DYNAMICS OF WEED POPULATIONS IN HILL AGROECOSYSTEMS OF MEGHALAYA

ABSTRACT

By

JAHNABA MISRA

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

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The crop fields under 'jhum' (slash and burn agriculture) and terrace cultivation in north-eastern India are heavily infested with a large variety of native and exotic weeds due to favourable climatic conditions of the region. In absence of any effective weed control measure, weeds pose a serious threat to the crop growth and yield under both the systems of cultivation. Since an understanding of their population and growth behaviour is important both from agronomic and ecological view points, a study of the population behaviour of the dominant weeds in different fields under 'jhum' and terrace agroecosystems was undertaken. The study was carried out during 1988-1990 in the 'jhum' and terrace fields located at Upper Shillong (high altitude site) and in terrace fields at Barapani (low altitude site) near Shillong. At high altitude site, the experimental fields of Central Potato Research Station, representing the terrace system and nearby crop fields of a farmer under 'jhum' system were selected for the study. At low altitude the study was conducted in the Research Complex of Indian Council of Agricultural Research for North-Eastern Hill Region. The study was carried out in potato, maize, radish and cauliflower crops at Upper Shillong and in maize, radish, groundnut and linseed crops at Barapani.

The composition of weed flora varied between 'jhum' and terrace fields and also between high and low altitudes. The altitudinal variation in composition was more prominent than the difference between 'jhum' and terrace fields. At high altitude, the number of weeds was much lower (16) than the low altitude fields (39). In 'jhum', the number of weeds identified in potato, maize, radish and cauliflower fields was 14, 15, 14 and 14, respectively, while the corresponding number in terrace was 14, 16, 16 and 15, respectively. At low altitude, in both maize and groundnut fields 39 species were recorded, while 31 and 22 weed species were identified in radish and linseed fields, respectively. The number of annual species was more than the perennials in all the fields at both the altitudes but the relative proportion of perennials was more at the low altitude.

At Upper Shillong, almost all fields under 'jhum' and terrace were dominated by *S. arvensis*, *P. alatum* and *G. ciliata*, which together shared more than 70% dominance. At Barapani on the other hand, dominance was shared by many species and three dominant species *E. sonchifolia*, *G. ciliata* and *R. pilosa*, selected for study shared *ca* 30-35% dominance. Peak density and mean IVI values of dominant weeds were always higher at Upper Shillong than Barapani and 'jhum' fields showed higher values than the terrace fields. The abundance of individual species varied from one crop field to another. Species diversity was higher in terrace fields than in 'jhum'.

In order to explain the population behaviour of the dominant weeds in different crop fields, four microenvironmental variables viz. photosynthetically active radiation (PAR), relative humidity, soil moisture and soil temperature were regularly measured at fortnightly interval during the study period. PAR was consistently higher at high altitude throughout the year. In all the crop fields, light interception by the crop-weed canopy increased up to 60 days of the crop age and then declined until harvest. Interception was significantly higher (56-68%) in 'jhum' than terrace fields (36-58%). Cropwise interception was 53-68% in potato, 50-65% in cauliflower, 49-65% in radish and 36-57% in maize field. Greater light interception in the 'jhum' fields was attributed to the plant population density, which was about two fold higher in 'jhum' than terrace fields. Seasonal variation in relative humidity was prominent at both the sites; the values were higher in rainy season than autumn and winter. Altitudinal difference in soil moisture i.e., relatively higher value at low altitude (23.5% at Barapani vs. 21.4% at Upper Shillong during peak rainfall period) despite low rainfall seemed to be related to soil texture, which was clay loam at Barapani and sandy loam at Upper Shillong. Higher mean soil temperature at Barapani (21.5°C) than Upper Shillong (17.5°C) was related to air temperature which was higher throughout the year at the former site.

In most of the crop fields weed seedlings were recruited in three distinct cohorts. The first cohort was recruited within 10 days of crop sowing, second and third cohorts emerged after about 15 and 45 days of emergence of the first cohort. In general, the emergence percentage decreased in successive cohorts, the value was much higher in the first cohort than the second and third cohorts. Emergence percentage in different cohorts of the dominant weed species varied significantly between the two altitudes among different crops, but the variation between 'jhum' and terrace was insignificant. The cohortwise seedling emergence was significantly influenced by PAR, relative humidity, soil moisture and soil temperature. The relative importance of these factors, however, varied from crop to crop and also from species to species.

The mean population density of total recruited seedlings of all the weed species, was significantly higher in 'jhum' (3014 plants/m^2) than the terrace fields (1541 plants/m^2) at high altitude. Low altitude site had much lower mean density (677 plants/m^2). The density of *G. ciliata* was higher in terrace, while that of *P. alatum* and *S. arvensis* was higher in 'jhum' fields. *G. ciliata* which was present at both the altitudes showed higher population density at the high altitude.

The survivorship curves of *P. alatum, S. arvensis, G. ciliata, E. sonchifolia* and *R. pilosa* were similar. The first and second seedling cohorts exhibited high juvenile mortality, while the third cohort was characterised by constant rate of mortality throughout the life. Half-lives of the early recruiting cohorts were significantly higher than the late recruiting cohorts.

In order to characterise the weed population flux in different crop fields, seedling recruitment (K), survivorship (p) and fecundity (F) rates and rate of increase in the viable buried weed seed population in soil (λ) were computed. The seedling recruitment rate ranged between 6-44% in terrace and 6-31% in 'jhum' depending on the crop. The survivorship rate ranged between 21-50% in 'jhum' and 25-47% in terrace. The fecundity rate was more in terrace than 'jhum' and was related to the population density of adult plants which was two fold higher in the latter than the former. The chief cause of higher annual rate of increase in viable buried seed population in 'jhum' than terrace was the traditional method of weed control in 'jhum' wherein the uprooted weeds, some of which bearing a large number of seeds are buried in the field it self. On the other hand, removal of uprooted weeds from the field and use of herbicides were responsible for the reduction in the total buried weed seed population in the terrace fields.

The growth of weeds was assessed on the basis of dry matter production, which varied between the two agroecosystems. Total average dry matter production of weeds was 1012 $g.m^{-2}$ in 'jhum' fields and 790 $g.m^{-2}$in terrace fields. At Upper Shillong major portions of dry matter production (66-78%) was contributed by *S. arvensis, P. alatum* and *G. ciliata* while that at Barapani (30-

39%) was contributed by *E. sonchifolia, G. ciliata* and *R. pilosa.* In all the species, first cohort contributed about 75%, while the share of second and third cohort was 20% and 5%, respectively. This clearly indicates that along with survival, growth of the late emerging cohorts was also adversely affected by the early recruited cohorts of different weed species as well as by the established crop plants in the field. PAR and soil moisture were the two most important environmental variables, which influenced the dry matter yield of different weeds. At low altitude, however, influence of soil moisture was stronger than PAR. The reduction in crop yield was more in 'jhum' (20-48%) than terrace fields (19-34%).

In a nutshell, the seedling emergence, survivorship and half-lives of dominant weeds as well as the dynamics of total weed population was broadly similar in 'jhum' and terrace agroecosystems. However, the dominance distribution pattern in the weed community, rates of seedling emergence and fecundity, population density of recruited seedlings and buried weed seed populations were different in the two agroecosystems and were also influenced by the altitudinal variation in the study sites.

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*I certify that the thesis entitled "**Dynamics of weed populations in hill agroecosystems of Meghalaya**" submitted by Miss Jahnaba Misra, for the degree of **Doctor of Philosophy** of North-Eastern Hill university, Shillong, embodies the record of original investigation by her under my supervision. She has been duly registered and the thesis presented is worthy of being considered for the award of the **Ph. D. Degree**. The work has not been submitted for any degree of any other University.*

Shillong
The 9th November, 1992.

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Contents

1. GENERAL INTRODUCTION 1

2. REVIEW OF LITERATURE 7

3. STUDY SITE 27

4. METHODOLOGY 28

5. WEED FLORA OF CROP FIELDS UNDER 'JHUM' AND TERRACE CULTIVATION 34

6. MICROENVIRONMENT OF CROP FIELDS UNDER 'JHUM' AND TERRACE CULTIVATION 49

7. POPULATION DYNAMICS AND GROWTH BEHAVIOUR OF TWO DOMINANT WEEDS IN DIFFERENT CROP FIELDS UNDER 'JHUM' AND TERRACE CULTIVATION AT UPPER SHILLONG 55

8. POPULATION DYNAMICS AND GROWTH BEHAVIOUR OF TWO DOMINANT WEEDS IN DIFFERENT CROP FIELDS UNDER TERRACE CULTIVATION AT BARAPANI 71

9. POPULATION DYNAMICS AND GROWTH BEHAVIOUR OF *GALINSOGA CILIATA* - A DOMINANT WEED AT HIGH AND LOW ALTITUDE CROP FIELDS 85

10. GROWTH AND POPULATION DYNAMICS OF WEEDS AND THEIR INFLUENCE ON CROP YIELD IN 'JHUM' AND TERRACE CULTIVATION 100

11. GENERAL DISCUSSION 115

SUMMARY 125

REFERENCES 131

Chapter 1

GENERAL INTRODUCTION

Agroecosystem is an altered natural system in which humans direct the flow of energy through the crops and humans in a typical grazing food chain (Mitchell 1979). More comprehensively, agricultural ecosystems or agroecosystems are energy subsidised man managed ecosystems which aim at enhancing the agricultural yield for sustenance of mankind. Agriculture is viewed throughout the world as the most reliable source of food and fibre and therefore, perhaps is the single most important activity of the mankind (Haines 1982).

Weeds - the unwanted plants in the crop fields, interfere in the management of agroecosystem and assume significance by reducing the crop yield. They compete with neighbouring crop plants for essential growth requirements and at the same time modify the physical environment within the community, which in turn influences the growth of crop plant as well as their own growth and population dynamics. During the process of struggle for their existence in the crop fields, they often succeed owing to their wide ecological amplitude and continue to multiply and flourish even in those environmental conditions where growth of crop plant is extremely difficult, if not impossible.

Weeds have drawn the attention of agronomists and ecologists alike and their effective control in agriculture, horticulture and human habitation has been the main concern of researchers during the last few decades. This involves a thorough understanding of the population biology of weeds.

