)
Cucumis sativa	0.7(0.001)	0.7(0.01)	0.6(0.04)	0.5(0.27)	0.5(0.27)	0.3(0.23)
Momordica charantia	0.5(0.004)	0.8(0.05)	0.10(0.008)	-	-	-
Total	5.5(1.09)	10.0(2.32)	3.9(0.95)	6.4(1.67)	6.6(1.69)	5.3(1.03)
Tuber crops:						
Manihot esculentus	0.2(0.14)	0.3(0.14)	0.3(0.11)	0.2(0.86)	0.20(0.89)	0.2(0.71)
Colocassia anticuorum	0.5(0.07)	0.5(0.07)	0.5(0.04)	0.4(0.08)	0.4(0.09)	0.3(0.08)
Xanthosoma sp.	-	-	-	0.2(0.12	0.2(0.12)	0.2(0.10)
Total	0.7(0.21)	0.8(0.21)	0.8(0.15)	0.8(1.06)	0.8(1.09)	0.7(0.9)
Grand Total (with S.E.values)	117.6(46.0) ±9.3(±2.1)	146.3(50.0) ±11.0(±3.3)	75.4(11.59) ±4.2(±0.6)	69.3(25.54) ±4.8(±1.4)	74.6(27.58) ±5.1(±1.5)	25.0(6.60) ±1.5(±0.03)

Table 8.3 Phosphorus output (Kg ha^{-1}) through non-edible and edible (within parentheses) crop biomass under different weeding regimes under 20 - and 5 - year jhum cycles.

Crop species	Jhum cycle (years) 20 Trw	Tow	Unw	5 Trw	Tow	Unw
Grain and seed:						
Oriza sativa	8.77(3.37)	9.60(3.67)	4.03(0.43)	4.77(1.80)	5.15(2.11)	0.80(0.11)
Seasamum indicum	1.37(0.04)	1.40(0.04)	0.81(0.01)	-	-	-
Zea mays	6.49(2.16)	7.70(2.93)	5.18(0.90)	4.00(1.60)	4.20(1.60)	4.00(1.00)
Seteria italica	1.90(0.11)	2.70(0.12)	1.00(0.02)	1.60(0.48)	1.68(0.42)	0.48(0.10)
Phaseolus mungo	0.07(0.06)	0.10(0.009)	0.03(0.001)	-	-	-
Ricinus communis	1.30(0.004)	1.30(0.004)	1.18(0.004)	-	-	-
Total	19.90(5.74)	22.80(6.77)	12.23(1.370)	10.37(3.88)	11.03(4.13)	5.28(1.20)
Leaf and fruit vegetables:						
Hybiscus sabdariffa	0.70(0.009)	1.44(0.02)	0.40(0.008)	1.11(0.13)	1.12(0.13)	0.94(0.07
Capsicum fructesence	0.02(0.0007)	0.18(0.008)	0.16(0.0001)	-	-	-
Cucurbita maxima	0.08(0.32)	0.20(0.64)	0.14(0.17)	0.05(0.006)	0.05(0.007)	0.03(0.003
Cucumis sativa	0.12(0.014)	0.10(0.014)	0.10(0.006)	0.07(0.36)	0.08(0.37)	0.05(0.32)
Memordica charantia	0.03(0.010)	0.10(0.012)	0.02(0.002)	-	-	-
Total	0.95(0.35)	2.02(0.694)	0.82(0.186)	1.23(0.50)	1.25(0.51)	1.02(0.39)
Tuber crops:						
Manihot esculentus	0.45(0.09)	0.05(0.092)	0.06(0.07)	0.47(0.50)	0.38(0.52)	0.30(0.41)
Colocassia antiquorum	0.37(0.20)	0.41(0.21)	0.42(0.11)	0.44(0.24)	0.44(0.25)	0.40(0.23)
Xanthosoma sp.	-	-	-	0.08(0.19)	0.09(0.20)	0.07(0.17)
Total	0.82(0.29)	0.46(0.300)	0.48(0.18)	0.99(0.93)	0.91(0.97)	0.77(0.81)
Grand total (with S.E.values)	21.67(6.38) ±1.3(±0.03)	22.28(7.76) ±1.42(±0.05)	13.52(1.74) ±0.9(±0.001)	12.60(5.31) ±0.8(±0.02)	13.19(5.60) ±0.7(±0.02)	7.07(2.40) ±0.3(±0.001)

Table 8.4 Nitrogen and phosphorus (within parentheses) content (Kg ha^{-1}) of weed biomass put back under two weeding regimes under 20 - and 5 - year jhum cycles. Mean ± S.E. values are given for total.

Category	Jhum cycle (years) 20		5	
	Trw	Tow	Trw	Tow
Herbaceous dicot weeds	16.3(1.95)	29.3(3.5)	40.3(4.3)	46.5(5.00)
Grasses	0.7(0.09)	0.9(0.11)	1.2(0.16)	2.70(0.36
Bamboo	7.9(0.63)	8.9(0.71)	2.7(0.24)	2.70(0.24
Shrubs and trees	18.5(1.72)	19.6(1.82)	5.3(0.48)	5.30(0.48
Total	43.4(4.39) ±2.8(±0.3)	58.7(6.14) ±3.0(±0.5)	49.5(5.18) ±2.9(±0.4)	57.2(6.08 ±3.7(±0.5

the post-burn soil pool. However, such a difference between the two cycles was significantly higher for phosphorus ($P<0.01$) under a 20-year cycle both before and after the burn. Both nitrogen and phosphorus added through slash and higher under a 20-year cycle compared to a 5-year one. The losses of nitrogen and phosphorus was markedly higher under a 20-year cycle compared to a 5-year one. Nitrogen losses due to volatilization was much higher than that of phosphorus under both the jhum cycles.

The amount of nitrogen and phosphorus stored in the crop biomass was higher under a 20-year jhum cycle compared to a 5-year cycle. (Table8.2&3). Larger proportion of nutrients were removed through grain and seed, crops, followed by leafy vegetables and tubers. The nutrients stored in the edible component was markedly lower than those stored in the non-edible portion. The nutrients removed by the crop was very low in unweeded plots and maximum under total weeding, followed by traditional weeding regimes.

Nitrogen and phosphorus quantities in herbaceous dicots and in grasses weeded out were significantly higher ($P<0.001$) under a 5-year cycle compared to a 20-year cycle (Table8.4). The reverse was true for the nutrient quantities in the bamboo, shrubs and tree sprouts that were slashed and removed. Traditionally weeded plots had significantly ($P<0.05$) lower levels of nutrients

Table 8.5 Nitrogen and phosphorus input and output (Kg ha^{-1} yr^{-1}) for different weeding regimes in 20 - and 5 - year jhum cycles. Values in parentheses are given f. phosphorus.

	Jhum cycle (years) 20			5		
	Trw	Tow	Unw	Trw	Tow	Unw
Inputs:						
Precipitation	4.0(0.72)	4.0(0.72)	4.0(0.72)	4.0(0.72)	4.0(0,72)	4.0(0.72)
Slash	489.0(64.00)	489.0(64.00)	489. (64.00)	143.0(20.00)	143.0(20.00)	143.0([illegible].00)
Weeds put back	43.0(0.40)	59.0(6.20)	-	50.0(5.20)	57.0(6.00)	-
By-products put back	8.0(0.50)	8.0(0.50)	4.0(0.10)	2.0(0.30)	2.0(0.30)	0.5(0.05)
Total	544.0(69.22)	600.0(71.42)	497.0(64.73)	199.0(26.22)	206.0(27.02)	147.5(20.77)
Outputs:						
Fire	1660.0(65.00)	1660.0(65.00)	1660.0(65.00)	550.0(7.20)	550.0(7.20)	550.0(7.20)
Sediment	32.8(0.33)	42.2(0.42)	14.4(0.14)	45.2(0.50)	55.6(0.61)	20.4(0.22)
Run-off	4.3(1.18)	5.3(1.63)	2.8(0.60)	4.8(0.83)	5.3(1.00)	3.0(0.64)
Percolation	6.9(0.04)	9.6(0.05)	4.9(0.21)	5.5(0.40)	7.9(0.06)	4.1(0.03)
Weed removal	43.0(4.40)	59.0(6.20)	76.0(8.50)	50.0(5.20)	57.0(6.00)	78.0(7.60)
Crop removal	163.6(28.05)	196.3(33.04)	87.0(15.30)	95.0(17.9)	102.0(18.80)	32.0(9.50)
Total	1910.6(99.00)	1972.4(106.30)	1845.1(89.75)	750.5(32.03)	777.8(33.67)	687.5(25.19)
Net difference	1366.0(29.78)	1372.4(34.88)	1348.0(25.02)	551.0(5.81)	571.8(6.65)	540.0(4.42)

Table 8.6 Net change of nitrogen and phosphorus (Kg ha^{-1}) under different weeding regimes in 20 - and 5 - year jhum cycles. Values in parentheses are for net difference.

		Jhum cycle (years)			
		20		5	
		Nitrogen	Phosphorus	Nitrogen	Phosphorus
Soil pool before burning ($x10^3$)		10.9	0.024	10.45	0.0073
Soil pool at the end of cropping ($x10^3$)	Trw	9.78	0.032	9.91	0.012
		(1.12)	(0.008)	(0.54)	(0.0047)
	Tow	9.23	0.027	9.63	0.008
		(1.67)	(0.003)	(0.82)	(0.0007)
	Unw	9.92	0.037	10.11	0.016
		(0.98)	(0.013)	(0.34)	(0.0087)

removed, compared to total weeding except for bamboo, shrubs and trees under a 5-year cycle.

The total input and output of nitrogen and phosphorus of the system is lower under a 5-year cycle compared to a 20-year cycle (Table 8.5). Input through slash, weed biomass and through by-products all were markedly lower under a 5-year jhum cycle. The net loss was also markedly lower under a 5-year jhum cycle compared to a 20-year one. The total input and output was lower in unweeded plots and maximum under total weeding. Though slash is shown as an important input, the nitrogen in particular and phosphorus to a lesser extent get volatilized along with that from the surface soil pool which is accounted as an output through fire.

Table 8.6 shows the net change in nutrient pool in the soil sub-system under the two jhum cycles. There was a net decrease in nitrogen in the soil pool at the end of the cropping phase but a net increase for phosphorus in the system. This decrease in nitrogen was maximum under total weeding, closely followed by traditional weeding, and least in unweeded plots. On the other hand, the net increase in phosphorus was least under total weeding closely followed by traditional weeding, and maximum in unweeded plots.

DISCUSSION

During slash and burn agriculture (jhum) drastic changes in the physico-chemical properties of the soil occur (Ramakrishnan and Toky, 1981; Mishra and Ramakrishnan, 1983b). One of the major causes for this is the slash and burn operation which by itself is a major perturbation of the system, apart from the subsequent cropping phase. At lower elevations of Meghalaya, where typical slash and burn agriculture involving clear-cutting and burning of the forest is done (Toky and Ramakrishnan, 1981a), changes in the soil ecosystem are more drastic than under the modified version at higher elevations. In the latter case, only a few branches of the sparsely scattered trees are slashed and burn in a controlled manner after covering the dried slash with a thin soil layer (Mishra and Ramakrishnan, 1983a). Therefore, it is reasonable to expect heavier losses of nitrogen through volatilization during the burn under the typical jhum than under the modified version. Thus, 2 to 3 times more losses through volatilization occurred in the present case compared to that at higher elevations under the modified version of jhum (Mishra and Ramakrishnan, 1984).

