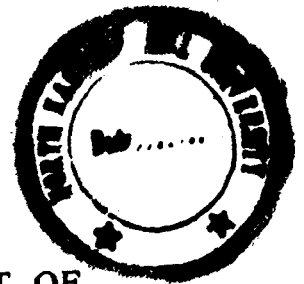


**STUDIES ON DIFFERENT JHUM (SLASH AND
BURN AGRICULTURE) PATTERNS AND POPULATION
DYNAMICS OF A FEW WEEDY SPECIES**

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**DEPARTMENT OF BOTANY
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**SUBMITTED IN FULFILMENT OF THE REQUIREMENT OF
THE DEGREE OF
DOCTOR OF PHILOSOPHY**

To



**NORTH - EASTERN HILL UNIVERSITY
SHILLONG, INDIA**

JUNE, 1981

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We certify that the thesis entitled "STUDIES ON DIFFERENT JHUM (SLASH AND BURN AGRICULTURE) PATTERNS AND POPULATION DYNAMICS OF A FEW WEEDY SPECIES" submitted by Shri Satya Prakash Singh Kushwaha, M.Sc., for the degree of Doctor of Philosophy of the North-Eastern Hill University, Shillong, embodies the record of original investigation carried out by him under our supervision. He has been duly registered and the thesis presented is worthy of being considered for the award of the Ph.D. degree. This work has not been submitted for any degree of any other university.

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DEDICATED
TO
MY PARENTS

ACKNOWLEDGEMENTS

It is my utmost pleasure to express my sincere gratitude to my revered supervisors, Dr. P.S. Ramakrishnan, F.N.A. and Dr. R.S. Tripathi, Professor and Reader respectively in Ecology, in the Department of Botany, North-Eastern Hill University, Shillong, whose able guidance, keen interest and constant encouragement throughout the course of this investigation has enabled me to complete the task.

I am grateful to Professor R.R. Mishra, F.N.A.Sc., Head of the Department of Botany and Dean, School of Life Sciences, for providing necessary laboratory facilities.

I am thankful to the faculty members of the department for extending their co-operation in various ways. The taxonomic help received from Dr. R.R. Rao, Reader in Plant Systematics, and his co-workers is highly acknowledged.

I sincerely thank my research colleagues who have been ever helpful and encouraging in so many ways during the tenure of this research work.

My grateful thanks are also due to Mr. P.S. Ingty, Director, Soil Conservation Department, Meghalaya, for providing me the land and accomodation facilities at Burnihat at my disposal and to the Principal, Government of India, State Forest Training College, Burnihat, Assam, for providing land for culture experiments.

Thanks are also extended to Miss G. Das for the help in data analysis, Mr. M.H. Barbhuiya for drawings and to Mr. B.K. Das for

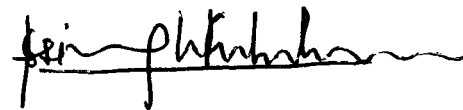
~~for~~ photography, The help received from Mr. Godfrey Pathaw for stencilling the thesis is duly acknowledged.

The financial help received from the Department of Science and Technology, Government of India in the form of a fellowship under "Man and Biosphere" programme (UNESCO), is gratefully acknowledged.

The last but not the least, I wish to express my feelings of indebtedness for the love, encouragement and help received from the friends like Messers Sarnam Singh, A. Nageswar Rao, N.V. Subba Rao, K.M. Joseph and elders like Mr. V. Krishnamoorthy and family.

Dated: June, 1981

Place: Shillong.



(S.P.S. KUSHWAHA)

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P R E F A C E

The results presented in the present thesis start with a consideration of three types of land use practices in the north-eastern hill region, namely, (i) slash and burn agriculture with jhum cycles of 5 and 10 years, (ii) valley cultivation of rice and (iii) terrace cultivation of rice which has recently been suggested as an alternative to jhum by the local governmental agencies. The various weeds coming up during cropping have been considered along with a study of the economic yield patterns.

The subsequent three chapters deal with the biology and population dynamics of two important early successional weeds namely Eupatorium odoratum L. and Imperata cylindrica (L.) Beauv. coming during and after jhum. These studies pertain to population dynamics during secondary succession after slash and burn agriculture which has been contrasted with a late successional weed, Scleria tessellata Willd. The next two chapters deal with competition between the plants of rhizome versus seed origin in I. cylindrica, followed by a study on competition between I. cylindrica and E. odoratum, the former of rhizome origin and the latter of seed origin as they come up in nature after jhum. This study considers the two nutrient levels as soil nutritional changes are significant after slash and burn. This is followed by studies on the behaviour of I. cylindrica and E. odoratum in response to different light and water regimes.

The thesis starts with a general introduction which includes an extensive study of literature and ends with bibliography. Some

repetition in writing up of the chapters could not be avoided as they are written as independent papers for publication. Through these studies it is hoped to get an understanding of the biological equipments of the weedy species.

GENERAL INTRODUCTION

Population ecology:

The history of population research dates back to the time of Malthus (1798) who observed that population exhibits a tendency to multiply geometrically as a result of the "passion between the sexes". The publication of a book "An Assay on the Principles of Population as it Affects the Future Improvement of Society" marked the beginning of the modern studies on populations. Acknowledging the ideas gained from Malthusian postulates, Darwin (1859) in his book "Origin of Species", emphasized the importance of the individuals in a population making frequent references to their numerical strength.

Verhulst (1838) proposed the first logistic mathematical expression of population growth under limiting means of subsistence which was later presented by Pearl and Reed (1920) in the following form:

$$\frac{dN}{dt} = rN (K-N)/K$$

where N is the number of individuals, t, the time, r, intrinsic rate of population growth, K, carrying capacity and $\frac{dN}{dt}$ represents the rate of change in population size. Verhulst's contribution was widely recognised after Pearl and Reed published their paper in 1920.

Most of the studies on population in 19th and 20th centuries have been done using animal populations. A theoretical model for

plant population was proposed for the first time by Nägeli (1874). Turesson (1922, 1925) established another landmark in population research by recognising the existence of micro populations or ecological races within a species population growing in contrasting micro climates.

Elton (1933) proposed the term "population dynamics" which according to him refers to the field of study "concerned with rates of increase, fluctuations in numbers and relation of problems of numbers to the environmental factors which influence the population". In the year 1928, Chapman introduced the two new terms "the biotic potential" and the "environmental resistance" which are widely used in population ecology. In his classical paper Chapman stated "it seems evident that we have in nature a system in which the potential rate of reproduction is pitted against the resistance of the environment, and that the quantity of the organisms which may be found, is a result of the balance between the biotic potential and the environmental resistance." Based on experimental data he derived a formula establishing a relationship between the two:

$$C = B_p/R$$

where C is the number of existing organisms, B_p , the biotic potential and R, the environmental resistance. He concluded that whatsoever the potential rate of development of an organism may be, its environment offers sufficient resistance to multiplication to cause the number to remain constant.

The work of Sukatshev (1928), Tadaki and Shidei (1959),

Harper and Gajic (1961), Harper and McNaughton (1962) and Raynal and Bazzaz (1975), opened new dimensions in population ecology with a conclusion that populations do have a self-regulatory mechanism. The rate of population growth is generally expressed as the increase in number of individuals per unit time and can be estimated if the data on birth, death, immigration and emigration rates are available. Thus, Lotka (1931) and Volterra (1931) calculated the intrinsic rate of change based on these parameters which was later confirmed by Gause, a Russian biologist, in the year 1934. Gause (1934) put forward the famous "Gause hypothesis" stating that "no two species can share exactly the same ecological niche for indefinite period of time; eventually one will replace the other". Further, he concluded that the displacement of one species by the other is inevitable if one of them has an advantage over the other. The displacement principle has been studied since then by many (Park, 1954; Frank, 1957; Harper, 1961; Tantawy and Soliman, 1967).

Part of the Darwinian tradition in the study of plant population dynamics is the observation of the behaviour of plants in permanent plots over a period of time. Charting the fate of individual plants (to grow, to flower, to remain vegetative, to die) has been undertaken by few people. Observations on the longevity of populations, rates of turnover in their vegetative and reproductive composition, etc. are extremely laborious. The work of Tamm (1956), Sagar (1959) and the Moscow School of Rabotnov and coworkers since the 1940's hint a regularities in natural population dynamics that are quite surprising. There is an impressive

tradition of field observation in Russia (Rabotnov and others) which has received too little attention hitherto. The long term data of foresters also provide valuable sources of information for the development of plant population dynamics (White and Harper, 1970) but they deal mainly with planted, managed systems. Some workers have been interested in quantitatively recording the spread of certain adventive species (Kent, 1956; Harper, 1970). The population changes of certain perennial plant species growing in meadow and forest community recorded by Tamm (1948, 1956) is one of the important and most systematic contributions. Tamm identified the position of each individual from year to year on permanent plots during a 14-year period and observed a constancy in numbers and a high rate of turnover.

Canfield (1957) presented data on the survivorship of the primary and secondary range grasses of south-eastern Arizona in relation to grazing and concluded that the mortality of "genets" of primary grasses was remarkably higher in the grazed area where the secondary grasses showed an increased life span probably due to reduction in the degree of interference from the primary grasses as a result of grazing. A similar type of work has also been done by Williams (1970). While studying the population structure and longevity of Festuca rubra, Herberd (1961) found that a single genet may spread over a vast area by extending its ramets through vegetative growth. Antonovics (1972) studied systematically the fate of the individuals from seedling stage onwards for their population flux, longevity of individuals, survivorship, natality and mortality and came to the conclusion

that the individuals recruited at different periods, have different decay rates. Further, he observed that the different populations, have different longevity depending upon their adaptation to a particular habitat and suggested that difference in longevity of individuals of different populations may be related to the environmental conditions.

The population studies of plants received the much needed impetus from the works of Harper and his coworkers during the last two decades. A number of plant biologists have also followed the trend and over the past 12 years a good amount of work on plant demography has been accumulated. A more detailed study of demographic nature has been recently made by Sarukhan and Harper (1973) with three species of Ranunculus, R. acris, R. bulbosus and R. repens in a grassland situation considering many important aspects of population ecology. Sarukhan and Gadgil (1974) analysed mathematically the data of this paper. Mack (1976) studied the survivorship of Cerastrium atrovirens and Hawthorn and Cavers (1976) studied the population dynamics of the perennial herbs, Plantago major and P. rugelii.

Callaghan (1976) suggested that the growth, reproduction and death of individuals in a plant population are affected by the environmental factors within the framework of their genetic programme. The environmental factors may be biotic such as grazing, predation and competition for the limited resources and abiotic such as cold, heavy precipitation, frost, storm etc. which destroy the populations catastrophically (Warren Wilson, 1967).

A great deal of work has been done on the mortality rates of the plant populations. Deevey (1947), on basis of the work with different populations, concluded that in general, the individuals follow three types of death and decay patterns; situations where there is high mortality in the juvenile phases (Hett, 1971; Sharitz and McCormick, 1973; Sarukhan and Harper 1973 ; Hett and Loucks, 1976) of the life when the plants pass through a transition stage between the dependence of seedlings on seed food reserve and their establishment when they become self-dependant. However, a change in climatic or edaphic factors may also play a major role (Tazaki, 1960; Peterson, 1966; Cavers and Harper, 1967; Friedman and Orshan, 1975; Marquis, 1976). In contrast to the seedlings, the adults show a constant risk of death throughout their life-span giving negative exponential curve (Tamm, 1956; Rabotnov, 1958; Sagar, 1959; Foster, 1964; Antonovics, 1972) the individuals with long life span generally show a third category of survivorship with higher mortality in the last part of their life. The curves which represent these three different mortality patterns are the Deevey Type I, Type II and Type III curves of mortality.

The studies on the population dynamics of the perennial plants, are often not attempted as it is difficult to determine their exact age due to the lack of any reliable technique for estimation. Various methods used to determine the age are based on anatomical and morphological features such as growth rings in stem or rhizome and leaf scars on the rhizome. Pigott (1955) found that the age of Cirsium acaulon can be accurately estimated

by counting the number of leaf scars on the rhizome. Kerster (1968) and Levin (1978) have considered the rings present in the corm of Liastris aspera for determination of its age. However, Werner (1978) did not agree with them and suggested that there is no relation between the age and number of rings in the corm of Liastris aspera. The most reliable method for estimating the age of perennial herbs, is to follow the fate of labelled seedlings or tillers of known age in permanent enclosures. This method has been successfully used by Tamm (1956, 1972a, 1972b),

An individual plant in the population, is comprised of various parts like stem, leaf, root, rhizome buds, tillers and flowers etc. Some of the latest trends in population ecology are to study the dynamics of these parts of sub-population level. Thus, Saeki (1960, in Phaseolus viridissimus and Nicotiana tabacum and Gill and Tomlinson (1970) in Rhizophora mangle studied the dynamics of leaf production. Halle and Oldeman (1970) worked on the dynamics of the branches, leaves and buds of a number of tropical trees. Gill (1971) observed the dynamics of buds in Fraxinus americana. Kays and Harper (1974) studied the change in population of Lolium perenne at the two levels of population organisation. Such a study was also undertaken by Ogden (1974) in Tussilago farfara. Bernard (1976) studied the life history and population dynamics of shoots of Carex rostrata and noted a constant rate of death with very high turnover rates. A comprehensive account of the latest investigations in the field of the dynamics at sub-population level has been reviewed by Harper (1978).

A population may be comprised of genets which include the seedlings and the adults besides ramets. According to Harper and White (1974), while studying the age-structure of the population of a perennial species, the seedling population may or may not be considered depending upon the observation period of the year as the number of seedlings in most of the species fluctuate in time and space with 100% mortality in perennial grasses (Putwain et al., 1968). Richards (1952), Emlen (1972) and Schaal (1978) suggested that the unstable age-structure of plant species may be observed due to large environmental fluctuations that may occur during critical periods in the plant's life. According to Rabotnov (1945, 1950a, 1950b, 1969), ~~an~~ ~~eco~~-population is characterised by various age groups of individuals based on the four main periods of life of the plants reproducing by seeds. These periods are (i) the period of primary dormancy, (ii), the virginal period, (iii) the generative period and (iv) the senile period. A detailed account of the longevity of the shoot modules has been presented by Noble et al. (1979) and Harper and Bell (1979).

The seeds constitute the dormant phase of the populations and a study pertaining to their dynamics in time and space, is of immense importance in understanding the population behaviour of a plant species. The role of the seeds in early phases of primary and secondary successional processes is of special significance as also emphasized by Oosting (1942), Keever (1950), Egler (1954), Bazzaz (1968, 1973), Holt (1972), Johnson (1975), and Archibold (1979).

The associated vegetation may also exercise considerable influence in regulating the population (Odum and Odum, 1959; Harper, 1964) as the natural habitats of the species are mostly shared by many thickly populated species affording resource competition through inter-specific interaction though intra-specific competition may also play a significant role (Ramakrishnan and Jeet, 1973; Ramakrishnan and Gupta, 1981). Poor seedling establishment has been reported in established communities by Tamm (1956) and Cavers and Harper (1967). Putwain and Harper (1970) and Dwivedi and Tripathi (1980) found that amongst the associated species, grasses exercise greater regulatory influence compared to dicots. Sagar (1970) noticed increased vegetative and reproductive growth of Plantago lanceolata when the associated vegetation was removed. Established plant populations of a species also affect the newly recruited seedlings of their own species (Friedman, 1971; Andel and Rozema, 1974; Gupta and Tripathi, 1979; Yadav and Tripathi, 1981).

Intra-and inter-specific population behaviour:

The behaviour of the individuals of one or the different species growing together and interfering with each other's mechanism of population growth is of great significance. The vegetation composition of an area can partly be considered the resultant of the competitive abilities of the individuals which in turn might be influenced by their environment.

The term "competition" refers to the greater growth in vigour of some individuals as compared to others when a certain require-

ment is in short supply for one or more individuals. Thus, competition results when the two organisms seek the same resource which in turn is below the combined demand of organisms (Donald, 1963). The competition is known to exist when growth of either one or both the individuals is reduced compared to their growth in isolation (Bleasdale, 1960). The degree of interference also depends upon the distance between the individuals. The extent to which the two individuals may compete also depends to a great extent upon their ecological amplitude and efficiency of their overall physiological makeup in a particular environment. Competition generally occurs in its severest form when physiology and the growth habits of individuals are similar and their niches overlap completely (Clement, 1929; Odum, 1969; Ramakrishnan, 1965a, 1970; Ramakrishnan and Gupta, 1972; Ramakrishnan and Jeet, 1972).

Thus inter-ecotypic competition between different ecotypes in marginal areas is a mechanism by which the populations in contrasting habitats are kept apart (Ramakrishnan, 1965a, 1965b, 1965c, 1966; Ramakrishnan and Nagpal, 1973; Ramakrishnan and Kumar, 1976).

Competition can be intra-specific i.e. between the individuals of the same species or inter-specific i.e. between two different species (Odum, 1969). Harper and Chancellor (1959) introduced the term "self-thinning" and "alien-thinning", the former describes the reduction of chance of a seed forming a mature plant due to increase in the density of the individuals of the same species while the latter describes the reduction in chance of a seed forming a mature plant due to increased density of

associated species.

Competition involves both the root and the shoot system for water, nutrients and the light. Bergh van den (1968) introduced the term "space" as a combined expression of all the resources required by the plants. - Tekekawa (1968) found that the competition for nutrients was the main reason for the decline in the yield of rice when rice plants were grown together with Potamogeton distinctus. Ramakrishnan (1961) has demonstrated that root competition in the two ecotypes, the red and green form of Euphorbia thymifolia, competing with each other does not permit the obligate calcifuge (green form) to establish seedlings in the calcareous soils.

The competition involving shoot system is for light due to the overlapping growth of the plants as a result one species succeeds, at the expense of the other (Harper, 1964), Black (1957, 1958, 1960) noted an increase in the competitive vigour of the plants grown from bigger seeds compared to those from smaller seeds of Trifolium spp. Ennik (1960), from his competition studies on pure and mixed stands of Lolium perenne and Trifolium repens under low and high light intensities found the replacement of grass by clover under high light intensities, but under low light intensities the two species tended to stabilize; those with excess of clover tending to increase the grass content and vice versa. In the latter case it is believed that the stabilizing influence between the two species is due to differential requirements of the two for nitrogen.

As an agronomic problem intra-specific interference has received much momentum with respect to (i) reactions of plants to

density which determines crop yield in pure stands and (ii) mutual interference between species under the the condition of mixed cropping. Yoda et al. (1963) concluded that:

- (i) the chance of a seed producing a mature plant declined with increasing density,
- (ii) irrespective of the density of the seeds sown, there is a maximum population size attained and densities beyond this level can not be realized no matter how many seeds are sown,
- (iii) the densities in overcrowded population converge with the passage of time irrespective of the differences in initial density. The converging densities are always lower on more fertile soils,
- (iv) this convergence is related to plant size so that plants having a certain average size always maintained more or less similar levels of surviving density regardless of this difference in stand age, initial density and fertilizer level.

Harper (1961), Ramakrishnan and Kumar (1971), Ramakrishnan (1971) and Ramakrishnan and Jeet (1972), concluded that with increase in density the proportional allocation of assimilatory products to aboveground organs of plants may change resulting in less reproductive output.

A few mathematical derivations related to the density and the yield response of crops, have been formulated. Amongst the most successful of these have been various forms of reciprocal laws:

$$\frac{1}{w} = a + bx$$

where x is the density and w, the mean plant weight.

Yoda et al. (1963) for the first time mathematically expressed the process of self-thinning and found that numbers of surviving plants could be related to its mean weight as:

$$W = C_p^{-\frac{3}{2}}$$

Where p is the density of surviving plants and W is the corresponding mean weight; the value of C varies with species. This was later confirmed by White and Harper (1970).

Individuals may respond to density by either a reduction in their vegetative or reproductive growth or the reduction in the chance of the survival of the individuals (Harper and Gajic 1961; Ramakrishnan and Kumar, 1971a, b). Sukatschev's attempt (1928) was the first pertaining to the self regulatory mechanisms of plant populations. He concluded that under the conditions of both the increased density as well as fertilizer levels, the mortality of the individuals was enhanced.

Working with pure stands, Harper and McNaughton (1962) too reached similar conclusions. Koyama and Kira (1956) have shown that under conditions of density stress only, there is a forced showing of limited resources with a compensatory plastic reduction in plant growth. A greater mortality and/or plasticity in mixtures and monocultures respectively was noted by Ramakrishnan and Kumar (1971b) in wheat and Cynodon dactylon, (Ramakrishnan and Kumar (1971) and Ramakrishnan and Gupta (1972b) on maize and Cynodon dactylon and in Oryzopsis holiciformis and Avena sterilis by Litav and Seligman (1969, 1970).

Many of the studies on population behaviour in mixtures are based on weed-crop interference. In general, weeds have greater potentialities to accumulate water, nutrients and light energy thereby decreasing the efficiency of crop production (Blackman and Templeman, 1938; Russell, 1961). In studies dealing with grass - legume associations different workers have shown the improved yield of the grass in the presence of legume (de Wit et al., 1968; Bergh van den, 1968; Abu-Shakra et al., 1969, and Reid, 1970). Such a response has also been shown in legume-crop interactions by Kapoor and Ramakrishnan (1975).

The famous experimental model of de Wit (1960) marked the beginning of a new era in the studies of behaviour of two species in mixtures. The model facilitates to study the performance of two species in pure and mixed stands with varied proportions of the species, keeping the overall mixture density constant. The behaviour of a species is compared in pure stands with its performance in variously proportioned mixtures and mutual aggressiveness of the two species is measured. de Wit et al. (1960) discussed different situations and suggested the following models.

- (i) Simplest form of competition occurs if two species compete for the same space.
- (ii) This model occurs when two species affect each other only by crowding for the same space, finish their growth in the same length of time and have similar growth curves.
- (iii) This more complex model occurs when two species having the same growing period crowd for the same space but have dissimilar growth curves.

- (iv) A very complicated pattern of competition in this model, if two species do not crowd for exactly the same space. This may occur if some requisite obtained from the soil limits the growth, and one species can explore the soil to a greater depth than the other. The same applies if one species has a more prolonged growing period. Such a stable equilibrium may also be found if one of the two species crowding for space, is benefitted from the presence of the other. Competition between grass and clover is an example of this model.
- (v) This model is applicable if one of the two species hamper the growth of the other, not only by crowding for same space, but also by some processes such as the production of toxic substances harmful to the other.

Reversal of habitat performance has also been shown by Harper and Chancellor (1959) who grew Rumex species on clayey soil with or without Lilium perenne and found that in the absence of the grass, the establishment of Rumex crispus and R. obtusifolius was more successful under maintained water table. In the presence of the grass, the most successful establishment of R. obtusifolius occurred under freely drained conditions. The reason for such a reversal of habitat preference as in the case of R. obtusifolius is yet not clear. However, in the case of Melilotus alba ecotypes the reversal of habitat preference is definitely related to their differential response to nutrients, particularly calcium (Ramakrishnan, 1968a, 1968b, 1970).



Present work:

Slash and burn agriculture (locally called "jhum") is a predominant form of agriculture in north-eastern hill region of India. It involves the slash and burn technique of clearing the forest, cropping for a year or two and then abandoning the land for forest fallow development, for the restoration of soil fertility (Ramakrishnan et al., 1980).

In the past, the jhum cycle (the intervening fallow period before the same land is again cultivated) was of 20-30 years which was ideal not only for the restoration of soil fertility under a forested fallow but also for keeping the noxious weeds under control. However, in recent times there has been a considerable shortening of jhum cycle to about 4-5 years due to increased population pressure and changed land use practices. As a result not only the soil fertility recovery of the system is adversely affected but also large tracts of land have been taken over by ruderal weeds like Eupatorium odoratum L., Imperata cylindrica (L.) Beauv. var. major. Shortening of the jhum cycle has also led to almost pure stands of these weeds occupying vast tracts of land in an arrested stage of succession, being rendered useless for cultivation on this account.

The two weeds, namely E. odoratum and I. cylindrica are also the pioneers in croplands and in the fallows developing after slash and burn agriculture. Eupatorium odoratum, a native of Mexico, grows abundantly at lower elevations of Meghalaya (Kushwaha et al., 1981). It is a high-seeding species. Seeds are extremely light

and are produced with pappus which help them in their dispersal to some degree. Seed germination in nature starts in May - June with the onset of monsoon. Large number of seedlings come up after few showers. The period between June and October represents the period of active growth, after which the plants start flowering. Maximum fruiting takes place in the month of January and seeds are mature by March.

The germination and growth behaviour of the populations of E. odoratum collected from seven localities from Old and New World Tropics, have been studied by Edwards (1974a, 1974b, 1975). He observed that these populations represent different ecotypes adapted to different climatic conditions. Further, he observed the ecotypic behaviour in the plants growing under different soil moisture conditions. The requirement of light for germination of E. odoratum has also been shown by Edwards (1974a) and Deb (1981). The development of embryo and female gametophyte has been described by Ghosh (1969). Khonglam and Singh (1980) reported that E. odoratum is a allohexaploid with chromosome number 60 and is apomictic. Yadav and Tripathi (1981) studied the dynamics and regulation of E. odoratum population and came to the conclusion that associated vegetation as well as the adults of the same species play a major role in the mechanism of population regulation. Kushwaha et al. (1981) studied the population dynamics of E. odoratum in early successional communities and concluded that:

- (i) Survivorship of seedlings and adults decreases with the increase in the age of the community upto certain years.
- (ii) the growth of the population is drastically reduced after about about 8 years of the growth of this species, when high canopy

species shade it out in the process of secondary succession. (iii) the fallows with maximum population density also suffered from maximum mortality probably due to intra-specific competition.

Imperata cylindrica has extensive underground rhizomes. The populations multiply through iterative production of tillers (leafy shoots). Besides, it also reproduces through seeds which are produced in large numbers and are widely wind dispersal.

There have been only few studies on the growth behaviour of this species. Richards (1952) and Nye and Greenland (1960) noted that under slash and burn agriculture in Africa, a short cycle is highly favourable for its vigorous growth compared to a long cycle when it gets eliminated from the system during the process of secondary succession (Beard, 1953). Schlippe (1956), while working on the ecology of "Zande system" of agriculture in Africa, observed that fire stimulates growth in this species. Further, he indicated that it may flower after dry season with little or no rain. In a recent study Eussen and Wirjahardja (1973) have even implicated allelopathy as an important factor for the success of this species.

However, these studies on the growth behaviour are relatively inadequate in the context of their wide spread dispersal and success which pose serious agronomic problems. A study pertaining to the detailed analysis of their population growth providing information about that natality, mortality, survivorship and age-structure and the environmental factors which influence these population attributes may not only prove helpful in devising effective weed-control measures but also provide an insight into our

understanding of their regulation in nature without environmental repercussions.

For the present study, therefore, these two major early successional weeds with contrasting life cycle strategies were selected. A third, late successional species, Scleria tessellata Willd. was also selected to compare the population behaviour of these two early successional weeds with a late successional one occurring in contrasting environmental conditions. Apart from the population dynamics studies and a few other related to competition and response to different environmental conditions, a few selected agro-ecosystems have been considered from the point of view of their organization and yield patterns.

CHAPTER 1

AN ANALYSIS OF SOME AGRO-ECOSYSTEM TYPES OF NORTH-EASTERN INDIA.

INTRODUCTION

Shifting agriculture (locally called "Jhum") is practised in the hill regions of north-eastern India which include Arunachal Pradesh, Assam, Manipur, Meghalaya, Mizoram, Nagaland and Tripura. This practice involves slash and burn of the forest, followed by cropping for a year or two before abandoning the site for fallow development and moving elsewhere for such an agriculture. The region is characterized by humid climate with sub-tropical to temperate vegetation mainly comprised of secondary formations. A population of over 1.6 million (Mukherjee, 1975) depends chiefly upon jhum annually cultivating about 0.5 m hectares of land whereas the total area affected by jhum is considered to be over 7.0 m hectares, approximately six times the annually cultivated area (Wadia, 1975). This, however, does not take into account the degraded land rendered useless for cultivation or for forest development (Ramakrishnan et al., 1980). In the past the jhum cycle (the intervening fallow period before the same site is again cropped) was of about 20 - 30 years which was ideal not only for physico-chemical improvement of the soil but also for keeping the noxious weeds like Eupatorium odoratum and Imperata cylindrica under check. However in recent times, the jhum cycle has become as short as 4 - 5 years due to increased population pressure, reduction in acreage due to site degradation and also due to changes in land tenure practices.

The terrace cultivation which has been suggested as an alternative to jhum by the local governmental agencies and valley cultivation of rice are also other land use practices in the region (Toky and Ramakrishnan, 1981; Mishra and Ramakrishnan, 1981).

There has been much confusion in the past, regarding the yield under jhum. Agro-Economic Research Centre, Jorhat, Assam conducted surveys on jhum yields of rice and concluded that the average yield of 800 - 900 kg/ha/yr of rice in Garo hills, Mizoram and Arunachal Pradesh is comparable to the average yield of 1145 kg/ha/yr for the country as a whole for 1971-72. Mishra (1976) reported 1200 kg/ha/yr of yield of rice under jhum in Tripura. According to Aurora et al. (1977), the yield of rice under jhum and dry land cultivation on terraces are not significantly different under comparable situations. Sahu (1978) noted an yield of 853, 738 and 3428 kg/ha/yr of rice under jhum, terrace and valley cultivation respectively suggesting that monetarily terracing is more productive compared to jhum or valley cultivation. Recently Bor̄thakur et al. (1978) reported very high yields of rice under terrace cultivation (1860 kg/ha) compared to jhum (190 kg/ha). However, these studies neither specify the jhum cycle or the cropping pattern under jhum, nor do they specify the various inputs that go into jhum or other sedentary forms of agriculture which would determine the ultimate yield. They also do not specify as to whether yield from other crops is compared since often as many as 30 crops may be involved in the mixture.