Agriculture is the backbone of Indian economy contributing more than 30% of the gross national product. About two third of the country's population has an agrarian base (Khanna 1989). The crop loss due to weeds in India has been estimated to be in the range of 10-80% (Chakravarty 1963). Therefore, sincere efforts have been made to control the growth of notorious weed species in different agroclimatic regions of the country. The north-eastern India comprising the states of Arunachal Pradesh, Assam, Manipur, Meghalaya, Mizoram, Nagaland, Sikkim and Tripura has been classified under eastern Himalayan agroclimatic region on the basis of homogeneity in agro-characteristics such as rainfall, temperature, soil, topography, cropping, farming systems and water resources (Khanna 1989). This region is characterised by high rainfall and has dense forest cover. The slash and burn agriculture or shifting cultivation on the hills and settled farming in the plains, valleys, foot hills and terraced slopes are the two major farming systems of the north-eastern India. The shifting cultivation is the most prevalent form of agriculture in this region and accounts for about 35% of the total cultivated area (Bora 1989).

In the age-old practice of shifting cultivation (locally called 'jhum'), a short but variable cultivation phase on slash and burn cleared land alternates with a long equally variable fallow period. The clearing of forest and other secondary vegetation is accomplished with simple hand tools leaving behind the useful trees and shrubs, which are pruned down to the level of stumps of varying heights for their regeneration and also to provide support to the viney crops requiring staking. The dry plant debris are burnt before seeds and other planting material are sown in holes on the flat, lightly tilled, or untilled mounds or ridges. During a short phase of cultivation, crops are grown in mixtures of several varieties and species. This is followed by a much longer (ten to twenty years) fallow period, when the land is allowed to revert to the natural vegetation or very rarely, voluntarily protected or planted vegetation (Okigbó 1984). Lately the duration of the fallow period has been reduced to 3-5 years due to increasing population pressure, causing irreparable damage ? to the hill ecosystem by causing depletion in the vegetal vegetational cover, accelerating soil erosion and nutrient loss from the system.

The terrace cultivation on hill slopes, a form of settled cultivation, was introduced in northeast India three decades ago to provide an improved production system, to conserve soil moisture and to prevent further land degradation. In this system, bench terraces are constructed on hill slopes running across the slopes. The space between two bunds is levelled by cut and hill method. The vertical interval between the terraces does not usually exceed one metre. Such measures help in controlling soil erosion and retaining maximum rain water within the slopes and safely disposing off the excess run off from the slopes to the foothills (Singh and Prasad 1987). Unlike 'jhum', chemical fertilizers and herbicides are applied regularly.

Innumerable studies have been carried out both in India and abroad to understand the nature of crop - weed competition and to assess the effect of the latter on the former in the agroecosystems. However, studies dealing with the analysis of weed community characteristics and the pattern of population dynamics of different weed species in crop fields are limited. It is also not well understood how the community composition and population behaviour of different weed species vary from one crop to another and to what extent cultural operations affect the demography of weeds in different agroecosystems.

Studies on plant population dynamics seek to answer many important questions about the differences in the number of organisms from place to place and from time to time. It is also concerned with the interactive influence of physical environment, which influences population growth and individual's survival (Harper 1977). It describes the sequence of events that determines the success of seeds leading to the production of more seeds. Seed germination and emergence initiates a chain of events in the sequence and lead to recruitment of individuals in a population. The heterogeneity in the microenvironment combined with the specific germination requirements determine the timing number and variety of seedlings that are recruited from the seed bank. Genetic constitution, dormancy characteristics, development pattern of seeds and their extent of exposure to the extraneous factors such as temperature, light and water determine the emergence pattern of weed seedlings in the crop fields. The interactions among these factors and variation in the time of seedling emergence gives rise to different successive cohorts of seedlings (Benjamin 1990). The behaviour of these seedling cohorts may differ from one another and therefore an analysis of their behaviour may provide important clues for understanding the population behaviour of weeds in the crop fields.

With the growth of both crops and weeds, the microenvironmental conditions change within the community. This change obviously depends on many factors including the growth form and density of the crops and weeds. Therefore, a study of the microclimatic conditions and their role on germination, seedling emergence, survival and growth of weeds may be useful in explaining their population behaviour within the agroecosystem.

Population dynamics of weeds studied in two major types of agroecosystems of Meghalaya i.e., 'jhum' and terrace encompasses all these aspects with the following main objectives:

- Phytosociological analysis of weed communities and dominance distribution pattern in different crop fields at two altitudes of Meghalaya.

- Study of temporal variations in microenvironmental conditions in different crop fields and their influence on population parameters and growth of weeds.
- Population dynamics of dominant weed species in 'jhum' and terrace agroecosystems.
- Dynamics of weed populations in different 'jhum' and terrace fields and their influence on crop yield.

The data collected on these aspects for two years (1988-1990) have been presented and discussed in this dissertation. General Introduction and Review of Literature outlining the objectives of study and the state-of-art on the subject have been given in chapters 1 and 2, respectively. The third chapter deals with the location, climate, geology, soil and vegetation of the study sites and includes calendar of agricultural operations in 'jhum' and terrace fields. Chapter 4 describes the methodology. Phytosociological analysis of weed communities are presented in chapter 5. Chapter 6 illustrates the microenvironment in different crop fields. Results of population dynamics and growth studies have been discussed through chapters 7 to 10. The major findings of the entire study have been discussed in chapter 11, which is followed by a summary, the gist of the thesis.

Chapter 2

REVIEW OF LITERATURE

Weeds have been accepted as an inevitable nuisance in the crop fields, since the time man started cultivation. The origin of weeds has been traced and discussed by Baker (1974) and De Wet and Harlan (1975). According to them, weeds evolved in the man-made habitats in three principal ways, (i) through natural selection from wild colonizers, which later on got adapted to continuous habitat disturbance, (ii) as the derivatives of hybridization between wild and cultivated races of the domestic species and (iii) as the abandoned domesticates which evolved through natural selection towards a less intimate association with man. Harlan (1965) has suggested a parallel evolution of crop and weed from a common ancestor.

Weeds, the unwanted component in an agroecosystem, compete with the crop plants for essential growth requirements such as light, water, nutrients and sometimes for carbon dioxide and space, causing a significant reduction in the quality and quantity of yield and an increase in the cost of cultivation. Holm *et al.* (1977) have presented quantitative data regarding the loss in crop production due to weed competition across the world. They reported that in certain situations, there may be cent percent loss in crop yield due to competition. Different aspects of competition between crops and weeds have been studied by a large number of workers all over the world (Bleasdale and Nelder 1960, de Wit 1960, Bornkamm 1961, Tripathi 1967, Misra 1969, Rogers *et al.* 1976, Dawson 1977, Zimdahl 1980, Pollard 1982, Spitters and Aerts 1983, Thornley 1983, Cousens 1985, Firbank and Watkinson 1986, Cousens *et al.* 1988, Firbank and Watkinson 1990). The nature of interference between weeds and crops has been discussed in detail by Glauninger and Holzner (1982). According to Aldrich (1984), competition for space in true sense is the competition for one or more of the five growth factors that space contains viz., nutrients, water, light, carbon dioxide and oxygen. Besides competition, weeds affect crop growth through allelochemics. This aspect has been investigated and discussed by Rice and his co-workers (1974), Sarma *et al.* (1976), Harvey and Linscott (1978) and Toai and Linscott (1979).

Study of floristic composition is one of the most important aspect of community ecology which has attracted the attention of ecologists all over the world. But compared to natural communities, floristic studies of the weed communities are limited. An over view of the weed flora in the Mediterranean countries has been given by Montegut (1974), Barralis (1976, 1977), Zaragoza and Maillet (1980), Guillerm and Maillet (1982) and Tanji and Boulet (1986). In southern Spain, Hernandez-Bermejo *et al.* (1984) studied the weed flora of irrigated crops. Similar data for orchards and horticultural crops were collected by Pujadas-Salva and Hernandez-Bermejo (1986), while weeds of cereals, rape field and olive groves were studied by Montegut

(1974), Garcia-Torres and Vazquez (1979) and Garcia-Torres *et al.* (1983). Saavedra (1987) and Saavedra *et al.* (1989) studied the weed flora of irrigated fields of Guadalquivir valley, Spain. Weed flora of arid crops in Cordoba, Spain was studied by Hidalgo *et al.* (1990). A survey of the dicotyledonous weeds of spring cereals in northeast Scotland was carried out by Carnegie (1974) and Simpson and Carnegie (1989). Weed flora of Italy was enumerated by Franzini (1982). Hubl and Holzner (1982) reviewed the weeds of Iran. In Mongolia, weeds in different farm lands were described by Hilbig (1982). Weeds of crop fields in Japan were described by Kasahara (1982), in New Zealand by Rahman (1982), in Canada by Alex (1982), in Brazil by Hashimoto (1982) and in South Africa by Wells and Stirton (1982). Saavedra *et al.* (1990) based on his studies conducted in different crop fields, concluded that the weed flora of cultivated fields markedly differ from the uncultivated areas.

In India, studies enumerating the weed flora of crop fields in different parts of the country are those of Singh and Mital (1941), Thakur (1954), Chakravarty (1957), Maheshwari (1961), Singh (1961), Datta and Maiti (1964), Tripathi (1964), Mahapatra *et al.* (1965), Singh (1969), Bir and Sidhu (1976), Ambasht and Chakhaiyar (1979), Sharma (1981), Ambasht (1982), Raina (1987) and Sundaramoorthy *et al.* (1988). Datta (1972) described the weed flora of tea estates in northeast India. Rao and Neogi (1978) studied the flora of Garo Hills. Neogi (1980) studied the weed flora of arable land in Meghalaya. Non-indigenous plants in the flora of Shillong have been described by Rao and Dam (1980). Other studies on the weed flora of Meghalaya are those of Rao (1978), Kumar (1984) and Pradhan (1990).

The growth and abundance of weeds in the crop fields are influenced by a large number of factors such as the general climate of the area, microclimatic conditions within the crop fields, soil conditions and cultural operations adopted during cultivation (Tripathi 1977). According to Heady (1956 a,b, 1958) and Pitt and Heady (1978), variation in rainfall is of prime importance in determining the relative abundance of annual species in the grasslands of California. Significance of environmental heterogeneity of different scales in maintaining species diversity within the community has also been emphasized by several workers (Levin and Paine 1974, Bazzaz 1975, Menge 1979, Hartgerink and Bazzaz 1984).