Though a 20-year jhum cycle starts with a higher soil pool of nitrogen compared with a 5-year cycle, the post-burn nitrogen level in the soil under a 20-year cycle was lower, inspite of a 19 fold higher input of slash under this cycle compared to the shorter one. Obviously, a much larger quantity of nitrogen is volatilized because of the higher fuel load and the consequent higher intensity burn under the longer cycle. This decline in soil nitrogen pool reported also by others (Weels, 1971; White *et al.*, 1973; Mishra and Ramakrishnan, 1984) could be related to the conversion of organic nitrogen to volatile forms during pyrolysis (Allen, 1964; Knight, 1965; Debel and Ralston, 1970). However, nitrogen recovery in the system is rapid and this may be related to the increased microbial activity, due to increased pH of the soil (Ahlgren and Ahlgren, 1965; Ramakrishnan and Toky, 1981) and perhaps partly also due to release of the soil ecosystem from allelo-chemical effects (Rice and Pancholy, 1972; 1974) of the fallow vegetation after slash and burn operation. However, Saxena and Ramakrishnan (1986) have attributed the initially higher nitrification potential of the soil during the younger fallow stages as due to increased heterotrophic potential during seral development which inturn would reduce ammonium availability to nitrifiers.

The effect of fire on phosphorus budget in the soil system is less clear. There are conflicting reports on the level of phosphorus after fire, some suggesting no change in the levels (Allen, 1964; Viro, 1974), others suggesting a significant addition to the soil pool (Nye and Greenland, 1960; Stark, 1971; Stromgaard, 1984) and yet others suggesting some losses due to the burn (Harwood and Jackson, 1975; Ashton, 1976). While the decline in available phosphorus after fire is suggested to occur through convective losses of particulates rather than volatilization (Freedman, 1981), this alone may not explain the loss of upto 65 Kg of phosphorus under a 20-year cycle reported here or even the massive losses reported by Llyod (1971). Apparently, it looks as if some losses of phosphorus may also occur due to volatilization (Raison, 1980; Aston, 1976; Mishra and Ramakrishnan, 1983b). The net loss in nitrogen and net gain in phosphorus occurring at the end of the cropping phase could be due to heavier losses of nitrogen through volatilization compared to phosphorus lossses.

The higher output on nitrogen through grain and seed crops may partly be due to higher crop density of this category of species and partly to higher uptake combined with poor nutrient use efficiency of the crops (P.S. Ramakrishnan, unpublished). However, nitrogen and phosphorus budgets are not significantly altered under traditional and total weeding regimes, unlike in the unweeded plots. With 20% of the weed biomass retained <u>in situ</u> under traditional weeding by the jhum farmer, the weeds help in conservation of nutrients through run-off and percolation (Toky and Ramakrishnan, 1981b; Mishra and Ramakrishnan, 1983a; Chacon and Gliessman, 1982). Though the total weeding done here was followed by the weeds being putback into the system, non-traditional farmers often remove it out of the system. This obviously would have more serious repercussions in terms of losses through hydrology, as the dead weed biomass is not able to give protection from the beating rain on the soil surface. Further the possibility of recycling of nutrients through dead weed biomass is absent. Such a total weed removal regime, however, was not considered during the present study.

Weeds thus play an important role in the tropical agro-ecosystems. Their positive role has started receiving attention only in recent times (Alteiri, 1977; Chacon and Gliessman, 1982; Cox and Atkins, 1979; Ramakrishnan, 1984). Under traditional farming where weeded biomass is not removed out of the agroecosystem, the transfer of nutrients from the crop to the weed and vice versa becomes an important mechanism for optimizing nutrient use within the system. Thus, the use of weeds in this manner but with least interference on the crop would provide a greater degree of integrated management capability for tropical agriculture of the future (Alteiri, 1983; Gliessman et al., 1981; Ramakrishnan, 1984; Chapter 7).

Unlike at higher elevations of Meghalaya with a modified jhum and a controlled burn (Mishra and Ramakrishnan, 1983a), where the net loss of nitrogen from the system during one

Cropping phase was estimated to be about 640 Kg ha^{-1}, in the typical jhum considered here the losses could be as higher as 980-1670 Kg ha^{-1} under a 20-year cycle or 340 to 820 Kg ha^{-1} under a 5-year cycle depending upon the weeding regime. The loss of nitrogen reaching upto such high levels is obviously related to total slashing and burning done under the low elevation jhum. Assuming that the land under a 5-year jhum cycle had a longer 20-year cycle preceding a 20-year period, then the system seems to have lost about 0.45×10^3 Kg of nitrogen ($10.9 - 10.45 \times 10^3$) during this 20-year period. It is reasonable to assume that this nitrogen lost from the system would be put back through natural processes within a fallow period of about 10 years (Mishra and Ramakrishnan, 1983b). The inability of the system to recover the lost nitrogen during a short jhum cycle period of 5-years has been partly implicated in site degradation and eventual desertification (Ramakrishnan and Saxena, 1983). Similarly, the system lost about 17 Kg of phosphorus ($0.024 - 0.0073 \times 10^3$) during this 20-year period under a 5-year cycle.

From the point of view of the 'non-weed' concept (Chacon and Gliessman, 1982) it may be noted that the net loss/gain in nitrogen/phosphorus in totally weeded plots is not very different from traditionally weeded plots, when compared with unweeded ones.

SUMMARY

Nitrogen and phosphorus budgets of a traditional slash and burn agricultural system (Jhum) has been analysed at lower elevations of Meghalaya in north-east India. Two jhum cycles of 20- and 5-years were considered along with three weeding regimes of total, traditional partial weeding with 20% of weed biomass left *in situ* and no weeding. While losses of nitrogen through volatilization was heavier, there is evidence to suggest some volatilization of phosphorus too. The net loss of nitrogen and the gain in phosphorus at the end of the cropping period are more under a 20-year-jhum cycle compared to a 5-year-cycle. However the 20-year-fallow period was sufficiently longer to recover the losses of nitrogen through natural recovery processes in the soil ecosystem. The nitrogen and phosphorus budgets under a given jhum cycle was not much altered under traditional weeding when compared with total weeding; the budget under un-weeded plots was markedly altered under short jhum cycle of 5-years considered on a time scale of 20 years a net loss of about 450 Kg of nitrogen occurred which was never put back into the system through natural recovery processes. Similarly the system lost about 14 Kg of phosphorus during a 20-year period under a 5-year jhum cycle.

CHAPTER 9

NUTRIENT BUDGET UNDER SLASH AND BURN AGRICLTURE (JHUM) AT LOWER ELEVATIONS OF MEGHALAYA IN NORTH-EASTERN INDIA. II. POTASSIUM, CALCIUM AND MAGNESIUM.

INTRODUCTION

In an earlier paper, the nitrogen and phosphorus budgets of slash and burn agriculture under two jhum cycles of 20- and 5-years were considered (Chapter 8). These studies and the studies earlier done by Mishra and Ramakrishnan (1983b) suggests that volatilization of nitrogen and to a certain extent phosphorus play an important role in determining the budget pattern, since volatilization is not a critical factor applicable to cations, it is reasonable expect that these elements would follow a different budget pattern. Further, in these traditional agricultural systems, weeding is incomplete and left-over weeds play an important conservatory role (Chacon and Gliessman, 1982; Ramakrishnan, 1984; Chapter 7). Therefore, the present study considers cation budgeting under 20- and 5-year jhum cycles at lower elevations of Meghalaya in north-east India under three weeding regimes.

METHODS

Agroecosystems under two slash and burn agriculture (jhum) cycles (intervening fallow phase between two successive croppings at the same site) of 20 and 5 years were identified at Lailad, taking care to ensure similar topographic and soil conditions. Each jhum cycle with three replicate fields of 2 ha. each were selected. Each replicate field was divided into three sub-plots of 50 X 50 m and in each of these sub-plots three weeding regimes were imposed, i.e., traditional weeding (Trw), which is partial as practiced by the farmer, total weeding (Tow) and unweeded plots (Unw). Both partial and total weeding regimes involved weeding through hand-hoeing, four times during the cropping period except that in the former case part of the weed biomass (20% of the total) was left in situ.

Direct fall through precipitation was collected from ten random points of each field. Soil was sampled at ten random points at each sub-plot upto a depth of 40 cm. Soil sampling was done on three different occassions: (i) a day before burning the slash in March, (ii) a day after the burn in March and (iii) at the end of cropping period in December.

Calculations of the amount of slash burnt and materials removed from the agroecosystem as economic yield through crop, crop byproducts and weeds or the last two components put back into the system under different treatments are based on three 100 m^2 quadrat samples from each sub-plot.

For studies pertaining to loss of potassium, calcium and magnesium through sediment and run-off water, the loss from a confined area of 1X 10 m along the slope was collected in large collectors and periodically removed for analysis. Percolation studies were made with the help of a simple lysimeter of the

Russian type (Buckman and Brady, 1960). The soil was cut into vertically, to expose the profile. A tunnel was then excavated at a depth of 40 cm (This is the depth to which most of the root system penetrate) and a collector of 30 X 30 X 15 cm was placed in the tunnel. By pressing from below, the rim of the collector was firmly inserted into the undisturbed soil above. The water percolating through the soil was tapped from the collector into receptacles from time to time for analysis. Formaldehyde (40%) was used to stop biological activity immediately after collection and preserved in polythene jars for subsequent analysis.

The soil sampling was done using a core sampler of 10 cm diameter. The amount of nutrients present in the soil pool (Kg ha^{-1}) was calculated to a depth of 40 cm using soil bulk density estimates calculated for each site, at depths of 0-7, 7-14, 14-28 and 28-40 cm, considered separately. Bulk density or volume weight (the quotient of the air drymass weight of soil to the total volume it occupies in the field) was determined from the air drymass of a known field volume of soil. Soil was air dried and plant samples were oven dried at 60^{o}c for 48 hours, before storage. Dried soil samples were ground, passed through 0.2 mm sieve and stored in glass jars for subsequent analysis. The estimation of cations in water, soil and plant samples were done after wet digestion of the plant material with triple acid or after extraction with 1 M ammonium acetate solution at pH 7 in the case of soil, following standard procedures given by Allen et al. (1974). Thus calcium and magnesium was estimated by EDTA titration and potassium by flame-emission methods.

Calculations of the amount of nutrients (potassium, calcium and magnesium) gained due to slash burning are based on the difference of that element present in the soil up to a depth of 40 cm between the pre-burn (a day before the burn) and including that added through the slash, that present in the soil a day after the burn. Input and output of elements for each sub-plot were calculated on the basis of amount of that particular input/output and the concentration of the element in it.

RESULTS

A significantly higher level of cations was present in the pre-burn and the post-burn soil pools under a 20-year-jhum cycle as compared with a 5-year-cycle (Table 1). As a result, there was a significantly higher gain ($P < 0.001$) to the soil system under a 20-year cycle than under a 5-year cycle. The gain was maximum for calcium under a 20-year cycle while it was potassium under a 5-year-cycle.

Table 9.1 Gain of nutrients (Kg ha^{-1}) through fire (with mean ± S.E. values) under 20 - and 5 - year jhum cycles.

	Jhum cycle (years)					
	20			5		
	Potassium	Calcium	Magnesium	Potassium	Calcium	Magnesium
Pre-burn soil pool(a)(x10^3)	1.40 ±0.01	2.30 ±0.02	1.40 ±0.01	0.479 ±0.001	0.873 ±0.003	0.930 ±0.004
Post-burn soil pool(b)(x10^3)	3.71 ±0.03	4.38 ±0.04	2.03 ±0.01	1.43 ±0.01	1.48 ±0.01	1.25 ±0.08
Gain(a)-(b) (x10^3)	0.93 ±0.008	1.64 ±0.01	0.40 ±0.002	0.76 ±0.002	0.528 ±0.001	0.255 ±0.0006

Table 9.2 Potassium output (Kg ha^{-1}) through non-edible and edible (within parentheses) crop biomass under different weeding regimes under 20 - and 5 - year jhum cycles.