Recently, however, Ramakrishnan and his coworkers (Toky and

Ramakrishnan, 1981; Mishra and Ramakrishnan, 1981) have considered the jhum pattern of these agro-ecosystems at low and high elevations of Meghalaya taking into consideration the various agronomic practices. The present study is an extension of this in order to understand cropping and productivity patterns of jhum in Garo hills of Meghalaya and in the Ao area of Nagaland under two jhum cycles of 5 and 10 years. This has been compared with valley cultivation of rice in Garo hills and Nagaland and terrace cultivation in the Angami area of Nagaland, where terracing is very common. All these sites in Garo hills and Nagaland are at lower elevations of about 800 m, under a sub-tropical climate.

DESCRIPTION OF AGRO-ECOSYSTEMS

Slash and burn agriculture is extensively practised by the tribal population of the north-eastern India. Jhum is done on slopes of 20-40°. Further the entire region is characterised by high rainfall ranging from 1200 to 2500 mm annually. The soil is mostly lateritic (oxysol) at lower elevations. Jhum cycle in Garo hills may vary from place to place whereas in Nagaland it is of about 10 years.

A short jhum cycle of 4-5 years is more common in Garo hills though in Nagaland it was 8-10 years long. The average size of jhum field is generally from 1.0 to 2.5 hectares cultivated by a family of two adults and four children. Adults as well children participate in work.

The operations start in December-January with felling of the trees, shrubs etc. on a selected plot which is mostly determined

by the chief of the village. Individual and clan ownerships are relatively rare but belongs to the community. Generally all the jhum fields are located at one place and before anyone could start the felling, a group of men are engaged by the chief to prepare the pathway leading to the place various festivals like "Saljong" (Sun God) worship (among Garos), "Ana Tsungram" worship (among Ao Nagas) are associated with the felling operation. Felling is mainly done by men. Sometimes big trees are left intact though their branches may be slashed. Species like alder, Alnus nepalensis are generally not cut down as they are considered by them to improve soil fertility. Large logs are often removed for housebuilding or put horizontally on the slope to check soil erosion. The slash is burnt in situ in April - May after drying it in winter months from January to March. Before burning, a fire line is cleared along the periphery of the field to check its spread. Sometimes a second burning may be required to complete the process.

Sowing starts just after burning in May - June. The proportions of various seeds in the mixture for broadcasting vary from place to place and family to family depending upon the family requirements as well as jhum cycle prevailing in the area. Cereals make the major part of the mixture with seeds of cucurbits, pulses and vegetables etc. These seeds are mixed with fine soil from the jhum and are broadcasted uniformly in the field by male members. Maize, ginger, Colocasia, tapioca and banana are sown at random chiefly by females. Brinjal, chillies, tomatoes, beans, spice plant (Hyptis spicigera) etc., which are mainly for the consumption of the family, are planted almost in monocultures around the field

hut which is made for field watching for one crop season. Often to avoid wild animals like tigers and elephants, field huts are made atop the trees.

As major constituents of jhum agro-ecosystem, weeds pose problem with the onset of the rainy season. They include root, stem and rhizome sprouts and various herbs and grasses. A long jhum cycle is helpful in keeping the weeds under control but under short jhum cycles, the problem gets aggravated. Imperata cylindrica sprouts vigorously through extensive underground rhizome system and repeated disturbances may induce flowering in this species, resulting in the production of large amount of seeds (Kushwaha et al., unpublished). Eupatorium odoratum is another noxious, fast growing, perennial weed with high seed output (Kushwaha et al., 1981). Besides these, there are also other weeds like Mikania micrantha, Ageratum conyzoides, Eregeron canadensis and Thysanolaena maxima, which afford inter-specific competition to crop plants. Weeds like I. cylindrica have also been reported to possess allelopathic inhibition of crop growth (Eusser and Wirjahardja, 1973).

Terrace cultivation :

Terrace cultivation has been suggested as an alternative to jhum by local governmental agencies. As incentives 1 - 2 hectares of land is allocated to a family, besides providing free inputs like seeds and plant, organic manure and fertilizers are also given for a year or two. However, in many places, these terraces are often cultivated just as under jhum when these

subsidies are withdrawn. In Nagaland, the Angami and Chakesang tribes, however, have been successfully practising terrace cultivation of rice for a fairly long time, particularly in areas where water is available for irrigation. Sometimes a second crop of Setaria italica or Coix lachryma-jobi may also be taken during winter on these terraces after rice cultivation in July-November. Polygonum is one of the vigorous weeds in terraced lands.

Valley cultivation :

Valley cultivation also has monoculture of rice as in terraces. The valleys are enriched by water and soil nutrients, like terraces, brought down from the adjoining slopes and therefore need no major fertilizer input. Both in Garo hills and Nagaland, rice is grown only once in a year in valley land, between May to November. During the dry winter months, cropping is not done for want of water. If sufficient water is available, a second crop may be raised in winter. Ploughing the land is done using bullocks. Seedlings are raised in nursery beds and are transplanted into the field when they attain about 30 cm height, early in July. Weeding is done 3 - 4 times by both male and female members of the family. Each family has, on an average, 0.5 to 1.0 hectare of such land depending upon the local topographic situations. Compared to terrace cultivation, valley cultivation has more weed infestation, mostly dominated by Polygonum, which is ploughed back into the system as green manure.

METHODS OF STUDY

The study sites are situated at Garo hills in Meghalaya (25°.29'N latitude and 90°.15'E longitude) and at the Ao (26°.15'N

latitude and 94°.12'E longitude) and Angami (25°.40'N latitude and 94°.10'E longitude) regions of Nagaland. A short, 5 year jhum cycle and valley cultivation studies were done at Garo hills, 15 km north of Tura. A long, 10 year jhum cycle and valley cultivation studies were done at Changki village, about 50 km west of Mokokchung district of Nagaland. The tribes involved are the Garos and the Aos. At another study site in Angami area around Kohima district of Nagaland, terrace cultivation done by the Angami tribe of the Nagas, was studied. In each study area, four replicate slopes of similar aspect and topography were selected.

Density, frequency, basal area and importance value indices of the weeds of the agro-ecosystem types were done in September, at the peak of their growing season. The total dry weights of different weeds were analysed in sample plots of 10 m², kept apart as control enclosures in each of the fields for study purposes. This ensured accurate estimation of the weed population at peak growth period which generally coincides with the peak growth periods of the crops.

The crops, which were about 30 in the two jhum types of 10 and 5 years, were also analysed quantitatively for their density, frequency and basal area using 100m² quadrates. The total basal area represents the area of the ground occupied by the stems of crops. The IVI values of crops as well as weeds, were calculated as the sum of relative density, relative frequency and relative basal area and are based on 20 quadrates per plot (Misra, 1968; Kershaw, 1973). The individual plant height and leaf area for crops were also calculated and are based on 20 randomly selected plants per plot. Plant spread is a measure of the average aerial spread of the shoot

of a given species (Kershaw, 1973) and was measured at the time of peak growth of the crops as average of 20 plants. The leaf area index (LAI) that is, the leaf surface exposed to light with respect to the ground surface (Odum, 1971) was also calculated for each crop and is based on 20 plants.

For individual crops, the biomass and the economic yield per plant were calculated on the basis of 20 plants per plot. The per hectare values are based on estimates for the entire plot. For terrace and valley cultivation only the economic yield was analysed for monetary cost-benefit studies. Labour inputs in man hours for various operations in three agro-ecosystem types were calculated. The labour charges for male and female workers, were calculated on the basis of the prevailing daily rates of Rs. 10/- and 8/- respectively (in Nagaland) and Rs. 8/- and Rs. 6/- respectively (in Garo hills, Meghalaya). Similarly the price of economic produce was also estimated based on local market price for each crop.

RESULTS

Table 1.1 represents the phytosociological characteristics of the different crops under two jhum cycles of 10 and 5 years. Under a 10 year jhum in the Ao region, rice was the most important crop followed by cotton. Amongst the cereals, Setaria italica and Sesamum indicum were emphasized. Colocasia which is used as pig feed was the most important of the tuber/root/rhizome crops, and represents the third high density crop. Amongst vegetables, brinjal and bitter gourd (Momordica charantia) are sown at low

Table 1.1. Phytosociology of crops under two ~~year~~ cycles in Garo hills and Nagaland.

Crops	Density/ha		% frequency		Basal area/ha		IVI	
	10 yr	5 yr	10 yr	5 yr	10 yr	5 yr	10 yr	5 yr
<u>Grain and seeds:</u>								
<u>Oryza sativa</u>	500000.0	560000.0	100	100	665000.0	439600.0	168.20	200.11
<u>Zea mays</u>	184.5	175.5	50	50	738.0	861.0	7.55	6.38
<u>Sorghum vulgare</u>	430.5	50.5	60	30	163.9	81.4	9.17	3.73
<u>Elytis spicigera</u>	147.6	120.0	10	10	116.6	60.3	1.52	1.26 ^{NS} ₀₀
<u>Setaria italica</u>	246.0	200.0	30	20	123.0	39.3	4.52	2.50
<u>Sesamum indicum</u>	246.0	350.0	20	20	277.9	175.8	3.02	2.57
<u>Coix lachryma-jobi</u>	35.0	10.9	10	10	61.6	16.8	1.49	1.23
<u>Leaf, stem, fruit and vegetables:</u>								
<u>Luffa cylindrica</u>	24.6	15.0	10	20	15.5	4.2	1.49	2.47
<u>Phaseolus spp.</u>	24.6	24.2	10	10	12.3	6.3	1.49	1.23
<u>Amaranthus spp.</u>	123.0	129.0	20	30	386.2	259.2	1.49	3.77
<u>Cucurbita pepo</u>	24.6	15.0	10	20	62.5	17.0	1.49	2.47
<u>C. maxima</u>	24.6	20.6	10	10	77.2	31.7	1.49	1.24
<u>Cucumis sativus</u>	30.0	12.0	10	10	9.0	1.4	1.49	1.23

<u>Lycopersicum esculentum</u>	28.0	18.0	10	20	26.3	6.9	1.49	2.47
<u>Capsicum frutescense</u>	196.8	175.6	20	30	98.4	34.5	3.01	3.74
<u>Musa sapientum</u>	190.0	200.0	30	50	33559.7	22608.0	7.67	10.81
<u>Vigna sinensis</u>	24.2	35.2	10	20	9.2	9.9	1.49	2.48
<u>Solanum melongena</u>	14.7	15.0	10	10	50.7	38.2	1.49	31.24
<u>Hibiscus esculentus</u>	32.0	39.0	10	20	100.5	88.5	1.49	2.50
<u>Citrus vulgaris</u>	29.5	20.2	10	20	8.3	2.5	1.49	2.47
<u>Saccharum officinarum</u>	14.7	30.5	10	10	4.1	3.8	1.49	1.24
<u>Momordica charantia</u>	17.2	17.0	10	10	3.3	2.1	1.49	1.23
<u>Hibiscus subdariffa</u>	123.0	200.0	20	20	26.0	100.5	3.02	2.53
<u>Gossypium hirsutum</u>	5000.0	6450.0	30	70	353500.0	20253.0	46.93	13.85
<u>Tuber, root and rhizomes:</u>								
<u>Manihot esculenta</u>	123.0	120.0	50	60	1184.5	376.8	7.59	7.50
<u>Ipomoea batatas</u>	19.6	10.2	10	10	12.5	3.9	1.49	1.23
<u>Dioscorea spp.</u>	49.2	30.0	20	60	38.9	5.9	2.98	7.41
<u>Zingiber officinalis</u>	49.2	500.0	20	30	37.4	392.5	3.01	3.87
<u>Allium sativum</u>	49.2	30.3	10	10	24.6	8.6	1.49	1.24
<u>Colocasia antiquorum</u>	565.8	469.7	40	20	15989.5	6504.1	6.08	3.87

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Table 1.2. Phytosociology of weeds under two jhum cycles in Garo hills and Nagaland.

Weeds	Density/m ²		% frequency		Basal area (cm ²)/m ²		IVI		Dry wt. yield(g) m ²	
	10 yr	5 yr	10 yr	5 yr	10 yr	5 yr	10 yr	5 yr	10 yr	5 yr
<u>Ageratum conyzoides</u>	6.0	6.4	100	100	18.8	3.1	45.34	12.91	109.0	120.0
<u>Borreria hispida</u>	1.5	3.2	100	80	1.7	2.0	19.30	10.14	171.0	358.0
<u>Dendrocalamus hamiltonii</u>	3.2	2.3	100	60	76.0	11.2	74.94	13.30	400.0	308.2
<u>Eregeron canadensis</u>	6.4	6.0	90	100	20.1	5.7	46.15	15.27	340.3	344.2
<u>Euphorbia odoratum</u>	1.2	2.1	80	90	19.0	14.1	27.41	17.81	156.0	298.8
<u>Imperata cylindrica</u>	-	200.0	-	100	-	100.0	-	152.34	-	500.2
<u>Mikania micrantha</u>	0.2	2.0	20	100	2.0	17.1	4.68	20.50	123.9	251.6
<u>Osbeckia crinita</u>	2.2	4.2	100	100	6.2	4.7	24.00	13.96	148.1	243.4
<u>Panicum maximum</u>	110.0	15.6	100	80	2.8	0.4	41.34	13.93	402.0	600.0
<u>Phragmites spp.</u>	0.1	0.7	10	17	0.4	1.2	1.98	7.58	11.7	78.9
<u>Saccharum spontaneum</u>	0.1	0.6	10	60	0.1	0.4	1.77	6.14	14.0	71.1
<u>Solanum spp.</u>	0.2	0.5	20	50	0.1	4.8	3.35	7.78	22.9	62.0
<u>Thysanolaena maxima</u>	0.2	0.8	20	80	0.5	0.5	3.65	8.12	33.9	50.0

densities compared to the others. Leaf, stem, fruit and vegetable crops were numerically more followed by cereals. The total number of cereals or tuber/root/rhizome crops were more or less the same.

Under a 5 year jhum in Garo hills, rice, cotton and ginger were emphasized more. Amongst the cereals Setaria italica was the next crop of importance, whereas it was banana in the case of vegetable and fruit crops and Colocasia amongst the tuber/root/rhizome crops.

In the Ao area of Nagaland under 10 year jhum cycle, the weed density in general was lower than that under a 5 year cycle in the Garo hills while I. cylindrica was totally absent in Nagaland site, it was a very important species in the Garo hills site.

Dendrocalamus hamiltonii comes up as sprouts from the underground rhizomes. Under a 10 year cycle, Panicum maximum, Ageratum conyzoides, Eregeron canadensis and Eupatorium odoratum are some of the important weeds. Whereas under the short cycle at Garo hills besides the most important Imperata cylindrica, Mikania micrantha, Eregeron canadensis and Panicum maximum were also important (Table 1.2). The vigour of the crops under the two jhum cycles at Garo hills and Nagaland are shown in Table 1.3. Except in the case of Amaranthus spp. height of all the crops were markedly reduced under a 5 year jhum cycle compared to that under a 10 year cycle. The leaf area and the plant spread also showed similar trends. Leaf area index was maximum for leafy vegetable crops like Hyptis spicigera, Phaseolus vulgaris and Vigna sinensis, Amaranthus and Hibiscus subdariffa with markedly lower values for cucurbits and cereals. The total leaf area index for all crops was much higher under a 10 year cycle compared to that under a 5 year one.

Table 1.3. The vigour of crops under two jhum cycles in Garo hills and Nagaland.

Crops	Plant height (cm)		Leaf area (m ²)/Plant		Plant spread(cm)		Leaf area index	
	10 yr	5 yr	10 yr	5 yr	10 yr	5 yr	10 yr	5 yr
<u>Grain and seeds:</u>								
<u>Oryza sativa</u>	106.7	60.2	0.3	0.2	45.7	24.4	3.2	2.1
<u>Zea mays</u>	213.4	160.6	1.0	0.6	91.4	45.7	2.0	1.1
<u>Sorghum vulgare</u>	300.5	250.0	1.0	0.4	106.7	61.1	2.8	1.7
<u>Hyptis spicigera</u>	92.4	60.8	4.5	3.0	88.4	36.0	5.1	2.5
<u>Sesamum indicum</u>	180.8	100.2	1.0	0.7	76.2	67.0	3.9	2.6
<u>Coix lachryma-jobi</u>	130.9	90.5	0.3	0.1	76.0	48.6	2.6	1.1
<u>Leaf, stem, fruit and vegetables:</u>								
<u>Luffa cylindrica</u>	480.0	290.0	2.1	1.3	365.8	213.4	2.9	2.0
<u>Phaseolus spp.</u>	530.0	371.2	29.7	18.0	304.8	182.9	4.2	2.9
<u>Amaranthus spp.</u>	91.4	120.0	2.5	1.4	76.2	45.7	4.9	2.9
<u>Cucurbita pepo</u>	303.4	190.1	2.2	1.1	457.2	243.8	2.1	1.2
<u>C. maxima</u>	289.7	191.5	3.2	1.8	450.3	213.4	2.6	1.7
<u>Cucumis sativus</u>	330.5	211.6	1.6	0.7	455.0	198.1	2.4	1.1
<u>Lycopersicum esculentum</u>	61.0	50.1	0.2	0.1	76.2	30.0	3.6	2.7
<u>Capsicum frutescens</u>	61.1	46.6	0.3	0.1	91.4	45.7	3.0	1.8
<u>Musa sapientum</u>	364.8	199.2	50.4	30.0	304.0	167.0	3.8	2.4
<u>Vigna sinensis</u>	500.9	298.7	32.4	17.2	121.9	57.9	5.6	3.5
<u>Solanum melongena</u>	70.0	40.3	0.6	0.5	91.4	60.0	3.0	1.9
<u>Hibiscus esculentus</u>	160.8	85.9	1.2	0.4	106.7	45.7	3.5	2.4
<u>Citrulus vulgaris</u>	465.3	300.3	1.0	0.4	426.0	213.4	2.8	1.7
<u>Saccharum officinarum</u>	350.6	250.0	0.5	0.3	100.6	60.9	3.3	2.0
<u>Momordica charantia</u>	425.7	261.8	1.2	0.4	91.4	45.7	4.8	3.5
<u>Hibiscus subderiffa</u>	162.2	93.4	1.5	0.9	91.4	91.4	4.5	13.3
<u>Gossypium hirsutum</u>	120.9	80.3	4.6	2.0	91.0	24.5	4.0	2.8
<u>Tuber, root and rhizomes:</u>								
<u>Manihot esculenta</u>	243.8	170.0	2.0	1.2	152.4	91.4	3.6	2.4
<u>Ipomoea batatas</u>	495.2	340.0	1.5	0.9	335.3	152.4	3.0	2.1
<u>Dioscorea spp.</u>	519.3	308.8	10.2	6.5	152.0	70.1	5.5	2.6
<u>Zingiber officinalis</u>	45.0	40.2	0.2	0.1	45.0	24.0	3.0	1.8
<u>Allium sativum</u>	30.0	18.2	0.1	0.1	45.7	15.0	1.9	1.0
<u>Colocasia antiquorum</u>	120.9	76.2	1.8	1.0	121.9	64.0	3.0	2.0
Mean							3.4	2.1

Table 1.4. Mean economic yields of crops under two jhum cycles in Garo hills and Nagaland.

Crops	Moisture (%)	Yield/ plant(g) 10 yr	Yield/ ha(kg) 10 yr	Yield/ plant(g) 5 yr	Yield/ ha(kg) 5 yr
<u>Grain and seeds:</u>					
<u>Oryza sativa</u>	19.5	4.3	2195.0	3.0	1600.0
<u>Zea mays</u>	15.0	85.0	15.7	45.0	7.9
<u>Sorghum vulgare</u>	12.0	40.0	17.2	23.0	0.9
<u>Hyptis spicigera</u>	95.0	2.8	0.4	1.6	0.2
<u>Setaria italica</u>	17.0	24.9	6.1	15.3	3.1
<u>Sesamum indicum</u>	7.0	21.3	5.7	10.0	3.5
<u>Coix lachryma-jobi</u>	18.0	26.6	0.9	11.6	0.1
<u>Leaf, stem and fruits:</u>					
<u>Luffa cylindrica</u>	93.0	250.0	6.1	170.0	2.6
<u>Phaseolus spp.</u>	25.0	1250.0	30.8	805.0	17.9
<u>Amaranthus spp.</u>	86.0	143.0	17.6	100.0	12.9
<u>Cucurbita pepo</u>	95.0	500.0	12.3	320.0	4.8
<u>C. maxima</u>	90.0	1200.0	29.5	800.0	16.5
<u>Cucumis sativus</u>	96.0	685.0	20.6	350.0	4.2
<u>Lycopersicum esculentum</u>	93.0	340.0	9.5	180.0	3.2
<u>Capsicum frutescens</u>	80.0	100.0	19.7	51.0	8.9
<u>Musa sapientum</u>	77.5	2250.0	425.5	1110.0	222.0
<u>Vigna sinensis</u>	88.0	60.0	1.5	35.0	1.2
<u>Solanum melongena</u>	93.0	340.0	5.0	195.0	2.9
<u>Hibiscus esculentus</u>	90.0	350.0	11.2	190.0	7.4
<u>Citrulus vulgaris</u>	96.0	400.0	11.8	250.0	5.1
<u>Saccharum officinarum</u>	75.0	1250.0	18.4	750.0	22.9
<u>Momordica charantia</u>	81.5	185.0	3.2	100.0	1.7
<u>Hibiscus subdariffa</u>	75.0	125.0	15.4	75.0	15.0
<u>Gossypium hirsutum</u>	5.0	9.5	475.0	6.0	38.7
<u>Tuber, root and rhizomes:</u>					
<u>Manihot esculenta</u>	59.0	2045.0	251.5	1500.0	180.0
<u>Ipomoea batatas</u>	81.0	965.0	18.9	675.0	6.9
<u>Dioscorea spp.</u>	75.0	1000.0	49.2	493.0	14.8
<u>Zingiber officinalis</u>	80.0	142.5	7.0	90.0	45.0
<u>Allium sativum</u>	96.0	4.0	0.2	2.0	0.1
<u>Colocasia antiquorum</u>	80.0	200.0	113.2	130.0	6.1

Table 1.5. Biomass yield of the crops under two jhum cycles in Garo hills and Nagaland.

Crops	10 yr		5 yr	
	Biomass(g) / Plant/yr	Biomass(kg) / ha/yr	Biomass(g) / Plant/yr	Biomass (kg) /ha/yr
<u>Grain and seeds:</u>				
<u>Oryza sativa</u>	30.0	15000.0	20.6	11536.0
<u>Zea mays</u>	425.0	78.4	225.0	39.5
<u>Sorghum vulgare</u>	60.5	26.0	33.0	1.3
<u>Hyptis spicigera</u>	3.3	0.5	2.1	0.3
<u>Setaria italica</u>	48.0	11.8	30.0	6.0
<u>Sesamum indicum</u>	46.0	11.3	22.0	7.7
<u>Coix lachryma-jobi</u>	34.7	1.2	18.0	0.2
<u>Leaf, stem, fruit and vegetables:</u>				
<u>Luffa cylindrica</u>	279.6	6.9	200.0	3.0
<u>Phaseolus spp.</u>	4230.0	104.1	2550.4	56.6
<u>Amaranthus spp.</u>	150.0	18.5	120.0	15.5
<u>Cucurbita pepo</u>	940.0	23.1	600.0	9.0
<u>Cucurbita maxima</u>	1740.0	42.8	1320.0	27.2
<u>Cucumis sativus</u>	1355.0	40.7	740.8	8.9
<u>Lycopersicum esculentum</u>	600.0	16.8	350.9	6.3
<u>Capsicum frutescens</u>	110.0	21.6	60.0	10.5
<u>Musa sapientum</u>	8870.0	1685.3	4100.9	820.2
<u>Vigna sinensis</u>	150.3	3.6	86.7	3.1
<u>Solanum melongena</u>	475.9	7.0	310.0	4.7
<u>Hibiscus esculentus</u>	450.0	14.4	280.0	10.9
<u>Citrullus vulgaris</u>	632.5	18.7	350.5	7.1
<u>Saccharum officinarum</u>	1386.6	20.4	900.5	27.5
<u>Momordica charantia</u>	726.0	12.5	580.2	9.9
<u>Hibiscus subdariffa</u>	375.0	46.1	231.7	46.3
<u>Gossypium hirsutum</u>	30.0	1500.0	20.3	130.9
<u>Tuber, root and rhizomes:</u>				
<u>Manihot esculenta</u>	3145.0	386.9	2200.0	264.0
<u>Ipomoea batatas</u>	1110.1	21.8	800.0	8.2
<u>Dioscorea spp.</u>	1111.0	54.7	600.0	18.0
<u>Zingiber officinalis</u>	280.0	13.8	101.5	95.8
<u>Allium sativum</u>	6.0	0.3	3.1	0.1
<u>Colocasia antiochorum</u>	320.0	181.0	200.0	93.3

The mean economic yield per plant as well as per hectare were markedly low under a 5 year jhum compared to a 10 year jhum and the decrease was more pronounced in crops like maize, sorghum, Coix lachryma-jobi, Dioscorea spp. and some of the cucurbits. In both type of jhums rice, banana, cotton and tapioca had higher yields compared to the other crops (Table 1.4).

Table 1.5 shows the biomass yields of different crops under the two jhum cycles. The total biomass per plant and per hectare of different crops was markedly reduced under a 5 year cycle compared to a 10 year cycle. Rice had the highest biomass yields per hectare under both jhum cycles. Under the valley cultivation, the yield of rice was 3960 kg/ha in Nagaland site compared to 2600 kg/ha in the Garo hills. However, the yield under terrace cultivation in Nagaland sites was even lower (2420 kg/ha).

The monetary inputs to the different agro-ecosystems include the labour costs and the cost of the seeds used for sowing. However, the labour charges for making terraces in the beginning under terrace cultivation have been excluded from the calculations. The labour input was found to be maximum under a 5 year cycle followed by that under terrace cultivation. The inputs under 10 year jhum cycle and into valley cultivation were quite similar. The monetary output was maximum (Rs. 5940) for valley cultivation in Nagaland site followed by that under a 10 year jhum (Rs. 5187); under a 5 year cycle in Garo hills the output was the least. The net monetary gain are the return per unit cost of production also followed similar trends (Table 1.6).

Table 1.6. Monetary input-output (Rs.ha/yr) in jhum, terrace and valley agro-ecosystems.

	Jhum		Valley cultivation		Terrace cultivation
	Nagaland (10yr cycle)	Garo hills (5yr cycle)	Nagaland	Garo hills	Nagaland
Input	1852	2353	1749	1857	1911
Output	5187	3530	5940	3900	3630
Net gain	3335	1177	4191	2043	1719
Output/input	2.8	1.5	3.4	2.1	1.9

DISCUSSION

Mixed cropping is such a common feature under shifting agriculture that the two terms have often become synonymous. As many as 40 - 50 crops have been noted in Philippines, almost all of which are sown at a time (Conklin, 1957). At lower elevations of Meghalaya, Toky and Ramakrishnan (1981) have reported mixtures of about 13 crops. However, simultaneous sowing is more common in north-eastern hill regions. In some cases, crops like banana and citrus are planted even at the end of the cropping tenure or when cereals are removed from the fields as in Ghana (Nye and Greenland, 1960). In the north-eastern region, however, often the land is abandoned after cropping for a year or two and sometimes pine apple and banana may be raised.

The crops sown, possess different growth and developmental strategies with diverse nutrient requirements which enable them for optimum use of available "space". In such a mixed community the canopies of the different crops are so stratified that they make maximum use of sun light which otherwise may not be utilized under monocultures. The high values for leaf area index for many of the crops, suggests that the yield potential of the different crops is high. A leaf area index of 4 is known to give maximum crop yields in various agriculture systems (Odum, 1971) which implies that under long jhum cycle of 10 years, the crop assembly may be efficient from the production point of view. Besides, mixed cropping also ensures a good return for at least some of the crops even if others fail. The sequential harvests of different crops create more space for the remaining ones and this reduces competition at

the peak period of growth and also provide organic manure through decomposing litter from the earlier crops.

A mixture of crops may also be more effective in checking soil erosion, as seen from the reduction of losses after crop cover is established (Toky and Ramakrishnan, 1981). Mixed cropping is also considered to be important from the point of view of pests and disease control.

Weeds pose a problem under jhum, more so under a short cycle as also reported by other workers (Zinke et al., 1981; Freeman, 1955; Cutting et al., 1950; Mutsaers et al., 1981). Under short jhum cycles these weeds not only compete for the limited resources but also hinder further regeneration of the vegetation and as a result the weed community is maintained more or less in a permanent state of arrested succession (Ramakrishnan et al., 1980; Kushwaha et al., 1981). However, following upto about 10 years under a 10 year cycle keeps the weeds under check due to secondary successional processes.

The yield under a 10 year cycle is markedly more than in the 5 year cycle, though these two cycles are not strictly comparable as they are located in different geographical areas. However, such a difference is still explainable on the basis of higher fertility status of the soil under a longer jhum cycles with better physical properties for the soil (Ramakrishnan and Toky, 1981). The soil fertility recovery under a 5 year cycle obviously is poor than under a 10 year cycle.

Valley cultivation has a natural advantage due to washout of nutrients alongwith water from adjoining hill slopes and thus it gives sustained yields from year to year. It is interesting to note that under terrace cultivation the output and the input ratio was close to that under a 5 year jhum cycle. Such a low value may be explained as due to poor physical and chemical properties of the soil under ontinuous cultivation. On the present study site, this is aggravated due to non-application of any ferilizer (organic or inorganic) as is done in many other such situations.

SUMMARY

The paper deals with studies on cropping patterns and the productivity of three agricultural systems, jhum, valley and terrace cultivation, at Garo hills (5 year jhum cycle and valley cultivation), Meghalaya, and Ao (10 year jhum cycle and valley cultivation) and Angami (terrace cultivation) areas of Nagaland in north-eastern India.

The plant height, leaf area, leaf area index and individual species spread were greatly reduced under a 5 year jhum cycle compared to that under a 10 year jhum cycle. The economic and total biomass yield also followed a similar trend. Rice was the major crop under jhum. Apart from about 28 crops which include cereal, vegetable, fruit, tuber and rhizomatous species. Besides, cotton may also be grown.

The monetary return per unit of the labour invested, was

highest under valley cultivation followed by that under a 10 year jhum in the Ao area. A 5 year jhum cycle at Garo hills gave lowest monetary gain while the return from the valley cultivation in this area was equal to that from terrace cultivation in Angami area. The implications of the results are discussed.