A large fraction of total seeds produced by plants is dispersed and/or lost by run off, wind, predation and grazing (Harper 1957, Sarukhan 1974, Keeley and Hays 1976, Keeley 1977). The remaining seeds enter into the soil and become a part of the soil seed bank. The composition, density and physiological state of weed seed population in the soil are important factors which influence the composition and abundance of species in the weed community of the arable land. The density and distribution of seeds in soil seed bank in cultivated fields and grasslands have been determined by many workers (Roberts 1958, 1962, Robinson and

Kust 1962, Wilson 1985, Chauvel *et al.* 1989). Studies of Kivilann and Bandursky (1981) showed that arable soils under different agricultural systems contain large number of weed seeds which remain viable for several decades, but majority of them fail to produce seedlings (Roberts 1979) due to loss in viability, predation, rotting etc. (Roberts and Feast 1972, Roberts 1979). Induced and enforced dormancy also delay germination and emergence of the seedlings (Sarukhan 1974, Baskin and Baskin 1975, Gorski *et al.* 1977, Yadav and Tripathi 1981, Purvis *et al.* 1985, Wilson 1985, Chauvel *et al.* 1989). The role of soil seed bank in the maintenance and dynamics of plant populations and communities has been emphasized by Baskin and Baskin (1978), Templeton and Levin (1979) Mallik *et al.* (1984) and Parker and Leck (1985).

Seed germination and seedling emergence are two important processes that lead to the recruitment of individuals in a population. Time of germination is also crucial since it determines the survival of seedlings and their successful growth and establishment under natural conditions. A great deal of work has been done on germination of weed seeds (Harrington 1916, Tester and McCormick 1954, Weir 1959, Taylorson and McWhortner 1969, Singh 1973, Toole 1973, Martin *et al.* 1975, Baskin and Baskin 1977, 1988, 1989, 1990, Bobstock 1978, Evans *et al.* 1979, Fenner 1980, Bewley and Black 1982, Groves *et al.* 1984, Forcella and Wood 1986, Manthey and Nalewaja 1987, Rai 1987, Dubey and Pandey 1988, Eddleman and Romo 1988, Pandey 1988, Pandey and

Dubey 1988, Egley 1990, Buhler and Mester 1991, Mester and Buhler 1991). Excellent review papers on the subject are those of Thompson (1973), Harper (1977), Fenner (1985) and Sindel (1991).

The weed species mostly emerge periodically (Boydston 1990) from the buried seed bank and pose a potential threat to the crop production. The time of weed emergence determines the competitive relationship between crops and weeds (Cousens *et al.* 1987, Kroff 1988a,b). The pattern of emergence for a species during a particular year remains remarkably similar regardless of the period of burial of the seed population (Brenchley and Warington 1930, Chepil 1946, Roberts 1964, Zimdhal *et al.* 1988). In his experiments with *Avena fatua*, Peters (1991) found that cultivation increased the emergence of seedlings after prolonged seed burial. The effect of burial depth on seedling emergence of various weed species was studied by Abul-Fatih and Bazzaz (1979), Tayalla *et al.* (1988), Boydston (1989), Lapham and Drennan (1990) and Shaw *et al.* (1990). They found that emergence percentage declined with increase in burial depth.

A plant population, which tends to colonize a habitat undergoes different phases of growth in time. It grows exponentially till the resources become limiting and thereafter if the natality and mortality become equal, the population gets stabilized showing fluctuations around a mean value. However, growth of the population itself brings about certain changes in the environment. The modified environment may prove to be unsuitable for the early colonizers and their populations may disappear due to increased mortality. The ecological success of a species in a given habitat therefore, depends on its capacity to adjust itself with the changing environmental conditions. The changes in the environment may however, be reflected in the fluctuations in population size. The study of the fluctuations in the population size in time and space is referred to as population dynamics, a term for the first time proposed by Elton (1933).

The history of plant population biology dates back to Nägeli's work in 1874, which was the first significant published work on the subject. Thereafter, Tansley (1917), Sukatschew (1928) and Clements *et al.* (1929) made pioneering studies on different aspects of population biology. Prof. J.L. Harper and his group (Harper and White 1971, Sarukhan and Harper 1973, Hawthorn and Cavers 1976, Harper 1977, Watkinson and Harper 1978) gave a new thrust to the population studies in plants. This was a departure from the traditional way of studying the population biology, which was largely based on mere counting and describing the populations. In addition to the natural dynamics, population studies include the dispersal and dormancy of plant propagules, recruitment of seedlings and the effects of neighbouring plants and predators on plant populations. The demographic approach for population analysis of weeds was introduced by Sagar and Mortimer (1976) and a complete review of the subject is found in the work of Cousens *et al.* (1987). The role of density on population dynamics of weeds has been emphasized by Harper and Gagic (1961), Wu and Jain (1979) and Law (1981). A good number of studies are also available on the effects of herbivores on growth, survival and reproduction of plant populations (Giellett 1962, Feeny 1976, Rausher and Feeny 1980).

Studies on the population dynamics of several perennial grasses and herbs have been carried out by Willams (1970), Antonovics (1972) Sarukhan and Harper (1973), Hawthorn and Cavers (1976), Bishop *et al.* (1978), Tripathi and Dwivedi (1978), Kushwaha *et al.* (1981), Yadav and Tripathi (1981), Auld and Myerscough (1986) and Kataoka *et al.* (1989). Holt (1972), Werner (1977), Klemow and Raynal (1981) and Kelly (1989 a,b) studied the population dynamics of biennial species. Some important works on the population dynamics of annuals on arable lands are those of Naylor (1972), Harper (1977), Snaydon (1980), Weaver and Lechowiez (1982), Peters and Arc (1983), Smith (1983), Rai and Tripathi (1984), Zimmerman and Weiss (1984), Fernandez-Quintanilla *et al.* (1986) and Gonzalez-Andujar and Fernandez-Quintanilla (1991). The above studies have been carried out mainly on a single or two weed species.

Seedling stage of the life cycle is often characterised by high mortality. Survival of weed seedlings under natural conditions depends on the action of a large number of climatic, edaphic and biotic variables of the environment. Studies carried out by Harper (1977), Silvertown and Dickie (1981) and Fenner

(1985) show that most of the seedlings survive within a narrowly defined limits of moisture, temperature and light. Burton and Muller-Dombois (1984) studied the effect of light on survival and growth of seedlings of different species. Van der Toorns and Pons (1988) studied the influence of photon flux density on survival and growth of *Plantago lanceolata* and *P. major*. All these studies explicitly reveal that light favourably affects the growth and survival of plant populations. Sorensen and Ferrel (1973) investigated the role of temperature on growth of juveniles, while the effect of soil moisture was studied by McLeod and Murphy (1977), Muller Dombois *et al.* (1980) and Schulte and Marshall (1983).

Distribution and abundance of a species in the community is significantly influenced by its associates (Putwain and Harper 1970, Rai and Tripathi 1984). The neighbouring plants, whether of same or of different species generally affect the growth of seedlings in various ways (Fenner 1978, Gross and Werner 1982, Gross 1984). Studies of Newell *et al.* (1981) on *Viola* species reveals that competition may be a cause of seedling death. A number of workers have studied the effect of interspecific competition on growth and survival of various plant species (Sagar 1959, Sagar and Harper 1961, Harper and McNaughton 1962, Harper and Clatworthy 1963, Cavers and Harper 1967, Bergh 1968, Palmblad 1968, Marshall and Jain 1969, Tripathi and Harper 1973, Pradhan and Tripathi 1980). These studies reveal that seedlings of different species may die due to a number of causes and only a few generalizations can be made in this regard, since even in the same species causes of mortality may vary from place to place and from one season to another season. High seedling mortality in populations of different plant species has been observed by many workers (Williams 1970, Sarukhan and Harper 1973, Sharitz and McCormick 1973, Hett and Loucks 1976, Bazzaz and Harper 1976, Yadav and Tripathi 1981, Silvertown and Dickie 1981, Law 1981, Rai and Tripathi 1984, Pandey and Dubey 1989). And a number of authors (Hett 1971, Sharitz and McCormick 1973, Mack 1976, King 1977, Watkinson and Harper 1978, Regehr and Bazzaz 1979, Solbrig *et al.* 1980, Gross 1980, Augspurger 1983, Mack and Pyke 1984) have attempted to specify the causes of seedling mortality in the field and they have even tried to quantify them. There have been many studies on the responses of plant populations to variation in a single factor but only a few of them evaluate the relative importance of multiple factors (Newman 1964, 1965, Sharitz and McCormick 1973, Greig-Smith and Sagar 1981, Mack and Pyke 1983, During *et al.* 1985, de Jong and Klinkhamer 1988).

The natural population is usually a mixture of individuals of different ages or cohorts. Early cohorts are often large in size and they show high fecundity and exhibit greater survival rate (Cook 1980, Zimmerman and Weiss 1984, Kalisz 1986, Miller 1987). Some studies have however, reported lower survival rate of early emerging cohorts (Baskin and Baskin 1972, Van der Toorn and Ten Hove 1982). Findings of a large number of studies on different species show that established plants affect the survival and growth of newly recruited individuals in the population (Friedman 1971, Andel Van and Rozema 1974, Gupta and Tripathi 1979, Singh 1980, Yadav and Tripathi 1981, Rai and Tripathi 1984). It has also been established that the species arriving late in the established population show very low density and survival in comparison to those which arrive early (Tamm 1956, Sagar and Harper 1960, Cavers and Harper 1967, Putwain *et al.* 1968, Hawthorn and Cavers 1976, Weaver and Cavers 1979, Weiss 1981, Rai and Tripathi 1984, Kotaoka *et al.* 1989, Pandey and Dubey 1989). Lee and Hamrick (1983) and Mack and Pyke (1983) have recorded the differences in survival and reproductive behaviour of different cohorts recruited to the same natural population. Newell *et al.* (1981) studied the demography of *Viola blanda* and *V. pallens* in relation to habitat types. Seedling recruitment, age specific survival and reproduction in the population of *Avena sterilis* were studied by Fernandez-Quintanilla *et al.* (1986). Lovett Doust (1981) studied the population dynamics of *Ranunculus repens*. Survival, fecundity and growth of wild cucumber, *Echinocystis lobata* were studied by Silvertown (1985). Young and Evans (1990) studied the survival and growth of *Artemisia tridentata*. Germination, emergence, growth and survival of *Ambrosia trifida* were investigated by Abul-Fatih and Bazzaz (1979). Among-site differences in seedling size, growth and survivorship in *Solidago flexicaulis* were studied by Krannitz and Carey (1988). Several studies (Cook 1980, Solbrig *et al.* 1980, Fowler and Antonovics 1981) have reported lower rate of mortality in larger seedlings than the smaller ones. Sharitz and McCormick

(1973) demonstrated that colonizing species having high fecundity suffer heavy mortality during seedling establishment.