Crop species	Jhum cycle (years) 20			5		
	Trw	Tow	Unw	Trw	Tow	Unw
Grain and seed:						
Oriza sativa	113.2(1.4)	117.3(1.4)	74.5(0.2)	65.8(0.8)	70.0(0.9)	9.5(0.05)
Seasamum indicum	6.0(2.1)	6.3(2.1)	6.2(1.3)	-	-	-
Zea mays	28.1(1.5)	2[illegible].9(1.8)	28.1(0.8)	15.4(1.2)	15.6(1.2)	9.6(0.5)
Seteria italica	6.1(0.9)	7.8(0.9)	6.5(0.4)	8.0(0.4)	5.9(0.4)	1.4(0.1)
Phaseolus mungo	0.2(0.05)	0.2(0.05)	0.1(0.02)	-	-	-
Ricinus communis	7.2(0.04)	7.2(0.04)	6.5(0.03)	-	-	-
Total	160.8(6.0)	166.7([illegible].3)	122.0(2.8)	89.2(2.4)	91.5(2.5)	20.5(0.7)
Leaf and fruit vegetables:						
Hybiscus suodariffa	4.2(0.6)	4.3(0.7)	2.4(0.5)	6.5(0.9)	6.9(0.9)	5.7(0.5)
Capsicum fructesence	1.7(0.003)	1.7(0.003)	0.3(0.0004)	-	-	-
Cucurbita maxima	1.9(0.6)	1.9(0.6)	2.2(0.4)	1.0(1.7)	1.1(1.7)	0.7(1.5)
Cucumis sativa	1.2(0.06)	1.2(0.06)	1.5(0.02)	0.7(0.01)	0.8(0.01)	0.4(0.007)
Momordica charantia	1.1(0.02)	1.3(0.02)	1.1(0.02)	-	-	-
Total	10.1(1.3)	10.4(1.3)	7.5(0.9)	8.5(2.6)	8.8(2.6)	[illegible]
Tuber crops:						
Manihot esculentus	0.3(0.3)	0.3(0.3)	0.3(0.2)	0.2(0.2)	0.2(0.2)	0.2(0.1)
Colocassia antiquorum	2.1(0.8)	2.2(0.8)	2.1(0.4)	1.6(1.0)	1.6(1.0)	1.5(0.9)
Xanthosoma sp.	-	-	-	0.6(1.4)	0.8(1.5)	0.6(1.3)
Total	2.4(1.1)	2.5(1.1)	2.4(0.6)	2.4(2.6)	6.82(2.7)	2.2(2.3)
Grand total	173.3(8.4) ±11.3(±0.03)	179.6(8.7) ±12.6(±0.04)	129.5(3.1) ±13.1(±0.01)	100.1(7.6) ±8.3(±0.04)	107.1(7.8) ±9.1(±0.03)	29.5(5.0) ±2.0(±0.02)

Table 9.3 Calcium output (Kg ha^{-1}) through non-edible and edible (within parentheses) crop biomass under different weeding regimes under 20 - and 5 - year jhum cycles.

Crop species	20 Trw	20 Tow	20 Unw	5 Trw	5 Tow	5 Unw
	Jhum cycle (years)					
Grain and seed:						
Oriza sativa	16.4(2.1)	17.3(2.1)	11.2(0.4)	9.3(1.0)	10.2(1.3)	3.7(0.05)
Seasamum indicum	4.5(1.4)	5.0(1.4)	4.7(0.9)	-	-	-
Zea mays	7.7(2.3)	7.7(2.6)	5.0(1.2)	4.6(1.6)	4.6(1.8)	2.9(0.7)
Seteria italica	2.0(0.1)	2.5(0.1)	1.9(0.5)	1.6(0.4)	1.7(0.4)	0.5(0.01)
Phaseolus mungo	0.1(0.002)	0.1(0.002)	0.1(0.001)	-	-	-
Ricinus communis	6.5(0.02)	6.6(0.02)	6.0(0.02)	-	-	-
Total	37.2(5.9)	39.2(6.2)	28.9(3.0)	15.5(3.0)	16.5(3.5)	7.1(0.8)
Leaf and fruit vegetables:						
Hybiscus subdariffa	6.0(1.8)	6.1(1.8)	3.6(1.5)	3.3(1.	3.4(1.2)	2.3(0.7)
Capsicum fructesence	1.0(0.002)	1.0(0.002)	0.4(0.0003)	-	-	-
Cucurbita maxima	1.6(0.3)	1.6(0.3)	3.0(0.1)	0.5(0.002)	0.6(0.003)	0.[illegible](0.001)
Cucumis sativa	2.0(0.005)	2.0(0.005)	1.6(0.002)	0.1(0.12)	0.1(0.12)	0.6(0.11)
Memordica charantia	1.1(0.004)	1.3(0.004)	1.1(0.004)	-	-	-
Total	11.7(2.1)	12.0(2.1)	9.7(1.6)	3.9(1.3)	4.1(1.3)	3.3(0.8)
Tuber crops:						
Manihot esculentus	0.1(0.1)	0.2(0.1)	0.1(0.08)	0.07(0.07)	0.09(0.07)	0.07(0.05)
Colocassia antiquorum	3.1(0.06)	3.3(0.06)	3.3(0.03)	1.8(0.07)	1.8(0.07)	1.6(0.07)
Xanthosoma sp.	-	-	-	0.06(0.13)	0.07(0.13)	0.06(0.11)
Total	3.2 (0.2)	3.5(0.2)	3.4(0.1)	1.9(0.27)	1.97(0.27)	1.77(0.23)
Grand total (with S.E.values)	52.1(8.2) ±3.4(±0.5)	54.7(8.5) ±4.1(±0.6)	42.0(4.7) ±3.2(±0.2)	21.3(4.6) ±1.8(±0.3)	22.3(5.1) ±1.4(±0.2)	12.7(1.8) ±0.9(±0.003)

Table 9.4 Magnesium output (Kg ha^{-1}) through non-edible and edible (within parentheses) crop biomass under different weeding regimes under 20 - and 5 year Jhum cycles.

Crop specieis	Jhum cycle (years) 20 Trw	Tow	Unw	5 Trw	Tow	Unw
Grain and seed:						
Oriza sativa	33.7(3.4)	34.7(3.4)	22.4(0.6)	15.5(1.8)	17.2(2.1)	15.4(0.1)
Seasamum indicum	2.3(1.5)	2.4(1.5)	2.3(0.9)	-	-	-
Zea mays	5.3(0.9)	5.3(1.0)	5.3(0.5)	3.2(0.6)	3.2(0.6)	2.0(0.3)
Seteria italica	3.8(0.4)	5.0(0.5)	3.8(0.2)	3.3(0.02)	3.8(0.02)	1.0(0.05)
Phaseolus mungo	0.07(0.03)	0.08(0.03)	0.07(0.01)	-	-	-
Ricinus communis	3.6(0.01)	3.6(0.01)	3.3(0.01)	-	-	-
Total	48.8(6.2)	51.1(6.4)	37.2(2.2)	22.0(0.5)	23.0(0.5)	18.4(0.5)
Leaf and fruit vegetables:						
Hybiscus subdariffa	2.1(0.4)	2.1(0.4)	1.2(0.3)	2.3(0.5)	2.3(0.5)	2.0(0.3)
Capsicum fructesence	0.3(0.003)	0.9(0.0003)	0.3(0.0005)	-	-	-
Cucurbita maxima	0.5(0.1)	0.5(0.1)	0.6(0.08)	0.4(0.2)	0.5(0.2)	0.3(0.2)
Cucumis sativa	0.8(0.007)	2.0(0.005)	0.7(0.003)	0.3(0.003)	0.6(0.003)	0.4(0.001)
Memordica charantia	0.08(0.004)	1.3(0.004)	0.08(0.004)	-	-	-
Total	3.8(0.6)	6.8(0.6)	2.9(0.4)	3.0(0.7)	3.4(0.7)	2.7(0.5)
Tuber crops:						
Manihot esculentus	0.6(0.8)	0.7(0.8)	0.8(0.6)	0.05(0.04)	0.05(0.04)	0.04(0.04)
Colocassia antiquorum	0.09(0.03)	0.09(0.03)	0.09(0.02)	0.07(0.03)	0.07(0.04)	0.07(0.03)
Xanthosoma sp.	-	-	-	0.05(0.11)	0.06(0.11)	0.05(0.10)
Total	0.7(0.8)	0.8(0.8)	0.9(0.6)	0.17(0.18)	0.18(0.19)	0.16(0.17)
Grand total (with S.E. values)	53.3(7.6) ±3.9(±0.3)	53.6(7.8) ±4.2(±0.05)	41.0(3.2) ±2.6(±0.02)	25.17(1.38) ±1.4(±0.001)	26.58(1.39) ±1.6(±0.001)	21.26(1.17) ±1.5(±0.001)

Table 9.5 Nutrient content (Kg ha^{-1}) of weed biomass put back under traditional and total (within parentheses) weeding regimes under 20 - and 5 - year jhum cycles. Mean ± S.E. values are given for total.

	Jhum Cycle (years)					
	20			5		
Weed category	Potassium	Calcium	Magnesium	Potassium	Calcium	Magnesium
Herbaceous dicots	11.5 (20.7)	4.9 (8.8)	4.5 (8.0)	21.4 (24.8)	8.2 (9.5)	7.7 (8.9)
Grasses	0.5 (0.6)	0.2 (0.2)	0.2 (0.2)	0.9 (2.1)	0.3 (0.7)	0.3 (0.7)
Bamboo	7.2 (8.2)	2.9 (3.3)	3.0 (3.4)	2.4 (2.4)	1.0 (1.0)	1.0 (1.0)
Shrubs and trees	12.5 (13.2)	11.2 (11.9)	5.5 (5.8)	3.6 (3.6)	3.3 (3.3)	1.6 (1.6)
Total	31.7±2.4 (42.7)±3.6	19.2±1.1 (24.2)±2.1	13.2±0.9 (17.4)±1.2	28.3±1.3 (32.9)±2.5	12.8±0.8 (14.5)±1.0	10.6±0.8 (12.2)±0.8

Table 9.6 Potassium input and output (Kg ha^{-1}) for different weeding regimes in 20 - and 5 - year jhum cycles.

	Jhum cycle (years)					
	20			5		
	Trw	Tow	Unw	Trw	Tow	Unw
Inputs:						
Precipitation	6.9	6.9	6.9	6.9	6.9	6.9
Slash-burn	930.0	930.0	930.0	760.0	760.0	760.0
Weeds put back	31.7	42.7	-	28.3	32.8	-
By products put back	175.6	182.1	134.8	100.1	107.1	29.5
Total	1144.2	1161.7	1071.7	895.3	906.8	796.3
Output:						
Sediment	48.7	62.6	21.4	26.7	32.8	12.0
Run-off	81.4	106.2	51.3	49.3	69.7	55.8
Percolation	12.2	16.3	8.2	7.9	13.6	8.3
Weed removal	31.7	42.7	135.7	28.3	32.9	65.5
Crop removal	181.7	183.3	132.6	107.7	114.9	34.5
Total	355.7	416.1	349.2	219.9	263.9	176.1
Nett difference	788.5	745.6	722.5	675.4	642.9	620.2

The amount of potassium (Table 9.2), calcium (Table 9.3) and magnesium (Table 9.4) stored in the crop biomass was higher under a 20-year-jhum cycle. The output of potassium was markedly higher ($P < 0.01$) compared to other two cations both in edible and non-edible crop biomass. The nutrients removed by crop biomass was least in unweeded plots and maximum under total weeding closely followed by traditional weeding. A larger proportion of nutrients were removed through grain and seed crops, followed by leafy vegetables and tubers. The cations stored in the edible component were markedly lower than those stored in the non-edible portion.

The nutrients putback into the agroecosystem through herbaceous dicots and grasses both under traditional and total weeding regimes are significantly higher ($P < 0.01$) under a 5-year-jhum cycle compared to a 20-year one (Table 9.5). On the other hand, the reverse was the case for the bamboo species, Dendrocalamus hamiltonii and for shrubs and trees. The total amount of different nutrients putback into the system was signivicantly higher ($P < 0.05$) under a 20-year jhum cycle than under a 5-year one. Potassium content was higher in the weed biomass followed by calcium and magnesium.