CHAPTER 2

POPULATION DYNAMICS OF EUPATORIUM ODORATUM L. IN SUCCESSIONAL ENVIRONMENTS FOLLOWING SLASH AND BURN AGRICULTURE (JHUM).

INTRODUCTION

Eupatorium odoratum L. is a noxious, perennial weed in many parts of the world. It was introduced to India from America during the Second World War and since then it has widely spread and has become a dominant weed in croplands, roadsides and other exposed areas. It is quite successful as an early colonizer. The light seeds (Cypsellas) which are produced in large numbers, are efficiently dispersed to far-off places by blowing wind. Seed setting is complete before the onset of rain in May and a large number of seedlings come up after the first few showers.

E. odoratum belongs to family Asteraceae. As a pioneer weed it possesses most of the characteristics to compete with other plant species. Since the seeds are taken far apart by wind, new areas are successively colonized every year. Seed germination in nature starts in May-June, with the onset of the rain showers. The period between June and October represents the period of active growth, after which the plants start flowering. Maximum fruiting takes place in the month of January and by March the seeds are mature. Strong winds during April and early May are highly favourable for seed dispersal. Seeds are very light and are provided with pappus which help them greatly in their dispersal.

General changes in plant species composition during early stages of secondary succession have been studied by Oosting (1942).

Keever (1950) and Bazzaz (1968). More recently the studies on population dynamics in early successional fields were done by Holt (1972), Autonovics (1972), Raynal and Bazzaz (1973). The aim of the present study was to identify the various factors governing the population size and reproductive behaviour of E. odoratum at different successional stages of community development following slash and burn agriculture (Jhum) which is extensively practised by the local tribal population of Meghalaya in north-east India.

METHODS OF STUDY

The experimental sites are situated at Burnihat in Meghalaya (26°02'N latitude and 91°52'E longitude) at an altitude of about 100 metres. Five fallows of different ages, viz., 1, 3, 5, 10 and 20 years, were selected as the study sites. The age was calculated from the time fields were left as fallows after slash and burn agriculture. For density, frequency and cover, the vegetation analysis of the different species in the fallows was done using 1 m² quadrat in case of herbaceous species and 100 m² quadrat for shrubs and trees. Importance value index (IVI) was calculated following the procedure outlined by Misra (1968) and Kershaw (1973).

Demographic studies were carried out in permanent quadrats of 1 m² with three replicates in each of the fallows. The fate of the seedlings and shoots of established plants was followed over a two year period from May 1978 to May 1980. The seedlings were marked by two different colour paints by putting a dot over

cotyledonary leaves in order to differentiate the seedlings of two cohorts, one appearing in May and the other in June in a year. The adult shoots already present at the start of the experiment, were taken as more than two year old and those which appeared in 1979 as two year old. The shoots appearing in 1979 were taken as one year old. The shoots were tagged with aluminium labels. Among the environmental parameters estimated, were maximum and minimum temperatures and rainfall.

The seed number per m^2 was estimated by counting the seeds produced by the plants in a quadrat of $1 m^2$ and is an average of three replicates. The seed number per plant was estimated by dividing the seed output per m^2 by the total number of plants per m^2 . Reproductive capacity is the product of the average seed output and the fraction represented by the percentage germination (Salisbury, 1942).

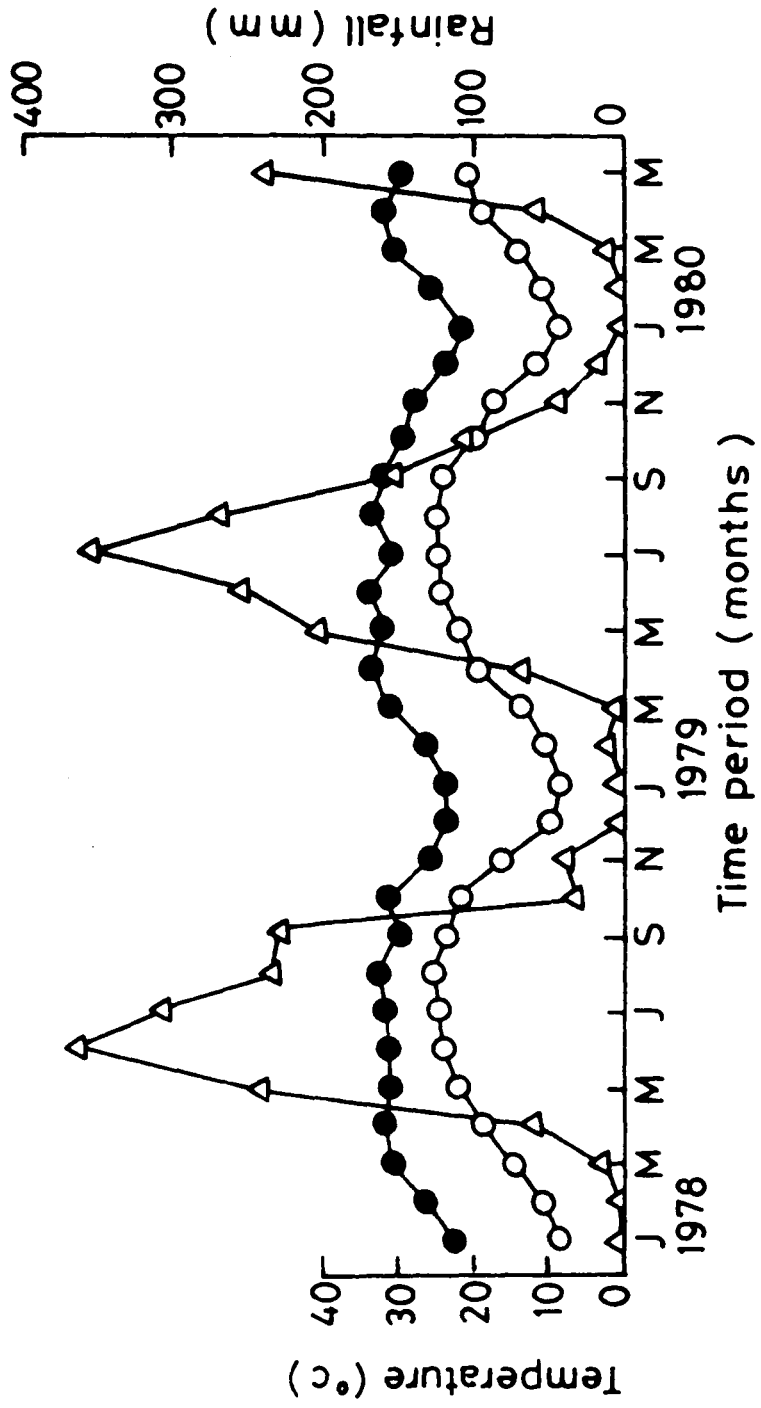
RESULTS

Climate :

The climate of Burnihat could be divided into three distinct seasons. The dry and windy summer is from mid-February to May with average maximum temperature of $32.2^{\circ}C$ and minimum temperature of $24.1^{\circ}C$. The rainy season extends from May to September with an average annual rainfall of about 2200 mm. This is a warm period with high humidity. The month of October represents the transition from rainy to winter season. The mild winter with an average maximum temperature of $24.8^{\circ}C$ and minimum temperature of $12.4^{\circ}C$ extends from November to mid-February. This period is practically rainless except for a few winter showers (Fig. 2.1).

Fig. 2.1. Ombrothermic diagram for the study area.
Monthly maximum (●) and minimum (○)
temperatures; monthly rainfall (Δ).

FIG.2.1



Vegetation :

The early stages of secondary succession upto five years are characterised by a number of weedy species like Eupatorium odoratum, Imperata cylindrica, Thysanolaena maxima and Arundinella bengalensis besides others like Grewia elastica. Dendrocalamus hamiltonii dominates older fallows with a few shrubs and tree species coming up as seedlings, stem or root sprouts. The importance value indices for different associated species are given in Table 2.1.

Population flux of E. odoratum :

In 1 and 3 year fallows there was an addition of 100 and 40 individuals per m² respectively over a 2 year study period while in 5 and 10 year fallows there was a net loss of 30 and 0.7 individuals per m². In a 20 year fallow the population size which was small, remained the same till the end of the study period. There was recruitment of 765, 4318 and 3248 individuals respectively as seedlings in 1, 3 and 5 year fallows while in 10 and 20 year fallows no seedling recruitment occurred. The mortality of adult plants, present at the start of the study, was highest in a 5 year fallow. The fallow characterised by maximum recruitment also suffered from maximum mortality and this happened in younger fallows upto five years (Table 2.2).

The shoots, more than two years old, present at the start of the study, were maximum in a 5 year fallow with sharp decline in younger and older fallows. While there was a net gain of 50.9 individuals in a 1 year fallow over a two year period, in 3 to 10

Table 2.1: Importance value indices of major associated plant species at different sites.

Species	Age of fallows (years)				
	1	3	5	10	20
<u>Ageratum conyzoides</u> L.	14.3	-	-	-	-
<u>Arundinella bengalensis</u> (Spreng) Druce	8.5	8.5	11.6	-	-
<u>Borreria hispida</u> (L.) K. Schum.	18.6	-	-	-	-
* <u>Bauhinia variegata</u> L.	4.4	6.1	7.2	16.9	-
<u>Cyperus globosus</u> Allioni	7.4	10.8	11.1	15.7	15.8
<u>Carex cruciata</u> Nees	-	-	7.9	15.8	16.8
* <u>Careya arborea</u> (Roxb.	6.6	10.7	-	15.2	17.1
* <u>Callicarpa arborea</u> Roxb.	3.1	4.3	6.6	10.4	18.8
* <u>Cedrella toona</u> Roxb.	2.9	4.1	4.2	5.7	12.0
* <u>Combretum decandrum</u> Roxb.	1.6	3.5	3.5	7.5	8.8
* <u>Desmodium triquetrum</u> DC.	3.9	4.5	6.5	-	-
<u>Dendrocalamus hamiltonii</u> Nees & Arn.	7.7	8.5	29.4	45.7	55.8
* <u>Dillenia indica</u> L.	3.6	-	11.2	-	30.5
<u>Eupatorium odoratum</u> L.	32.4	171.2	62.1	8.1	5.4
* <u>Eugenia tetragona</u> Wight	3.0	4.8	5.3	9.5	12.5
<u>Ficus hispida</u> L.	5.6	7.3	-	15.9	15.9
<u>Grewia elastica</u> Royle	5.7	6.5	-	-	-
<u>Imperata cylindrica</u> (L.) Beauv.	23.9	34.1	15.2	-	-
* <u>Litsaea assamica</u> Hk. f.	4.6	6.2	-	7.8	-
<u>Mikania micrantha</u> H.K. & K.	6.6	4.8	-	-	-
* <u>Macaranga denticulata</u> Muell.	6.7	-	12.2	-	23.5
* <u>Melia azadirachta</u> L.	-	-	3.9	4.2	-
* <u>Machillus khasyana</u> Meissn.	1.9	2.9	-	-	-
* <u>Maesa indica</u> Wall.	4.8	-	5.2	10.0	-
<u>Osbeckia crinita</u> Benth.	5.1	9.3	-	-	-
<u>Panicum maximum</u> Jacq.	7.2	9.3	12.4	14.3	17.8
<u>P. khasianum</u> Munro	7.9	10.5	10.6	-	-
<u>Setaria glauca</u> Beauv.	6.9	7.1	15.0	-	-
<u>Scleria tessellata</u> Willd.	-	7.0	7.1	16.3	16.6
* <u>Sapium buccatum</u> Roxb.	2.0	4.7	-	7.8	11.8
* <u>Schima wallichii</u> (DC.) Korth	5.2	5.8	-	13.3	22.9
<u>Thysanolaena maxima</u> Kuntze	5.8	6.7	11.4	-	-
* <u>Vitex peduncularis</u> Wall.	9.9	-	11.7	42.1	-
<u>V. glabrata</u> Br.	5.7	7.6	10.6	30.1	31.0
* Stump sprouts					

Table 2.2. Population flux of E. odoratum in different fallows.

	Age of the fallows (years)				
	1	3	5	10	20
(a) No. of plants/m ² , May 1978	0.0	5.0	35.0	3.3	2.0
(b) No. of plants/m ² , May 1980	100.3	45.0	5.0	2.6	2.0
(c) Net change (b-a)	+100.3	+40.0	-30.0	-0.7	0.0
(d) Rate of increase (b/a)	∞	9.0	0.1	0.8	1.0
(e) No. of plants arrived between May 1978 and May 1980	765.6	4318.5	3248.6	0.0	0.0
(f) Total No. of plants lost between May 1978 and May 1980	665.3	4278.5	3278.6	0.0	0.0
(g) Plants present May 1978 alive by May 1980	0.0	5.0	5.0	2.6	2.0
(h) % survival of plants in (a) (g/a X 100)	-	100.0	14.3	78.8	100.0
(i) Expected time for complete turnover (years) (2/100-h X 100)	-	∞	2.3	9.4	∞
(j) Total No. of plants recorded during study	765.6	4323.5	3283.6	3.3	2.0
(k) % mortality of all individuals (f/j X 100)	86.9	99.0	99.9	21.2	0.0
(l) % mortality of arrivals	86.9	99.0	100.0	-	-

Table 2.3. Population flux of E. odoratum shoots in different fallows.

	Age of fallow (years)				
	1	3	5	10	20
(a) No. of shoots/m ² , May 1978	0.0	23.3	77.0	5.0	2.0
(b) No. of shoots/m ² , May 1980	50.9	19.0	5.0	3.0	2.0
(c) Net change (b-a)	+50.9	-4.3	-72.0	-2.0	0.0
(d) Rate of increase (b/a)		0.8	0.1	0.6	1.0
(e) No. of shoots/m ² recruited between May 1978 and May 1980	64.7	71.6	110.6	0.0	0.0
(f) No. of shoots/m ² lost recruited May 1978 and May 1980	13.8	75.9	182.6	2.0	0.0
(g) Shoots present May 1978 alive by May 1980	0.0	9.0	2.0	3.0	2.0
(h) % survival of shoots in (a) (g/a X 100)	-	38.6	2.6	60.0	100.0
(i) Expected time for complete turnover (years) (2/100-h X 100)	-	3.3	2.1	5.0	∞
(j) Total No. of shoots recorded during Study	64.7	94.9	187.6	5.0	2.0
(k) % mortality of all shoots (f/j X 100)	21.3	80.3	97.3	40.0	0.0
(l) Mortality of recruits	21.3	86.0	100.0	-	-

Table 2.3. Population flux of E. odoratum shoots in different fallows.

	Age of fallow (years)				
	1	3	5	10	20
(a) No. of shoots/m ² , May 1978	0.0	23.3	77.0	5.0	2.0
(b) No. of shoots/m ² , May 1980	50.9	19.0	5.0	3.0	2.0
(c) Net change (b-a)	+50.9	-4.3	-72.0	-2.0	0.0
(d) Rate of increase (b/a)		0.8	0.1	0.6	1.0
(e) No. of shoots/m ² recruited between May 1978 and May 1980	64.7	71.6	110.6	0.0	0.0
(f) No. of shoots/m ² lost recruited May 1978 and May 1980	13.8	75.9	182.6	2.0	0.0
(g) Shoots present May 1978 alive by May 1980	0.0	9.0	2.0	3.0	2.0
(h) % survival of shoots in - (a) (g/a X 100)		38.6	2.6	60.0	100.0
(i) Expected time for complete turnover (years) (2/100-h X 100)	-	3.3	2.1	5.0	∞
(j) Total No. of shoots recorded during Study	64.7	94.9	187.6	5.0	2.0
(k) % mortality of all shoots (f/j X 100)	21.3	80.3	97.3	40.0	0.0
(l) Mortality of recruits	21.3	86.0	100.0	-	-

year fallow there was a net loss which was maximum in a 5 year fallow. In a 20 year fallow, the shoot population remained the same. Maximum mortality of shoots also occurred in a 5 year fallow which had maximum recruitment. In 10 and 20 year fallows no new recruitment of shoots occurred (Table 2.3).

Survivorship of *E. odoratum* :

Survivorship of seedlings was maximum in 1 year fallow. In a 3 year fallow less than 3% of the seedlings alone survived with a slightly better survival for the second cohort of seedlings. In a 5 year fallow, however, mortality was complete by the following January. Maximum seedling mortality occurred during the monsoon, between May and October. If 50% seedling mortality could be considered as a criterion for expressing relative incidence of mortality, this occurred within the first 132 days (1 year fallow) 36 and 75 days (first and second cohorts of 3 year fallow) and 24 and 48 days (first and second seedling cohort of 5 year fallow).

Shoots, more than a year old, showed maximum mortality in a 5 year fallow followed by a 3 year fallow. Mortality of these was negligible in a 10 year fallow (Fig. 2.2). Only one cohort of shoots was recruited in a year in the month of May. Compared to the most of the shoots that were more than a year old, the mortality amongst shoots recruited during the period of observation was higher. Mortality, however, was negligible in a 1 year fallow. Only 38% shoots survived in a 3 year fallow and all died in a 5 year fallow. In 3 and 5 year fallows the mortality of the new shoots was maximum in the first year. 10 and 20 year fallows did not have any new recruitment of shoots (Fig. 2.3).

Fig. 2.2. Survivorship curve of seedlings of E. odoratum recruited in 1978. One year old fallow (○); three year old fallow (◻■); five year old fallow (△▲). Open symbol, first seedling cohort; closed symbol, second seedling cohort.

FIG. 2.2

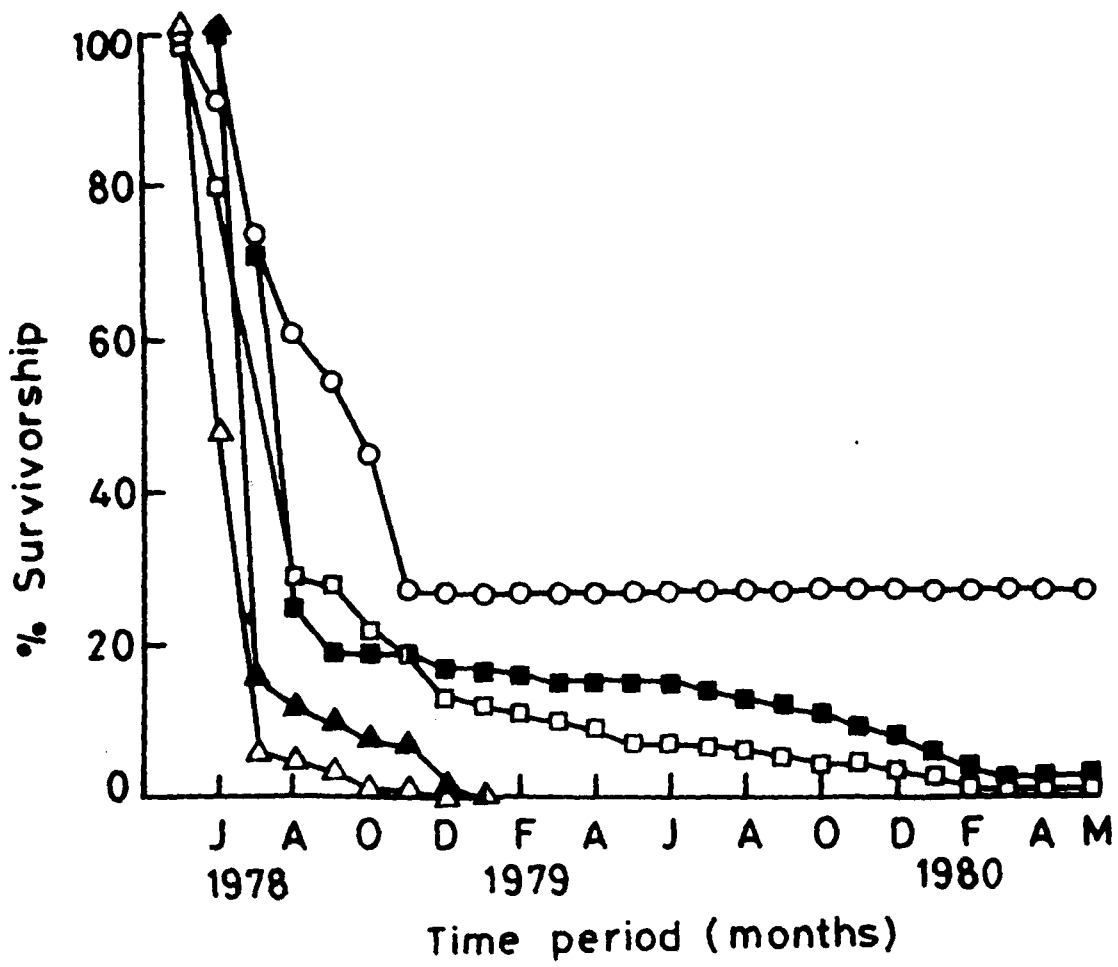
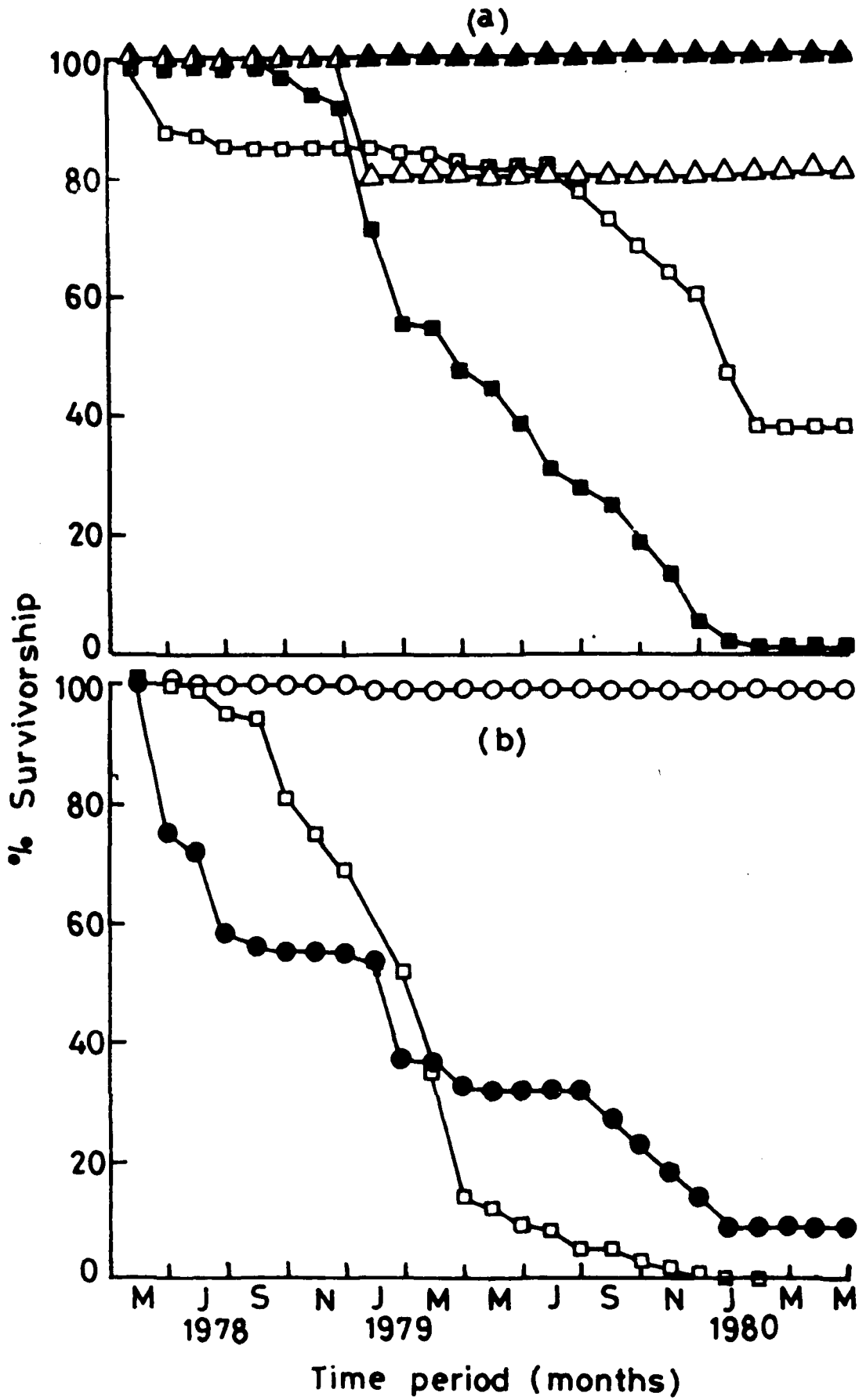


Fig. 2.3a. Survivorship curves of shoots of E. odoratum recruited prior to the start of the study. Three year (□); five year (■); ten year (△); twenty year (▲).

2.3b. Survivorship curves of shoots of E. odoratum recruited in 1978. One year (○); three year (●); five year (□).

FIG.2.3



Age-distribution of dead seedlings and shoots :

Owing to the high turnover rates the number of seedlings that were born and died during the study period was large, indeed larger than the whole living population at the end of the study period. Very few seedlings lived for more than 1.5 year. Highest mortality was observed in the seedlings of 0 - 0.5 year age-class (Fig. 2.4a). In the case of shoots, higher mortality occurred amongst those of 0 - 0.5 and 0.6 - 1.0 year age-classes (Fig. 2.4b).

Age-structure of the living populations :

Age-structure of the populations, already present when the study was started, is shown in Fig. 2.5a which has the individuals, recruited in 1978 and those arising earlier to that date. Observations on the age-structure in May 1979 and in May 1980 showed (Fig. 2.5b and c) that 1 year fallow has maximum number of new recruits originating in 1979 followed by that of 1978. Three and five year fallows had maximum number of new recruits of 1979 followed by those originating prior to the start of the study period. In still older fallows of 10 and 20 years of age no new recruits were found and only those originating prior to the study period, were present.

Reproductive potential of the populations :

The reproductive performance of the individuals in the natural populations was found to be inversely proportional to the fallow age. The seed number per plant also showed similar tendencies. During the second year of the study, there was an increase

Fig. 2.4a. Age-distribution of seedlings of E. odoratum born and died during the study period. Age-classes(year)-0-0.5 (a); 0.6-1.0 (b); 1.1-1.5 (c); 1.6-2.0 (d).

2.4b. Age-distribution of shoots of E. odoratum born and died during the study period. Age-classes (year)-0-0.6 (a); 0.6-1.0 (b); 1.1-1.5 (c); 1.6-2.0 (d).

FIG.24

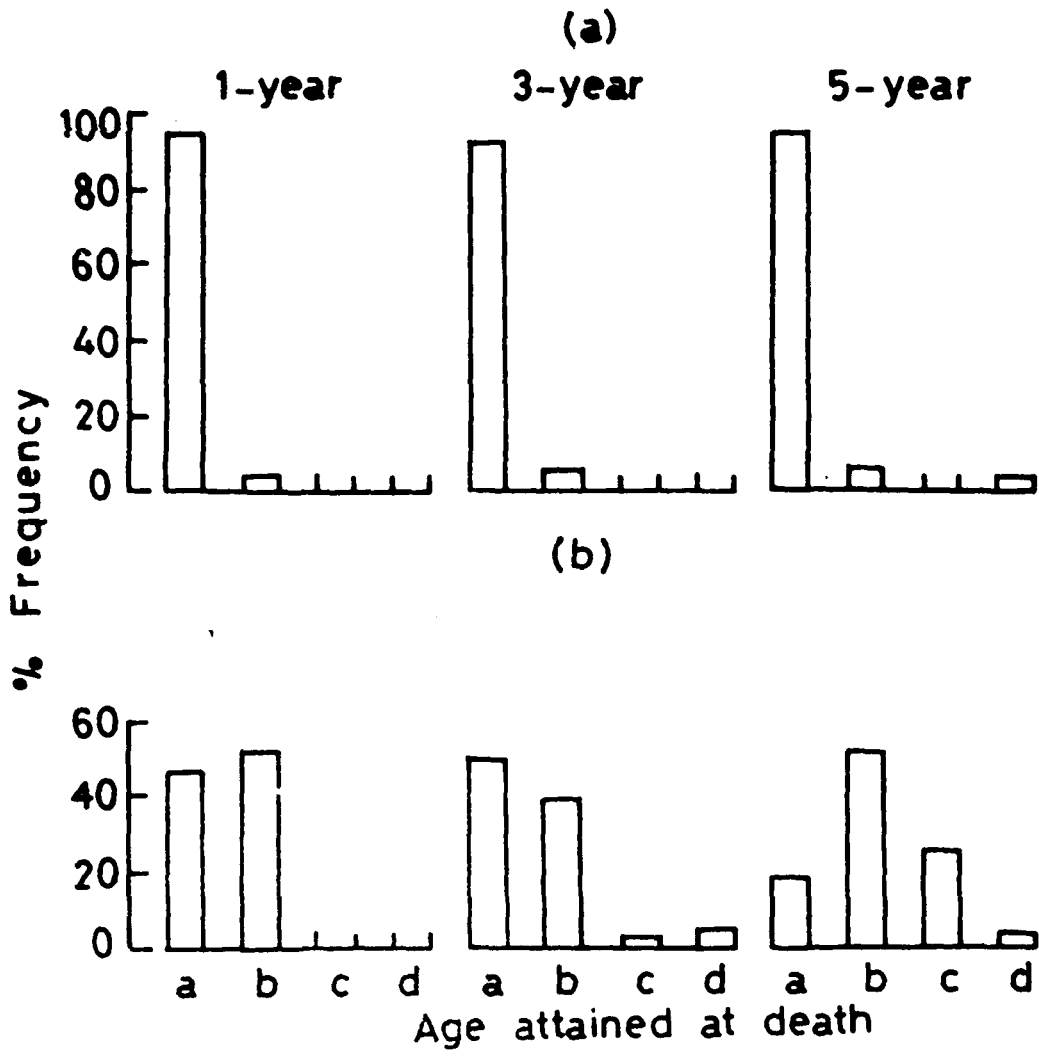


Fig. 2.5. Age-structure of E. odoratum populations in 1978 (a), 1979 (b), and 1980 (c).