Survivorship curves of many annual weeds show an uniform mortality risk throughout the life of the population. However, certain species like *Danthonia caespilosa* (Williams 1970), *Galinsoga ciliata* and *G. parviflora* (Rai and Tripathi 1984) and *Parthenium hysterophorus* (Pandey and Dubey 1989) differ in this respect by showing high mortality during young stage. Deevey's type I (Deevey 1947) survivorship curve characterised by less risk of death during young and middle ages and high mortality risk at old age is rarely found in plant populations. Canfield (1957) reported such a survivorship curve in case of *Trichache californica, Boutelova hirsuta* and *B. chondrosoides* populations. According to Mack (1976) and Watkinson and Harper (1978) the species that produce large number of seeds show Deevey's type II and type III survivorship curves in contrast to those which produce lesser number of seeds and exhibit type I survivorship curve.

In north-eastern India, 'jhum'- the slash and burn agriculture and recently introduced terrace cultivation are the two main agricultural systems. Crop fields under both 'jhum' and terrace cultivation show heavy infestation of a large number of native and exotic weeds owing to favourable climatic conditions of the region and inefficient weed control measures. Although weeds are known for their harmful effects on crop yield all over the world, their effects are far more serious in slash and burn agriculture practised in many parts of the humid tropics. Studies of Cutting *et al.* (1959), Zinke *et al.* (1978) and Kushwaha *et al.* (1981) show that weed problem under a short 'jhum' cycle is more acute than under a long 'jhum' cycle. In the former case, weeds compete for the limited resources and do not allow the progression of vegetation on 'jhum' fallows. As a result, the weed community persists in a state of arrested succession (Kushwaha *et al.* 1981). Ecology of shifting cultivation has been studied by a large number of workers both in India and abroad. In India, phytosociological study and successional pattern on 'jhum' fallows have been investigated by Toky and Ramakrishnan (1983a) and Saxena and Ramakrishnan (1984). Kushwaha *et al.* (1981) have analysed the community structure on 'jhum' fallows of different ages in northeast India. Mishra and Ramakrishnan (1981) studied the energy flow and Toky and Ramakrishnan (1983b) investigated the nutrient dynamics in 'jhum' ecosystem. Economic aspects of 'jhum' cultivation have been worked out by Mishra and Ramakrishnan (1981) and Tawnenga (1990). A number of similar studies carried out in other countries are discussed in FAO Soils Bulletin (1984).

The terrace cultivation was introduced in the north-eastern India about three decades ago to provide an improved alternative method for enhancing crop yield and checking physical deterioration of soil, which is a serious environmental problem in the entire north-eastern part of the country. Ecological studies, particularly dealing with the crop-weed relations in the terrace fields are meagre in this part of the country. A study carried out by Kushwaha and Ramakrishnan (1987) shows that energy output/input ratio under terrace cultivation is similar to a 5 year 'jhum' cycle. Recently population dynamics and growth of a few weeds in different farming systems under terrace cultivations have been studied by Pradhan (1990) who identified as many as 93 weed species in different farming systems at Barapani in Meghalaya.

Chapter 3

STUDY SITES

LOCATION

The study was carried out during 1988-1990 in the crop fields under 'jhum' and terrace cultivation at high and low altitudes of Meghalaya (Fig. 3.1). The high altitude fields (Plate 3.1) are located at Upper Shillong (alt. 1825m, lat. 25°34′ N, long. 91°56′ E) about 12 km south of Shillong, the capital of Meghalaya, India. At low elevation, the study was conducted in the experimental fields of the Farming System Research plots of Indian Council of Agricultural Research (ICAR) Complex for north-eastern hill region, Barapani (Plate 3.2) (alt. 952m, lat. 25°28′ N, long. 91°53′ E), situated about 22 km north of Shillong.

The terrace field at Upper Shillong is a part of the Central Potato Research Station (CPRS) farm and the 'jhum' field, owned by a local farmer, is situated about 4km south of CPRS. The terrace field was established in 1969 and since then it is under cultivation. The 'jhum' field was left fallow for a period of four years before it was cropped again in 1987.

The Farming System Research, which aims to evaluate the integrated land use system in micro-watersheds of ICAR was initiated in 1984. Before that, the land was a fallow. Bench terraces were introduced along the slope of the eight watersheds,