The input of potassium into the system and the output from it was much higher under a 20-year cycle compared to a 5-year one (Table 9.6). This was reflected in the net gain

Table 9.7 Calcium input and output (Kg ha^{-1}) for different weeding regimes in 20 - and 5 - year jhum cycles.

	Jhum cycle (years) 20			5		
	Trw	Tow	Unw	Trw	Tow	Unw
Inputs:						
Precipitation	8.5	8.5	8.5	8.5	8.5	8.5
Slash-burn	1640.0	1640.0	1640.0	528.0	528.0	528.0
Weeds put back	19.2	24.3	-	12.7	14.4	-
By-products put back	53.2	56.5	43.3	21.3	22.3	12.7
Total	1941.0	1729.3	1691.8	572.3	573.2	549.2
Output:						
Sediment	35.5	45.6	15.6	26.7	28.2	10.3
Run-off	23.7	31.5	14.6	12.9	15.7	16.1
Percolation	5.0	6.4	3.0	3.1	4.5	2.4
Weed removal	19.2	24.2	60.1	12.8	14.5	32.2
Crop removal	60.3	63.2	46.7	25.9	27.4	14.5
Total	143.7	171.5	140.0	81.4	90.3	75.5
Net difference	1797.3	1558.4	1551.8	490.9	482.9	473.7

Table 9.8 Magnesium input and output (Kg ha^{-1}) for different weeding regimes in 20 - and 5 - year jhum cycles.

	Jhum cycle (years)					
	20			5		
	Trw	Tow	Unw	Trw	Tow	Unw
Input:						
Precipitation	4.4	4.4	4.4	4.4	4.4	4.4
Slash-burn	400.0	400.0	400.0	255.0	255.0	255.0
Weeds put back	13.1	17.4	-	10.5	12.0	-
By-products put back	59.0	65.0	48.2	25.7	26.6	21.3
Total	476.5	486.8	452.6	295.6	298.0	280.7
Output:						
Sediment	13.8	17.6	6.0	12.9	15.9	5.8
Run-off	10.6	15.3	9.0	10.5	12.5	9.9
Percolation	2.3	3.1	1.5	1.5	2.1	1.3
Weed removal	13.2	17.4	55.2	10.6	12.2	30.5
Crop removal	60.9	66.4	44.2	26.5	28.0	22.4
Total	100.8	119.8	115.9	62.0	70.7	69.9
Net difference	375.7	367.0	336.7	233.6	227.3	210.8

Table 9.9 Net change of exchangeable cations (Kg ha^{-1}) under different weeding regimes in 20 - and 5 - year jhum cycles at the end of cropping period. Values in parentheses are for net gain.

		Jhum cycle (years)					
		20			5		
		Potassium	Calcium	Magnesium	Potassium	Calcium	Magnesium
Soil pool before burning(x10^3)		1.40	2.30	1.40	0.48	0.87	0.93
Soil pool at the end of cropping period (x10^3)	Trw	1.44 (0.04)	2.49 (0.19)	1.52 (0.12)	0.58 (0.10)	0.91 (0.04)	0.96 (0.03)
	Tow	1.41 (0.01)	2.38 (0.08)	1.45 (0.05)	0.56 (0.08)	0.89 (0.02)	0.93 (0.0)
	Unw	1.51 (0.11)	2.78 (0.48)	1.66 (0.26)	0.64 (0.16)	0.99 (0.12)	0.99 (0.06)

too. This difference between the two jhum cycles was pronounced for calcium compared to potassium (Table 9.7). The input/output pattern for magnesium was also similar to potassium (Table 9.8). The output/input through weed was higher under a 20-year cycle compared to a 5-year cycle. Similarly, the output through sediment, run-off and percolation was higher under the longer cycle. The crop removal was also higher under a longer cycle, and consequently input of the non-edible biomass component putback into the system. For all the three elements, traditional weeding showed maximum gain, followed by total weeding and least for unweeded plots.

DISCUSSION

After slash and burn operation, considerable amount of cations are added to the soil through ash released during the burn resulting in a rapid increase in the cation level in the soil pool at the post-burn stage (Ramakrishnan and Toky, 1981; Mishra and Ramakrishnan, 1983b), as also shown here, However, the increase in the cation level in the soil pool far exceeds that added through slash. Such an increase probably is more due to effects of heat and less caused by ash itself. Perhaps, there is an interchange between non-exchangeable and exchangeable forms due to burning (Stromgaard, 1984). This is an aspect that needs further study. With longer time available for natural recovery under a 20-year cycle it is reasonable to expect higher levels of nutrients in the pre-burn soil pool (Toky and Ramakrishnan, 1983b; Mishra and Ramakrishnan, 1983c). Further the higher level under a longer jhum cycle in the post-burn stage is partly related to fuel load and partly to better physical characteristics of the soil here that would contribute to higher cation exchange capacity compared to the shorter cycle.

A very high uptake of potassium compared to other elements by cereals and tuber crops was also observed by others (Nye and Greenland, 1961). Generally higher input of nutrients by these two categories of crop species compared to others may partly be due to greater emphasis on these species by the farmer in his jhum plot. Further, generally higher nutrient uptake efficiencies and lower use efficiencies have been suggested for cereals (Ramakrishnan, 1984).

The higher nutrient content for herbaceous weeds under a short jhum cycle of 5-year compared to 20-year-cycle is a consequence of increased herbaceous weed potential under a shorter cycle (Saxena and Ramakrishnan, 1984b). However, the higher nutrient content for the total weed biomass under a longer cycle is because of the bamboo species, *Dendrocalamus hamiltonii*, and shrubs and trees that predominate here.

It may be noted here that the contribution of potassium under a 20-year cycle through the bamboo (Dendrocalamus hamiltonii) is very high compared to other elements, because of its affinity to this element (Toky and Ramakrishnan, 1982; Toky and Ramakrishnan, 1983b).

Unlike nitrogen and phosphorus that follow a different input/output pattern because of relatively higher or lower levels of volatilization of these two elements reported by us (Mishra and Ramakrishnan, 1984; Chapter 8), there is a net gain for all cations because of greater input into the system. This gain was maximum for calcium followed by potassium and magnesium.

Traditional weeding regime, with 20% weed biomass left *in situ*, has a conservatory role for nutrients as seen from this study, where the net gain into the system is maximal compared with other weeding regimes. Unweeded plots had the least gain which is largely due to reduced crop vigour and the consequently lower recycling through crop biomass and also due to total absence of recycling through weed biomass put back into the system.

It may be concluded that the nutrient budget analysis presented here is in sharp contrast to the nitrogen and phosphorus budgets discussed earlier (Chapter 8). The net increase in soil cation levels after burn and after cropping is the reverse of what was observed for nitrogen where volatilization plays an important role in the net loss from the system; even phosphorus gain into the system was only marginal. With the shortening of the jhum cycle to 5-years or lesser (Ramakrishnan *et al.* 1981a; Ramakrishnan, 1984), the cation levels in the soil too are adversely affected contributing to poorer soil fertility recovery after successive croppings.

SUMMARY

Potassium, calcium and magnesium budget analysis was done under two slash and burn agriculture (jhum) cycles (the intervening fallow phase between two successive croppings at the same site) of 20- and 5-years with traditional, total and no-weeding regimes, at lower elevations of Meghalaya in north-east India. The net gain observed in soil cation levels in the post-burn soil is partly due to addition through slash and partly perhaps to heat related interchange between non-exchangeable and exchangeable forms. The input of nutrients was generally higher under a longer jhum cycle with a consequent net higher gain here, in spite of higher output. Though the nutrient content in the total weed biomass was higher under a 20-year jhum cycle, the contributing through herbaceous weed biomass was higher under a 5-year cycle due to increased herbaceous weed potential. The traditional weeding regime with 20% weed biomass retnetion *in situ* contributed to conservation of nutrients in the agroecosystem as reflected in the generally higher net gain, when compared with other weeding regimes.

REFERENCES

Abrahamson, W.G. 1979. Patterns of resource allocation in wildflower populations of fields and woods. Am. J. Bot., 66: 71-79.

Abrahamson, W.G. 1980. Demography and vegetative reproduction, p. 89-106. In: O.T. Solbrig (ed.). Demography and Evolution in Plant Populations. Blackwell Scientific Publications, Oxford.

Abrahamson, W.G. and Caswell, H. 1982. On the comparative allocation of biomass, energy and nutrients in plants. Ecology, 63: 982-991.

Abrahamson, W.G. and Gadgil, M. 1973. Growth form and reproductive effort in goldenrods (Solidago, compositae). Am. Nat., 107: 651-661.

Achland, J.D. 1971. East African Crops. Longman, London.

Ahlgren, I.F. and Ahlgren, C.E. 1960. Ecological effects of forest fires. Bot. Rev., 26: 483-497.

Ahlgren, I.F. and Ahlgren, C.E. 1965. Effects of prescribed burning on soil microorganisms in Minnesota Jack-Pine forest. Ecology, 46: 304-310.

Allen, S.E. 1964. Chemical aspects of heather burning. J. Appl. Ecol., 1: 347-367.

Allen, S.E., Grimshaw, H.M., Parkinson, J.A. and Quarmby, C. 1974. Chemical Analysis of Ecological Materials. Blackwell Scientific Publications, Oxford.

Altieri, M.A. 1983. Agroecology: The Scientific Basis of Alternative Agriculture. Div. Biolo. Cont., University of California, Berkeley. 162p.

Antonovics, J. 1972. Population dynamics of the grass Anthoxanthum odoratum on a zinc mine. J. Ecol., 60: 351-365.

Ashton, D.H. 1976. Phosphorus in forest ecosystems at Beenak, Victoria. J. Ecol., 64: 171-186.

Baker, H.G. 1965. Characters and modes of origin of weeds, p.147-172. In: H.G. Baker and G.L. Stebbins (eds.). The Genetics of Colonizing Species. Academic Press, New York.

Bamber, M. 1909. The cultivation of Passiflora foetida and Mikania scandens to keep down other weeds. J. Royal Bot. Gard., 41: 141.

Barkham, J.P. 1980a. Population dynamics of the wild daff-odil (Narcissus pseudonarcissues) I. Clonal growth, seed reproduction mortality and effects of density. J. Ecol., 68: 607-633.

Barkham, J.P. 1980b. Population dynamics of the wild daffodil (Narcissus pseudonarcissus) II. Changes in number of shoots and flowers, and the effect of bulb depth on on growth and reproduction. J.Ecol., 68: 634-664.

Bartholomew, W.V., Meyer, J. and Laudelout, H. 1953. Mineral nutrient immobilization under forest and grass fallow in the Yangambi (Belgian Congo) region. Publications de L'Institute National pour L' Etude Agronomique du Congo Belge, Serie Scientifique, 57: 1-27.

Bazzaz, F.A. 1979. Physiological ecology of plant succession. Ann. Rev. Ecol. Syst., 351-371.

Beatley, J.C. 1967. Survival of winter annual in the northern Majave Desert. Ecology, 48: 745-750.

Bell, K.L., Hiatt, H.D. and Niles, W.E. 1979. Seasonal changes in biomass allocation in eight winter annuals of Mojave Desert. J. Ecol., 67: 781-787.

Bieleski, R.L. 1973. Phosphate pools, phosphate transport and phosphate availability. Ann. Rev. Plant. Physiol., 24: 225-252.

Bennett, F.D. and Rao, V.P. 1968. Distribution of an introduced weed Eupatorium odoratum Linn (compositae) in Asia and Africa and possibilities for its biological control. PANS., 14: 277-281.

Benzing, D.H. and Davidson, E.A. 1979. Oligotrophic Tillandsia circinnata Schlecht. (Bromeliaceae): An assessment of its patterns of mineral allocation and reproduction. Am. J. Bot., 66: 386-397.

Bierzychudek, P. 1982a. Life histories and demography of shade-tolerant temperate forest herbs: a review. New Phytol., 90: 757-776.

Bierzychudek, P. 1982b. The demography of jack in the pulpit, a forest perennial that changes sex. Ecol. Monogr., 52: 335-351.