FIG.25

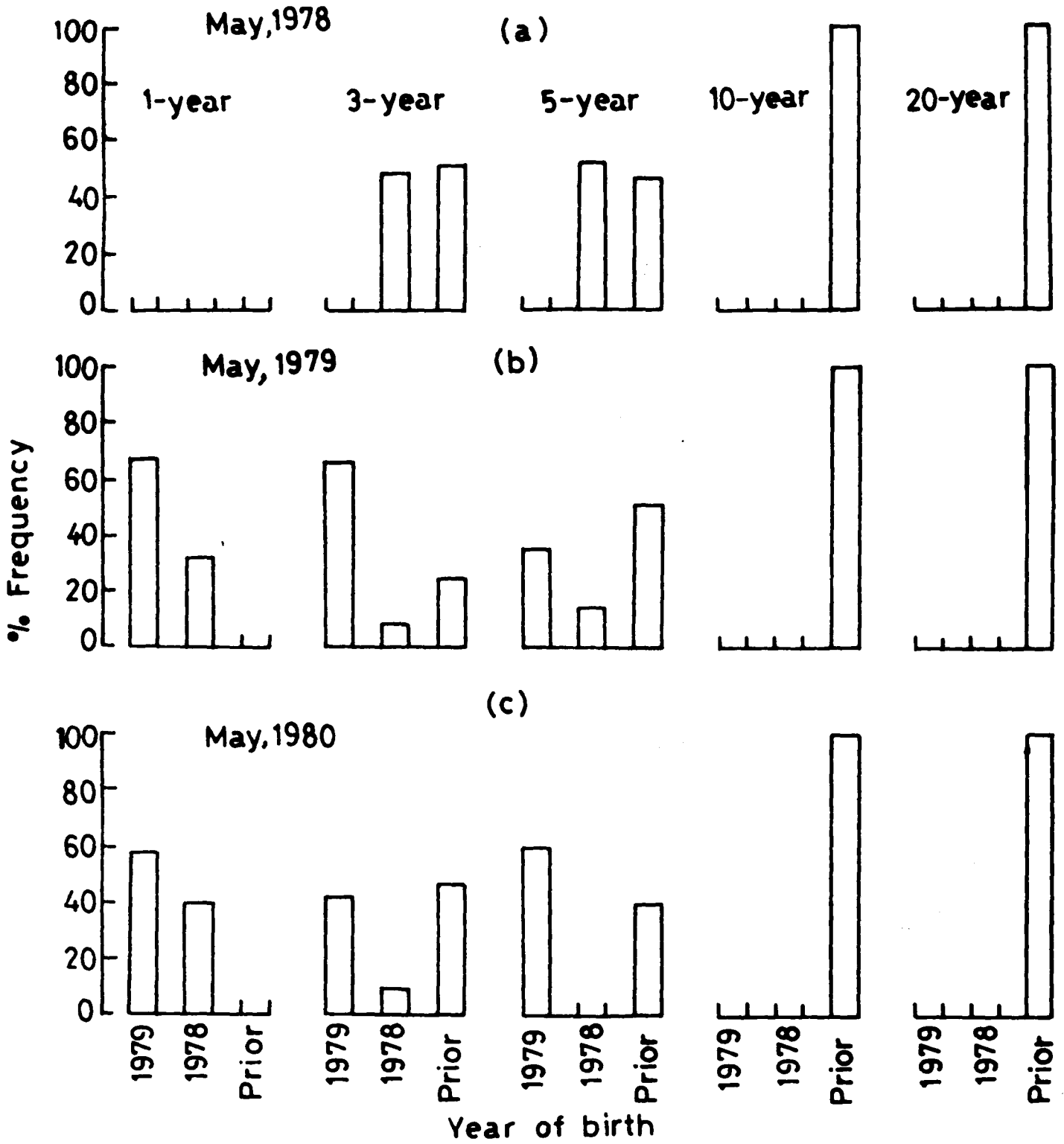


Table 2.4. Reproductive potential of E. odoratum in relation to age of the fallow (based on observations made in May 1979 and 1980).

	Age of the fallow (years)				
	1	3	5	10	20
No. of plants/m ²	100.3 (5.3)	45.0 (153.6)	5.0 (35.0)	2.0 (2.6)	2.0 (2.0)
No. of capitula/plant	188.8 (83.4)	159.0 (97.9)	4.6 (13.8)	0.0 (0.0)	0.0 (0.0)
No. of seeds/plant	5475.2 (2418.5)	4612.2 (2839.7)	133.4 (399.3)	0.0 (0.0)	0.0 (0.0)
No. of seeds/m ²	549160.0 (12818.0)	207548.0 (436185.0)	667.0 (13975.0)	0.0 (0.0)	0.0 (0.0)
Reproductive capacity	2135.3 (943.0)	1798.8 (1107.0)	52.0 (155.0)	0.0 (0.0)	0.0 (0.0)

Data given in parenthesis pertain to the year 1979.

in the number of plants and seeds per m² in 1 year fallow. However, in 3 and 5 year fallows an opposite trend was noted. In 10 and 20 year fallows all plants were sterile. The reproductive capacity worked out to a maximum in a 3 year fallow for 1979 and for a 1 year fallow in 1980. In a 5 year fallow this was very low and was 0 in 10 and 20 year fallows (Table 2.4).

DISCUSSION

During successional development of plant communities a number of edaphic and micro-environmental changes occur. Mineral nutrients and soil moisture status is improved along with the changes in pH conditions of soil with litter accumulation and decomposition. An open community changes into closed one which results in poor light availability and increased potential evapo-transpiration. E. odoratum present in such seral communities, is exposed to these factors during its germination, establishment and development.

The present results show that seedling survival is totally absent in fallow of 5 years of age or older. Recruitment of individuals reached its peak, in a 3 year fallow with no recruitment in the older fallows. The vigour of the population also declined sharply with increase in the age of fallow beyond 3 years. The very few adult individuals already present in 10 and 20 year fallows showed very small or no mortality indicating that adult plants could get adapted to shady habitat without any significant change in their population size as also reported in other species (Chippindale, 1948; Cooper, 1948; Epling and Lewis,

1952; Hutchinson, 1967; Rabotnov, 1969). Thus this species may be able to resume vigorous growth in the open when the vegetation is slashed during jhum.

High rates of mortality during active growth period may be attributed to the increased inter and intra-specific competition for available resources (Ramakrishnan and Kumar, 1971; Sarukhan and Harper, 1973; Hawthorn and Cavers, 1976). The rate of mortality decreased with increase in the age of the seedlings in 1 and 3 year fallows confirming the general assumption that mortality rate declines with age (Sharitz and McCormick, 1973; Sarukhan and Harper, 1973). The survivorship curve thus obtained is Deevey Type III (Deevey, 1947) exhibiting high mortality early in their life cycle.

Such a mortality pattern is also seen for shoots less than a year old, an observation also made by Hutchings and Barkham (1976). The high mortality of seedlings and shoots during the winter season may be due to soil moisture stress as also emphasized by other workers (Raynal and Bazzaz, 1975; Platt, 1975; Sterk, 1975; Johnson and Thomas, 1978). The dryness of the soil may be accentuated by steep slopes and thin soil cover.

The associated species might also play a significant role in governing the population size of a species to a great extent (Odum and Odum, 1959; Harper, 1964). The natural habitats of E. odoratum are often shared by many other thickly populated early and late colonizers offering resource competition to this species though intra-specific competition may also play a significant role (Ramakrishnan and Jeet, 1972).

E. odoratum is a noxious weed coming up in the fallows after slash and burn agriculture which is practised extensively in north-eastern hill region of India. As is evident from this study, the vigour of this species is drastically reduced during secondary succession after about five years. This would imply that this weed was naturally controlled under situations when the jhum cycle was longer. In the past, the jhum cycle used to be about 20 - 30 years which was ideal not only for the recovery of soil fertility under a forested fallow but also for keeping noxious weeds like E. odoratum under control. However, in recent times there has been considerable shortening of the jhum cycle to about 4 - 5 years due to increased population pressure, reduction in the available land for cultivation due to the changed land tenure practices and the consequent changes in man/land ratio. As a result not only the soil fertility recovery of the system is adversely affected but large tracts of land have been taken over by the weeds like the present one and the weed community is maintained more or less in a permanent state of arrested succession.

SUMMARY

This paper reports the studies on the population dynamics of Eupatorium odoratum L. particularly with respect to its recruitment, mortality, population flux and reproductive efficiency in successional plant communities following slash and burn agriculture (jhum). The recruitment and mortality patterns of the individuals in 1, 3, 5, 10 and 20 year old fallows showed

that the seedling population experienced severe mortality in older fallows whereas it was quite low in newer fallows. No recruitment occurred in 10 and 20 year old fallows. The mortality of the adult shoots gave peak values in 5 year old fallow. An attempt has been made to relate the changes in the population size and reproductive efficiency with changing ecological conditions, particularly light in seral plant communities. The implications of the results are discussed in relation to jhum cycle.

CHAPTER 3

POPULATION DYNAMICS OF IMPERATA CYLINDRICA (L.) BEAUV.
VAR. MAJOR RELATED TO SLASH AND BURN AGRICULTURE (JHUM)
IN NORTH-EASTERN INDIA.

INTRODUCTION

Most investigations on plant demography have used annual species, grown either under partly controlled conditions or in glasshouses. Such an approach may enable to study the effect of single variable upon the population to be investigated and to overcome the problems of defining the individual when vegetative reproduction occurs (Hutchings and Barkham, 1976). The population of perennial species, especially the rhizomatous ones under natural conditions, has not received much attention except for some isolated studies (Sarukhan and Harper, 1973; Thomas, 1975).

Imperata cylindrica (L.) Beauv. var. major is a ruderal, weed growing abundantly in cultivated fields, along roadsides and other exposed areas. It is also an early colonizer coming up in the abandoned fallows after slash and burn agriculture (locally known as "Jhum") and is a vigorous weed during the first few years of secondary succession.

A number of observations made by earlier workers show that under slash and burn agriculture in Africa, a short fallow period after cropping encourages vigorous regeneration of this species (Richards, 1952; Nye and Greenland, 1960). According to Beard (1953) this species is highly susceptible to eradication under shade during fallow development. Schlippe (1956) reported that

fire stimulates growth in this species and indicated that it may flower during dry season with little or no rain. According to him repeated burning may create pure stands. In a recent study Eussen and Wirjahardja (1973) have even implicated allelopathy as an important factor governing the succession in this species.

Apart from the above which contribute to its success after fire as an early colonizer, I. cylindrica has extensive underground rhizomes distributed in the top 30 cm of the soil and because of the highly interwoven nature of its rhizomes, it is difficult to demarcate the individuality and age of the clones. Branches which may eventually separate out from the parent, arise from the axillary buds of the nodes of the parent rhizomes. Rhizomes travel horizontally inside the soil for a distance and subsequently may become erect to produce a leafy shoot (tiller). From this erect portion of the rhizome upto a depth of about 5 cm inside the soil, branch rhizomes arise spreading out in all directions. Such a pattern of rhizome production in this species, with clonal growth, helps greatly in its local dispersal.

While vegetative reproduction is more predominant, regeneration also occurs through seeds that are abundantly produced under constant disturbance during April-May. The seeds are light and are easily dispersed during the dry windy period of the year. Seed germination starts with the onset of the monsoon towards the end of May or early June and the active growth period continues upto October with a steady increase in the tiller population. Flowering occurs during March-April only if the plants are clipped or burnt during the dry winter months of December to April. Even late disturbance in May may also induce flowering.

The present study, therefore, was undertaken in order to investigate the population dynamics of I. cylindrica, coming up naturally in jhum fields and in the subsequently developing fallows at the lower elevations of Meghalaya in north-eastern India. The study also involves an analysis of the behaviour of the introduced populations of this species into jhum fallows of upto 20 years age.

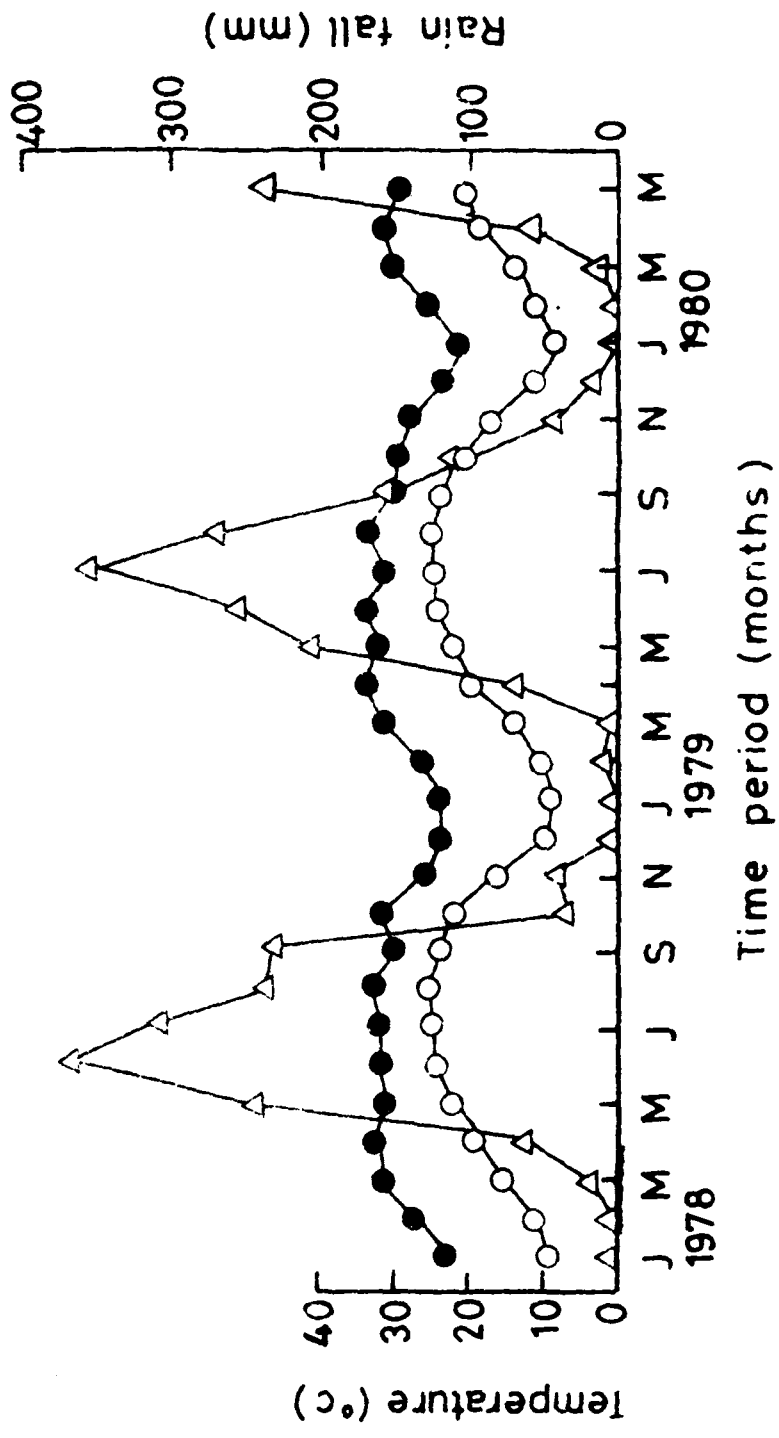
Study area and climate :

The experimental sites are located at Burnihat in Meghalaya (26°02'N latitude and 91°52'E longitude) at an altitude of 100 metres and is about 85 km north of Shillong. Shifting cultivation (jhum) is the predominant form of agriculture in the area and is practised by the Garo tribe. Jhum cycle (the intervening fallow period in between two successive croppings) is often 4-5 years and as a result, I. cylindrica dominates most of the fallows. The area has hilly topography with the angle of slope between 20-40°.

The climate at Burnihat could be divided into three distinct seasons. The dry and windy summer is from mid-February to May with average maximum temperature of 32.2°C and minimum temperature of 24.1°C. The rainy season extends from May to September with an average annual rainfall of 2200 mm. This is warm period with high humidity. The month of October represents the transition from rainy to winter season. The mild winter with an average maximum temperature of 24.8°C and minimum temperature of 12.4°C extends from November to mid-February. This period is practically rainless except for a few winter showers (Fig. 3.1).

Fig. 3.1. Ombrothermic diagram for the study area. Monthly maximum (●) and minimum (○) temperatures; monthly rainfall (Δ).

FIG.3.1



METHODS OF STUDY

Six jhum fallows of 0, 1, 3, 5, 10 and 20 years of age were identified at Burnihat. The age is calculated from the time the site was allowed naturally to regenerate after slash and burn agriculture. Care was taken to select sites of similar exposure and slope conditions. The 0 year fallow was devoid of any I. cylindrica population due to intense weeding by the farmers.

Demographic studies of natural populations of I. cylindrica were carried out in 1, 3 and 5 year fallows in permanent quadrats of 1 m² with three replicates in each of the fallows. In the 3 year fallow alone three additional 1 m² quadrats were placed after removing the other associated species from them. This permitted the study of the effect of associated vegetation on the population. In a preliminary experiment, clipping/burning was done in a 3 year fallow at different times of the year in order to observe the effect of those on flowering of this species. Since clipping/burning was found to induce flowering, only this treatment with 3 replicates was investigated in detail for tiller dynamics and flowering behaviour.

In another experiment, seeds were introduced into 0 (fresh) 5, 10 and 20 year fallows to observe the collective effect of different ecological factors on the seedling emergence and establishment. 3000 healthy seeds/m² were introduced into the fallows in May 1979. Fate of these introduced seeds was followed till the end of the study period for one year upto May 1980. The viability of these seeds as estimated through tetrazolium test, was found to be 90% and they had no dormancy.

Seedlings were labelled with colour paint by putting a dot over the first leaves whilst individual tillers were marked with aluminium labels. A label was fastened to the tiller base at the time it was noted first. A tiller was considered recruited after it emerged and projected aboveground attaining about 3 cm height. Observations were made ~~fortnightly~~ during the growth period (May to October) and at monthly intervals during the lean period (November to April). This permitted the estimation of the current recruitment and mortality at appropriately regular intervals. All the tillers present at the start of the study were assumed to be mature tillers. The populations at the clipped and burnt sites flowered at the end of the dry season. The number of seeds produced by the weed and the seed germination and seedling establishment were recorded.

The rate of death (Lotka, 1925) of mature tillers was calculated as follows:-

$$\text{Rate of death or decay} = \frac{\log_e X_n - \log_e X_{n+1}}{t_{n+1} - t_n}$$

where X_n = surviving plants at time t_n and X_{n+1} = surviving plants at time interval $t_{n+1} - t_n$.

The associated vegetation was studied quantitatively in the fallows using 1 m² quadrats for herbaceous species and 100 m² quadrats for shrubs and trees. Importance value index for each species was calculated as the sum of relative density, relative frequency and relative basal area (Kershaw, 1973). For convenience, the fresh fallow, 1 year fallow, 3 year fallow with associates, 3 year fallow without associates, 3 year fallow burnt,

3 year fallow clipped, 5, 10 and 20 year fallows have been given F_0 , F_1 , $F_3^{(a+)}$, $F_3^{(a-)}$, $F_3^{(b)}$, $F_3^{(c)}$, F_5 , F_{10} and F_{20} as code names in that order.

RESULTS

Associated vegetation :

The early stages of secondary succession upto five years are dominated by a number of weedy species like Imperata cylindrica, Eupatorium odoratum, Thysanolaena maxima, Arundinella bengalensis, Grewia elastica and stump sprouts of many woody climbers, shrubs and trees. Dendrocalamus hamiltonii is one of the important dominants in comparatively older fallows upto 20 years age with a number of other dicot shrubs and trees. The importance value indices for commonly associated species are given in Table 3.1.

Seedling regeneration and its population flux :

The percentage germination of 3000 introduced seeds into each fallow decreased with the increase in the age of the fallow from 72% in 0 year fallow to 31% in 20 year fallow. A majority of loss due to mortality occurred during the first two months (Fig. 3.2a). Out of the 3000 seeds introduced into 0, 5, 10 and 20 year fallows, only about 20% of the germinated seedlings survived in the fresh fallow (0 year) but with 100% mortality in all the others.

3000 and 6001 seedlings/m² respectively were observed in quadrats in a 3 year fallow that were either clipped or burnt.

Table 3.1. Importance value indices of major associated plant species at different sites.

Species	F ₁	F ₃ (a ⁺)	F ₅	F ₁₀	F ₂₀
<u>Ageratum conyzoides</u> L.	14.3	-	-	-	-
<u>Arundinella bengalensis</u> (Spreng) Druce	8.5	8.5	11.6	-	-
<u>Borreria hispida</u> (L.) K. Schum.	18.6	-	-	-	-
* <u>Bauhinia variegata</u> L.	4.4	6.1	7.2	16.9	-
<u>Cyperus globosus</u> Allioni	7.4	10.8	11.1	15.7	15.8
<u>Carex cruciata</u> Nees	-	-	7.9	15.8	16.8
* <u>Careya arborea</u> Roxb.	6.6	10.7	-	15.2	17.1
* <u>Callicarpa arborea</u> Roxb.	3.1	4.3	6.6	10.4	18.8
* <u>Cedrela toona</u> Roxb.	2.9	4.1	4.2	5.7	12.0
* <u>Combretum decandrum</u> Roxb.	1.6	3.5	3.5	7.5	8.8
* <u>Desmodium triquetrum</u> DC.	3.9	4.5	6.5	-	-
<u>Dendrocalamus hamiltonii</u> Nees & Arn.	7.7	8.5	29.4	45.7	55.8
* <u>Dillenia indica</u> L.	3.6	-	11.2	-	30.5
<u>Eupatorium odoratum</u> L.	32.4	171.2	62.1	8.1	5.4
* <u>Eugenia tetragona</u> Wight	3.0	4.8	5.3	9.5	12.5
<u>Ficus hispida</u> L.	5.6	7.3	-	15.9	15.9
<u>Grewia elastica</u> Royle	5.7	6.5	-	-	-
<u>Imperata cylindrica</u> (L.) Beauv.	23.9	34.1	15.2	-	-
* <u>Litsaea assamica</u> Hk. f.	4.6	6.2	-	7.8	-
<u>Mikania micrantha</u> H.B.K.	6.6	4.8	-	-	-
* <u>Macaranga denticulata</u> Muell.	6.7	-	12.2	-	23.5
* <u>Melia azadirachta</u> L.	-	-	3.9	4.2	-
* <u>Mactillus khasyana</u> Meissn.	1.9	2.9	-	-	5.3
* <u>Maesa indica</u> Wall.	4.8	-	5.2	10.0	-
<u>Osbeckia crinita</u> Benth.	5.1	9.3	-	-	-
<u>Panicum maximum</u> Jacq.	7.2	9.3	12.4	14.3	17.8
<u>P. khasianum</u> Munro	7.9	10.5	10.6	-	-
<u>Setaria glauca</u> Beauv.	6.9	7.1	15.0	-	-
<u>Scleria tessellata</u> Willd.	-	7.0	7.1	16.3	16.6
* <u>Schima wallichii</u> (DC) Korth.	5.2	5.8	-	13.3	22.9
* <u>Sapium buccatum</u> Roxb.	2.0	4.7	-	7.8	11.8
<u>Thysanolaena maxima</u> Kuntze	5.8	6.7	11.4	-	-
* <u>Vitex peduncularis</u> Wall.	9.9	-	11.7	42.1	-
* <u>V. glebrata</u> Br.	6.7	7.6	10.6	30.1	31.0

*Stump sprouts.

Fig. 3.2a. Survivorship of the introduced seedlings at different sites. $F_0(\circ)$; $F_5(\bullet)$; $F_{10}(\triangle)$; $F_{20}(\blacktriangle)$.

Inset figure represents percentage germination of introduced seeds at different sites. F_0 (closed column); F_5 (hatched column); F_{10} (stippled column); F_{20} (open column).

3.2b. Survivorship of the natural seedlings at clipped and burnt sites. $F_3^{(c)}(\circ)$; $F_3^{(b)}(\bullet)$.

FIG.3.2

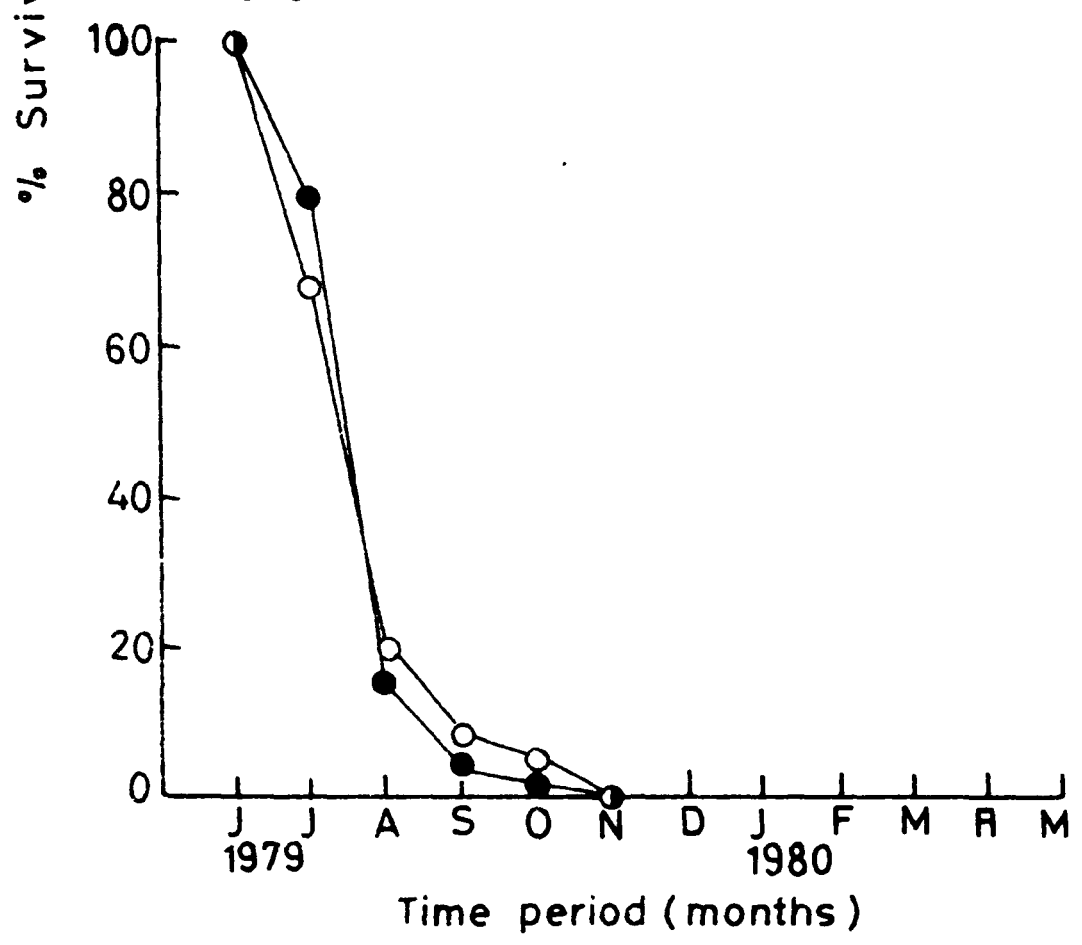
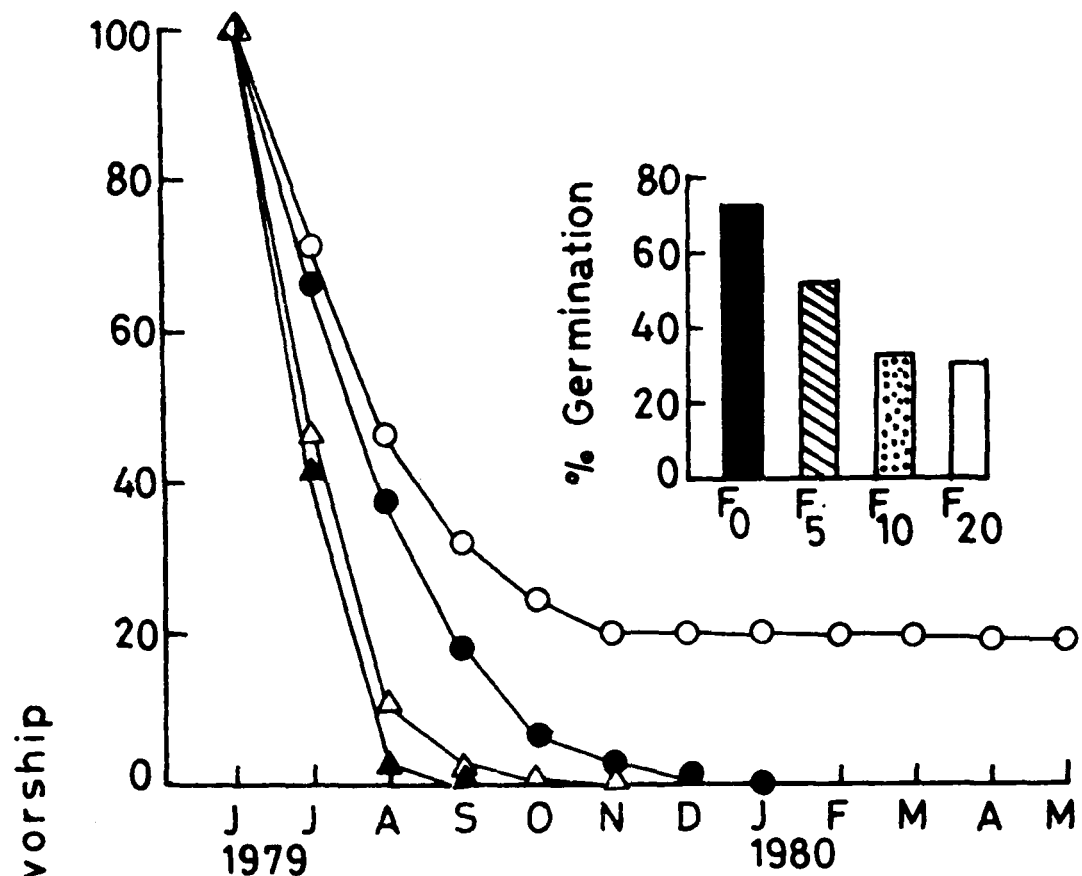


Table 3.2. Population flux of I. cylindrica at different sites.