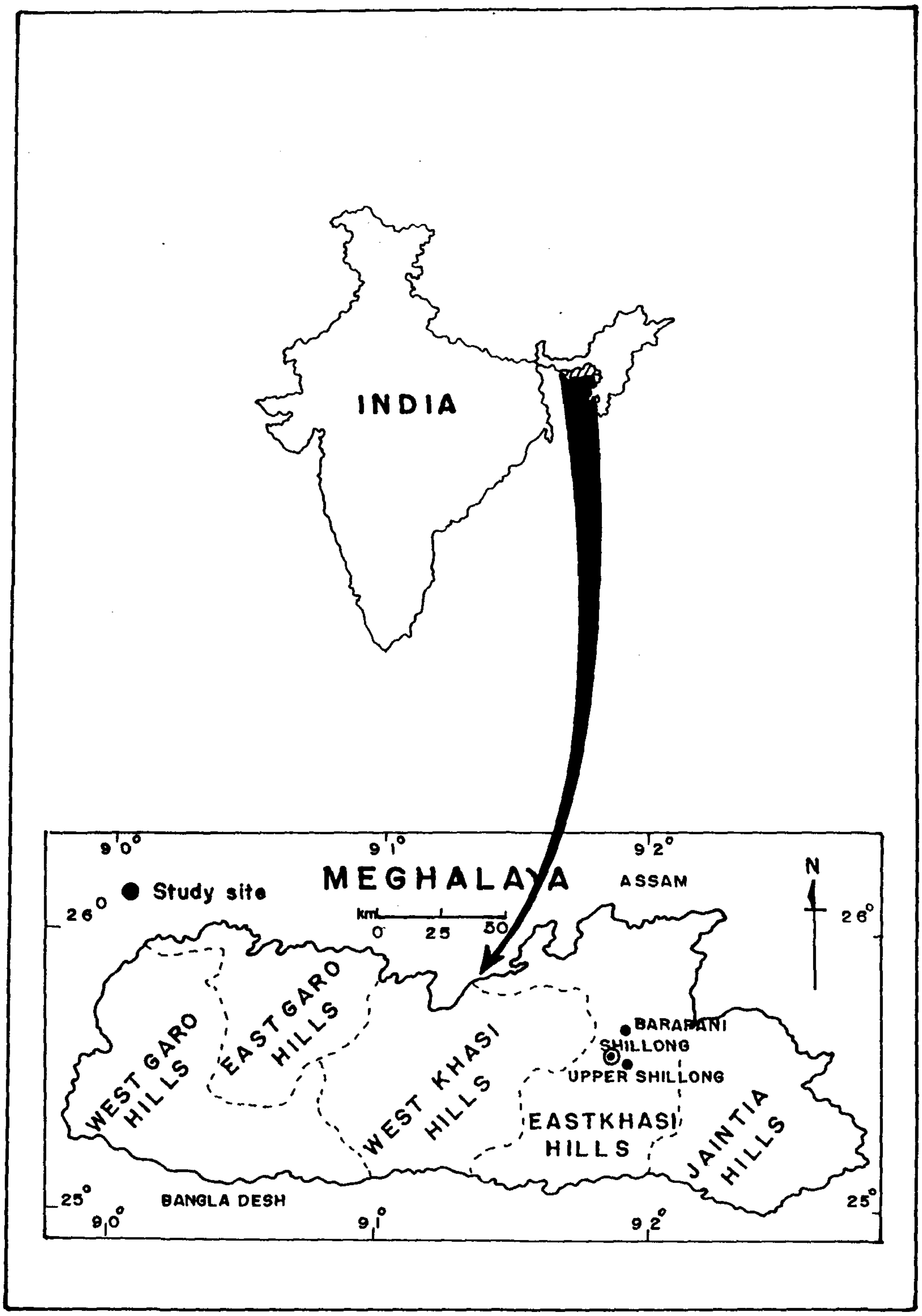

Fig. 3.1. Location of study sites

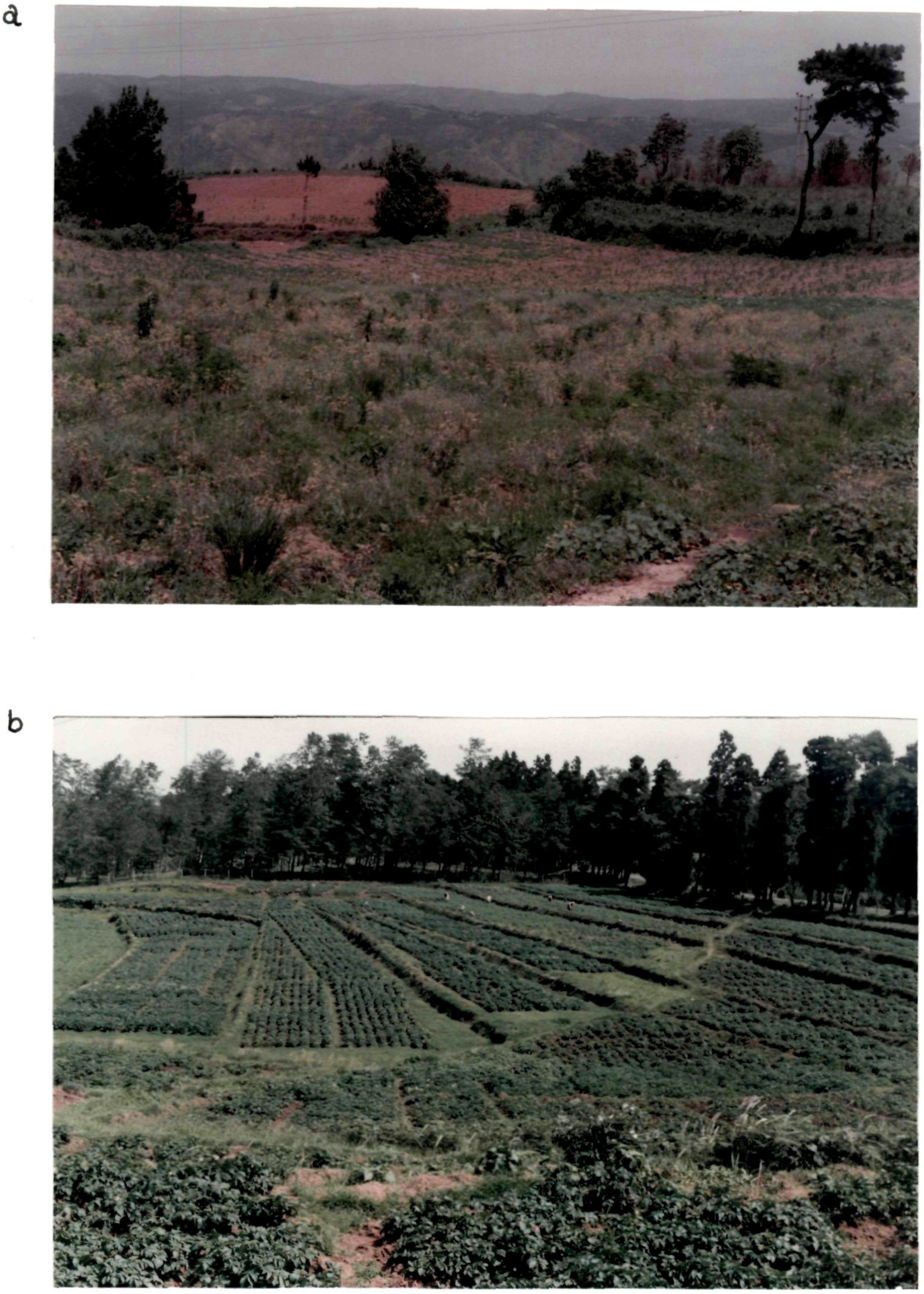

Plate 3.1. An overview of the (a) 'jhum' and (b) terrace field at Upper Shillong.

Plate 3.2. An overview of the terrace field at Barapani.

each representing a different type of farming system such as livestock, forestry, agroforestry, agriculture-based farming system, horticulture system, control (natural fallow) and 'jhum' fallow. This study was carried out on agriculture-based farming system (FS-W_4). Study in the 'jhum' field could not be carried out at this altitude due to difficulty in getting the field.

CLIMATE

The southwest monsoon and northeast winter winds influence the climate of Meghalaya. The climate in general, is characterised by high relative humidity (50-95%) and heavy precipitation. The average annual rainfall for last five years is 2500mm, about 65-80% of which occurs during summer (May-September). The weather is moderate in autumn (October-November), cold and dry during winter (December-February) with occasional showers. March-April representing spring, is usually dry, relatively warmer and windy (Fig. 3.2).

GEOLOGY

The Shillong plateau is situated at 1500m above the alluvial plain of the Brahmaputra Valley. Its southern slopes are abrupt scarps following fault zones rejuvenated in the late Tertiary. On northern side, the plateau slopes towards the Brahmaputra River with a cover of alluvium. Major portion of the Shillong plateau is formed by the Archaean gneisses and granites. The gneisses

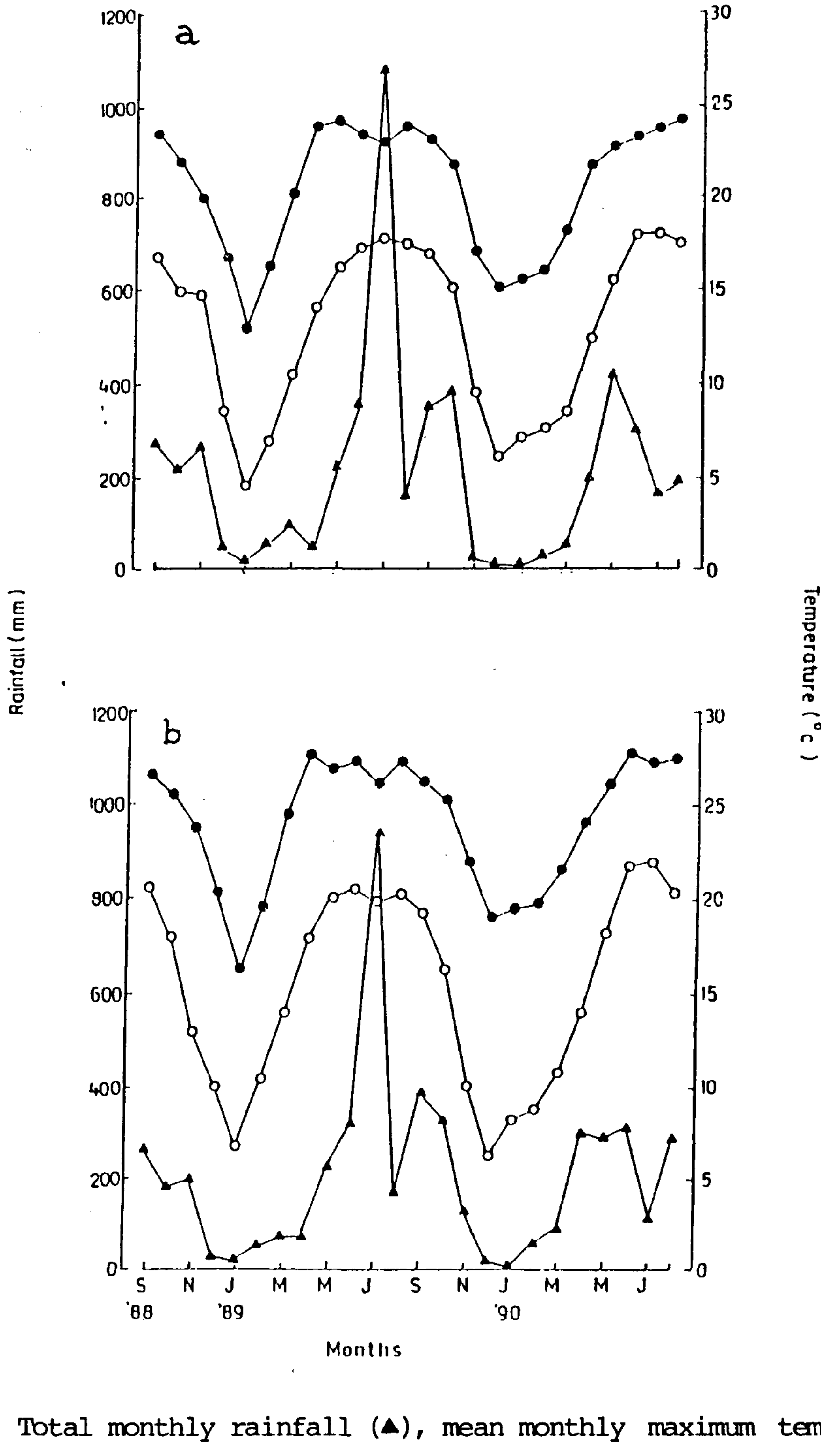

Fig. 3.2. Total monthly rainfall (▲), mean monthly maximum temperature (●) and mean monthly minimum temperature (o) at Upper Shillong (a) and Barapani (b) during the study period.

are finely banded, grey to pinkish in colour and contain microcline, biotite, subordinate quartz and plagioclase. The intrusive granites are mostly porphyritic with large flesh-coloured microcline and some plagioclase, orthoclase and biotite (Gansser 1964).

SOIL

Soils of Meghalaya are formed predominantly from the weathering of sedimentary and metamorphic rocks. At high altitude site, texture of soil is sandy loam and at low altitude, it is clay loam. Soil of 'jhum' fields is slightly more acidic than terrace fields. Other physico-chemical properties of the upper layer soil (0-10 cm depth) were similar at the two sites, except total nitrogen and total phosphorus contents which were lower in 'jhum' than in the terrace fields both at Barapani and Upper Shillong (Table 3.1).

Loss of top soil is a serious problem in the state. Reduction of forest cover and reduced 'jhum' cycle on hill slopes coupled with heavy rainfall are the major causes of erosion and decline in fertility of soil.

VEGETATION

The natural vegetation of Meghalaya ranges from moist deciduous to subtropical broadleaved wet hill forests (Champion

Table 3.1 Soil characteristics of the study sites.

Soil characteristics	Upper Shillong		Barapani
	'Jhum'	Terrace	Terrace
Texture	Sandy loam	Sandy loam	Clay loam
WHC (%)	82	87	89
pH	5.1	5.6	5.5
Organic carbon (%)	4.4	4.6	3.0
Total N (%)	0.30	0.32	0.38
Total P (%)	0.019	0.026	0.028
Total K (%)	0.023	0.011	0.018

and Seth 1968). The moist deciduous forest occurring at lower elevation is dominated by *Adina cordifolia* Hk. f., *Artocarpus chaplasha* Roxb., *Dendrocalamus hamiltonii* Nees & Arn, *Michelia champaca* Linn. *Schima wallichii* Chois.,*Shorea robusta* Gaertn and *Terminalia belerica* Roxb. At high altitude, the climax formation represented by broadleaved forests are dominated by *Q. dealbata* L. *Quercus griffithii* Hk. f. & T., and *Schima khasiana* Dyer. Subtropical pine (*Pinus kesiya* Royle) forest is an important constituent of the vegetation of the state between the altitude of 800 and 1800m. Grasslands in the state occupy the degraded hill slopes. They have been classified under *Themeda-Arundinella* type by Dabadghao and Sankarnarayan (1973). Apart from the two main types of natural vegetation i.e., forests and grasslands, agricultural fields and abandoned 'jhum' fallows infested with a wide variety of native and exotic weeds constitute an important part of the landscape.

CROPPING PRACTICES IN 'JHUM' AND TERRACE FIELDS

At high altitude cropping is done twice a year i.e., during April-August (summer crop) and August-December (autumn crop). Maize, potato, radish, beans etc. are common summer crops, while potato, cabbage, cauliflower, radish, and mustard are grown during autumn. Paddy, maize, groundnut, linseed, green peas, lentil, soyabeans, radish, turnip etc. are the common crops cultivated at Barapani. Maize and groundnut are grown during spring and summer, while radish and linseed crops are grown during autumn and winter seasons.

The calendar of agricultural activities for different crops studied at high and low altitudes are given in Fig. 3.3. It shows that the sowing time was similar for all crops in 'jhum' and terrace fields at Upper Shillong. But the crops such as maize and radish which were cultivated at both high and low altitude sites had different sowing time. In all the crop fields irrespective of their elevational variation, first batch of weed seedlings emerged within 8-10 days of crop sowing.

The details of agricultural practices followed in 'jhum' and terrace fields at the study sites are given in Table 3.2. The 'jhum' fields were dug by spade and weeding was done manually. Chemical fertilizers and herbicides were seldom used. On the contrary, in the terraces ploughing was done mechanically. Use of chemical fertilizers and better weed control measures through more frequent hand weeding and herbicide applications were the characteristic features of terrace cultivation.