Bishop, G.F., Davy, A.J. and Jeffries, R.L. 1978. Demography of Hieracium pilosella in a Breck grassland. J. Ecol., 66: 615-629.

Blair, C.J. and Cordero, S. 1978. The phosphorus efficiency of three annual legumes. Plant and Soil, 50: 387-398.

Bormann, F.H. and Likens, G.E. 1979. Pattern and Process in a Forested Ecosystem. Springer-Verlag, New York. 253p.

Bormann, F.H., Likens, G.E., Fisher, D.W. and Pierce, R.S. 1968. Nutrient loss accelerated by clear cutting of a forested ecosystem. Science, 159: 882-884.

Borthakur, D.N. 1977. Mikania and Eupatorium: two noxious weeds of N.E. region. Indian Farming, 26: 25-26.

Brady, C.J. 1973. In: Chemistry and Biochemistry of herbage. Butler, G.W. and Bawley, R.W. (eds.). Academic Press, London. 2: 317-351.

Bray, P. and Kurtz, L.T. 1945. Determination of total, organic and available forms of phosphorus in soils. Soil Science, 59: 39-45.

Brown, R.H. 1978. A difference in N use efficiency in C_3 and C_4 plants and its implication in adaptation and evolution. Crop Science, 18: 43-48.

Buckman, H.O. and Brady, N.C. 1960. The Nature and Properties of Soils. Macmillan, New York. 567p.

Budowski, G. 1961. Studies on forest succession in Costa Rica and Panama. Ph.D. Thesis, School of Forestry Yale University, New Haven, Conn.

Buell, M.F. and Cantlon, E. 1953. Effects of prescribed burning on ground cover in the New Jersey Pine region. Ecology, 34: 602-610.

Burkill, I. 1935. A Dictionary of the Economic Products of the Malay Peninsula. London. 2,402p.

Canfield, R.H. 1957. Reproduction and life span of some perennial grasses of Southern Arizona. J. Range Manage., 10: 199-203.

Caum, E. 1940. A devastating weed. Hawaiian Planters' Record., 44: 243-249.

Cavers, P. and Harper, J.L. 1967. Studies in the dynamics of plant population. 1. The fate of seeds and transplants introduced in the various habitats. J. Ecol., 55: 59-71.

Chacon, J.C. and Gliessman, S.R. 1982. Use of 'non-weed' concept in traditional agroecosystems of south-eastern Mexico. Agro-Ecosystems, 8: 1-11.

Chapin III, F.S. 1980. The mineral nutrition of wild plants. Ann. Rev. Ecol. Syst., 11: 233-260.

Chapin, F.S. and Cleve, K.V. 1981. Plant nutrient absorption and retention under differing fire regimes. p.301-321 In: H. Mooney, T.M. Bonnicksen, N.L. Christensen, J.E. Botan and W.A. Reiners (eds.). Fire Regimes and Ecosystem Properties. USDA. Forest Serv. Gen. Tech. Rept.,W.O.26, Washington, D.C.

Christensen, N.L. 1981. Fire regimes in south-eastern ecosystems. p.112-137. In: H. Mooney, T.M. Bonnicksen, N.L. Christensen, J.E. Lotan, W.A. Reiners (eds.). Fire Regimes and Ecosystem Properties. USDA. Forest Serv. Gen. Tech. Rept., W.O.26, Washington, D.C.

Christensen, N.L. and Muller, C.H. 1975. Effects of fire on factors controlling plant growth in Adenstoma Chaparral Ecol. Monogr.,45: 29-55.

Clements, F.E. 1916. Plant succession: analysis of the development of vegetation. Carn. Inst. Wash. Publ., 242: 512p.

Cock, M.J.W. 1981. An assessment of the occurrence and potential of natural enemies of Mikania sp. in neotropics.

Cody, MLL. 1966. A general theory of clutch size. Evolution, 20: 174-184.

Colinvaux, P.A. 1973. Introduction to Ecology. John Wiley & Sons, Inc., New York, 512p.

Conklin, H.C. 1957. Hanonoo Agriculture. F.A.O. Forestry Development Paper No.12. F.A.O., Rome.

Cook R.E. 1980. Germination and size dependent mortality in Viola blanda. Oecologia, 47: 115-117.

Cook, R.E. 1983. Clonal plant populations. American Scientist, 71: 244-253.

Cook, R.E. and Lyons, E.E. 1983. The biology of Viola fimbriatula in a natural disturbance. Ecology, 64: 654-660.

Cornell, J.H. and Slatyer, R.O. 1977. Mechanisms of succession in natural communities and their role in community stability and organization. Amer. Nat., 111: 1119-1144.

Cox, G.W. and Atkins. 1979. Agricultural ecology. W.F. Freeman, San Francisco, California, 397-399p.

Craig, N. and Evans, H. 1946. Preliminary reports on the progress of weed control investigations in Mauritius. 2. Mikania scandens known in Mauritius as "liane marzoge", "Line Pauline," and "liane raisan." Revue agricole de l'Ile Maurice, 25: 198-203.

Cruttwell, R.E. 1968. Preliminary survey of potential biological control agents of Eupatorium odoratum in Trinidad. Proc. 9th British Weed Cont. Conf., 836-841.

Cutting, C.V., Wood, R.A., Brown, P. and Ambrose, H.B. 1959. Assessment of fertility status and the maintenance of productivity of soils in Nyasaland. Paper No.69. Third Inter. Afr. Soils Conf. Dalaba.

Das, A.K. and Ramakrishnan, P.S. 1985. Litter dynamics in khasi pine (Pinus kesiya Royle Ex Gordon) of north-eastern India. For. Ecol. Manage., 10: 135-153.

Debell, D.S. and Ralston, C.W. 1970. Release of nitrogen by burning light forest fuels. Soil Sci. Soc. Am. Proc., 34: 936-938.

De Las Salas, G. and Folster, H. 1976. Bioelement loss on clearing a tropical rain forest. Turrialba, 26: 179-186.

Deevey, E.S. 1947. Life tables for natural populations of animals. Q. Rev. Biol., 22: 283-314.

Dutta, A.C. 1977. Biology and control of Mikania. Two and Bud, 24: 17-20.

Dutta, S. 1965. Weed control in tea of north-east India. PANS., 11: 9-12.

Dutta, S.K., Sarkar, S.K. and Barbora, B.C. 1968. Control of Mikania in tea with 2,4-D and M.C.P.A. Two and Bud, 15: 83-84.

Egler, F.E. 1954. Vegetation science concepts. I. Initial floristic composition - a factor in old field vegetation development. Vegetatio, 4: 412-417.

Elton, C. 1933. The Ecology of Animals. London, Methuen.

Emerson, R.A. 1953. A preliminary survey of the milpa system of maize culture as practised by the Maya Indians of the northern part of the Yucatan peninsula. Ann. Missouri Bot. Gard. 40: 51-62.

Ernst, W.H.O. 1979. Population biology of Allium ursinum in northern Germany. J. Ecol., 67: 347-362.

Eussen, E.H.H. and Wirjahardja, S. 1973. Studies of an alang-alang (Imperata cylindrica L.) Beauv. Vegetation. Biotrop. Bull., 6: 24p.

Ewel, J.J. 1971. Biomass changes in early tropical succession. Turrialba, 21: 110-112.

Ewel, J.J. 1976. Litter fall and leaf decomposition in a tropical forest succession in eastern Guatemala. J. Ecol., 64: 293-308.

Farnworth, E.G. and Golley, F.G. 1974. Progress in Tropical Ecology. Springer-Verlag, Berlin and Heidelberg.

Fischer, R.A. 1958. The General Theory of Natural Selection. Dover, New York.

Foster, M.M. Vitousek, P.M. and Radolph, P.A. 1980. The effects of ragweed (Ambrosia artemisiifolia L.) on nutrient cycling in a first year old-field. Am.Midl.Nat. 62: 106-113.

Freedman, B. 1981. Intensive forest harvest: a review of nutrient budget considerations. Res. Centre, Frederiction, N.B. M-X-121, April 1981.

Freeman, J.D. 1955. Iban Agriculture. A report on the shifting cultivation of hill rice by the Iban of Sarawak. H.M.S.O., London, 148p.

Friedman, J. and Orshan,G. 1975. The distribution, emergence and survival of Artemisia herba-alba in the Negave desert of Israel in relation to distance from the adult plants. J. Ecol., 55: 59-71.

Gadgil, M. and Bossert, W.H. 1970. Life historical consequences of natural selection. Am. Nat., 104: 1-24.

Gadgil, M. and Solbrig, O.T. 1972. The concept of r- and k-selection: evidence from wild flowers and some theoretical considerations. Am. Nat., 106: 14-31.

Gaines, M. Vogt, K.J. Hamrick, J.L. and Caldwell, J. 1974. Reproductive strategies and growth patterns in sunflowers (Helianthus). Am. Nat., 108: 889-894.

Garten, C.T. Jr. 1978. Correlations between concentrations of elements in plants. Nature, 261: 686-688.

Gause, C.F. 1934. The Struggle for Existence. Williams and Wilkins, Baltimore.

Gill, A.M. 1981. Fire adaptive traits of vascular plants. p.208-231. In: H. Mooney, T.M. Bonnicksen, N.L. Christensen, J.E. Lotan, W.A. Reiners (eds.). Fire Regimes and Ecosystem Properties. USDA. Forest Serv. Gen. Tech. Rept., W.O. 26, Washington, D.C.

Gliessman, S.R., Garcia, S.R. and Amador, A.M. 1981. The ecological basis for the application of traditional agricultural technology in the management of tropical agroecosystems. Agro-Ecosystems, 7: 173-185.

Golley, F.B. and Medina, E. (eds.). 1975. Tropical Ecological Systems, Trends in Terrestrial and Aquatic Research. Springer-Verlag, New York.

Golley, F.B., McGinnis, J.T., Clements, R.G., Child G.I. and Duever, M.J. 1975. Mineral Cycling in a Tropical Moist Forest Ecosystem. Univ. of Georgia Press, Athens, Georgia.

Gomez-Pompa, A. 1971. Possible papel de la vegetacion secundaria en la evoluction de la flora tropical. Biotropica, 3: 125-135.

Gomez-Pompa, A. and Vazquez-Yanes, C. 1974. Studies on secondary succession of tropical lowlands: the life cycle of secondary species. Proc. First. Int. Cong. Ecol., 336-342.

Gopalan, C., Ramasastri, B.V. and Balasubramanian, S.C. 1978. Nutritive Value of Indian Foods. Nat. Inst. Nutrition, Hyderabad, India, 204p.

Granhall, V. and Hendriksson, E. 1969. Nitrogen fixing blue green algae in Swedish soils. Oikos, 20: 175-197.

Greenland, D.J. and Kowal, J.M.L. 1960. Nutrient content of the moist tropical forest of Ghana. Plant and Soil, 12: 154-174.

Griffith, G. 1949. Fertility problems in Uganda. Commonwealth Bureau of Soil Science. Tech. Comm. No.46: 160-164p.

Grime, J.P. 1974. Vegetation classification by reference to strategies. Nature, 242: 344-347.

Grime, J.P. 1977. Evidence for the existence of three primary strategies in plants and its relevance to ecological and evolutionary theory. Am. Nat. ., 111L 1169-1194.

Grime, J.P. 1979. Plant Strategies and Vegetation Processes. John Willey and Sons.

Grubb, P.J. and Edwards, P.J. 1982. Studies of mineral cycling in a montene rain forest in New Guinea III. The distribution of mineral elements in the aboveground material. J. Ecol., 70: 623-648.

Guha, H. and Watson, G. 1958. Effects of cover plants on soil nutrient status and on growth of Hevea.I. Laboratory studies on the mineralization of nitrogen in different soil mixtures. J. Rubber Res. Inst. Malaya, 15: 175.

Harcombe, P.A. 1972. Plant succession and ecosystem recovery. Rice University, Houston, Texas.