	F ₀	F ₁	F ₃ ^(a+)	F ₃ ^(a-)	F ₃ ^(c)	F ₃ ^(b)	F ₅
(a) No. of tillers/seedlings/m ² , May 1978.	0.0	149.0	92.3	73.0	0.0	0.0	7.6
(b) No. of tillers/seedlings/m ² , May 1980.	(430.0)	98.4	13.9	321.3	390.0	413.0	0.0
(c) Net change (b-a)	(+430.0)	-50.6	-78.4	+248.3	+390.0	+413.0	-7.6
(d) Rate of increase (b/a)		0.7	0.2	4.4			0.0
(e) No. of tillers/seedlings/m ² arrived between May 1978 and May 1980.	(2164.0)	493.8	100.3	582.3	729.0 (3000.0)	974.0 (6001.0)	35.0
(f) Total number of tillers/ seedlings/m ² lost between May 1978 and May 1980	(1734.0)	544.4	178.7	334.0	339.0 (3000.0)	561.0 (6001.0)	42.6
(g) Tillers/seedlings present May 1978 alive by May 1980	-	40.0	2.0	20.0	-	-	0.0
(h) Percentage survival of tillers/ seedlings in (a) (g/a X 100)	-	26.8	2.1	27.3	-	-	0.0
(i) Expected time for complete turn over (years) $(\frac{2}{100-h} \times 100)$	-	2.8	2.0	2.7	-	-	2.0
(j) Total tillers/seedlings/m ² recorded during study	(2164.0)	642.8	192.6	655.3	729.0 (3000.0)	974.0 (6001.0)	42.6
(k) Annual mortality (%) of tillers/seedlings $(\frac{f}{j} \times 100)$	(80.1)	84.6	92.7	50.9	46.5 (100.0)	57.6 (100.0)	100.0

The values for seedlings are given in parenthesis.

None of these survived till the end of the study period with 100% mortality. Most of the loss of seedlings occurred during the first two months after germination. The survivorship curve was found to be of a negative exponential type with a half life of 39 and 42 days respectively at clipped and burnt sites (Fig. 3.2b).

Tiller regeneration and its population flux :

A net loss of 50.6, 78.4 and 7.6 tillers/m² was noted from the population at the end of the two year study period in 1, 3 and 5 year fallows. A net increase of 248.3, 390 and 413 tillers/m² respectively occurred in the sites in a 3 year fallow which were altered either by removing the associates, by clipping or by burning. The tiller mortality was 84.6, 92.7 and 100% respectively in 1, 3 and 5 year fallows thus showing an increase in the mortality with increase in age of the fallow. The mortality in 3 year fallow sites which were without associates, were clipped or burnt, showed lesser mortality in comparison with the unaltered sites (Table 3.2).

The rate of decay of mature tillers during a 2 year study period starting from June 1978 upto May 1980 in the different fallows is given in Fig. 3.3. In the unaltered fallows of 1, 3 and 5 years the decay rate increased with the passage of time. Peak periods of decay occurred during the peak growth season, during August-September. While in a 1 year old fallow the decay rate was only 1.3% at the end of the 2 year study period, it was 36.9% in a 3 year fallow; in a 5 year fallow 100% decay occurred during a shorter period of less than one year. In 3 year fallow sites that were devoid of associates, decay rate was markedly lower than in the control.

Fig. 3.3. Monthly death rates of mature tillers at different sites. $F_1(\bigcirc)$; $F_3^{(a+)}(\bullet)$; $F_3^{(a-)}(\triangle)$; $F_5(\blacktriangle)$.

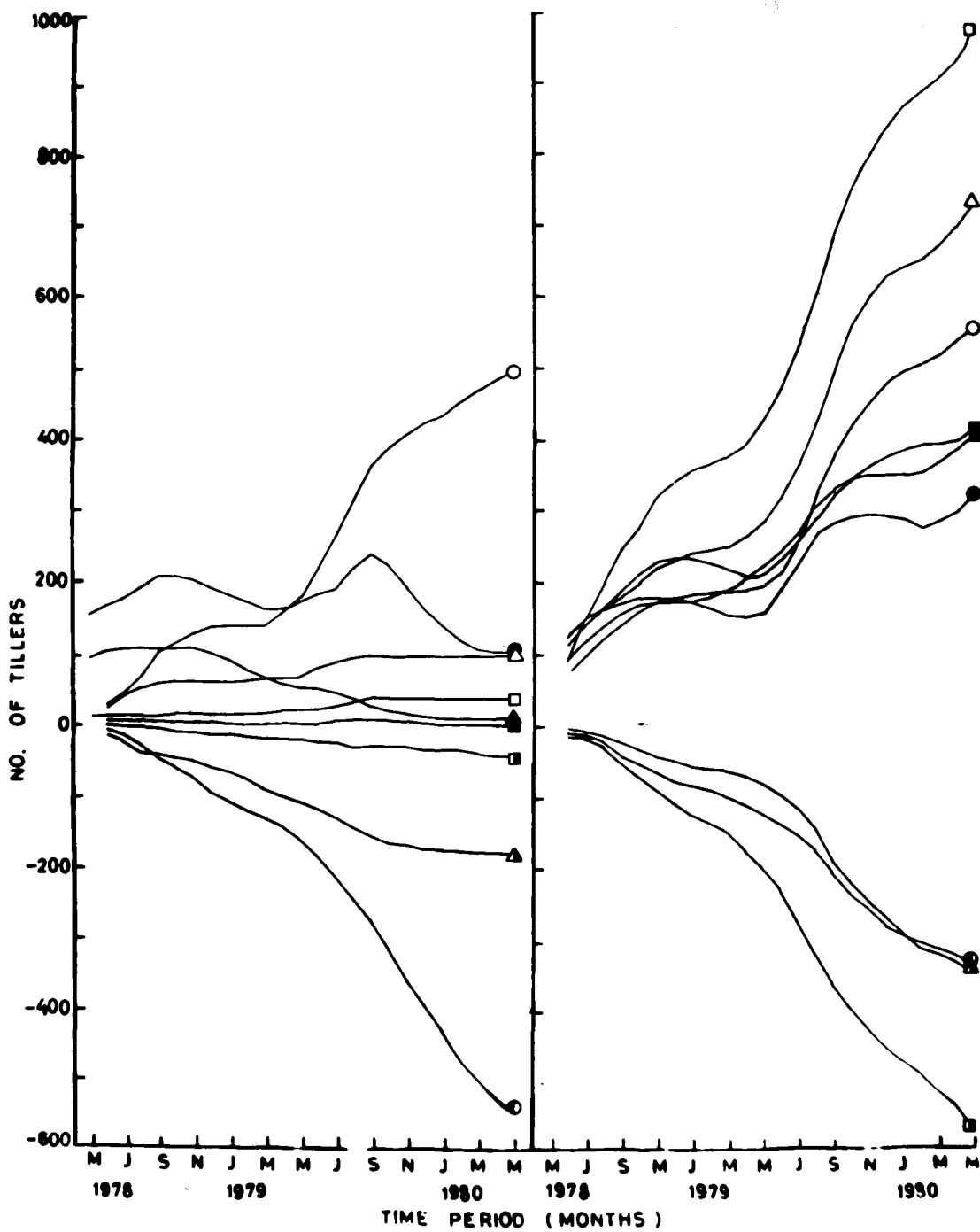
Fig. 3.4a and b show the mortality/natality pattern of tillers in the different fallows of 1, 3 and 5 years of age and in a 3 year fallow that received different alterations. In a 1 year fallow recruitment and mortality increased more sharply during the second year than in the first. However, the net population size decreased at the end of the study period with marked fluctuations in between in such a way that peak population size occurred during September - October. In 3 year fallow, recruitment and mortality did not show any marked seasonal fluctuations but the mortality was much higher than recruitment so that the net population size decreased more sharply at the end of 2 years. In a 5 year fallow, however, the mortality was steady throughout the study period and was higher than recruitment so that even the few tillers that were there in the beginning died away.

In the sites, in a 3 year fallow that were altered (Fig. 3.4b) burning had the most pronounced effect on both recruitment and mortality. Though clipping resulted in lesser tiller recruitment and mortality in comparison to burning, the ultimate population size in both cases was not very different. Removal of the other associates had more adverse effect on recruitment, the net population size remaining smaller due to higher mortality, in comparison with the other two alterations. The seasonal fluctuations in different parameters were similar to that in a 1 year old fallow. Compared to an unaltered 3 year fallow, the altered sites showed higher mortality, recruitment and net population size.

Fig. 3.4a. Changes in the sizes of the tiller populations at unaltered sites. F_1 (circles); $F_3^{(a+)}$ (triangles); F_5 (squares). Open symbol, cumulative recruitment; half closed symbol, cumulative mortality; closed symbol, net population size.

3.4b. Changes in the sizes of the tiller populations at altered sites in a 3 year fallow. $F_3^{(a-)}$ (circles); $F_3^{(c)}$ (triangles); $F_3^{(b)}$ (squares). Open symbol, cumulative recruitment; half closed symbol, cumulative mortality; closed symbol, net population size.

FIG.3.4



Age-structure of tiller populations :

The age-distribution of tillers that came and died during the study period is shown in Fig. 3.5a. This shows that mortality of tillers is maximum in age-classes of 0 to 0.5 year and 1.1 to 1.5 year. This mortality pattern gets more pronounced in the unaltered fallows with age. In the altered sites in a 3 year fallow, particularly those clipped or burnt, the mortality in age-class 1.1 to 1.5 year was much more than in other age-classes.

The age-distribution of the tillers that came prior to study, during 1978 and 1979 and survived till the end of the study period is shown in Fig. 3.5b. Here a larger proportion of older tillers were present in a 1 year fallow. This was reversed in a 3 year fallow and old tillers were eliminated in a 5 year fallow. In altered sites in a 3 year fallow, however, 1 year old tillers dominated the population.

Flowering and seed production :

Flowering occurred only at the sites which were either clipped or burnt during the dry season. The number of tillers/m² at all these sites increased markedly after treatment with slightly more tillers flowering and more seeds per spike in the burnt area than in the clipped area, so that the seed output was more in the former situation. With seeds having about 90 germinability, the reproductive capacity (Salisbury, 1942) of the population in the burnt area was better than in the clipped area (Table 3.3).

Fig. 3.5a. Distribution of ages attained at death by the tillers born during the study at different sites. Age classes (year)-0-0.5 (a); 0.6-1.0 (b); 1.1-1.5 (c); 1.6-2.0 (d).

3.5b. Age-structure of the living tillers in May, 1980 at different sites.

FIG.3.5

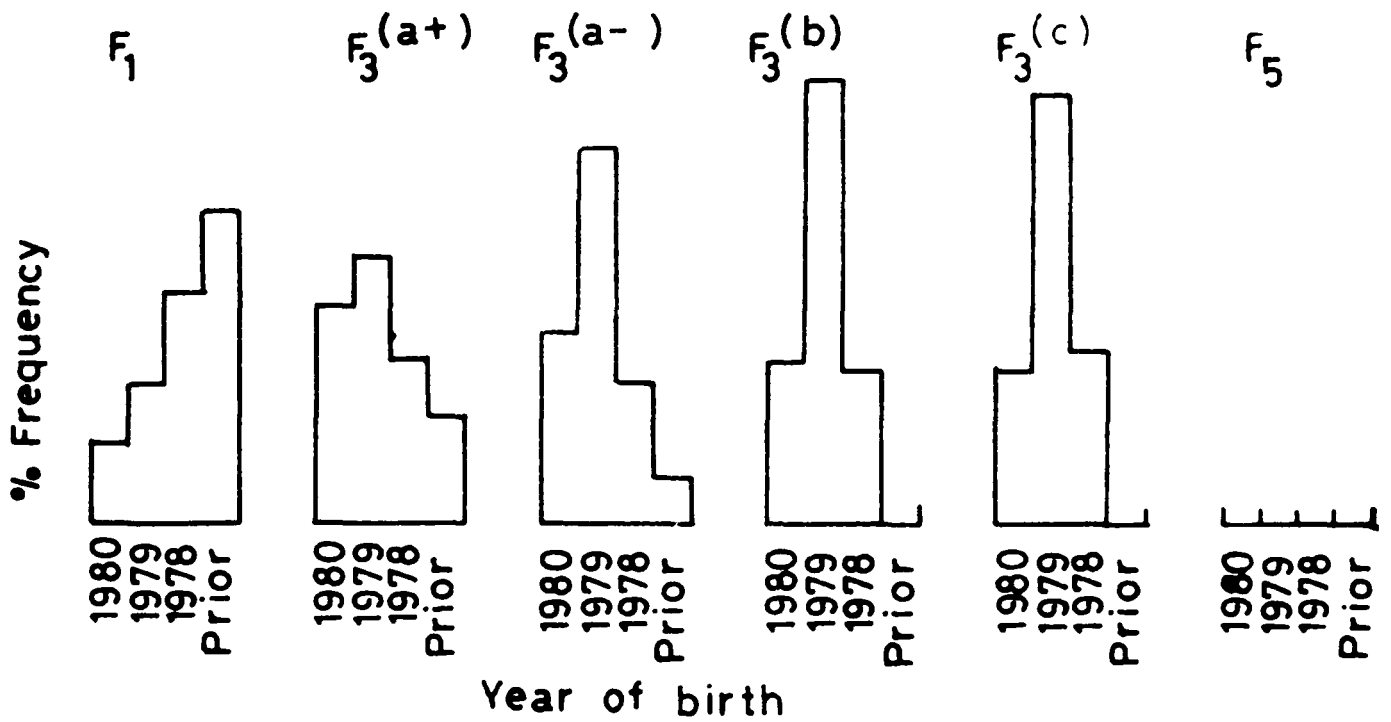
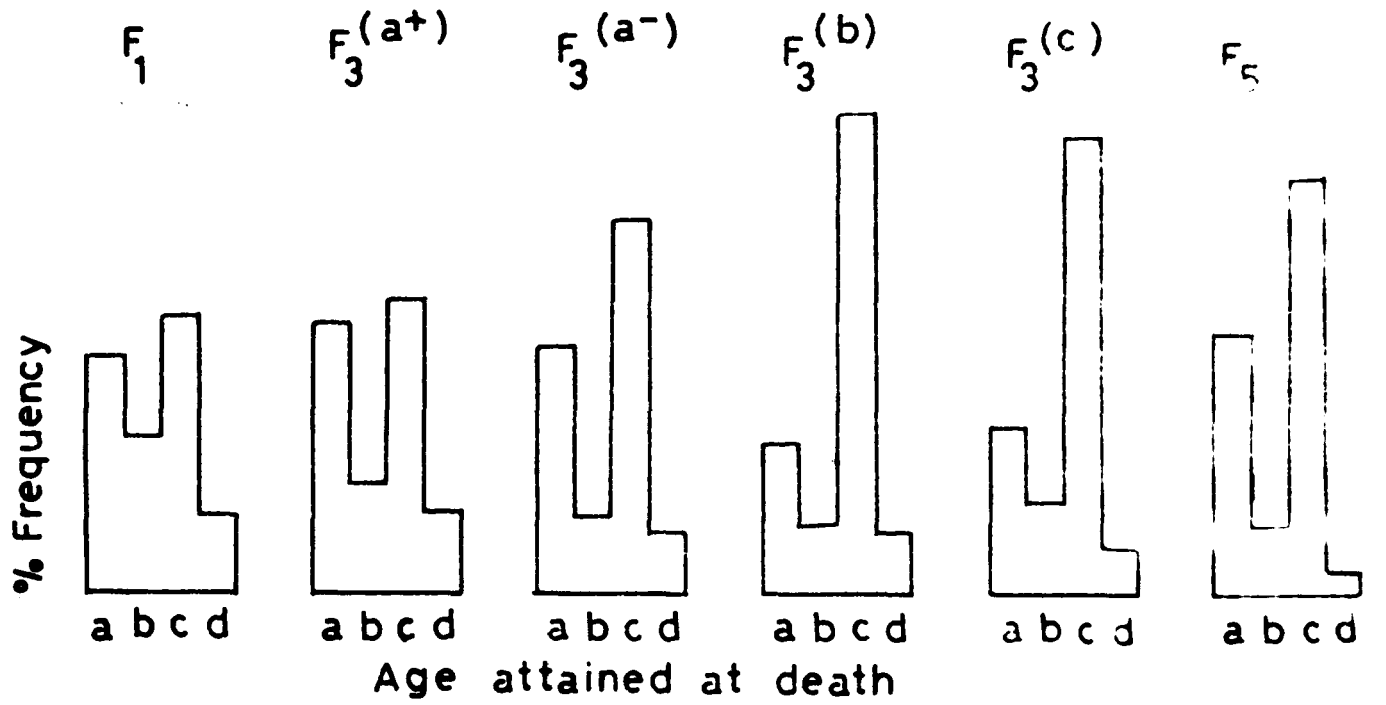


Table 3.3. Reproductive potential of I. cylindrica at clipped and burnt sites.

	Clipped	Burnt
No. of tillers/m ²	390	413
No. of spikes/m ²	130	160
No. of seeds/spike	291	306
No. of seeds/m ²	37830	48960
Mean spike length (cm)	16	19
Average No. of seeds/tiller	97	118
Reproductive capacity/m ²	34047	44064

Mortality, natality and longevity are critical elements in the life cycle of a species. A balance resulting from complex interactions between these three, usually decides whether a species would maintain stability. Population stability is a rare phenomenon in successional habitats where a number of environmental factors change with community development. Seral stages may be short or long lived depending upon the state of disturbance. I. cylindrica found in early successional fallows after jhum, is subjected to frequent cutting and burning which may influence its behaviour and population growth.

In 1, 3 and 5 year fallows the losses to the population may be attributed to the increased stress conditions due to the presence of a large number of associates with their overlapping niches. Thus, introduced seedling regeneration occurred only in a fresh fallow. Further the few individuals of this species present in a 5 year fallow got eliminated completely during the seventh year. These observations along with slow growth rates of this species in shade (Kushwaha et al., unpublished) are indicative of light being an important ecological factor.

The high rates of recruitment and mortality of tillers at the site from where the associated vegetation was removed or the sites that were clipped or burnt, may be attributed partly to the increased availability of light and nutrients and to decreased inter-specific competition. The recruitment of seedlings occurring only in freshly disturbed sites may also be related to the

induction of flowering and fruiting subsequent to disturbance. It may be, however, noted that natural seedling regeneration does not occur even in a freshly abandoned fallow after jhum cultivation.

While the recruitment pattern of the tillers in a 1 year fallow, tended to fluctuate seasonally peaking during the active growth phase, this was not evident in older fallows; in older fallows the net population size declined sharply with the passage of time due to increased mortality in comparison to recruitment. In 1, 3 and 5 year fallows mortality was higher in younger tillers compared to the 3 year fallow sites that were clipped or burnt. This may be indicative of the inter-and intra-specific competition adversely affecting younger tillers in the former sites whereas the age of the tillers is prolonged in the altered sites. The competition in tiller population may get further accentuated due to the interdependency of the individual tillers (through their rhizomes) deriving the resources from same common pool.

Clipping and burning definitely promotes the population growth of I. cylindrica, but flowering is promoted only in those sites which were clipped or burnt during the dry season. Thus the growth strategy of this species seems to be closely adapted to the biotic disturbances during the slash and burn procedures associated with the hill agroecosystems.

I. cylindrica is a noxious weed coming up in fallows after slash and burn agriculture which is prevalent in north-eastern hill region of India. As is evident from the study cutting and

burning have an important role on the growth and reproduction of this species especially when the jhum cycle is short (4-5 years). The vigour of this species is drastically reduced during secondary succession after 3 years when the species with higher canopies shade it out. However, the underground rhizomes do not die and may resume regeneration as soon as the same land is again used for cultivation after 4-5 years.

In the past the jhum cycle was about 20-30 years which was ideal not only for the recovery of soil fertility under a forested fallow but also for keeping noxious weeds like I. cylindrica under control. However, in recent times, there has been considerable shortening of jhum cycle to about 4-5 years due to increased population pressure and consequent changes in man/land ratio. As a result, not only the soil fertility recovery of the system is adversely affected but also large tracts of land have been taken over by weeds like the present one. The shortening of the jhum cycle has also led to the almost pure stands of this weed, occupying vast tracts of land being rendered useless for cultivation on this account.

SUMMARY

Imperata cylindrica (L.) Beauv. var. major is an early successional weed coming up in abandoned fallows after slash and burn agriculture in north-eastern hill region of India and this study concerns itself with the population dynamics and the reproductive potential of this in successional communities. Natural regeneration through seeds occurred to a certain extent only in

freshly burnt or clipped fallows though none of the seedlings survived. Seeds introduced into fallows of different ages of 0, 5, 10 and 20 years could establish upto 20% only in the 0 year fallow. Natural regeneration was mainly through tillers which declined sharply in older fallows so that this species was completely eliminated in fallows older than 5 years. This has been related to the changing micro-environmental conditions in the developing communities.

CHAPTER 4

POPULATION DYNAMICS OF SCLERIA TESSELLATA WILLD. - A SHADE TOLERANT SECONDARY SUCCESSIONAL SPECIES IN SLASH AND BURN AGRICULTURE (JHUM) FALLOWS.

INTRODUCTION

Recruitment of new genets is often rare among clonal plants and the dynamics of their populations is dominated more by birth and death of clonal modules than that of whole genets. The ability of a single genotype to form fragmented phenotypes is just one of the variants in the life history patterns of modular organisms (Harper and Bell, 1979).

The life histories of shoot modules have been studied on spaced populations of several agriculturally important grasses (Lamp, 1952; Langer et al., 1964; Robson, 1968). These studies have shown a definite seasonal pattern of shoot births and deaths ultimately dominated by flowering. Some studies (Gorham and Somers, 1973; Bernard and MacDonald, 1974; Bernard, 1976; Noble et al., 1979) have also been made on the longevity and the reproductive performance of shoot modules.

Scleria tessellata Willd. (Cyperaceae) is a rhizomatous, perennial, sedge found in 5 - 20 year old secondary successional communities coming in fallows after slash and burn agriculture (jhum) in north-eastern India. This species makes its appearance in jhum fallows older than 5 years and increases in density in older fallows. The production is very low and vegetative growth is common with iterative production of shoot modules. The

orthotropic shoots are produced from plagiotropic underground rhizomes. The apical and axillary buds of the rhizomes are protected by dense scale leaves. May to September is the active growth period when maximum shoot recruitment occurs. Shoots start flowering from July onwards with maximum flowering in September - October though some flowering shoots could be identified throughout the year. Seed setting is maximum in November. The large size of seeds does not facilitate its dispersal to far-off places. The present study is an attempt to investigate the dynamics of the clonal and shoot populations in S. tessellata.

METHODS OF STUDY

The fallows of similar exposure (south facing slope) and topography but of different ages, viz., 5, 10 and 20 years, were selected as study sites at Burnihat in Meghalaya (26°.02'N latitude and 91°.52'E longitude) at an altitude of about 100 metres. The age was calculated from the time fields were left as fallow after slash and burn agriculture. For density, frequency and cover, the vegetation analysis of the different associated plant species in the fallows, was done using 1 m² quadrats in the case of herbaceous species and 100 m² quadrats for shrubs and trees. Importance value index was calculated using relative frequency, realative density and relative basal area of the species and are based on 20 quadrats in each site (Misra, 1968; Kershaw, 1973).

Demographic studies were carried out in permanent quadrats of 1 m² with four replicates in each of the fallows. The fates

of the individual clones and shoots of established plants, were followed at monthly intervals over a two year period from May 1978 to May 1980. Both categories of the populations were marked with aluminium labels. Much of the shoot recruitment occurred in June and the fate of these and the others which came afterwards, was followed till the end of the study period. The shoots already present at the start of the study, were taken as more than two years' old, those coming in 1978 as two years' old and those coming in 1979 as one year old. Monthly records of maximum and minimum temperatures and the rainfall were noted for the study period. The number of seeds produced per plant was estimated in 1978 and 1979. The seeds were tested for viability (using trichloro tetrazolium chloride solution) and germinability in petridishes at an alternating temperature regime of 25°/15°C with alternating light and dark periods for 12 hours.

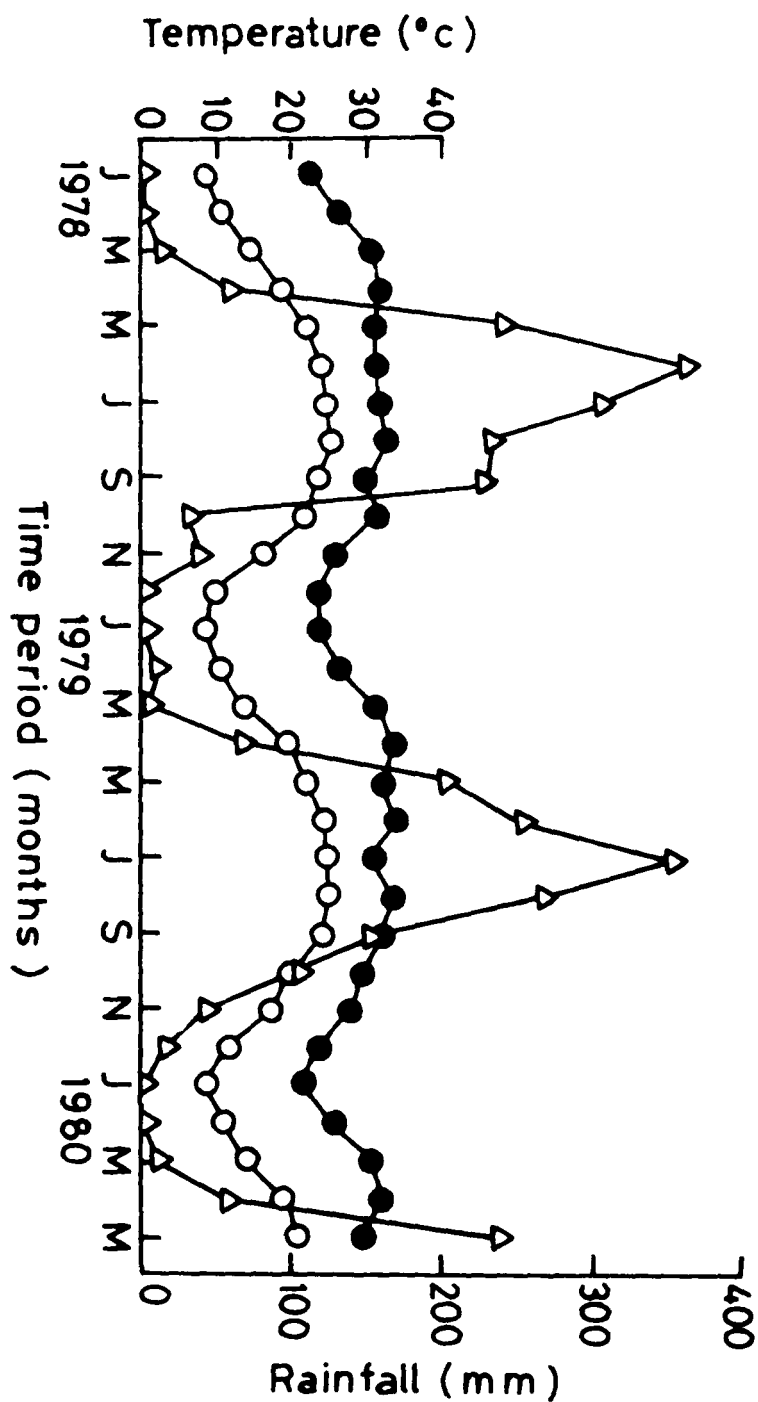
RESULTS

Climate :

The climate at Burnihat could be divided into three distinct seasons. The dry and windy summer extends from mid-February to May with average maximum temperature of 32.2°C and minimum temperature of 24.1°C. The rainy season runs from May to September with an average annual rainfall of 2200 mm. This is a warm period with high humidity. The month of October represents the transition from rainy to winter seasons. The mild winter with an average maximum temperature of 24.8°C and minimum temperature of 12.4°C extends from November to mid-February.

Fig. 4.1. Ombrothermic diagram for the study area. Monthly maximum (●) and minimum (○) temperatures; monthly rainfall (Δ).

FIG4.1



This period is practically rainless except for a few winter showers (Fig. 4.1).

Vegetation :

The early stages of secondary succession upto five years had a number of weedy species like Imperata cylindrica, Eupatorium odoratum Thysanolaena maxima, Arundinella bengalensis, Grewia elastica and stump sprouts of many woody climbers, shrubs and trees. Dendrocalamus hamiltonii is one of the important species coming up in 5 year old fallows, and reaching maximum numbers in 20 year fallows, alongwith a few dicot shrubs and trees. The importance value indices for the commonly associated plant species are given in Table 4.1.

Population flux and survivorship of clones :

If clones are considered as individuals, no loss was noticed in 5 and 10 year fallows. Only in a 20 year fallow there was a loss of one plant per m² during the two year study period. No seedling recruitment could be noted during the study period (Table 4.2).

Population flux and survivorship of shoots :

An addition of 3.4 and 3.0 shoots was noted in 5 and 10 year fallows during the two year period whereas 16 shoots were eliminated from a 20 year fallow. Shoot recruitment increased from 15.2 to 56.0 with increase in the age of the fallow from 5 to 20 years. Mortality of the shoots already present at the

Table 4.1. Importance value indices of commonly associated plant species in the fallows of different ages.