The density of crop plants was same in both 'jhum' and terrace fields and also at both the altitudes. The crop density (plants m^{-2}) was 16 in potato, 12 in maize, 25 in radish and 12 in cauliflower crop.

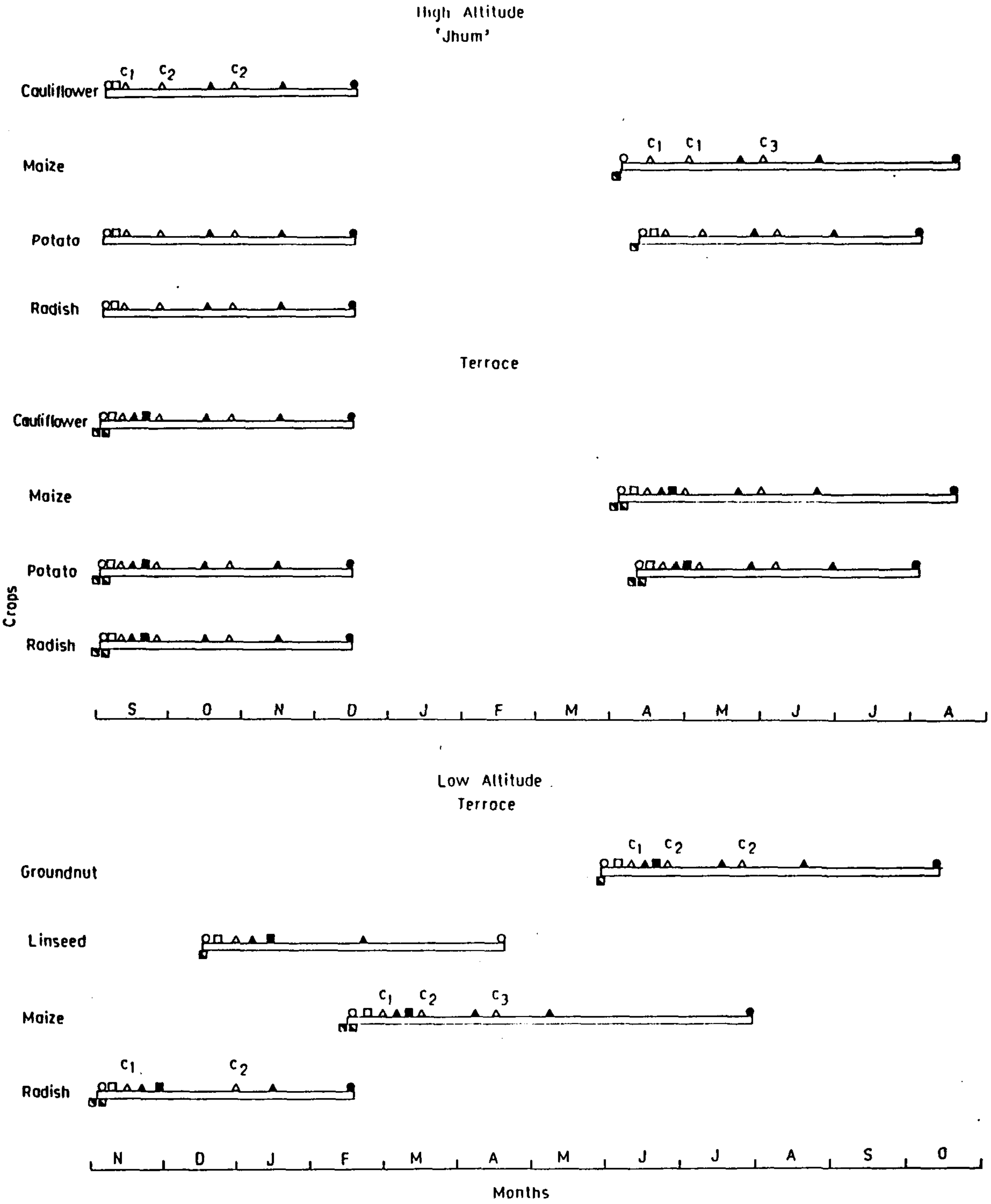

Fig. 3.3. Calendar of agricultural activities for different crops studied under 'jhum' and terrace cultivation at Upper Shillong (high altitude) and Barapani (low altitude). ▨ -manuring, ▨ -fertilizer application, o - crop sowing, □ -quadrats laid, △ -weed emergence, ▲ -weeding, ■ - herbicide application, and ●-crop harvest.

Table 3.2 Agricultural practices followed in 'jhum' and terrace fields.

Cultural operation	'jhum'	Terrace
Cultivation	Manual spading	Mechanical hoeing
Depth of ploughing	Up to 15 cm	Up to 20 cm
Weeding operation	Hand weeding (twice during a cropping season)	Hand and mechanical weeding (thrice during a cropping season)
Application of farmyard manure	10 t/ha at the beginning of summer crop	10 t/ha at the beginning of each summer and autumn crop
Application of chemical fertilizer	Nil	60kg N/ha, 80kg P/ha, 40kg K/ha before sowing of each crop.
Herbicide application	Nil	During seedling stage of weeds
Harvesting of root crops	Down to 15-25 cm	Down to 15-20 cm

Chapter 4

METHODOLOGY

WEED COMMUNITY ANALYSIS

At Upper Shillong (high altitude site), maize, potato, cauliflower and radish crop fields under 'jhum' and terrace cultivation were extensively surveyed to study the weed flora. Out of these, three fields were randomly selected during August, 1988 for phytosociological study of weed communities. The size and number of quadrats for the study of weed community were determined according to Misra (1968). Accordingly, seven permanent quadrats of 50cm * 50cm were randomly laid in each of the fields immediately after crop sowing. The weeds which emerged in the quadrats were identified and their density, frequency, dominance (basal cover) were determined at an interval of 15 days until crop harvest (Misra 1968). Relative density, relative frequency, relative dominance and importance value were calculated for each species. At Barapani (low altitude site), the weed community was studied in maize, radish, groundnut, and linseed crops in ICAR Research Complex by adopting the same method. Weeds in each field were ranked on the basis of their importance value.

The discriminant analysis was performed using the IVI values of the species present in 'jhum' and terrace fields. This method was applied to test whether the abundance of the species occurring in the 'jhum' fields is significantly different from those in terrace fields and if so, to know the species which are most responsible for the observed difference between the two fields. The discriminant weights of the linear discriminant function were used to rank the species in order of their importance in differentiating the two weed communities. Coefficients of linear discriminant function representing the importance of each of the variable in a multivariate sample have been used to separate two different groups/areas (Anderson 1958, Poole 1974).

Shannon's diversity index ($\bar{H}$) has been calculated using the following formula:

$$\bar{H} = -\Sigma(n_i/N \log (n_i/N)$$

where n_i=importance value of each species

N = total of importance values

MONITORING OF MICROENVIRONMENT IN CROP FIELDS

In each crop field photosynthetically active radiation (PAR), relative humidity, soil moisture and soil temperature were measured at 20 places between 11-1200 hr. at fortnightly interval. PAR and relative humidity were measured both above and below the crop canopy (about 2 cm above the ground). PAR was measured with a PAR sensor attached to a carbon dioxide gas analyser (ADC, London) and relative humidity was measured using a hygrometer. Soil moisture was measured using a digital soil moisture meter (OSK-2800, Tokyo) with its sensor placed at a depth of 10 cm. Temperature of the top 10 cm soil was determined by a soil thermometer. Analysis of variance (fixed effects model) was performed on the microenvironmental data to study the variation between different crop fields located at two altitudes.

POPULATION DYNAMICS

Population dynamics of a few dominant weeds in all the above mentioned crop fields under 'jhum' and terrace cultivation at Upper Shillong and in maize and radish crop fields under terrace cultivation at Barapani was studied by collecting time series data on seedling survival in the above said permanent quadrats laid in each crop field. Maize and radish crops were selected for study at Barapani in order to compare the population behaviour of weeds in the same crops cultivated at two different altitudes. Weed seedlings, which emerged in different batches at different times were marked with waterproof paints on the top of their cotyledon as well as on the first eophyll by different colours (Yadav and Tripathi 1981). These batches of seedlings were designated as cohorts. At least three cohorts were recognized in each crop field. The fate of the marked seedlings in each cohort was monitored at fortnightly interval until crop harvest. Half-life period (time from emergence to 50% survival) and mortality pattern for each cohort of a given weed species were studied using time series density data (Harper 1977). Weed seed production was determined in each quadrat by multiplying the density of fertile plants with the average number of seeds per plant. Data on viable seed population in soil is taken from Sahoo (1992) who determined it by analysing twenty soil cores (diameter 5.7 cm, depth 20 cm), randomly collected at monthly interval from each field. Weed seeds in soil samples were recovered by floatation method (Roberts and Ricketts, 1979) and their viability tested with 0.1% 2,3,5-triphenyl tetrazolium chloride.

The total weed population flux in each field was studied by computing seedling recruitment rate (K) (the ratio between the emerged seedlings and the number of viable seeds in soil seed bank), survivorship (p) (the probabilities of emerged seedlings surviving to set seeds), and fecundity (F) (total seed production m^{-2} divided by the number of mature plants m^{-2} present at harvest) according to Mortimer *et al.* (1980). Seasonal and annual growth of seed population in the soil (λ) was determined by the following formula (Mortimer *et al.*, 1980):

$$\lambda = \sqrt[t]{N_{t+1} * N_t^{-1}}$$

where N_t is the seed population at the beginning and N_{t+1} is the seed population at the end of the t season/year.

Seed loss (SL) from the system has been estimated as follows:

$$SL = (SB_t + SP_t) - (ES_t + SB_{t+1})$$

where SB_t is the seed population in the soil, SP_t is the seed production, ES_t is the emerged seedlings at the beginning of the season and SB_{t+1} is the seed population at the end of the season. The effect of different crops and cultivation practice on percentage emergence of the seedlings in different cohorts and their half-lives were studied for dominant species using three-way ANOVA. Tukey's multiple comparison test was also performed for half-life values to examine the difference between all possible pairs. The relative importance of microenvironmental variables i.e., PAR, relative humidity, soil moisture and soil temperature on seedling emergence percentage was evaluated using partial correlation analysis (Zar 1974).