Harcombe, P.A. 1977a. Nutrient accumulation by vegetation during the first year of recovery of tropical forest ecosystem, p.347-378. In: J. Cairns, K.L. Dickson and E.E. Herricks (eds.). Recovery and restoration of damaged ecosystems. University Press of Virginia, Charlottesville.

Harcombe, P.A. 1977b. The influence of fertilization on some aspects of succession in a humid tropical forest. Ecology, 58: 1375-1383.

Harnett, D.C. and Bazzaz, F.A. 1985. The integration of neighbourhood effects by clonal genets of Solidago canadensis. J. Ecol., 73: 415-22.

Harper, J.L. 1961. Approaches to the study of plant competition. Mechanism of Biological Competition. F.L. Milthorpe(ed.). Symp. Soc. Exp. Biol., 15: 1-39.

Harper, J.L. 1977. The Population Biology of Plants. Academic Press, London.

Harper, J.L. 1978. The demography of plants with clonal growth. Structure and functioning of plant populations. A.H.J. Freysen and J.W. Woldendorp (eds.). North Holland, Amsterdam, 27-41p.

Harper, J.L. and Bell, A.D. 1979. The population dynamics of growth form in organisms with modular construction. In: R.M. Anderson, B.D. Turner and L.R. Taylor (eds.). Population Dynamics. 20th Sym. Brit. Ecol. Soc.,29-52.

Harper, J.L. and Gajic, P. 1961. Experimental studies of the mortality and plasticity of a weed. Weed Res.,1: 91-104.

Harper, J.L. and McNaughton, I.H. 1962. The comparative biology of closely related species living in the same area.VII. Interference between individuals in pure and mixed populations of _Papaver species._ New Phytol, 61: 175-188.

Harper, J.L. and Ogden, J. 1970. The reproductive strategy of higher plants. I. The concept of strategy with special reference to _Senecio vulgaris_ L. J. Ecol., 58: 681-698.

Harper, J.L. and White, J. 1974. The demography of plants. Ann. Rev. Ecol. Syst., 5: 419-463.

Harper, J.L.,Lovell, P.H. and Moore, K.G. 1970. The shapes and sizes of seeds. Ann. Rev. Ecol. Syst., 1: 327-356.

Hart, R.D. 1980. A natural ecosystem analog approach to the design of a successional crop system for tropical forest environments. Biotropica, 12: 73-82.

Harword, C.E. and Jackson, W.D. 1975. Atmospheric losses of four plant nutrients during a forest fire. Aust. For., 38: 92-99.

Howthorn, W.R. and Cavers, P.B. 1976. Population dynamics of the perennial herbs _Plantago major_ L. and P. _rugelli_ Decne. J. Ecol., 64: 511-527.

Hawthorn, W.R. and Cavers, P.B. 1978. Resource allocation pattern in young plants of two perennial species of plantago. Can. J. Bot. 56: 2533-2537.

Haynes, R.J. and Goh, K.M. 1978. Ammonium and nitrate nutrition of plants. Biol. Rev., 53: 465-510.

Hett, J.M. 1971. A dynamic analysis of age in suger seedlings. Ecology,52: 1071-1074.

Hett, J.M. and Loucks, O.L. 1976. Age-structure models of balsamfir and eastern hemlock. J. Ecol., 64: 1029-1044.

Hickman, J.C. 1975. Environmental unpredictability and plastic energy allocation strategies in the annual Polygonum cascadense (Polygonaceae). J. Ecol., 63: 689-701.

Hickman, J.C. and Pitelka, L.F. 1975. Dry weight indicates energy allocation in ecological strategy analysis of plants. Oecologia, 21: 117-121.

Holland, P.G. 1981. The demography of trout lily (Erythronium americanum Ker.) in Nova Scotia. Vegetatio, 345: 97-106.

Holm, L.D., Pluckett, D.L., Pancho, J.V. and Herperger, J.P. 1975. The World's Worst Weeds: Distribution and Biology. The Univ. Press, Hawaii, Honolulu.

Hutchings, M.J. 1983. Shoot performance and population structure in pure stands of Mercurialis perennis L. a rhizomatous perennial herb. Oecol., 58: 260-264.

Hutchings, M.J. and Barkham, J.P. 1976. An investigation of shoot interactions in Mercurialis perennis L., a rhizomatous perennial herb. J. Ecol., 64: 723-743.

Hughes, A.P. and Freeman, P.R. 1967. Growth analysis using frequent small harvests. J. Appl. Ecol., 4: 553-560.

Jefferey, D.W. 1968. Phosphate nutrition of Australian heath plants. II. The formation of polyphosphate by fire heath species. Aust. J. Bot., 16: 603-613.

Jefferies, R.L., Davy, A.J. and Rudmik, T. 1981. Population biology of the salt marsh annual Salicornia europea agg. J. Ecol., 69: 17-31.

Jordan, C.F. and Kline, J.R. 1972. Mineral cycling: Some basic concepts and their application in a tropical rain forest. Ann. Rev. of Ecol. and Syst., 3: 33-50.

Kasasian, L. 1971. Weed Control in the Tropics. Leonard Hill, London.

Keeley, J.E. and Keeley, S.E. 1977. Energy allocation patterns of a sprouting and a nonsprouting species of Arctostophylos in the California chaparral. Am. Midl. Nat., 98: 1-10.

Keeley, J.E. and Zedler, P.H. 1978. Reproduction of chaparral shrubs after fire: a comparison of the sprouting and seeding strategies. Am. Midl. Nat., 97: 120-132.

Keever, C. 1950. Causes of succession on old fields of the Piedmont, North Carolina. Ecol. Monogr. 20: 229-250.

Kellman, M.C. 1969. Some environmental components of shifting cultivation in upland Mindanao. J. Trop. Geog., 28: 40-56.

Kelting, R.W. 1957. Winter burning in Oklahoma grassland. Ecology, 38: 520-522.

Kenoyer, L.A. 1929. General and successional ecology of the lower tropical rainforest at Barro Colorado island, Panama. Ecology, 10: 201-222.

Kershaw, K.A. 1973. Quantitative and Dynamic Plant Ecology. Edward Arnold, London.

Klemow, K.M. and Raynal, D.J. 1983. Population biology of an annual plant in a temporally variable habitat. J.Ecol., 71: 691-703.

Kilgore, B.M. 1981. Fire in ecosystem distribution and structure: western forests and serublands. P.58-90. In: H. Mooney, T.M. Bonnicksen, N.L. Christensen, J.E. Lotan, W.A. Reiners (eds.). Fire Regimes and Ecosystem properties. USDA. Forest Serv. Gen.Tech. Rept., W.O. 26, Washington, D.C.

King, L. 1966. Weeds of the World: Biology and Control. John Wiley & Sons, Interscience, New York.

Knight, H. 1966. Loss of nitrogen from the forest floor by burning. For. Chron. 42: 149-152.

Kushwaha, S.P.S. and Ramakrishnan, P.S. 1982. Observations on growth of Eupatorium odoratum L. and Imperata cyclindrica (L) Beauv. Var. Major under different light and moisture regimes. Proc. Indian natn. Sci. Acad., B48: 689-693.

Kushwaha, S.P.S., Ramakrishnan, P.S. and Tripathi, R.S. 1981. Population dynamics of Eupatorium odoratum in successional environments following slash and burn agriculture. J. Appl. Ecol., 18: 529-535.

Kushwaha, S.P.S., Ramakrishnan, P.S. and Tripathi, R.S. 1983. Population dynamics of Imperata cylindrica (L.) Beauv. Var. Major related to slash and burn agriculture (Jhum) in north-eastern India. Proc. Indian Acad. Sci.(Plant Sci.), 92: 313-321.

Laudelout, H. and Meyer, J. 1954. Mineral element and organic material cycles in the equatorial forest of the Cong. Oecologia Plantarum, 7: 1-21.

Lemon, R.C. 1967. The effect of fires on herbs of the S.E. U.S.A. and central Africa . Proc. Ann. Tall Timber Fire Ecol., 6: 112-127.

Leverich, W.J. and Levin D.A. 1979. Age specific survivorship and reproduction in Phlox drummondii. Am. Nat., 113: 881-903.

Lawrence, D.B., Schoenike, R.E., Quispel, A., and Bond,G. 1967. The role of Dryas drummondi in vegetation development following ice recession at Glacier Bay, Alaska with special reference to its nitrogen fixation by root nodules. J. Ecol., 55: 793-813.

Leach, G. 1976. Energy and Food Production. Guildford,IPC Science and Technology Press, 137p.

Lewis, Jr. W.M. 1974. Effects of fire on nutrient movements in a south in a south carolina pine forest. Ecology, 55: 1120-1127.

Lloyd, P.S. 1971. Effects of fire on the chemical status of herbaceous communities of the Derbyshire Daks. J. Ecol., 59: 261-273.

Loneragan, J.F. and Asher, C.J. 1967. Response of plants to phosphate concentration in solution culture: II. Rate of phosphate absorption and its relation to growth. Soil. Sci., 103: 311-318.

Lotka, A.J. 1931. The structure of a growing population. Human Biol., 3: 459-493.

Loucks, O.L. 1970. Evolution of diversity, efficiency and community stability.Am. Zool. 10: 17-25.

Loucks, O.L. 1977. Emergence of research on agroecosystems. Ann. Rev. Ecol. Syst., 8: 173-192.

Lovett-Doust, L. 1981. Population dynamics of local specialization in a clonal perennial (Ranunculus repens).I. The dynamics of ramets in contrasting habitats. J.Ecol., 69: 743-755.

Lugo, A. 1973. Tropical ecosystem structure and function. p.67-111. In: Fragile Ecosystems. Edward G Farnworth and F.B. Golley (eds.). Springer-Verlag, Berlin.

Macalpine, R. 1959. A note on Mikania scandens. Two and Bud, 6: 6-8.

MacArthur, R.H. and Wilson, E.O. 1967. The Theory of Island Biography. Princeton University Press. Princeton.

Mack, R.N. 1976. Survivorship of cerastium atroviens at Aberffraw, Anglesey. J. Ecol, 64: 309-312.

McNaughton, I.H. and Harper, J.L. 1960a. The comparative biology of closely related species living in the same area. I. External breeding barriers between Papaver species. New Phytol, 59: 15-26.

McNaughton, I.H. and Harper, J.L. 1960b. Comparative biology of closely related species living in the same area. III. The nature of barriers isolating sympatric populations of Papaver dibium and P. Lecuqui. New Phytol, 59: 129-137.

Mainstone, G. and Wong Phui Weng, 1966. If Mikania invades. Planter. (Kuala Lumpur), 42: 3-7.

Marks, P.L. 1974. The role of pin cherry (Prunus pensylvanica L) in the maintenance of stability in northern hardwood ecosystems. Ecol. Manog., 44: 73-88.

Marks, P.L. and Bormann, R.H. 1972. Revegetation following forest cutting: mechanism for return to steady state nutrient cycling. Science, 176: 914-915.

Marshall, D.R. and Jain, S.K. 1969. Interference in pure and mixed population of Avena fatue and A. barbata. J. Ecol., 57: 251-257.

Misra, R. 1968. Ecology Workbook. Oxofrd and IBH Publ.Co. New Delhi, 244p.

Mishra, B.K. and Ramakrishnan, P.S. 1981. The economic yield and energy efficiency of hill agroecosystem at higher elevations of Meghalayain north-east India. Acta Oecol./ Oecol. Applic. 2: 369-389.

Mishra B.K. and Ramakrishnan, P.S. 1982. Energy flow through a village ecosystem with slash and burn agriculture in north-eastern India. Agric. Systems. 9: 57-72.

Mishra, B.K. and Ramakrishnan, P.S. 1983a. Slash and burn agriculture at higher elevations in north-eastern India I. Sediment, water and nutrient losses. Agric.Ecosyst. Envrion., 9: 69-82.

Mishra, B.K. and Ramakrishnan, P.S. 1983b. Slash and burn agriculture at higher elevations in north-eastern India. II. Soil fertility changes. Agric. Ecosyst. Environ., 9: 83-96.