Species	Age of the fallows (years)		
	5	10	20
<u>Ageratum conyzoides</u> L.	-	-	-
<u>Arundinella bengalensis</u> (Spreng) Druce	11.6	-	-
<u>Borreria hispida</u> (L.) K. Schum.	-	-	-
<u>Bauhinia variegata</u> L.	7.2	16.9	-
<u>Cyperus globosus</u> Allioni	11.1	15.7	15.8
<u>Carex cruciata</u> Nees	7.9	15.8	16.8
* <u>Careya arborea</u> Roxb.	-	15.2	17.1
* <u>Callicarpa arborea</u> Roxb.	6.6	10.4	18.8
* <u>Cedrela toona</u> Roxb.	4.2	5.7	12.0
* <u>Combretum decandrum</u> Roxb.	3.5	7.5	8.8
<u>Desmodium triquetrum</u> DC.	6.5	-	-
<u>Dendrocalamus hamiltonii</u> Nees & Arn.	29.4	45.7	55.8
* <u>Dillenia indica</u> L.	11.2	-	30.5
<u>Eupatorium odoratum</u> L.	62.1	8.1	5.4
* <u>Eugenia tetragona</u> Wight	5.3	9.5	12.5
<u>Ficus hispida</u> L.	-	15.9	15.9
<u>Grewia elastica</u> Royle	-	-	-
<u>Imperata cylindrica</u> (L.) Beauv.	15.2	-	-
* <u>Litsaea assamica</u> Hk. f.	-	7.8	-
<u>Mikania micrantha</u> H.B. & K.	-	-	-
<u>Macaranga denticulata</u> Muell.	12.2	-	23.5
* <u>Melia azadirachta</u> L.	3.9	4.2	-
* <u>Machillus khasyana</u> Meissn.	-	-	5.3
* <u>Maesa indica</u> Wall.	5.2	10.0	-
<u>Osbeckia crinita</u> Benth.	-	-	-
<u>Panicum maximum</u> Jacq.	12.4	14.3	17.8
<u>P. khasianum</u> Munro	10.6	-	-
<u>Setaria glauca</u> Beauv.	15.0	-	-
<u>Scleria tessellata</u> Willd.	3.2	-	-
* <u>Schima wallichii</u> (DC) Korth	7.1	16.3	16.6
* <u>Sapium buccatum</u> Roxb.	-	7.8	11.8
<u>Thysanolaena maxima</u> Kuntze	11.4	-	-
* <u>Vitex peduncularis</u> Wall.	11.7	42.1	-
* <u>V. glabrata</u> Br.	10.6	30.1	31.0

Table 4.2. Population flux of the clones of
S. tessellata.

	Age of the fallows (years)		
	5	10	20
(a) No. of plants/m ² , May 1978	1.3	4.0	7.0
(b) No. of plants/m ² , May 1980	1.3	4.0	6.0
(c) Net change (b-a)	0.0	0.0	-1.0
(d) Rate of increase (b/a)	1.0	1.0	0.9
(e) No. of plants arrived between May 1978 and May 1980	0.0	0.0	0.0
(f) No. of plants lost between May 1978 and May 1980	0.0	0.0	1.0
(g) Plants present May 1978 alive by May 1980	1.3	4.0	6.0
(h) % survival of plants in (a) (g/a x 100)	100.0	100.0	85.7
(i) Expected time (years) for complete turnover (2/100-h x 100)	∞	∞	14.0
(j) Total plants recorded during study	1.3	4.0	7.0
(k) % mortality of individuals (f/j x 100)	0.0	0.0	14.3

Table 4.3. Shoot population flux of S. tessellata.

	Age of the fallows (years)		
	5	10	20
(a) Shoots/m ² , May 1978	2.6	16.0	42.0
(b) Shoots/m ² , May 1980	6.0	19.0	26.0
(c) Net change (b-a)	+3.4	+3.0	-16.0
(d) Rate of increase (b/a)	2.3	1.2	0.6
(e) No. of shoots arrived between May 1978 and May 1980	15.2	36.0	56.0
(f) No. of shoots lost between May 1978 and May 1980	11.8	33.0	72.0
(g) Shoot present May 1978 alive by May 1980	0.0	2.0	6.0
(h) % survival of shoots in (a) (g/a x 100)	0.0	12.5	14.3
(i) Expected time for complete turnover (years) (2/100-h x 100)	2.0	2.3	2.3
(j) Total shoots recorded during study	17.8	52.0	98.0
(k) % mortality of all shoots (f/j x 100)	66.3	63.5	73.5
(l) % mortality of arrivals	60.5	52.8	64.3

beginning of the study period was 100% in a 5 year fallow due to flowering and subsequent death of the population whereas this decreased in 10 and 20 year fallows. The mortality amongst the new arrivals was less than the mortality amongst the whole population which ranged between 66 - 74%. The mortality of shoots was generally high with a maximum in a 20 year fallow (Table 4.3). Survivorship of shoots showed age specific mortality with Deevey Type II (Deevey, 1947) curves (Fig. 4.2).

Age-distribution of dead shoots :

The age-distribution attained at death by the shoots which came and died during the study period, is shown in Fig. 4.3. The shoots which flowered during September - November, died in the following November - January. The shoots recruited in June either flowered in the same year upto October or remained vegetative until the next flowering season (July - October) of the following year. Shoot mortality was maximum after the flowering season rather than in between during vegetative growth period as seen from column (a) and (c) in Fig. 4.3a which represent the vegetative period of growth. On the other hand mortality was maximum under column (b) and (d) which represent the end of the flowering period. In general, more mortality occurred in shoots of 1.5 to 2 years of age rather than after 0.5 to 1 year.

Age-structure of living shoot populations :

At the end of the study period, one year old shoots were more frequent than those of 2 years or more of age. While there was a slight decline of one year old shoots in 10 and 20 year

Fig. 4.2. Survivorship of shoots of S. tessellata in different fallows. 5 year old fallow (○); 10 year old fallow (△); 20 year old fallow (□).

FIG.4.2

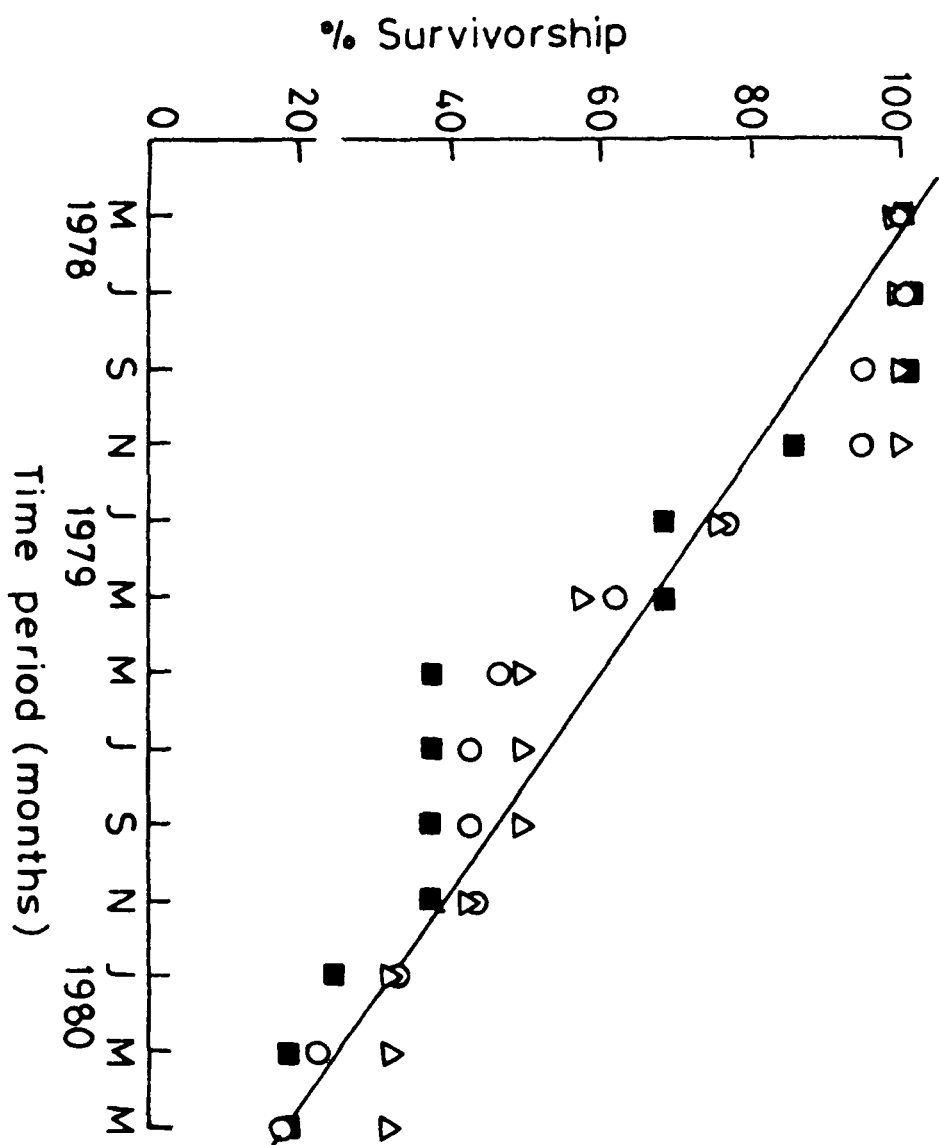
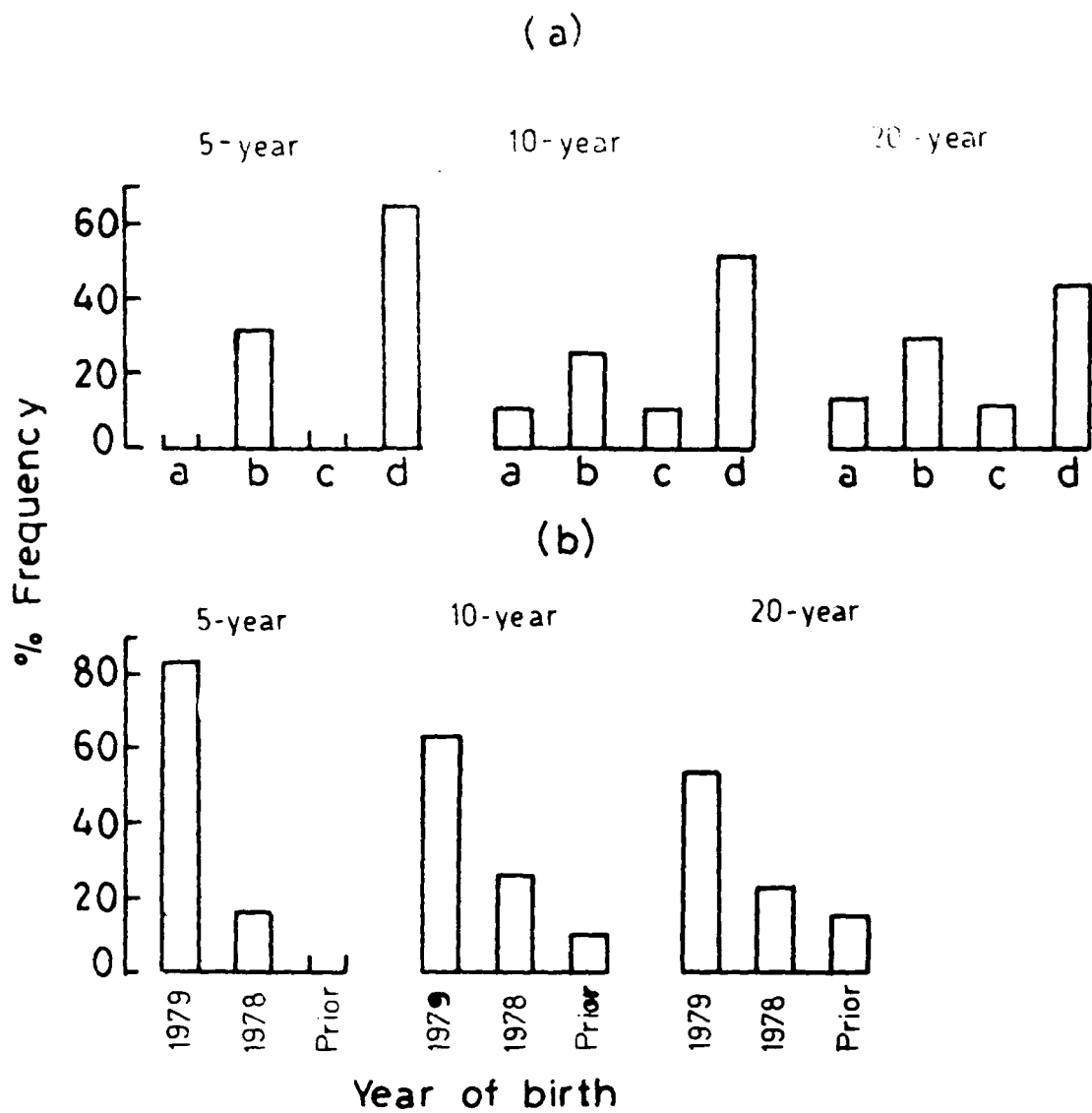


Fig. 4.3a. Age-distribution of the shoots of S. tessellata born and died during the study period in different fallows. Age-classes(year)-o-0.5 (a); 0.6-1.0 (b); 1.1-1.5 (c); 1.6-2.0 (d).

4.3b. Age-structure of the living shoots of S. tessellata in May, 1980 in different fallows.

FIG.4.3



fallows compared to a 1 year fallow, the older shoots had higher frequency in older fallows (Fig. 4.3b).

Reproductive potential of the populations :

The percentage of fertile shoot population declined with the age of the fallow between 5 and 20 years. However, because of the larger clone size in a 20 year fallow, the seed output per m² here was markedly higher (Table 4.4).

DISCUSSION

Clonal growth is a common feature in the life of herbaceous perennials that may help in the extension of a population of shoots of a single genet in time and space. The present investigations reveal that the population size of the clones of S. tessellata, is relatively stable in different fallows and that most of the changes occur at the sub-population level (shoots). The number of clones present at the start of the study varied in the three fallows. This is indicative of either clonal spread of the species by vegetative growth or by seedling recruitment. However, since no seedling could be detected in the sites throughout the study period, it is probable that seeds have little significance in maintenance and spread of this as is also shown by Major and Pyott (1966) for other species. In a survey of a wide range of British species, Salisbury (1942) showed that the species from shaded habitats rarely produce more than $3 - 4 \times 10^2$ seeds per plant. In S. tessellata, most of the seeds are non-viable lacking properly developed embryo. Herberd (1967)

Table 4.4. Reproductive potential of S. tessellata in different fallows.

	Age of fallows (years)		
	5	10	20
No. of clones/m ²	1.3 (1.3)	4.0 (4.0)	6.0 (7.0)
% fertile shoots/m ²	80.0 (100.0)	62.5 (68.7)	63.6 (83.3)
No. of shoots/m ²	5.0 (2.6)	16.0 (16.0)	22.0 (42.0)
No. of seeds per clone	20.0 (12.0)	15.0 (14.3)	18.0 (16.0)
No. of seeds/m ²	15.6 (26.0)	60.0 (57.0)	108.0 (112.0)

The values in parenthesis pertain to the values obtained in 1979.

too, demonstrated the significance of vegetative growth for the persistence of the populations in older successional communities. According to him, seeds have very little chance of survival in a closed community of perennials and the role of sexual reproduction may be obscure in such communities.

The changes at sub-population level (shoots) are particularly significant when the species turnover is slow. The survivorship of shoots showed a constant mortality risk with seasonal fluctuations. The period with comparatively higher mortality mostly coincides with flowering. The flowering shoots were observed dying after seed production. Some mortality was also noted just after emergence of shoots when they have attained an age of about a month. The mortality of such newly emerged shoots might be due to their susceptibility to inter-specific competition afforded by the associated vegetation. However, if once the shoot development proceeds normally, the chances of mortality become lesser. Thus the shoot mortality seems to be age-dependant giving a Deevey Type II, negative exponential curve and is less influenced by environmental conditions.

The seed output in this species is exceptionally low with only about 5% seed viability. None of the seeds germinated in the laboratory indicating that possibly they require some after-ripening period for germination. Seeds are heavy and do not possess any morphological specialisation for their wide dispersal and thus there is a fair chance of their dispersal around the parent plant. The absence of seedlings at the sites colonized by S. tessellata implies that the seeds are either predated upon or

lost otherwise. In contrast, individuals produced asexually, have the advantage of belonging to the genotypes already tested for suitability in the environment and of obtaining from the parent a good material start in life.

SUMMARY

Scleria tessellata Willd. is a sedge coming up in 5 - 20 year old secondary successional communities, developing after slash and burn agriculture (Jhum) in north-eastern hill region of India. While the clone populations in all the fallows remained considerably stable throughout the study period, the shoot populations had high turnover rates. The vegetative vigour and the seed output by the clones increased with the increase in the fallow age. The seed output in general was very low, the reproductive strategy being directed towards vegetative regeneration.

CHAPTER 5

COMPETITIVE RELATIONSHIPS OF THE PLANTS OF IMPERATA CYLINDRICA
(L.) BEAUV. VAR. MAJOR ESTABLISHED FROM RHIZOMES AND FROM SEEDS.

INTRODUCTION

Some studies have been done on the performance of species populations in mixtures which normally do not coexist in nature (Tripathi and Harper, 1973; Gupta and Ramakrishnan, 1977a, 1977b). Many studies have also been made to compare the growth in mixture of closely related species which commonly coexist in nature (Harper and Chancellor, 1959; Sagar and Harper, 1961; Harper and McNaughton, 1962; Harper and Clatworthy, 1963; Cavers and Harper, 1967; Marshall and Jain, 1969; Ramakrishnan and Jeet, 1972; Ramakrishnan and Bala, 1976). However, the study on the relative competitive ability of individuals of the same species, produced from seeds (genets) and from rhizomes (ramets) has not received due attention. An investigation into their competitive behaviour may add to our understanding of natural coexistence of the two categories of plants and their ultimate contribution to the population maintenance. Such an experiment may be of great significance under the situations where a particular plant species reproduces sexually as well as asexually (through vegetative means). The plant species selected for the present study, Imperata cylindrica, falls in this category. The species is an early successional weed coming up in fallows developing after slash and burn agriculture (locally called 'jhum') in north-eastern hill areas of India (Ramakrishnan et al., 1980).

It has been shown that the seeds of I. cylindrica, when introduced into natural communities, have rare chance of survival except in fresh fallows with sparse vegetation (Kushwaha et al., unpublished). The failure of individuals to survive on such sites may be in part a function of the competitive interaction between established and the establishing individuals of this species which can be studied conveniently by growing them in mixtures and in monocultures. This experiment was planned to simulate the natural conditions where the light seeds in this species are blown off and dispersed widely into alien community, dominated by I. cylindrica, where on getting favourable conditions, they may germinate to give rise to the genets. The success of these genets would depend upon the "stress" created by its own asexually produced allies and the other associated plant species.

METHODS OF STUDY

Seeds and rhizomes were collected from Burnihat in Meghalaya. Pure and mixed populations were raised from the two categories of reproductive units in plastic pots of 20.8 cm diameter in the experimental garden at Burnihat. Pots were filled with 2:1 mixture of garden soil and the organic manure. Soil and manure mixture was thoroughly mixed to remove any soil heterogeneity before transplantation. Plants from rhizome cuttings (each cutting had a node and a healthy bud) and from seeds were raised separately for monocultures. Monoculture studies comprised of 30, 60, 120, 240, 480 and 960 plants/m². For mixed culture studies, de Wit's replacement method (de Wit, 1960), with varying

proportions of the two populations keeping overall density constant, was used. Transplantation of rhizome cuttings and seedlings was done early in the month of June, when plants were two-leaved and uniformly 2 cm in height. The mixture proportions for the two types were: 600+0, 300+300 and 0+600 per m².

Plants were watered daily till the last harvest (after 24 weeks) so as to provide sufficient moisture to them. Three harvests were taken for mixture experiments after 8, 16 and 24 weeks but only one harvest was done after 24 weeks, for pure cultures. The harvests coincided with different growth periods of the plant. At each harvest, plants were thoroughly washed at the spot with water and were taken to the laboratory for various estimates. From the yield data relative yield total (RYT) (de Wit and van den Bergh, 1965), and relative yield quotient (RYQ) (Tripathi and Harper, 1973), and relative replacement rate (RRR) (van den Bergh, 1968), were derived. For convenience, the plants produced from rhizomes and from seeds, have been designated as "rhizome" and "seed" respectively wherever required.

RESULTS

Performance of the two populations in pure stands:

The two categories of plants showed varied degree of mortal and plastic responses to increasing density. In general, the height of the plant, leaf area, number of tillers and rhizomes, all decreased with increase in density in monocultures. Generally, the populations raised from rhizomes had higher values for these

Fig. 5. . Effect of density on plant height (3a), leaf area (3b), number of tillers (3c) and rhizomes (3d) per plant of I. cylindrica plants grown from rhizomes (open columns) and from seeds (closed columns).

FIG.5.1

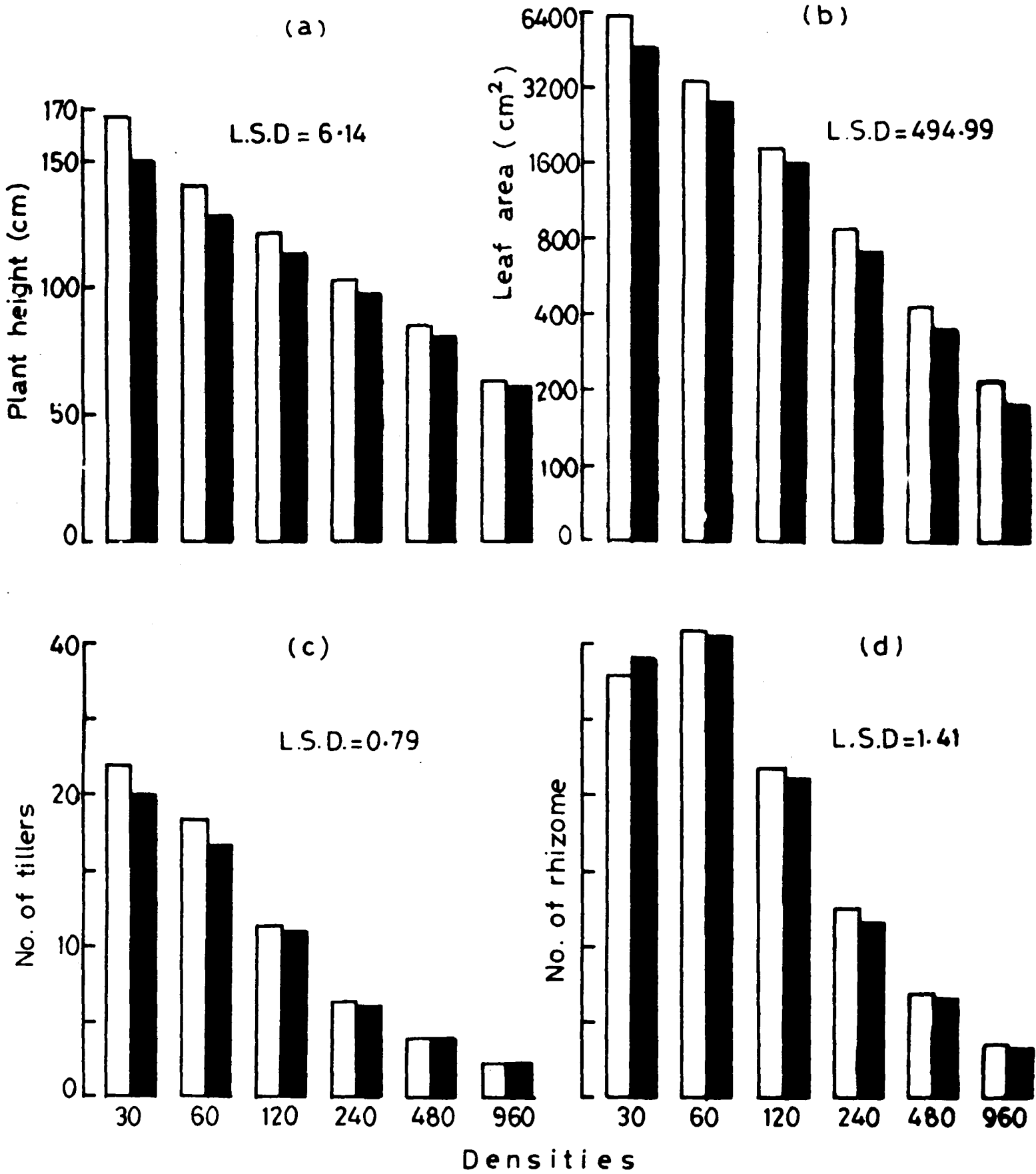
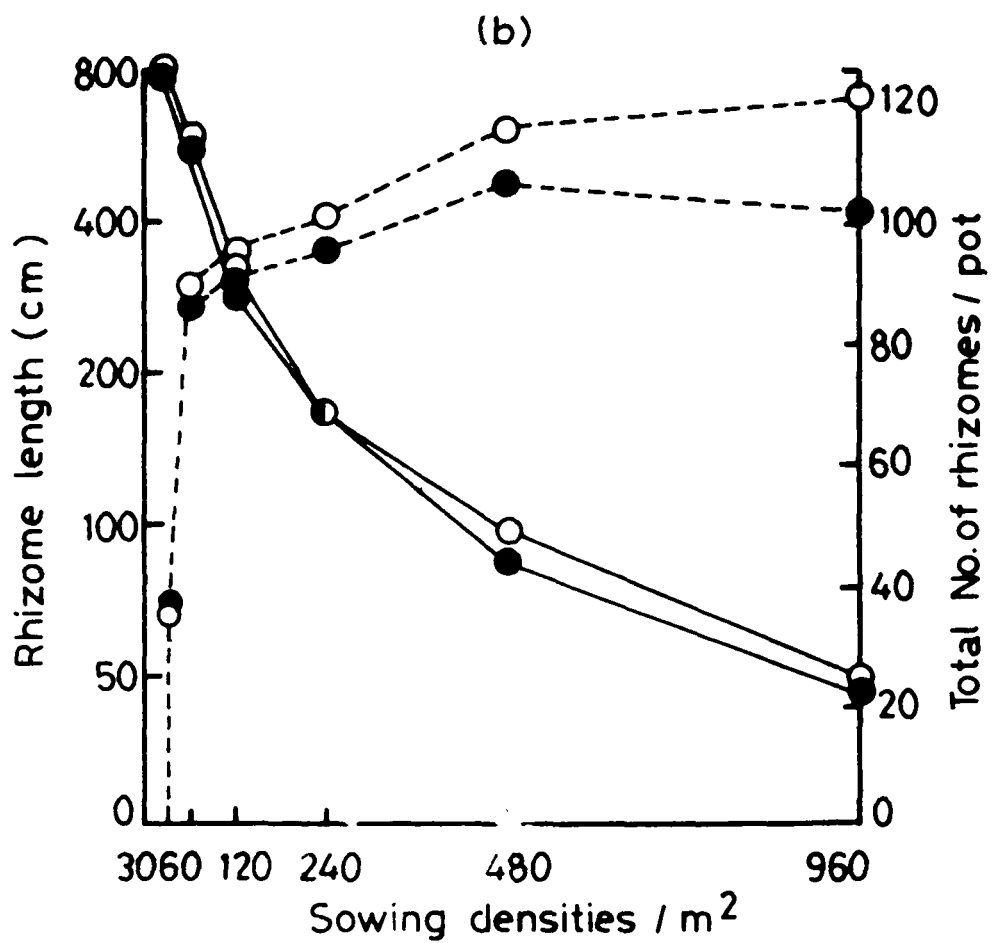
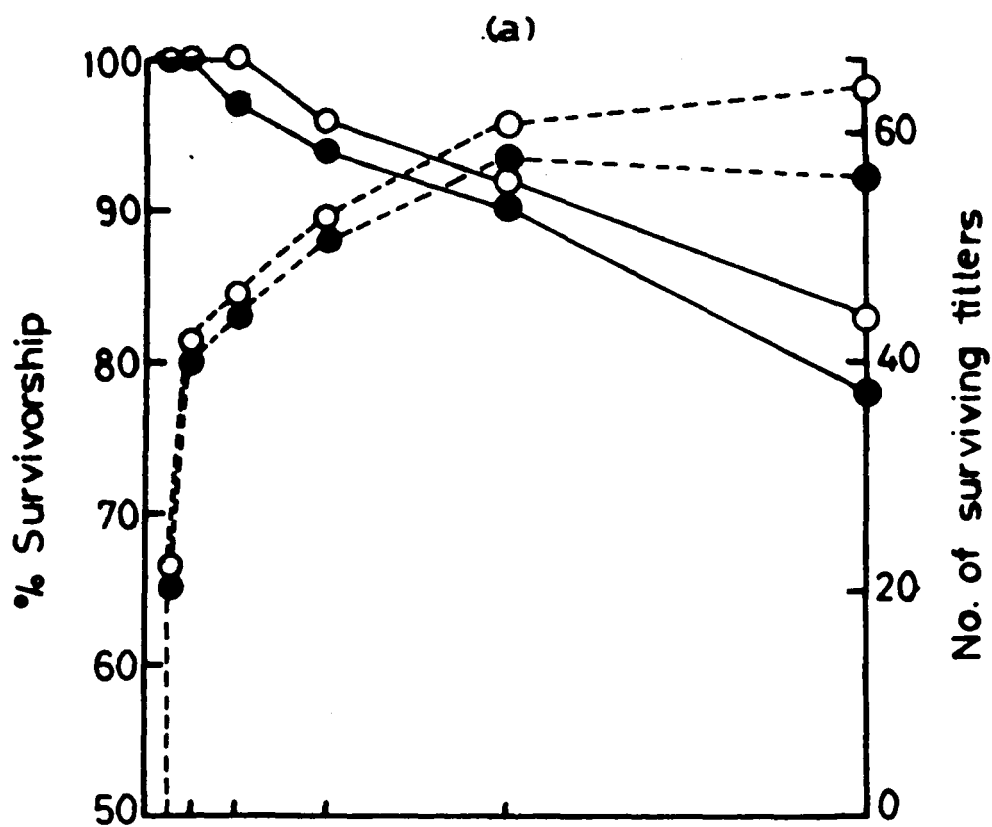


Fig. 5.2a. Effect of density on survivorship (—) and total number of surviving tillers (---) of I. cylindrica. Open symbol, I"rhizome"; closed symbol, I"seed".

5.2b. Effect of density on rhizome length per plant (—), and total number of rhizomes per pot (---) of I. cylindrica. Open symbol, I"rhizome"; closed symbol, I"seed".

FIG.5.2



parameters compared to that raised from seeds. Further these differences between the two categories were more pronounced at lower densities than at higher densities (Fig.5.1).