DRY MATTER PRODUCTION

For growth studies, ten quadrats of 1m * 1m size were randomly laid at the time of crop sowing in each field selected for the study. The weed biomass in different crop fields was determined by collecting plants on each sampling date from the quadrats distributed in three replicate fields laid for this purpose. The weed plants were extracted by digging monoliths of size 25 cm *25 cm * 25 cm from each quadrat and separated from soil by washing following the method given by (Roberts *et al.* 1985). Dry weight was determined by oven drying the shoot and washed root samples at 80 °C to a constant weight.

Cohortwise data were analysed using three-way ANOVA to study the effect of different crops and mode of cultivation on weed biomass production. The relative importance of most important microenvironmental variables, i.e., PAR and soil moisture on dry matter production was evaluated using partial correlation coefficients and multiple regression models have been proposed to estimate their biomass in a given set of PAR and soil moisture conditions.

EFFECT OF WEEDS ON CROP YIELD

To study the effect of weed growth on crop yield an experiment was set in the beginning of the crop sowing in each field. Twenty 1m * 1m size quadrats were laid in each of the crop field under 'jhum' and terrace cultivation. Ten quadrats were left unweeded, while in the remaining ten quadrats weeding was done at regular interval. The economic yield of each crop was determined by weighing the crop after harvest. The tuber part in potato, inflorescence in cauliflower, taproot of radish and grain in maize were considered for measuring the economic yield. Analysis of variance on yield was performed to test the variation between weeded and unweeded plots and under 'jhum' and terrace fields.

Chapter 5

WEED FLORA OF CROP FIELDS UNDER 'JHUM' AND TERRACE CULTIVATION

Farmlands situated at different altitudes and under different cultivational practices vary considerably in composition of weed flora due to differences in crops and edapho-climatic conditions (Saavedra *et al.* 1989, Andreasen *et al.* 1991). Crop cycle has also been reported to greatly influence the composition of weed community in the crop field (Barralis 1976). Agrestal weed flora also differs under different modes of weed control measures (Montegut 1974). Some recent studies on weed flora of crop fields are those of Simpson and Carnegie (1989) in Scotland, Hidaglo *et al.* (1990) in Spain and Thomas and Ivany (1990) at Prince Edward Island.

In India, Tripathi (1964) studied the weed flora of crop fields at Varanasi. Weeds in various crop fields in different parts of the country were listed by Singh and Mital (1941), Thakur (1954), Singh (1961), Ambasht and Chakhaiyar (1979), Sharma (1981), Ambasht (1982) and Sundaramoorthy *et al.* (1988).

In north-eastern India, both agrestal and ruderal weeds grow abundantly due to favourable edapho-climatic conditions and the crop fields as such are heavily infested with a large number of native and exotic weed species (Plate 5.1-5.2). A taxonomic study

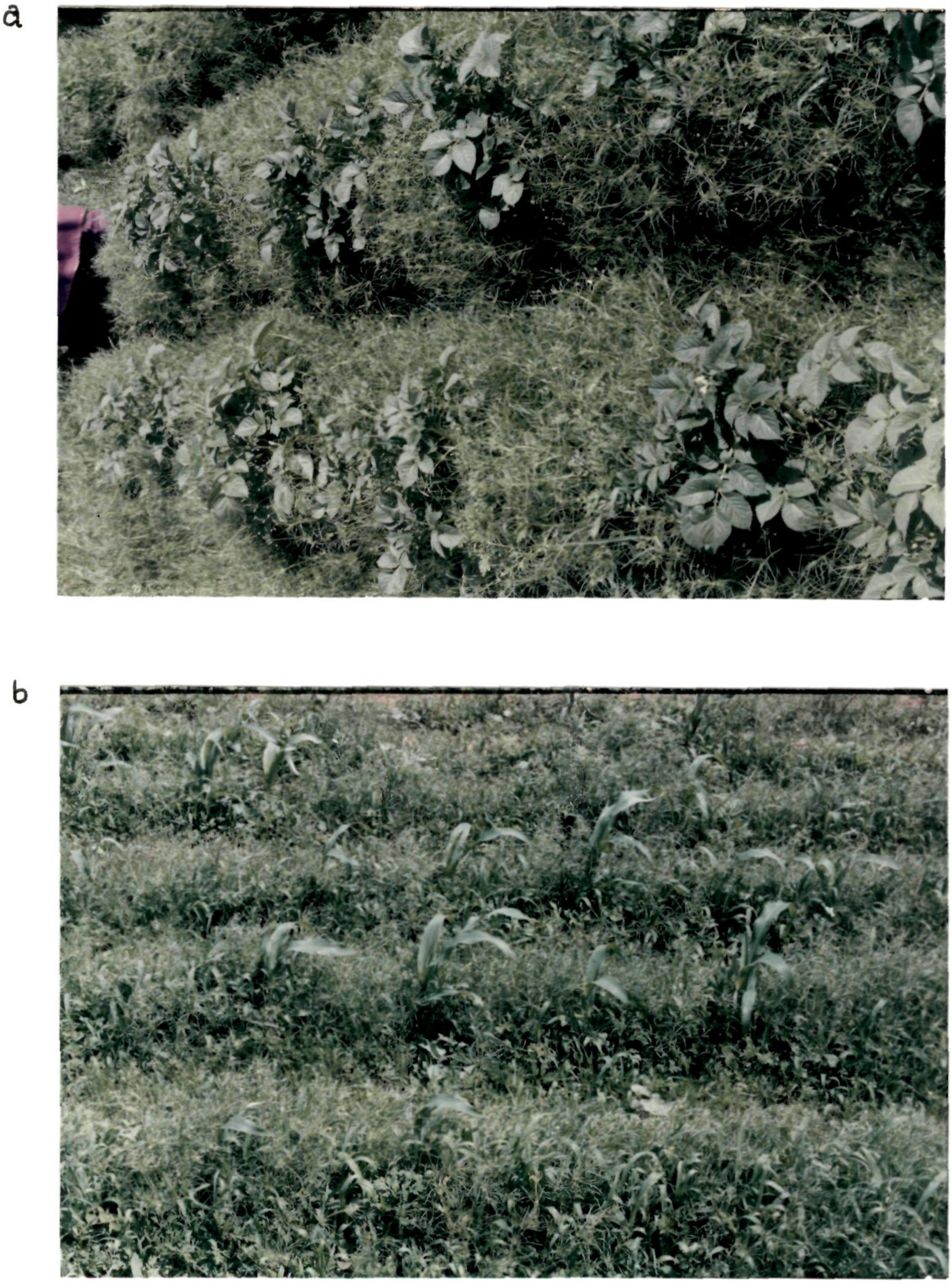

Plate 5.1. Weed infestation in (a) potato and (b) maize crops.

Plate 5.2. Weed infestation in (a) cauliflower and (b) radish crops.

on the weed flora of arable lands of Meghalaya was conducted by Neogi (1980). The weed flora of abandoned 'jhum' fallows in Meghalaya was studied by Kushwaha *et al.*(1981) and Saxena and Ramakrishnan (1984). This chapter presents the quantitative analysis of weed community in different crop fields under 'jhum' and terrace cultivation. The main objective of the study was to identify the dominant weeds in different crop fields and to find out the possible reasons for the difference in their abundance in different crop fields under two cultivation methods.

RESULTS

WEED FLORA

Crop fields at low altitude (Barapani) had higher species richness than those at high altitude (Upper Shillong). At Barapani, maize and groundnut fields had highest species richness (39 species each), while linseed had the lowest number of species (22 species). Radish field had 31 species (Table 5.1). At Upper Shillong, the number of weeds were much lower than Barapani. In 'jhum', total number of weeds identified in potato, maize, radish and cauliflower fields was 14, 15, 14 and 14, respectively, while the corresponding number in terrace was 14, 16, 16 and 15, respectively. The weed community at Barapani had greater representation of perennial species, whereas at Upper Shillong annuals were more common. In this respect 'jhum' and terrace fields at Upper Shillong did not differ from one another.

Table 5.1 : Floristic composition of weeds in different crop fields (Cauliflower-C, Groundnut-G, Linseed-L, Maize-M, Potato-P, Radish-R) under 'jhum' and terrace cultivation at Upper Shillong (high altitude) and Barapani (low altitude) in Meghalaya. Present (+), Absent (-), Annual (A), Perennial (P).

Sl.No.	Species	Life cycle	Family	Upper Shillong								Barapani			
				'Jhum'				Terrace				Terrace			
				C	M	P	R	C	M	P	R	G	L	M	R
1.	*Acrocephalus indicus* (Burnm.f.) O.Ktze.	A	Lamiaceae	-	-	-	-	-	-	-	-	+	-	+	+
2.	*Ageratum conyzoides* L.	A	Asteraceae	-	-	-	-	-	-	-	-	+	+	+	+
3.	*Ageratum houstonianum* Mill	A	Asteraceae	-	-	-	-	-	-	-	-	+	+	+	+
4.	*Alternanthera philoxeroides* Griseb	A	Amaranthaceae	-	-	-	-	-	-	-	-	+	-	+	+
5.	*Ambrosia artemisiifolia* L.	A	Asteraceae	+	+	+	+	+	+	+	+	+	-	+	-
6.	*Anaphalis adnata* DC.	A	Asteraceae	-	+	-	+	+	+	-	+	-	-	-	-
7.	*Bidens pilosa* L.	A	Asteraceae	-	-	-	-	-	-	-	-	+	+	+	+
8.	*Borreria articularis* (L.f.) F.N. Williams	A	Rubiaceae	-	-	-	-	-	-	-	-	+	-	+	+
9.	*Brachiaria villosa* (Lamk.) A. Camus	A	Poaceae	+	+	+	+	+	+	+	+	-	-	-	-
10.	*Carex composita* Boott.	P	Cyperaceae	-	-	-	-	-	-	-	-	+	-	+	-
11.	*Centella asiatica* (L.) Urb.	P	Apiaceae	-	-	-	-	-	-	-	-	+	+	+	+
12.	*Commelina paludosa* Bl.	A	Commelinanceae	-	-	-	-	-	+	-	-	+	-	+	+
13.	*Crassocephalum crepidiodes* (Benth.) S.Moore	A	Asteraceae	-	-	-	-	-	-	-	-	+	+	+	+
14.	*Cynodon dactylon* (Linn.) Pers.	P	Poacae	-	-	-	-	-	-	-	-	+	+	+	+
15.	*Cyperus tuberosus* Rottb.	P	Cyperaceae	-	-	-	-	-	-	-	-	+	+	+	+
16.	*Desmodium heterophyllum* DC.	P	Papilionaceae	-	-	-	-	-	-	-	-	+	+	+	+
17.	*Digitaria adscendens* (HBK) Hern.	A	Poaceae	+	+	+	+	+	+	+	+	-	-	-	-

Table 5.1 (contd.)