Secondary Succession Subsequent to

Mishra, B.K. and Ramakrishnan, P.S. 1983c. Slash and burn agriculture at higher elevations in north-eastern India. I. Species diversity, biomass and litter production. Acta Oecologica Oecol. Applic., 4: 97-107.

Mishra, B.K. and Ramakrishnan, P.S. 1983d. Secondary succession subsequent to slash and burn agriculture at higher elevations of north-east India. II. Nutrient cycling. Acta Oecologica Oecol. Applic., 4: 237-245.

Mishra, B.K. and Ramakrishnan, P.S. 1984. Nitrogen budget under rotational bush fallow agriculture (Jhum) at higher elevations of Meghalaya in north-eastern India. Plant and Soil, 80: 237-246.

Moody, K. 1975. Weeds and shifting cultivation. PANS. 21: 188-194.

Moore, A.W. and Joyebo, E.O. 1963. The influence of cover on nitrate and nitrifiable nitrogen content of the soil in a tropical rain forest environment. Empl.J. Exp.Agric., 31: 189-198.

Mutchler, C.K., McDowell, L.L. and Greer, J.D. 1984. Soil loss from no -till cotton. Am. Soc. Agri. Engineers, Univ. of Tennessee, Knoxville, Michigan, 12p.

Natr, L. 1975. Influence of mineral nutrition on photosynthesis and use of assimilates. In: J.P. Cooper(ed.). Photosynthesis and productivity in different environments Cambridge Univ. Press, Cambridge.

Naylor, R.E.L. 1972. Aspects of the population dynamics of the weed Alopecuris myosuriodes Huds. in winter cereal crops. J. Appl. Ecol, 9: 127-139.

Newbould, P.J. 1967. Methods for Estimating the Primary Production of Forests. IBP, Hand book No.2, Blackwell Sci. Publ. Oxford.

Newell, S.J. and Tramer, E.J. 1978. Reproductive strategies in herbaceous plant communities during succession. Ecology, 59: 228-234.

Nobel, J.C., Bell, A.D. and Harper, J.L. 1979. Population biology of plants with clonal growth. I. The morphology and structural demography of Carex arenaria. J. Ecol., 67:983-1008.

Noble, I.R. and Slatyer, R.O. 1977. Post fire succession of plants in Mediterranean ecosystems. In: Proc. Symp. Environmental consequences of Fire and Fuel Management in Mediterranean Ecosystems. Mooney,H.A. and Conrad, E.E. (eds.). U.S.D.A. For. Serv. Gen. Tech. Report. 27-36.

Nye, P.H. and Greenland, D.J. 1960. The soil under shifting cultivation. Tech. Comm. 51, Comm. Bur. Soils, Harpenden.

Nye, P.H. 1961. Organic matter and nutrient cycles under moist tropical forest. Plant and Soil, 12: 333-346.

Odum, E.P. 1983. Basic Ecology. Holt-Saunders, Japan. 613p.

Odum, E.P. 1969. The strategy of ecosystem development. Science, 164: 262-270.

Odum, H.T. 1970. Rain forest structure and mineral cycling homeostasis. In: A Tropical Rain Forest H.T. Odum and R.F. Pigeon (eds.). USAEC, H.3-52p.

Ogden, J. 1974. The reproductive strategy of higher plants. II. The reproductive strategy of Tussilago farfara L.J. Ecol., 61: 291-324.

Old, S.M. 1969. Microclimates, fire and plant production in an Illinois Prairie. Ecol. Monogr., 39: 355-384.

Palit, S. 1981. Mikania- a growing menace in plantation forestry in West Bengal. India Forester, 107: 97-107.

Parenti, R.J. and Rice, E.L. 1969. Inhibition effects of Digitaria sangucinalis and possible role on oldfield succession. Bull. Torr. Bot. Club. 96: 70-78.

Parker, C. 1972. The Mikania problem. PANS. 18: 312-315.

Pterson, D.L. and Bazzaz, F.A. 1978. Life-cycle characteristrics of _Aster pilosus_ in early successional habitats. Ecology, 59: 1005-1013.

Pianka, E.R. 1970. On r- and k-selection. Am. Nat., 104: 592-597.

Picket, S.T.A. 1976. Succession: an evolutionary interpretation. Am. Nat., 110: 107-119.

Pitelka, L.F.,Hansen, S.B. and Ashmun, J.W. 1985. Population biology of _Clintonia borealis_ I. Ramet and patch dynamics. J. Ecol., 73: 169-183.

Popenoe, H. 1959. The influence of the shifting cultivation cycle on soil properties in central America. Proc. 9th Pacific Sci. Cong., 7: 148-160.

Rabotnov, T.A. 1978. Structure and method of studying coenotic populations perennial herbaceous plants. Sov. J. Ecol., 9: 99-105.

Radford, P.J. 1967. Growth formular-their use and abuse. Crop Sci., 7: 171-175.

Raison, R.J. 1980. Possible forest site deterioration associated with slash-burning. Search, 11: 68-72.

Ramakrishnan, P.S. 1980. Ecological impact of jhum (slash and burn agriculture) on forested ecosystem of north-eastern India. INSA News Letter, 60: 3-7.

Ramakrishnan, P.S. 1984. The science behind rotational bush fallow agriculture systems (Jhum). Proc. Indian Acad. Sci. (Plant Sci.), 93: 379-400.

Ramakrishnan, P.S. 1985a. Research on humid tropical forests. In: Proc. of Regional meeting of the national MAB committees of central and south Asian countries, New Delhi, India.

Ramakrishnan, P.S. 1985b. Jhum cultivation-prospects for developing countries. Science-Technology and Development (COSTED), 9: 1-3.

Ramakrishnan, P.S. 1985c. Tribal man in the humid tropics of the north-east. Man in India. 65: 1-32.

Ramakrishnan, P.S. and Kumar S. 1971. Mortality, Plasticity and productivity of interfering model populations of maize and Cynodon dactylon (L) pers. J. Indian Bot. Soc., 50: 320-331.

Ramakrishnan, P.S. and Jeet, N. 1972. Competitive relationships existing between two closely related species of Argemone living in the same area. Oecologia; 9: 279-288.

Ramakrishnan, P.S. and Mishra, B.K. 1981. Population dynamics of *Eupatorium adenophorum* Spreng. during secondary succession after slash and burn agriculture (Jhum) in north-eastern India. Weed Res., 22: 77-84

Ramakrishnan, P.S. and Toky, O.P. 1981. Soil nutrient status of hill agroecosystems and recovery pattern after slash and burn agriculture (Jhum) in north-eastern India. Plant and Soil, 60: 41-64.

Ramakrishnan, P.S. and Saxena K.G. 1983. Nitrification potential in successional communities and desertification of Cherrapunjii. Curr. Sci., 53: 107-109.

Ramakrishnan, P.S. and Das A.K. 1983. Studies on Pine ecosystem functions in Meghalaya. Trop. Plant. Sci. Res., 1: 15-24.

Ramakrishnan, P.S.,Toky, O.P., Mishra, B.K. and Saxena, K.G. 1981. Slash and burn agriculture in north-eastern India. p.570-586. In: H. Mooney, T.M. Bonnicksen, N.L. Christensen, J.E. Lotan, W.A. Reiners (eds.). Fire Regimes and Ecosystem Properties. USDA. For. Serv. Gen. Tech. Rept., W.O.26, Washington,D.C.

Ramakrishnan, P.S.,Toky,O.P. and Mishra, B.K. 1981. Jhum-an ecological assessment. p.41-49. In: Souvenir, Silver Jubilee Symp. Internat. Soc. Trop. Ecol., Bhopal, India.

Ramakrishnan, P.S., Shukla, R.P. and Boojh, R. 1982. Growth strategies of trees and their application to forest management. Curr. Sci., 9: 448-455.

Raynal, D.J. 1979. Population ecology of Hieracium florentinum (Compositae) in a central New York limestone quarry. J. Appl.,Ecol. 16: 287-298.

Reed, W.E. 1951. Reconnaissance soil survey of Liberia Agric. Inf. Bull. 66. U.S. Dept. of Agriculture. Washington.

Reiners, W.A. and Reiners, N.M. 1970. Energy and nutrient dynamics of forest floors in three Minnesota forests. J. Ecol., 58: 497-519.

Reiners, W.A. Worley, I.A. and Lawrence, D.B. 1971. Plant diversity in a chronosequence at Glacier Bay, Alaska, Ecology, 52: 55-69.

Rice, E.L. 1974. Allelopathy. Acad. Press, New York.

Rice, E.L. and Pancholy, S.K. 1972. Inhibition of nitrification by climax vegetation. Am. J. Bot., 59: 1033-1040.

Robinson, B. 1934. Mikania scandens and its near relatives. Contributions from the Gray Herbarium of Harvard Univ. 104: 55-71.

Roos, F.H. and Quinn, J.A. 1977. Phenology and reproductive allocation in Andropogon scoparius (Graminae) populations in communities of different successional stages. Am. J. Bot., 64: 535-540.

Sarukhan, K.J. 1964. Estudio successionale de un area talada en Tusctepec, Oaxaca. Pub. Esp. Inst. Nac. Invest. For. Mexico, 3: 107-172.

Sarukhan, J. and Gadgil, M. 1974. Studies on plant demography: Ranunculus repens L., R. Acris L. III. Amathematical model incorporating multiple modes of reproduction J. Ecol., 62: 921-936.

Sarukhan, J. and Harper, J.L. 1973. Studies on plant demography: Ranunculus repens L., R. bulbosus L. and R. acris L. I Population flux and survivorship. J. Ecol., 61: 675-716.

Saxena, K.G. and Ramakrishnan, P.S. 1982. Partitioning of biomass and nutrients in the secondary successional herbaceous populations subsequent to slash and burn. Proc. Indian natn. Sci. Acad., 48: 807-818.

Saxena, K.G. and Ramakrishnan, P.S. 1983a. Growth resources allocation pattern and nutritional status of some dominant annual weeds of shifting agriculture (JHum) in north-eastern India. Acta Oecologica Oecol. Plant., 4: 323-333.

Saxena, K.G. and Ramakrishnan, P.S. 1983b. Growth and allocation strategies of some perennial weeds of slash and burn agriculture (Jhum). in north-eastern India. Can. J. Bot., 61: 1300-1306.

Saxena, K.G. and Ramakrishnan, P.S. 1984b. Herbaceous vegetation development and weed potential in slash and burn agriculture (Jhum) in N.E. India. Weed Res., 24: 135-142.

Saxena, K.G. and Ramakrishnan, P.S. 1984a. Growth and patterns of resource allocation in Eupatorium odoratum in the secondary successional environment following slash and burn agriculture (Jhum). Weed Res., 24: 127-134.

Saxena, K.G. and Ramakrishnan, P.S. 1986. Nitrification during slash and burn agriculture (Jhum) in north-eastern India. Acta Oecologica/Oecologica Plantarum, 21: 319-331.

Schlippe, P. DE. 1956. Shifting cultivation in Africa. Routledge and Kegan Paul, London.

Seth, A. 1971. Control of Mikania cordata (Burn.f) B.L. Robinson in plantation crops using paraquat. Weed Research, 11: 77-83.

Sharp, W.M. 1970. The role of fire in rufted grous habitat management. Proc. Annu. Tall. Timbers Fire Col. Conf., 10: 47-62.

Sharitz, R.R. and McCormick, J.F. 1973. Population dynamics of two competing annual plant species. Ecology, 54: 723-740.

Sharma, S.N. 1985. Biology of Imperata cylindrica (L.) Beauv. Ph.D Thesis, North-Eastern Hill University, Shillong, India.

Small, E. 1972. Photosynthetic rates in relation to nitrogen recycling as an adaptation to nutrient deffciency in peat bog plants. Can. J. Bot., 50: 2227-2233.

Smith, B.H. 1983a. Demography of Floerkea proserpinacoides, a forest floor annial. I. Density-dependent growth and mortality. J. Ecol. 71: 391-404.