Increase in its own density resulted in greater percentage mortality of both categories of plants. The ultimate number of tillers, that survived, tended to attain a plateau level at higher densities after a sharp rise with initial density increase. The population raised from rhizomes tended to have higher survivorship compared to that raised from seeds and this became more marked at higher densities (Fig.5.2a). Average length of rhizome per plant, decreased with increase in density, whereas the number of rhizomes produced increased, for both categories of plants. This latter parameter was higher for plants originating from rhizomes compared to the seed produced ones, particularly at higher densities (Fig.5.2b).

Tiller production in both categories of plants increased sharply upto 16 weeks of growth, which was marked only at lower densities of 30 and 60 plants/m². At higher densities of (e.g. 960 plants/m²), tiller production did not increase markedly with time. At a given density, the differences between the plants raised through rhizome and seed, were not much different though it was slightly higher in the case of rhizome population (Fig.5.3).

Performance of the two populations in mixed stands:

The total yield of mixtures was lower than the yield in monocultures of equal density. At the final (third) harvest, both

Fig. 5.3. Effect of density on tiller production of the plants of I. cylindrica grown from rhizome (—) and from seeds (---). Densities: 1(○); 2(●); 4(△); 8(▲); 16(□); 32(■).

FIG5.3

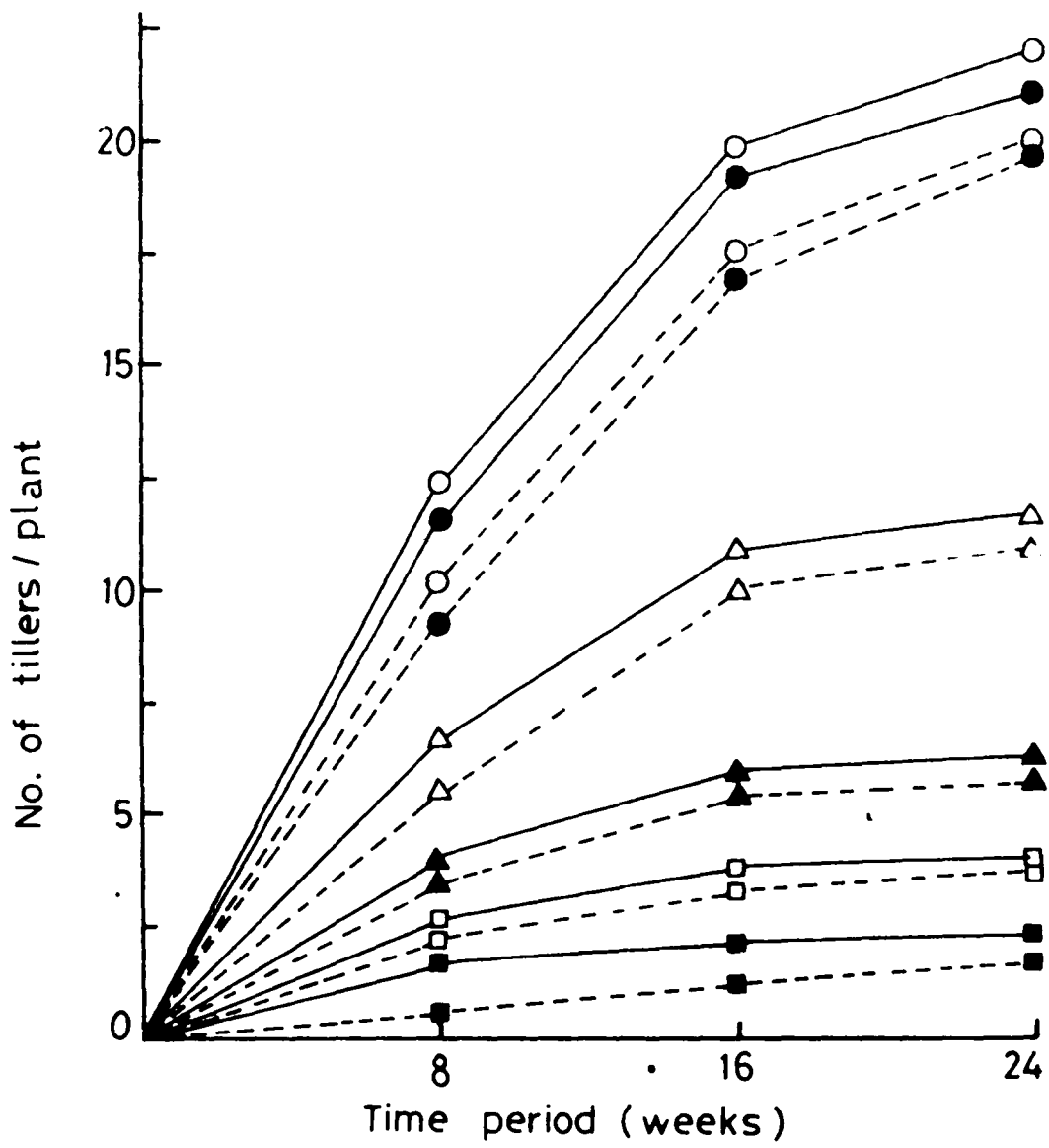


Table 5.1. Effect of plant density on shoot and rhizome dry weight(g) per plant of the populations grown from rhizomes and from seeds.

Density/m ²	Shoot weight		Rhizome weight	
	"Rhizome"	"Seed"	"Rhizome"	"Seed"
30	55.50	44.00	16.70	12.30
60	31.65	24.40	10.50	7.50
120	17.10	14.48	5.88	4.55
240	8.08	6.61	3.27	2.60
480	4.00	3.25	1.64	1.31
960	1.96	1.56	0.81	0.65
L.S.D. ($P < 0.05$)-	4.40		1.76	

Table 5.2. Effect of plant density on root and total dry weight (g) per plant of the populations grown from rhizomes and from seeds.

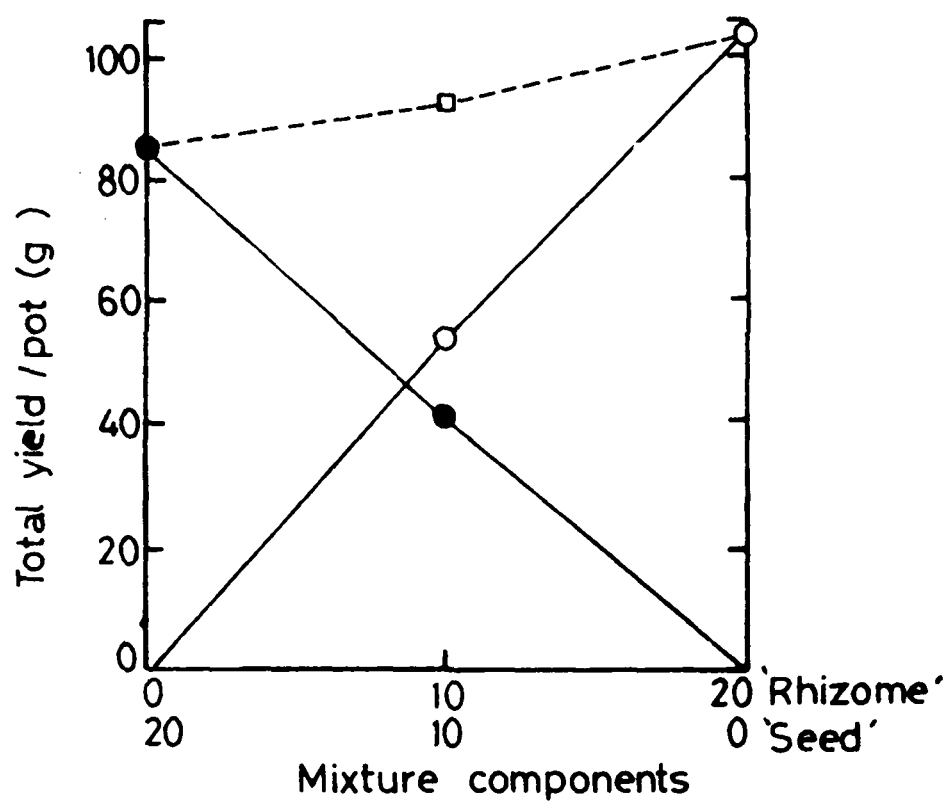
Density/m ²	Root weight		Total dry weight	
	"Rhizome"	"Seed"	"Rhizome"	"Seed"
30	5.50	5.00	77.70	61.30
60	3.00	2.60	45.15	36.50
120	1.65	1.48	24.63	20.51
240	0.86	0.75	12.21	10.02
480	0.44	0.41	6.08	4.97
960	0.22	0.20	2.99	2.41
L.S.D. ($P < 0.05$)-	0.20		6.35	

Table 5.3. Relative yield total (RYT), relative yield quotient (RYQ) and relative replacement rate (RRR) at three harvests.

Harvests	Relative yield		RYT (r_1+r_2)	RYQ (r_1/r_2)	RRR "Rhizome" with res- pect to "Seed"
	"Rhizome"(r_1)	"Seed"(r_2)			
H ₁	0.69	0.31	1.00	2.22	-
H ₂	0.53	0.47	1.00	1.12	0.51
H ₃	0.51	0.49	1.00	1.04	0.92

Fig. 5.4. Replacement diagram at the third harvest.
Dry weight yield of plants grown from
rhizomes (○) and from seeds (●); total
yield of the mixture (□).

FIG.5.4



populations had tiller mortality (Fig.5.4). Mortality in the mixture was much higher in "seed" (50%) than in "rhizome" (30%). The relative yields of rhizome plants, progressively decreased upto third harvest though at the first harvest, it was much greater than that for the "seed". In contrast, the relative yield values of the latter increased during later harvests. The relative yield quotient values were much higher (2.22) at the first harvest but were markedly lower in later harvests. The relative yield total worked out to be one at all harvests while the relative replacement rate values increased from 0.5 to 0.9 at the third harvest. RRR values were all the time ≤ 1 (Table 5.3).

DISCUSSION

The results obtained for both populations in pure stands, indicate that increase in density resulted in both mortality and the reduction in vegetative growth (Ramakrishnan and Jeet, 1972; Ramakrishnan and Gupta, 1972). The reactions of both types of plants to similar density stresses, were found to be strikingly similar except at lower densities, which implies that although the plants from rhizomes had better material start for regeneration, **their** response to high density stress was no better than that of "seeds". In general, the increase in the number of plants/ m^2 is compensated by plastic reduction in plant growth.

The relative competitive superiority in terms of dry weight production by the plants in mixture, was sufficiently greater for the "rhizome" compared to the "seed". The higher relative yield

values for the "rhizome", depict its higher competitive ability than the "seed". However, the progressive decrease in relative yield till the third harvest, may be due to the loss of this ability gradually. In contrast, the increase in the relative yield with time for "seed", depicts its increasing aggressiveness in mixtures, as also noted earlier for another species (Tripathi and Harper, 1973).

The unit RYT values reveal that the two categories of populations compete for the same "space" (van den Bergh, 1968) though the plants from rhizomes possess competitive superiority in mixtures particularly at early stages of growth. This is also confirmed by the decreasing RYQ values with passage of time. It is partly in conformity with our earlier observations on the survival and establishment of the introduced seedling populations of I. cylindrica, which failed to establish in already established plant communities, dominated by I. cylindrica, but showed good establishment in fresh fallows (Kushwaha et al., unpublished).

SUMMARY

The present paper deals with the growth of the populations of Imperata cylindrica (L.) Beauv. var. major grown from rhizomes and from seeds in pure and mixed stands. Whilst mortality and plasticity in pure stands of both categories, was negatively correlated with density increase, there was insignificant difference in the total growth and dry matter production in the two categories except at lower densities. In mixtures, the plants

from rhizomes proved to be more aggressive compared to plants through seeds though the aggressiveness decreased with the passage of time. Both categories of plants compete for the same "space".

CHAPTER 6

COMPETITION BETWEEN IMPERATA CYLINDRICA (L.) BEAUV. AND EUPATORIUM ODORATUM L. AT TWO LEVELS OF NPK TREATMENT.

INTRODUCTION

Competitive relationships existing between natural species populations have been considered by many from the point of view of coexistence of closely related species (Harper and Chancellor, 1959; Marshall and Jain, 1960; Harper and McNaughton, 1962; Ramakrishnan and Jeet, 1972; Ramakrishnan and Gupta, 1981; Tripathi and Harper, 1973). According to Bergh van den and Braakhekke (1978) coexistence between two species is possible when they are able to occupy different ecological niches of the same area avoiding niche overlap. Thus, the studies of Ramakrishnan and Gupta (1981) have implicated the differential response of two closely related species of Argemone mexicana and A. ochroleuca to NPK nutrition as partly responsible for their apparent coexistence in nature.

The present study pertains to two important weeds, namely Imperata cylindrica (L.) Beauv. and Eupatorium odoratum L. which occur in early successional herbaceous communities developing during secondary succession, after slash and burn agriculture (jhum) in north-eastern India (Ramakrishnan et al., 1980). Both these species coexist in jhum fallows upto a period of about 5 - 6 years at lower elevations of Meghalaya (Kushwaha et al., 1981) while the former species also occurs in jhum fallows at higher elevations (Ramakrishnan and Mishra, 1981). The competitive relationships existing between these two species may explain their

adjustment to each other under conditions of fluctuating nutrient conditions of early secondary successional communities arising after slash and burn agriculture. An attempt, therefore, has been made to study the growth of the two weeds in relation to intra- and inter-specific competition as affected by NPK nutrition.

METHODS OF STUDY

Experiments were performed at Burnihat (26°.02'N latitude and 91°.52'E longitude) experimental garden. Populations were raised separately from rhizome fragments with one node in the case of I. cylindrica and from seeds in E. odoratum collected from Burnihat in Meghalaya. Rhizome fragments in the case of I. cylindrica and seeds in the case of E. odoratum were used to simulate the natural regeneration of these two weeds after slash and burn agriculture. Pots (20.8 cm diameter) were filled with garden soil which was thoroughly mixed to remove soil heterogeneity. Monoculture studies comprised of 30, 60, 120, 240, 480, and 960 plants per m². For mixed culture studies, de Wit's replacement series (de Wit, 1960) with varying proportions of the two species keeping the overall density constant, was used. The mixture proportions for the two species were 240 + 0, 120 + 120 and 0 + 240 plants per m². The transplantation of the individuals of both the species for pure and mixed culture studies was done on 5th of June, 1979, when individuals of both the species were uniformly 2-leaved and 2 cm in height.

Three series of 36 pots were maintained for the de Wit's series of set up. The first series was kept as control while the

second and the third series were supplied with low NPK (1.2 g NaNO_3 , 0.5 g $\text{Na H}_2 \text{PO}_4$ and 0.22 g $\text{K}_2 \text{SO}_4$ per pot) and high NPK (4.8 g Na NO_3 , 2.0 g $\text{Na H}_2 \text{PO}_4$ and 0.88 g $\text{K}_2 \text{SO}_4$ per pot) fertilizer doses determined on the basis of the soil fertility status. The total dose was given in two equal parts, the first when plants had established in early July and the other at the time of peak vegetative growth in August. The nutrients were dissolved in water and then applied to the pots. Monoculture studies did not receive any fertilizer alteration. Plants were watered daily till the third harvest (after 24 weeks) so as to provide sufficient moisture to them. Three harvests were taken for the mixed culture experiments after 8, 16 and 24 weeks but only one harvest, after 24 weeks, was done for the monoculture studies. At harvest, the plants were thoroughly washed with water and dried at 80°C for 48 hours, for determining dry matter yields. From the yield data, relative yield total (RYT), relative yield quotient (RYQ) and the relative replacement rate (RRR) (Bergh van den, 1968) were determined.

RESULTS

Pure culture studies:

The percentage survivorship of both the species decreased with increase in the population density. Mortality, however, was more pronounced in I. cylindrica than in E. odoratum. The two species also showed varied degrees of plastic responses to increasing density. Although both the species showed reduced plant height and leaf area with increase in density, the decrease in plant height

Table 6.1. Effect of increasing density on survivorship, plant height, leaf area, number of branches/tillers of I. cylindrica and E. odoratum and number of rhizomes and total length of rhizomes per plant of I. cylindrica.

Density/m ²	Survivorship (%)		Height (cm)		Leaf area (cm ²)		No. of branches/tillers		<u>I. cylindrica</u> No. of rhizomes Total length of rhizomes (cm)	
	IC	EO	IC	EO	IC	EO	IC	EO		
30	100.0	100.2	168.1	198.5	87298	10771	22.0	8.0	35.6	786.2
60	100.0	100.0	140.0	186.0	5077	6262	21.0	6.1	32.1	621.6
120	100.0	100.0	122.5	142.3	2766	3757	11.4	3.5	23.0	336.0
240	99.0	100.0	104.2	95.7	1460	1252	6.9	1.5	12.4	175.5
480	87.5	92.1	86.3	52.0	730	475	4.1	0.0	6.7	91.0
960	61.2	78.0	68.2	30.3	387	125	2.4	0.0	3.0	49.1

Table 6.2. Effect of increasing density on dry weight yield per plant and per m² of I. cylindrica and E. odoratum.

Density/m ²	Dry weight yield (g)		Dry weight yield (g)	
	IC	EO	IC	EO
30	77.7	43.0	2331.9	1290.0
60	45.2	25.1	2712.0	1500.6
120	24.5	15.2	2955.5	1824.4
240	13.0	5.1	3120.2	1224.3
480	6.5	1.9	3216.6	912.0
960	3.4	0.5	3312.7	480.0

Table 6.3. Effect of increasing density on number of fertile plants and the seed output of E. odoratum.

Density/m ²	Fertile plants (%)	Seed output	
		Per plant	Per m ²
30	100.0	6000	180000
60	100.0	4500	270000
120	100.0	3200	384000
240	87.0	2250	240120
480	37.0	1230	182928
960	8.5	875	71400

was more marked in E. odoratum, whereas the decrease in leaf area was steeper for I. cylindrica. Leaf area for I. cylindrica was markedly higher than for E. odoratum at very high densities. Tiller number in the case of I. cylindrica was drastically reduced under high density stress. E. odoratum did not show any branching at high densities. Number of rhizomes and total rhizome length per plant, both declined sharply with increase in density stress, in the case of I. cylindrica (Table 6.2).

The dry weight yield per plant too decreased with increase in density and this decrease was more marked in E. odoratum than in I. cylindrica. The dry weight yield per m^2 increased in the case of E. odoratum, the increase was only upto 120 plants per m^2 after which it declined drastically (Table 6.3).

The percentage reproductive plants in E. odoratum decreased with the increase in density and at the highest density of 960 plants/ m^2 only about 9% of the plants reproduced. No flowering occurred in I. cylindrica at all densities. The seed output per plant of E. odoratum also showed a decline with increase in density and a similar trend was also noted for seed output (Table 6.4).

Mixed culture studies:

There was no mortality of the plants of either of the species in this experimental set up. The total yield of the mixture (Fig. 6.1) at all the harvests and at each treatment, was intermediate to the yields of the either of the species in monocultures. There was an increase in the dry matter production from lower to

Fig. 6.1. Replacement diagrams (dry weight yields) at three harvests and at two nutrient levels. H_1 , H_2 and H_3 refer to the three harvests taken after 8, 16 and 24 weeks. I. cylindrica (○); E. odoratum (●); total yield of the mixture (□).

FIG.6.1

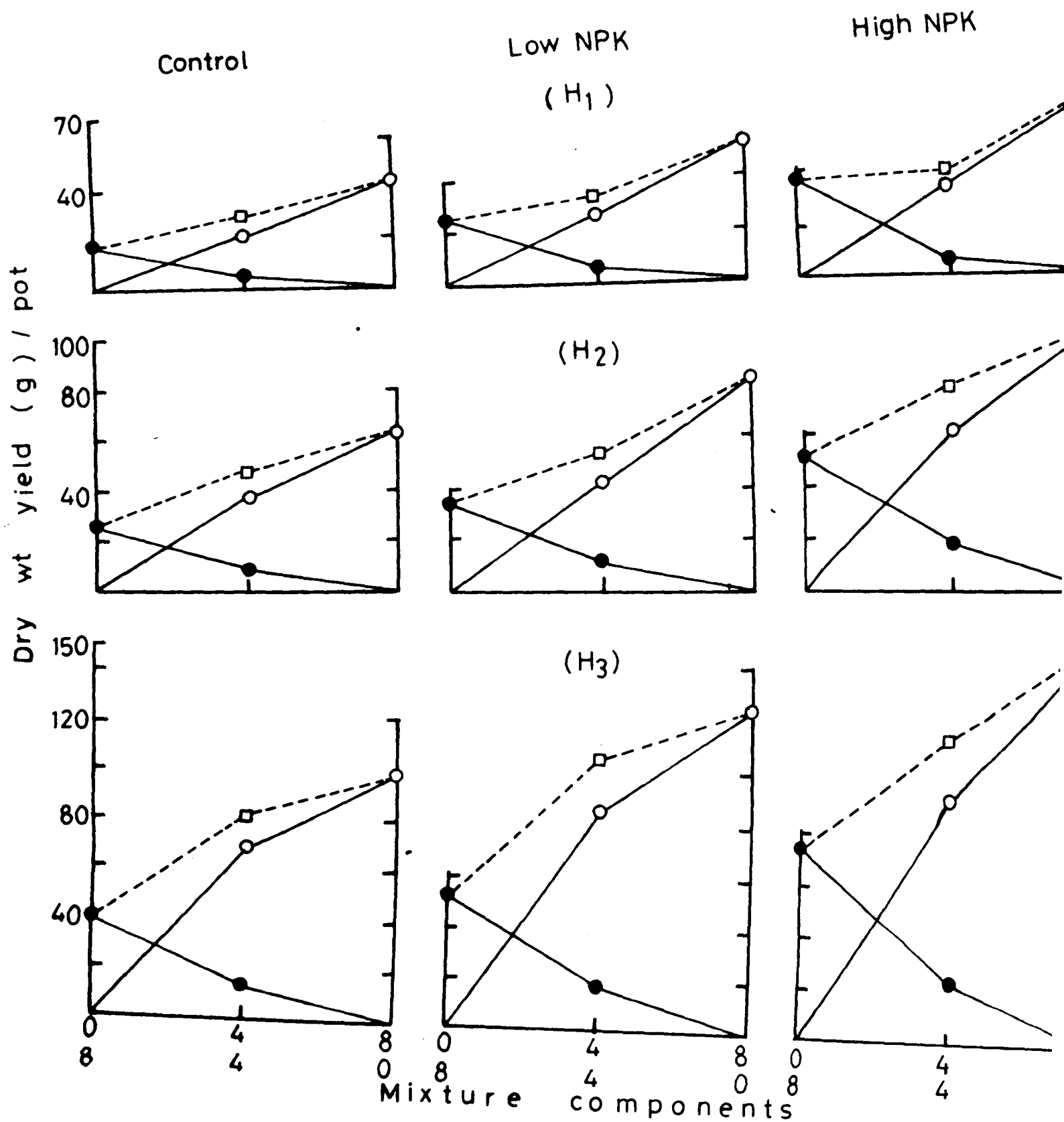


Table 6.4. Relative yield, relative yield quotient (RYQ), relative yield total (RYT), and the relative replacement rate (RRR) (reference to H₁) at three harvests.

Treatment	Harvests	Relative yield IC	Relative yield EO	RYQ IC/EO	RYT IC + EO	RRR IC with res- pect to EO
Control	H ₁	0.5	0.3	1.67	0.8	-
	H ₂	0.6	0.3	2.00	0.9	1.19
	H ₃	0.7	0.3	2.33	1.0	1.17
Low NPK	H ₁	0.5	0.2	2.50	0.7	-
	H ₂	0.6	0.3	1.67	0.8	0.67
	H ₃	0.7	0.3	2.33	1.0	1.39
High NPK	H ₁	0.5	0.2	2.50	0.7	-
	H ₂	0.6	0.4	1.50	1.0	0.60
	H ₃	0.6	0.3	2.00	0.9	1.33

higher NPK nutrition but I. cylindrica responded better to increased fertilizer doses than E. odoratum. The relative concavity/convexity in the replacement curve suggests that I. cylindrica is more aggressive than E. odoratum in both unaltered and altered soils. The aggressiveness of I. cylindrica seems to be more at later harvests. In general, there was an increase in the relative yields of I. cylindrica from first to the third harvest. However no clear cut trend was noted in the relative yields of E. odoratum. The relative yield quotient values were always more than one. Further, the relative yield total for both the species, progressively increased from the first to third harvest. The relative replacement rate of I. cylindrica with respect to E. odoratum, decreased with passage of time in the control series while in the altered sets, the I. cylindrica seems to be better with time (Table 6.4).

DISCUSSION

The results obtained for both the species in pure stands, indicate that increase in the density resulted in both mortality and plastic reduction in vegetative growth of the plants. The reactions of the two species to similar density stress, were found to be different. While mortality was more severe in the case of I. cylindrica than in E. odoratum, the reverse was the case as far as plasticity is concerned. This is reflected in leaf area and dry weight yield per plant. This differential plastic behaviour may be a consequence of the differential reduction in numbers of the two species. Thus the species suffering



from mortality exhibited greater vegetative growth. The plastic reduction in plant growth with increase in density is an important population regulating mechanism (Ramakrishnan and Kumar, 1971). Dry weight yield per m^2 is shown to increase with increase in the density in pure stands reaching a plateau value beyond a certain point. However, it is interesting to note a differential behaviour in the two species studied here where at the density levels tried, I. cylindrica tended to show an increase in yield per m^2 , whereas there was a drastic decline in the yield in E. odoratum beyond a particular density level. This again may be related to the greater susceptibility of E. odoratum to density stress, as far as plasticity is concerned.

The yield per pot data suggest that I. cylindrica is more aggressive than E. odoratum as seen from the relative convexity/concavity of the replacement curves. A comparison of the relative yields of the two species also showed that E. odoratum reacts to the presence of I. cylindrica by a strong decrease in yield, whereas I. cylindrica does not suffer from any yield loss at different harvests and nutrient levels. The fact that, in general, the RYT ≤ 1 , implies that E. odoratum is more affected than might be expected from crowding for the same space (Sandfaer, 1970). Apparently there is some factor in I. cylindrica plants which reduces the space for E. odoratum as has also been shown by Eussen et al. (1976) for some crop species. In a similar set of experiments with I. cylindrica and sorghum, they noticed a reduction in the RYT values which was later confirmed by them to be due to certain allelopathic substances produced by the former

species. The increase in the RYT values with progressive harvests in all the treatments, however, may be on account of the compensatory increase in the yield of I. cylindrica during later stages of competition due to availability of additional free space (Trenbath, 1974). Trenbath also pointed out that the occurrence of the $RYT = 1$ is not conclusive for the absence of any allelopathic effect and that an RYT value below 1 occurs only in situations where the reduction of space caused by one of the mixture components is not compensated for by additional utilization of space by the other; $RYT = 1$ reveals that it does utilize the space. The competitive superiority of I. cylindrica is suspected to be due to its allelopathic property which reduces the available space for E. odoratum in the initial stages of growth though this space is occupied by I. cylindrica, as a result of which there is compensatory yield gain which is also reflected in RYQ and RRR values.

It is interesting that inspite of the start from vegetative propagules in pure stands in the case of I. cylindrica, the mortality is more severe than that in E. odoratum, starting from small seed resources. However, this trend may not hold good for I. cylindrica when the resources are normally utilized from a massive net work of rhizomes as it occurs in nature (in contrast to small cut pieces of rhizomes used for this study). However, I. cylindrica once established seems to have a better competitive ability over E. odoratum both in pure and mixed cultures, though nutrient status does not influence much the outcome of competition between the two species.

SUMMARY

The study deals with intra- and inter-specific competition related to NPK nutrition between Imperata cylindrica (L.) Beauv. and Eupatorium odoratum L., two noxious weeds coming up in the early successional plant communities after slash and burn agriculture (jhum) in north-eastern India. I. cylindrica was more susceptible to mortality under pure stand density stress compared to E. odoratum, probably due to which the yield per plant and per m² of the latter was more affected compared to the other. In mixtures, I. cylindrica had an advantage over E. odoratum by reducing the "space" for the latter through allelopathic inhibition of growth of this species. The significance of these results are discussed.

CHAPTER 7

EFFECT OF DIFFERENT LIGHT AND SOIL MOISTURE REGIMES ON THE GROWTH OF EUPATORIUM ODORATUM L. AND IMPERATA CYLINDRICA (L.) BEAUV. VAR. MAJOR.

INTRODUCTION

Eupatorium odoratum L. and Imperata cylindrica (L.) Beauv. var. major are two perennial weeds of contrasting life strategies (Kushwaha et al., 1981; Kushwaha et al., unpublished), growing abundantly in cultivated fields, wastelands and other exposed areas. These two are also important components of the secondary successional communities developing soon after slash and burn agriculture (jhum) in the north-eastern hill region (Ramakrishnan et al., 1980). Both the species produce seeds in large numbers. Besides seed production, I. cylindrica has extensive underground rhizome system. Seed germination, in nature, of both the species starts in May-June with the onset of the monsoon. The period between June and October represents the period of active growth after which E. odoratum starts flowering. However, flowering in I. cylindrica commences only after dry winter months, i.e., in April. Maximum fruiting takes place in the month of January (for E. odoratum) and in April-May (for I. cylindrica).

There have been many agronomic attempts on the control of these two species (Cruttwell, 1970; Salgado, 1972; Nair, 1973; Madrid, 1974; Eussen, 1978). A few studies are also available on life cycle attributes (Kushwaha et al., 1981; Yadav and Tripathi, 1981; Kushwaha, unpublished) and on the growth characteristics (Edwards, 1974a, 1974b, 1977; Soerjani, 1970) of both these

species. An investigation into the responses of the two weeds to various ecological factors might be helpful in understanding the mechanism of the regulation of their populations in nature. The present study was, therefore, undertaken to investigate the growth behaviour of these two species as affected by different light and soil moisture regimes.

METHODS OF STUDY

Seeds of both the species, collected from Burnihat in Meghalaya (26°.02'N Latitude and 91°.52'E Longitude), were used for culture in the experimental garden located there. Four week old seedlings, separately raised, were transplanted into pots of 20.8 cm diameter filled with 2:1 mixture of soil and organic manure. The soil and manure mixture was thoroughly mixed to remove any soil heterogeneity, before transplantation. Two sets of experiments, one related to two levels of light intensities and another with three watering regimes were done. The experiments with two light regimes had two sets of sixteen pots each. One set received full sun light and the other only about 30% of full sun light. The reduction in light was done artificially by covering the four walls and the roof, of the chamber, where pots were kept, with muslin cloth.

The experiments with three watering regimes had three sets of sixteen pots each. One set was watered daily, another on alternate days and a third at weekly intervals. The percentage soil moisture in the pots, receiving three moisture treatments, was determined prior to watering and was found to be about 40%,

25% and 15% on soil dry weight basis. The leaf area of the samples was determined by knowing the leaf area/weight ratio of the mature leaves, separately for all the treatments. Leaf area ratio (LAR), net assimilation rate (NAR) and relative growth rate (RGR) were determined following the procedure outlined by Watson (1947) and Hammerton (1965). Aboveground (AG) and belowground (BG) dry weight yields of plants were determined after drying the plants in an oven at 80°C for 48 hours. The statistical analysis of the data was done using student 't' test. The probability level for all the tests of significance was 0.05.

RESULTS

Experiment 1 :

There were significant differences in plant height, AG and BG dry weights between sun and shade grown plants of E. odoratum with extremely low values for the latter. Differences between sun and shade treatments, were significant for all parameters at all harvests except for AG/BG ratio which was significantly different only for the first harvest. While the increase in various parameters, in general, was more pronounced in the case of sun grown plants compared to shade grown ones, AG/BG ratio increased in E. odoratum, in the case of sun grown plants and it decreased for shade grown plants in subsequent harvests (Table 7.1).

Leaf area, NAR and RGR were all significantly higher for the sun grown plants at all harvests while LAR was significantly high only during the first harvest (Table 7.2). The leaf area increase during subsequent harvests, was more pronounced in the

Table 7.1. Plant height (cm), aboveground (AG), belowground (BG) dry weight (g) and the AG/BG ratio of E. odoratum in sun and shade.

Harvests	Plant height		AG dry weight		BG dry weight		AG/BG ratio	
	Sun	Shade	Sun	Shade	Sun	Shade	Sun	Shade
H ₁	54.2	50.0*	3.5	1.5*	1.2	0.4*	2.8	3.7*
H ₂	162.0	150.6*	66.8	8.7*	23.4	3.0*	2.8	2.8
H ₃	182.1	164.0*	76.8	12.5*	24.3	4.4*	3.1	2.8
H ₄	186.0	166.5*	78.9	13.8*	25.0	5.5*	3.1	2.5

* Significant at $P < 0.05$.

Table 7.2. Leaf area (cm²), leaf area ratio (cm²/g) net assimilation rate (g/cm²/week) and the relative growth rate (g/g/week) of E. odoratum in sun and shade.

Harvests	Leaf area		Leaf area ratio		Net assimilation rate		Relative growth rate	
	Sun	Shade	Sun	Shade	Sun	Shade	Sun	Shade
H ₁	280.0	110.0*	37.5	25.4*	0.0070	0.0042*	0.2614	0.1070*
H ₂	5418.0	707.2*	59.9	59.2	0.0082	0.0051*	0.4891	0.3043*
H ₃	6072.0	1018.2*	59.5	60.0	0.0003	0.0010*	0.0190	0.0607*
H ₄	6262.5	1161.6*	60.3	59.0	0.0001	0.0004*	0.0046	0.0220*

*Significant at $P < 0.05$.

case of sun grown plants than in shade grown plants of E. odoratum while increase in leaf area ratio was not very much different. NAR increased during second harvest but decreased in subsequent ones more markedly in the case of sun grown plants. RGR, in this species, also followed a similar pattern as NAR at different harvests.

The plant height, AG and BG dry weights of I. cylindrica were significantly reduced in shade grown plants compared to sun grown plants. AG/BG ratio, for sun grown plants, was significantly higher only in the third and fourth harvests. While plant height increase did not vary much between sun and shade grown plants during subsequent harvests, AG/BG dry weights improved markedly for sun grown plants compared to the other. The AG/BG ratio in this species decreased from first to fourth harvest though in shade grown plants it increased after an initial decline (Table 7.3).

The difference between sun and shade grown plants with respect to leaf area was significant at all harvests but it was so only in some of the harvests with respect to LAR, NAR and RGR. At different harvests, leaf area improved markedly for sun grown plants compared to shade grown plants of I. cylindrica, while LAR was not significantly affected. NAR of sun grown plants decreased at different harvests while that of shade grown plants improved initially followed by a decline. RGR declined under both conditions, more markedly so for sun grown plants (Table 7.4).

Experiment 2:

Plant height, AG and BG dry weights, all declined sharply in treatments where watering was done only once in a week in

Table 7.3. Plant height (cm), aboveground (AG), belowground (BG) dry weight (g) and the AG/BG ratio of I. cylindrica in sun and shade.

Harvests	Plant height		AG dry weight		BG dry weight		AG/BG ratio	
	Sun	Shade	Sun	Shade	Sun	Shade	Sun	Shade
H ₁	75.0	30.0*	4.0	1.9*	2.6	1.1*	1.5	1.7
H ₂	126.2	50.3*	19.6	3.2*	15.2	2.1*	1.2	1.5
H ₃	136.5	59.0*	23.8	4.1*	19.4	2.5*	1.2	1.6*
H ₄	143.0	61.4*	23.4	4.3*	21.8	2.6*	1.0	1.6*

*Significant at $P < 0.05$.

Table 7.4. Leaf area (cm²), leaf area ratio (cm²/g), net assimilation rate (g/cm²/week) and the relative growth rate (g/g/week) of I. cylindrica in sun and shade.

Harvests	Leaf area		Leaf area ratio		Net assimilation rate		Relative growth rate	
	Sun	Shade	Sun	Shade	Sun	Shade	Sun	Shade
H ₁	741.4	340.3*	111.7	111.6	0.0028	0.0017*	0.3145	0.1842*
H ₂	4000.0	610.0*	113.9	130.4	0.0024	0.0028	0.2771	0.0953*
H ₃	4853.1	775.0*	113.6	115.3	0.0003	0.0003	0.0361	0.0363
H ₄	5000.2	800.8	111.5	116.1	0.0001	0.0001	0.0075	0.0074

*Significant at $P < 0.05$.

E. odoratum (Table 7.5). The plant height, AG and BG dry weights, for a given treatment increased more markedly at the second harvest than at subsequent harvests for all the parameters except AG/BG ratio where no clear cut pattern was note.

The leaf area and NAR were significantly lower treatments with weekly watering compared to the other two. Except for the initial increase, RGR decreased in subsequent harvests. The increase in leaf area, between first and fourth harvests, was more pronounced in the plants that were watered daily. However, the decrease in NAR at the fourth harvest compared to the first one was also markedly pronounced in treatments with watering done either daily or on alternate days (Table 7.6).

The plant height, AG and BG dry weights in I. cylindrica were significantly lower for those that were watered weekly compared to other treatments. BG dry weight increased significantly at the fourth harvest compared to the first one, 16-fold in the case of plants that were watered weekly, while in other two treatments it increased only 7-fold. The AG/BG ratio increased in the treatment where plants were watered daily or on alternate days but decreased in the case where watering was done weekly (Table 7.7).

The leaf area and RGR of I. cylindrica were significantly lower in treatments where watering was done weekly compared to the other two treatments. LAR in subsequent harvests was reduced in treatments where watering was done weekly but was not affected in the other treatments. NAR at subsequent harvests decreased in the treatment where watering was done daily or on alternate days but it increased initially and then decreased in treatments where watering was done weekly (Table 7.8).

Table 7.5. Plant height, aboveground (AG), belowground (BG) dry weight and AG/BG ratio of E. odoratum at three moisture levels.

Har-vests	Plant height (cm)				AG dry weight (g)				BG dry weight (g)				AG/BG ratio			
	DW	ADW	WW	L.S.D.	DW	ADW	WW	L.S.D.	DW	ADW	WW	L.S.D.	DW	ADW	WW	L.S.D.
H ₁	50.1	50.0	23.0	8.1	3.5	3.7	2.2	1.2	1.2	1.3	0.6	0.4	2.8	2.8	3.6	0.6
H ₂	178.0	171.2	60.0	3.5	66.8	74.5	37.4	7.0	23.4	24.8	12.5	2.8	2.8	3.0	2.9	0.6
H ₃	190.0	174.0	80.0	20.2	76.8	79.3	43.7	5.3	24.3	26.5	14.6	4.9	3.1	2.9	2.9	0.6
H ₄	197.1	187.9	90.2	75.3	81.9	82.6	51.0	10.6	22.0	24.8	13.0	6.3	3.7	3.3	3.9	0.5

Table 7.6. Leaf area (cm^2), leaf area ratio (cm^2/g), net assimilation rate ($\text{g}/\text{cm}^2/\text{week}$), and the relative growth rate ($\text{g}/\text{g}/\text{week}$) of E. odoratum at three moisture levels.

Har-vests	Leaf area				Leaf area ratio				Net assimilation rate				Relative growth rate			
	DW	ADW	WW	L.S.D.	DW	ADW	WW	L.S.D.	DW	ADW	WW	L.S.D.	DW	ADW	WW	L.S.D.
H ₁	280	300	168	30.7	37.5	38.5	32.6	3.3	0.0070	0.0069	0.0053	0.0013	0.2614	0.2682	0.1716	0.0452
H ₂	5418	5958	2994	2012.7	59.5	60.0	60.0	1.7	0.0082	0.0083	0.0080	0.0001	0.4891	0.4981	0.4801	0.0357
H ₃	6072	6348	3498	1202.4	59.9	60.8	60.0	1.3	0.0003	0.0002	0.0004	0.0001	0.0190	0.0105	0.2593	0.0391
H ₄	6262	6444	3840	776.2	60.3	57.0	60.0	1.3	0.0001	0.0001	0.0003	0.0001	0.0046	0.0025	0.0156	0.0072

Table 7.7. Plant height (cm), aboveground (AG), belowground (BG) dry weight and the AG/BG ratio of I. cylindrica at three moisture levels.

Har-vests	Plant height				AG dry weight				BG dry weight				AG/BG ratio			
	DW	ADW	WW	L.S.D.	DW	ADW	WW	L.S.D.	DW	ADW	WW	L.S.D.	DW	ADW	WW	L.S.D.
H ₁	73.0	73.0	28.0	4.7	4.4	4.4	3.4	0.2	2.2	2.1	1.6	0.4	2.0	2.0	2.1	0.4
H ₂	130.0	125.0	70.0	8.5	23.8	27.1	20.1	6.3	11.0	12.5	11.5	1.8	2.1	2.1	1.7	0.5
H ₃	142.0	135.0	75.6	5.8	29.6	33.4	24.0	8.7	13.6	15.1	14.8	2.3	2.1	2.2	1.6	0.2
H ₄	150.1	140.0	80.0	8.7	31.2	35.2	24.4	7.7	14.0	15.7	16.0	2.7	2.2	2.2	1.5	0.2

Table 7.8. Leaf area (cm²), leaf area ratio (cm²/g), net assimilation rate (g/cm²/week) and the relative growth rate (g/g/week) of *I. cylindrica* at three moisture levels.

Har-vests	Leaf area				Leaf area ratio				Net assimilation rate				Relative growth rate			
	DW	ADW	WW	L.S.D.	DW	ADW	WW	L.S.D.	DW	ADW	WW	L.S.D.	DW	ADW	WW	L.S.D.
H ₁	741.4	742.5	560.0	35.9	111.5	111.6	111.6	1.0	0.0028	0.0028	0.0024	0.0014	0.3145	0.3145	0.2682	0.05
H ₂	4000.0	4504.8	3027.5	1370.2	113.9	112.3	101.7	11.8	0.0024	0.0027	0.0030	0.0002	0.2771	0.3007	0.3067	0.05
H ₃	4853.1	5617.0	3658.8	706.7	113.6	112.3	99.2	16.8	0.0003	0.0003	0.0004	0.0001	0.0361	0.0368	0.0353	0.01
H ₅	5000.2	5920.3	3724.5	1317.4	111.5	112.3	97.0	11.6	0.0001	0.0001	0.0001	0.0000	0.0076	0.0088	0.0867	0.02

DISCUSSION

The results of the experiments with light and shade grown plants, indicate that shade had an adverse impact on the growth and development of the two species resulting in drastic reduction in leaf area and dry weight yields. Such a reduction in overall growth has also been found in shade grown plants of the two species by other workers (Bennett and Rao, 1968; Cruttwell, 1968; Eussen and Wirjahardja, 1973; Kushwaha et al., unpublished). In light grown plants of both the species, the higher values of NAR and RGR, at the second harvest, coincide with their peak growth period. The much lower and gradually decreasing NAR and RGR, after second harvest, indicates that in the later stages of development, the relative photosynthetic efficiency and thus the growth of E. odoratum is considerably reduced. This period also coincides with the maturation phase of the plants.

The increase in the AG/BG ratio at later stages of growth in light grown plants of E. odoratum may be due to the increased allocation to the aboveground reproductive parts as is evidenced by its vigorous flowering and fruiting. However, the decrease in this ratio for shade grown plants of this species suggests that the strategy here is to allocate more to belowground parts which might be helpful in survival and perennation of E. odoratum under adverse conditions. In I. cylindrica, however, no definite allocation pattern was observed.

The leaf area, LAR, NAR and the RGR in both the species, was markedly reduced when plants were provided with reduced soil

moisture. Edward (1974) also found a significant correlation between the precipitation and growth of E. odoratum. High rainfall occurring during the growth season of these two species may help in the colonization and rapid spread of these in north-eastern India. A decrease in AG/BG ratio, at later harvests in I. cylindrica that were under maximum water stress is due to the increased allocation to belowground parts which may be an adaptation for increasing water absorption surface and to ensure its survival through perennating organs.

The results of this study confirm the suggestion (Kushwaha et al., 1981; Kushwaha et al., unpublished) that the two species are sensitive to shading during secondary succession after "jhum", where the two get rapidly eliminated in fallows older than 5-8 years as shown from our studies on population dynamics. The shift in the allocation pattern due to shading of E. odoratum is significant from the point of view of its survival. In spite of the high rainfall, brief periods of drought, as often happens during the monsoon, may not only affect survival but also contribute towards the vigour of growth and allocation pattern in the case of I. cylindrica.

SUMMARY

This study deals with the effect of different light and soil moisture regimes on the growth and development of Eupatorium odoratum L. and I. cylindrica (L.) Beauv. var. major, two early secondary successional weed species. The growth of both the species was adversely affected under shade and under reduced soil

moisture. In E. odoratum, shade not only affects growth but also the allocation pattern in a way favouring belowground parts. A shift in allocation from above to belowground organs under moisture stress was noted in case of I. cylindrica. The significance of these results is discussed.

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Publications arising out of the thesis:

- (i) Population dynamics of Eupatorium odoratum L. in successional environments following slash and burn agriculture (jhum).
J. Appl. Ecol. 18, (in press).
- (ii) Population dynamics of Imperata cylindrica (L.) Beauv. var. major related to slash and burn agriculture (jhum) in north-eastern India. Communicated to J. Appl. Ecol..
- (iii) Population dynamics of Scleria tessellata Willd. - A shade tolerant secondary successional species in slash and burn agriculture (jhum) fallows. Communicated to Proc.(B) Ind. Nat. Sci. Acad..
- (iv) Competitive relationships of the plants of Imperata cylindrica (L.) Beauv. var. major established from rhizomes and from seeds. Communicated to Proc. Ind. Acad. Sci..
- (v) Competition between Imperata cylindrica (L.) Beauv. and Eupatorium odoratum L. at two levels of NPK treatment. Communicated to Trop. Ecol.,
- (vi) Effect of different light and soil moisture regimes on the growth of Eupatorium odoratum L. and Imperata cylindrica (L.) Beauv. var. major. Communicated to Proc. Nat. Acad. Sci.,
- (vii) An analysis of some agro-ecosystem types of north-eastern India. Communicated to Agric. Environ..

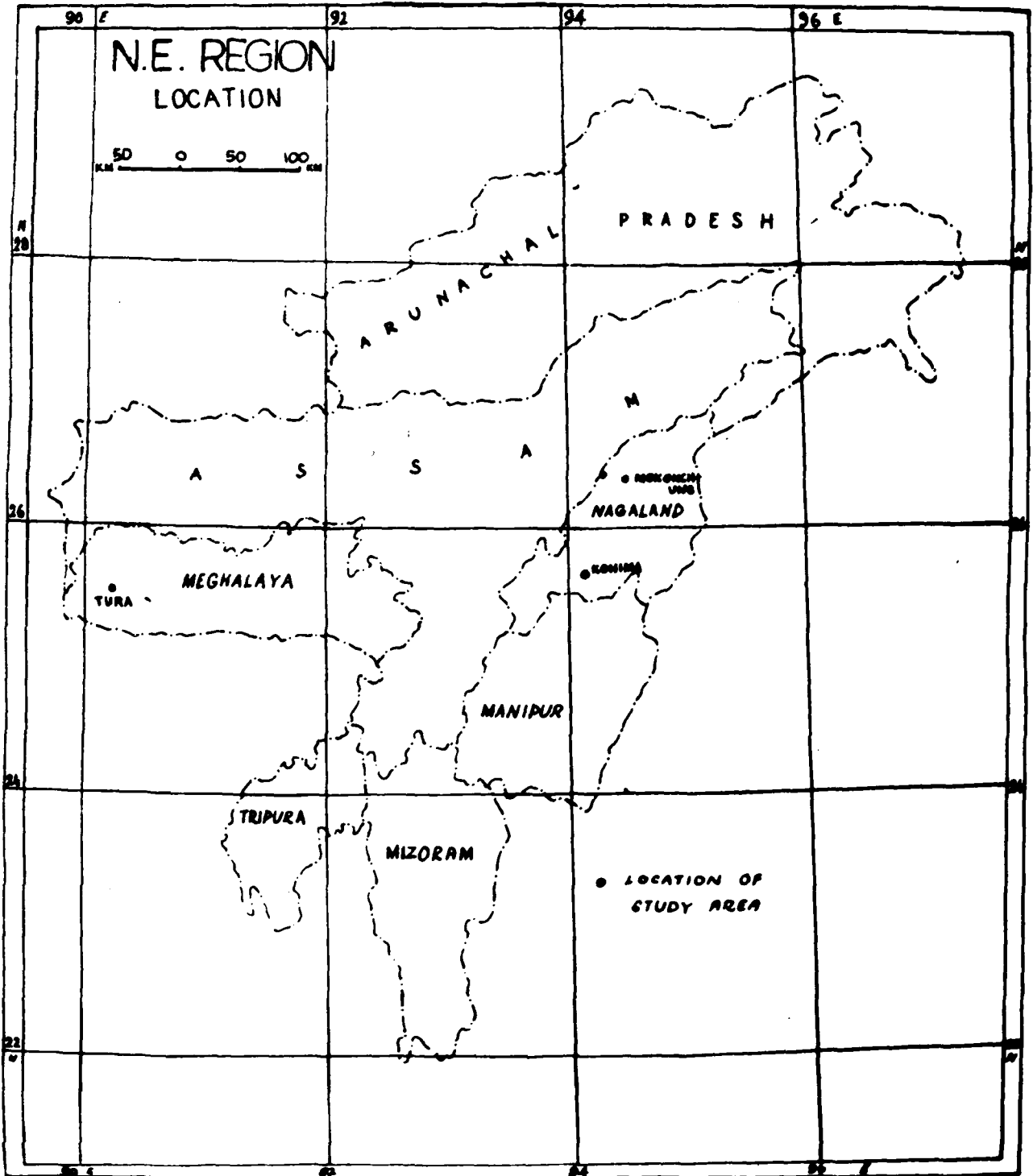


PLATE 1



PLATE 2



PLATE 3

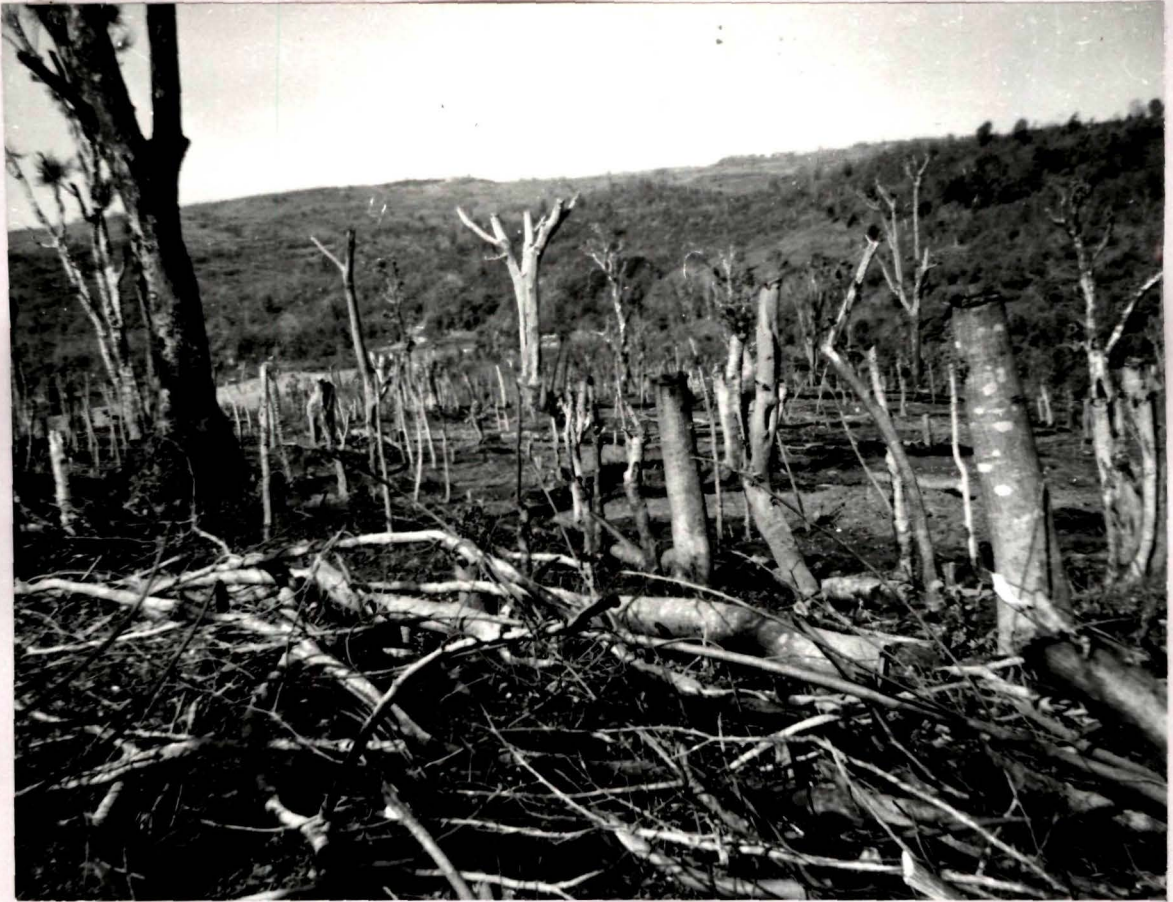


PLATE 4



PLATE 5



PLATE 6



PLATE 7

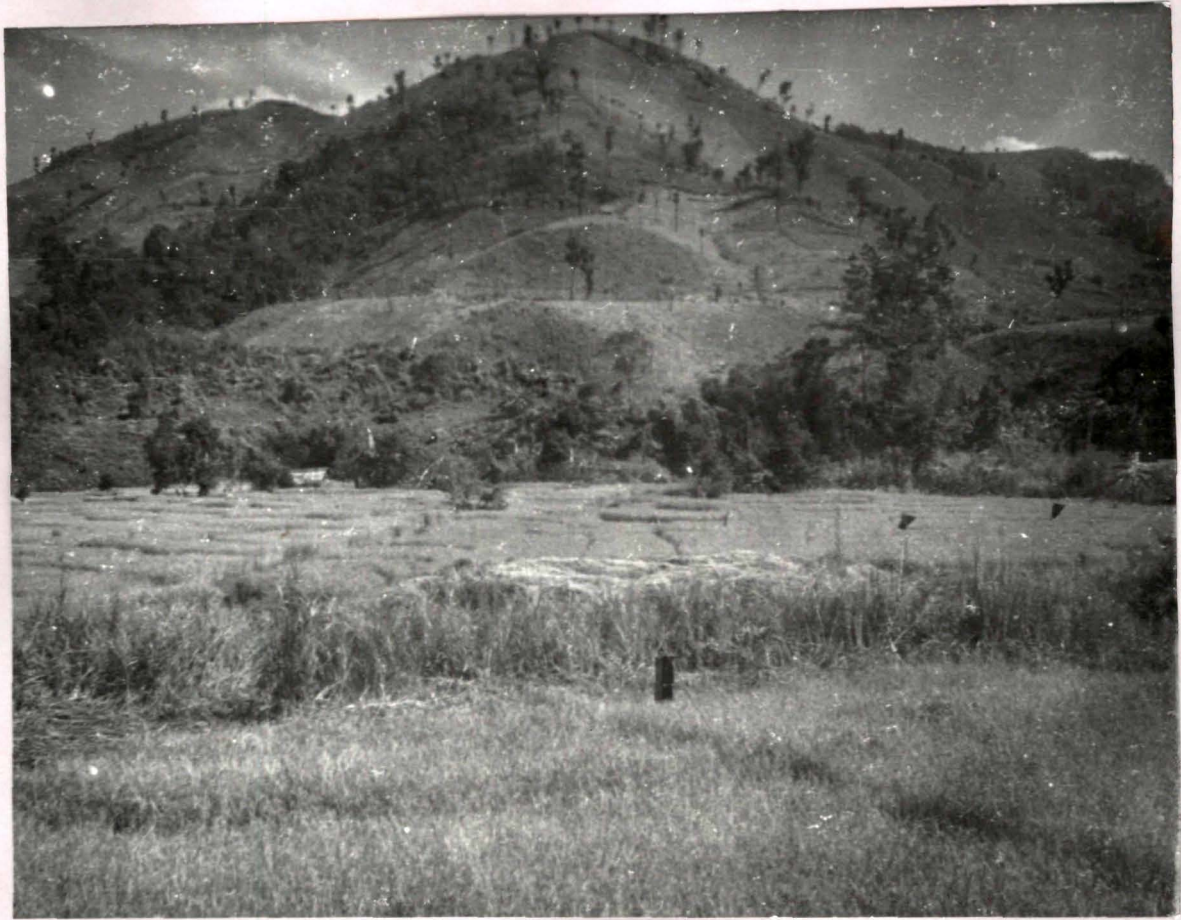


PLATE 8



PLATE 9



PLATE 10





PLATE 12





PLATE 14



PLATE 15

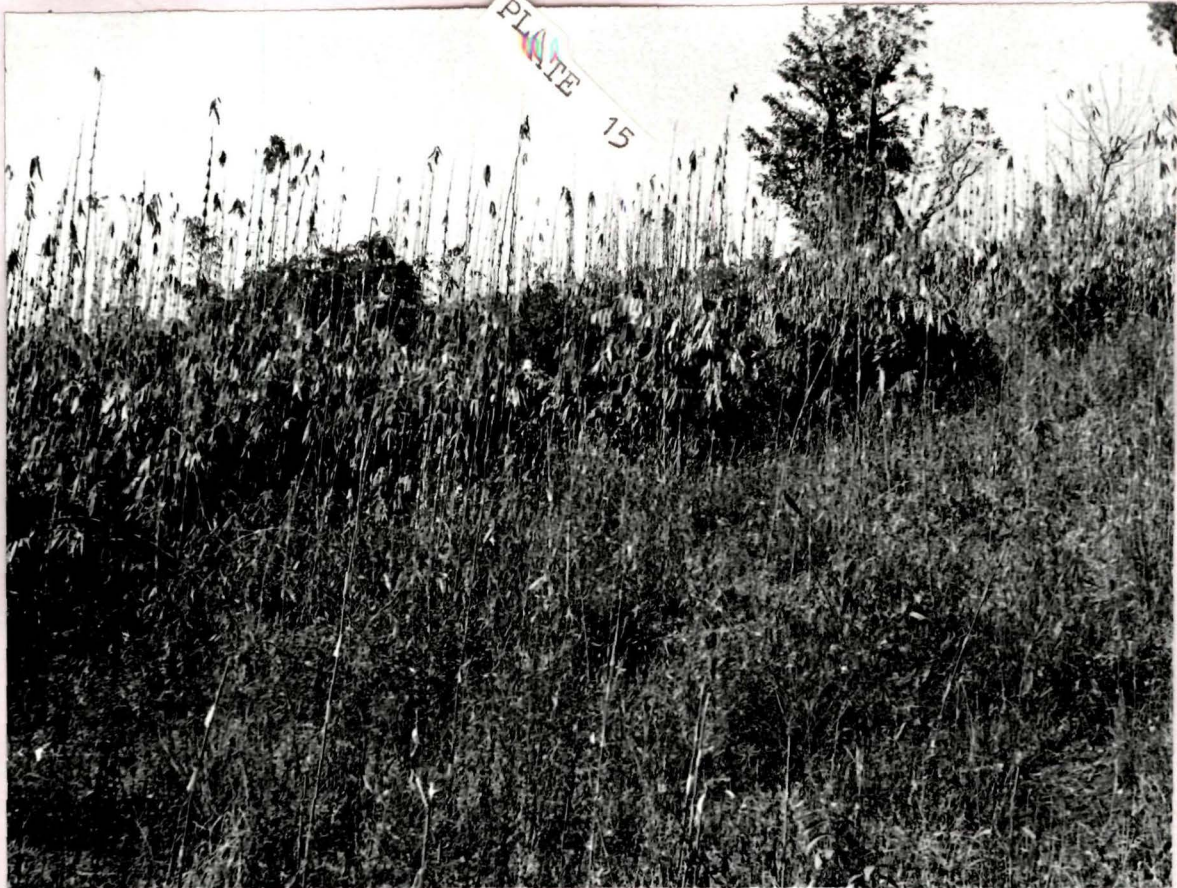


PLATE 16