Smith, B.H. 1983b. Demography of Floerkea proserpinacoides, a forest floor annual II. Density-dependent reproduction. J. Ecol. 71: 405-412.

Smith,W.H.,Bormann, F.H. and Likens, G.E. 1968. Response of chemoautotrophic nitrifiers to forest cutting. Soil Sci., 106: 471-473.

Snaydon, R.W. 1982. Weeds and crop yield. In: Proc. British Crop Protection Conference Weeds. 729-739p.

Snedaker, S.C. 1970. Ecological Studies on Tropical Moist Forest Succession in Eastern Lowland Gautemala. Ph.D Thesis, Univ. of Florida.

Solbrig, O.T. 1981. Studies on the population biology of the genus Viola I. The effect of plant size on the fitness in Viola sororia. Evolution, 35: 1080-1093.

Solbrig, O.T., Newell, S.J. and Kicaid, D.T. 1980. The population biology of the genus Viola I. The demography of Viola Sororia, J. Ecol., 68: 521-546.

Spedding, C.R.W. 1975. The study of agricultural ecosystems. p.3-19. In: G.E. Dalton (ed.). Study of Agricultural Systems.Applied Sci. Publ. London,England. XIV + 441p.

Stark, N. 1970. The nutrient of plants and soils from Brazil and Surinam. Biotropica, 2: 51-60.

Stark, N. 1971a. Nutrient cycling I. Nutrient distribution in some Amazonian soils. Trop. Ecol., 12 ; 25-50.

Stark, N. 1971b. Nutrient cycling II. Nutrient distribution in Amzanian vegetation. Trop. Ecol., 12: 177-201.

Stigter, C.J. 1984. Examples of mulch use in microclimate management by traditional farmers in Tanzania. Agric. Ecost. Env., 11: 173-176.

Stromgaard, P. 1984. The immediate effect of burning and ash-fertilization. Plant and Soil, 80: 307-320.

Symonides, E. 1974. Populations of Spergula vernalis Willd. on dunes in the Torun Basin. Eklogia Polska, 22: 379-416.

Tamm, C.O. 1956. Further observations on reproduction and survival of some perennial herbs. I. Oikos,7: 273-292.

Terry, N. and Ulrich, A. 1973. Effects of phosphorus deficiency on the photosynthesis and respiration of leaves of sugarbeet. Plant Physiol., 51: 43-47.

Toky, O.P. and Ramakrishnan, P.S. 1981. Cropping and yields in agricultural systems of the north-eastern hill region of India. Agro-Ecosystems, 7: 11-25.

Toky, O.P. and Ramakrishnan, P.S. 1981b. Run-off and infiltration losses related to shifting agriculture in north-eastern India. Environ. Conserv., 8: 313-321.

Toky, O.P. and Ramakrishnan, P.S. 1982. Role of Bamboo (Dendrocalamus hamiltonii Nees Arn.) in conservation of potassium during slash and burn agriculture (Jhum) in north-eastern India. J. Tree Sci., 1: 17-26.

Toky, O.P. and Ramakrishnan, P.S. 1983. Secondary succession following slash and burn agriculture in north-eastern India. I. Biomass, litterfall and productivity. J. Ecol., 71: 735-745.

Toky, O.P. and Ramakrishnan, P.S. 1983. Secondary succession following slash and burn agriculture in north-eastern India. II. Nutrient cycling. J. Ecol., 71: 747-757.

Toky, O.P. and Ramakrishnan, P.S. 1984. Litter decomposition related to secondary succession and species type under slash and burn agriculture (Jhum) in north-eastern India. Proc. Indian Nat. Sci. Acad., B50: 57-65.

Tripathi, R.S. 1977. Weed problem - an ecological perspective. Tropical Ecol., 18: 138-148.

Uhl, C. 1982. Recovery following disturbances of different intensities in the Amazon rain forest of Venezuela. Interciencia, 7: 19-24.

Uhl, C. and Jordan, C.F. 1984. Succession and nutrient dynamics and burning in Amzonia. Ecology, 65: 1476-1490.

Viro, P.J. 1974. Effects of forest fire on soil. In: T.T. Kozlowski and C.E. Ahlgren (eds.). Fire and Ecosystems. Acad. Press, New York, 7-44p.

Vitousek, P.M. and Reiners, W.A. 1975. Ecosystem succession and nutrient retention: a hypothesis. Bioscience, 25: 376-381.

Volterra, V. 1931. Variation and fluctuations of the number of individuals in animal species living together. In: Animal Ecology R.N. Chapman (ed.). McGrow-Hill, New York.

Watkinson, A.R. and Harper, J.L. 1978. The demography of a sand dune annual; Vulpia fascilata. I. The natural regulation of populations. J. Ecol., 66: 15-33.

Watt, J. and Breyer-Brandwijk, M. 1932. The Medicinal and Poisionous Plants of Souther Africa. E and S living-stone, Edinburg and London, 314p.

Waters, R.F. 1971. Shifting cultivation in Latin America. F.A.O. For. Dev. Paper No.17. Rome.

Webster, J.R., Waide, J.B. and Patten, B.C. 1975. Nutrient cycling and the stability of ecosystems, p.1-27. In: F.G. Howell, J.B. Gentry and M.H. Smith (eds.). Mineral Research and Development Administration Symposium Series CONF-740513, National Technical Information Service, Washington, D.C.

Wells, C.G. 1971. Effects of prescribed burning on physical properties of soil. In: Prescribed burning symposia, USDA., For. Serv. South. Eastern For. Exp. Stn.,Asheville, NC, 80-97p.

Weels, T.C.E. 1981. Population ecology of terrestrial orchids. The Biological Aspects of Rare Plant Conservation (ed.) H. Synge), p. 281-296., Wiley, Chichester.

West, N.E. and Chileote, W.W. 1968. Senecio sylvaticus in relation to Douglas-fir clear-cut succession. Ecology, 49: 1101-1107.

Whelan, R.J. and Main, A.R. 1979. Insect grazing and post fire plant succession in southeast Australian woodland. Aust. J. Ecol., 4: 387-398.

White, R.E. 1972. Studies on mineral ion absorption by plants. I. The absorption and utilization of phosphates by Stylosanthes humilis, Phaseolus atropurpureus and Desmodium intortum. Plant Soil, 36: 427-447.

White, J. 1980. Demographic factors in populations of plants, Ch.2, p.21-48 In: O.T. Solbrig (ed.). Demography and Evolution in Plant Populations Blackwell, Oxford; Univ. of California Press, California.

White, E.M., Thompson, W.W. and Gartner, F.R. 1973. Heat effects on nutrient release from soils under ponderosa pine. J. Range Manage., 22: 22-24.

Whittaker, R.H. and Lavine, S.A. 1977. The role of mosaic phenomena in natural communities. Theor. Pop. Biol, 12: 117-139.

Wilbur, H.M. , Tinkkla, D.W. and Collins, J.P. 1974. Environmental certainity, trophic level and resource availability in life-history evolution. Am. Nat., 108: 805-817.

Williams, G.C. 1966. Natural selection, the costs of reproduction and a refinement of Lack's principle Am.Nat., 100: 687-692.

Williams-Linera, G. 1983. Biomass and nutrient content in two successional stages of tropical wet forest uxpanapa, Mexico. Biotropica, 15: 275-284.

Williams, O.B. 1970. Population dynamics of two perennial grasses in Australian semi-arid grassland. J.Ecol., 38: 869-875.

Williams, R.B. and Bell, K.B. 1981. Nitrogen allocation in Mojave Desert annuals. Oecologia (Berl.), 48: 145-150.

Wit, C.T. DE. 1960. On competition. Can. J. Bot., 92: 45-57.

Woodwell, G.M., Whittaker, R.H. and Houghton R.A. 1975. Nutrient concentrations in plants in the Brookhawen Oak-Pine forest. Ecology, 56: 318-332.

Wong, R. 1964. Evidence for the presence of growth inhibitory substances in Mikania cordata (Burm.f.). B.L. Robinson. J. Rubber Res. Inst. Malaya, 18: 231-242.

Wycherley, P. and Chandapillai, M. 1969. Effects of cover plants. J. Rubber Res. Inst. Malaya, 21: 140-157.

Yadav, A.S. and Tripathi, R.S. 1981. Population dynamics of the ruderal weed Eupatorium odoratum L. and its regulation in nature. Oikos, 23: 355-361.

Zimmerman, J.K. and Weis, I.M. 1984. Factors affecting survivorship, growth, and fruit production in beach population of Xanthium strumarium. Can. J. Bot., 62: 2122-2127.

Zinke, P.J. Sabhastri, S. and Kunstadter, P. 1978. Soil fertility aspects of the 'Lua' forest fallow system of shifting cultivation. In: P. Kunstadter, E.C. Chapman and S. Sabhastri (eds.) Farmers in the Forest. East-West Centre, Honululu, Hawaii.

Plate I Various life history stages in the development of *Mikania micrantha* (A), seedlings (B), a stolon with attached ramets; (C) a rosette from an open field (Road side (D) at flowering stage.

Plate II *Mikania micrantha* in successional fallows (A), Lailad village with jhum fallows in the background (B) colonization in 1-year old fallow (C) co-habitation and smoothering over the shrub community in a 5-year old fallow (D) closer view of *M. micrantha* at almost suppressed state in a 10-year old fallow.

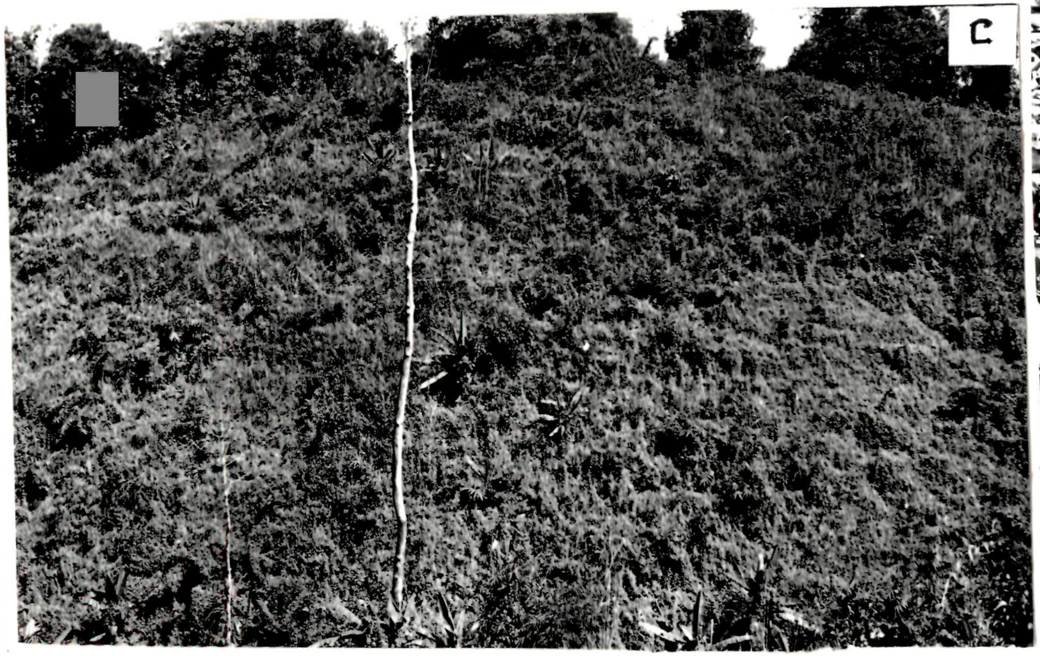


Plate III *M. micrantha* under plantation conditions. (A) on trees along the periphery of a forest (B), on citrus trees in a citrus plantation (C) on a young teak plantation.

Plate IV Cropping phase of slash and burn agriculture (jhum) on a steep slope at lower elevations of Meghalaya (A) A view of early phases of mixed cropping (B) dibbling of rice and simultaneous weeding by a Garo farmer in progress (C) weeded out biomass heaped in the jhum plot (D) A closer view of part of mixed cropping at early stages under jhum.