Sl.No.	Species	Life cycle	Family	Upper Shillong								Barapani			
				'Jhum'				Terrace				Terrace			
				C	M	P	R	C	M	P	R	G	L	M	R
18.	*Drymaria cordata* (Linn.) Wild. ex Roem & Schult.	A	Caryophyllaceae	+	+	+	+	+	+	+	+	+	-	+	+
19.	*Eleusine indica* (Linn.) Gaertn.	A	Poaceae	-	+	-	-	+	+	+	+	+	+	+	+
20.	*Emilia sonchifolia* (Linn.) DC.	A	Asteraceae	-	-	-	-	-	-	-	-	+	+	+	+
21.	*Eragrostis nigra* Nees ex Steud.	A	Poaceae	-	-	-	-	-	-	-	-	+	-	+	+
22.	*Erigeron bonariensis* L.	A	Asteraceae	-	-	-	-	-	-	-	-	+	+	+	+
23.	*Eupatorium adenophorum* Spreng.	P	Asteraceae	-	-	-	-	-	-	-	-	+	-	+	-
24.	*Eupatorium odoratum* L.	P	Asteraceae	-	-	-	-	-	-	-	-	+	-	+	-
25.	*Fimbristylis complanata* (Retz.) Link	A	Cyperaceae	+	-	+	+	-	-	-	+	+	+	+	+
26.	*Galinsoga ciliata* (Rafin.) Blake	A	Asteraceae	+	+	+	+	+	+	+	+	+	+	+	+
27.	*Hypochaeris radicata* L.	A	Asteraceae	-	-	-	-	-	-	-	-	+	+	+	+
28.	*Imperata cylindrica* Beauv.	P	Poaceae	-	-	-	-	-	-	-	-	+	+	+	+
29.	*Lantana camara* L.	P	Verbenaceae	-	-	-	-	-	-	-	-	+	-	+	-
30.	*Lindernia nummularifolia* Don.	A	Scrophulariaceae	+	+	+	+	+	+	+	+	-	-	-	-
31.	*Mimosa pudica* L.	P	Mimosaceae	-	-	-	-	-	-	-	-	+	+	+	+
32.	*Osbeckia crinita* Benth.	P	Melastomaceae	-	+	-	-	-	+	-	-	+	-	+	-
33.	*Oxalis corniculata* L.	A	Oxalidaceae	+	+	+	+	+	+	+	+	+	+	+	+
34.	*Oxalis latifolia* HBK	P	Oxalidaceae	+	+	+	+	+	+	+	+	+	+	+	+
35.	*Panicum montanum* Roxb.	P	Poaceae	-	-	-	-	-	-	-	-	+	-	+	+
36.	*Polygonum alatum* Buch-Ham. ex D.Don	A	Polygonaceae	+	+	+	+	+	+	+	+	+	-	+	-
37.	*Pycreus latispicatus* Cl.	A	Cyperaceae	+	-	+	+	+	-	+	+	-	-	-	-

Tabel 5.1 (contd.)

Sl.No.	Species	Life cycle	Family	Upper Shillong								Barapani			
				'Jhum'				Terrace				Terrace			
				C	M	P	R	C	M	P	R	G	L	M	R
38.	*Richardsonia pilosa* HBK	A	Rubiaceae	-	-	-	-	-	-	-	-	+	-	+	+
39.	*Rubus moluccanus* L.	P	Rosaceae	-	-	-	-	-	-	-	-	+	-	+	-
40.	*Setaria glauca* Beauv.	A	Poaceae	+	+	+	+	+	+	+	+	+	+	+	+
41.	*Setaria pallidefusca* (Schumach) Stapf & Hubb.	A	Poaceae	+	+	+	+	+	+	+	+	+	+	+	+
42.	*Sonchus oleraceous* L.	A	Asteraceae	-	-	-	-	-	-	-	-	+	+	+	+
43.	*Spergula arvensis* L.	A	Caryophyllaceae	+	+	+	+	+	+	+	+	-	-	-	-
44.	*Spilanthes paniculata* Wall ex DC.	A	Asteraceae	-	-	-	-	-	-	-	-	+	+	+	+
45.	*Stylosanthes guianensis* SW.	P	Papilionaceae	-	-	-	-	-	-	-	-	+	-	+	+
	Total Number of species			14	15	14	14	15	16	14	16	39	22	31	39
	(i) Annual			13	13	13	13	14	14	13	15	24	15	22	24
	(ii) Perennial			1	2	1	1	1	2	1	1	15	7	9	15

Weeds at Barapani were largely represented by the members of Asteraceae (13) followed by Poaceae (7), Cyperaceae (3), Rubiaceae (2), Oxalidaceae (2) and Papilionaceae (2). On the other hand, at Upper Shillong members of Poaceae family (5) were most common followed by Asteraceae (2), Caryophyllaceae (2), Cyperaceae (2) and Oxalidaceae (2).

DENSITY AND IMPORTANCE VALUE

At Upper Shillong, on the basis of peak densities and mean importance values, *S. arvensis, P. alatum* and *G. ciliata* may be considered as dominant weeds in autumn and summer potato fields in both 'jhum' and terrace fields (Table 5.2). However, their peak density and IVI were generally higher in 'jhum' than that in the terrace fields. The maize field under 'jhum' and terrace differed in this respect. In the former, *S. arvensis* and *P. alatum* were dominant and co-dominant, respectively, while in the latter they were replaced by *E. indica* and *D. adscendens* (Table 5.3). In cauliflower and radish fields *S. arvensis, P. alatum* and *G. ciliata* were the most abundant species. Peak density of the first two species was invariably higher in 'jhum' than in the terrace fields but the third one had a higher value in the latter (Table 5.4).

At Barapani, crop fields were infested by a large number of weeds and dominance in the weed community was shared by many species such as *E. sonchifolia, A. haustonianum, G. ciliata, A.*

Table 5.2 : Peak density (D = Plants m^2) and mean importance value index (IVI) of weed species in patato fields under 'jhum' and terrace cultivation at Upper Shillong. Values in percentheses are species rank.

Species	'Jhum'								Terrace							
	Autumn Potato				Summer Potato				Autumn Potato				Summer Potato			
	1988		1989		1989		1990		1988		1989		1989		1990	
	D	IVI	D	IVI	D	IVI	D	IVI	D	IVI	D	IVI	D	IVI	D	IVI
A. artemisiifolia	47	14.8 (4)	45	16.7 (4)	18	15.4 (3)	16	13.5 (4)	33	23.3 (4)	33	15.6 (5)	21	23.6 (3)	35	18.2 (7)
B. villosa	29	11.0 (8)	50	10.8 (6)	20	11.0 (5)	29	7.0 (7)	27	14.6 (6)	40	11.7 (9)	17	20.3 (4)	46	16.0 (8)
D. adscendens	33	12.0 (5)	25	10.2 (7)	12	8.2 (8)	17	11.9 (5)	30	17.0 (5)	16	10.8(11)	6	9.6(10)	25	9.7(11)
D. cordata	34	10.8 (9)	45	11.9 (5)	27	10.8 (6)	21	5.3 (8)	33	13.3 (7)	113	17.3 (4)	58	17.2 (7)	88	19.2 (5)
E. indica	-		-		-		-		14	11.3(10)	26	12.1 (7)	10	12.6 (9)	16	11.2 (9)
F. complanata	3	2.0(13)	7	6.3(12)	2	1.5(11)	20	2.3(12)	-		-		-		-	
G. ciliata	117	16.7 (3)	144	21.9 (3)	129	28.3 (2)	81	22.6 (3)	254	73.8 (2)	373	69.0 (2)	94	48.4 (2)	308	63.2 (2)
L. nummularifolia	29	11.0 (6)	36	9.9 (8)	20	9.2 (7)	13	7.9 (6)	52	12.0 (8)	79	15.4 (6)	46	18.3 (6)	69	19.1 (6)
O. latifolia	6	5.3(10)	-		-		-		140	27.8 (3)	39	11.0(10)	-		28	19.9 (4)
P. alatum	698	55.6 (2)	839	85.8 (2)	63	12.6 (4)	223	89.5 (2)	9	6.5(12)	148	31.0 (3)	43	20.0 (5)	82	29.9 (3)
P. latispicatus	8	5.2(11)	5	6.4(11)	8	5.9(10)	10	2.5(11)	9	8.8(11)	4	4.1(13)	-		5	3.2(13)
S. glauca	4	2.5(12)	21	9.3(10)	-		7	3.9(10)	-		7	7.3(12)	-		10	5.4(12)
S. pallidefusca	23	11.0 (7)	16	9.3 (9)	9	7.2 (9)	27	4.6 (9)	15	11.4 (9)	23	11.9 (8)	8	12.7 (8)	10	10.3(10)
S. arvensis	2176	141.0 (1)	1210	101.4 (1)	1974	190.1 (1)	1742	128.9 (1)	295	74.6 (1)	619	82.8 (1)	302	116.9 (1)	547	74.4 (1)

Dashes indicate species absence

Table 5.3 : Peak density (D = Plants m^2) and mean importantance value index (IVI) of weed species in maize fields under 'jhum' and terrace cultivation at Upper Shillong. Values in parentheses are species rank.

Species	'Jhum'				Terrace			
	1989		1990		1989		1990	
	D	IVI	D	IVI	D	IVI	D	IVI
A. Artemisiifolia	37	13.9 (4)	24	14.2 (5)	30	21.2 (4)	26	18.5 (5)
A. adnata	3	1.5(15)	2	1.5(14)	12	3.0(13)	5	2.1(15)
B. villosa	85	13.3 (5)	96	13.4 (7)	143	30.0 (3)	98	22.3 (4)
C. paludosa	-		-		8	7.2 (8)	11	7.0 (9)
D. adsendens	21	8.6 (8)	30	13.5 (6)	115	36.4 (2)	103	32.9 (2)
D. cordata	35	5.2(10)	16	5.3(10)	46	7.7 (7)	34	6.6(10)
E. indica	31	12.1 (7)	27	6.2 (9)	550	135.9 (1)	536	136.4 (1)
G. ciliata	121	21.5 (3)	96	19.2 (3)	20	5.9(10)	26	7.4 (8)
L. nummularifolia	21	5.3 (9)	15	4.0(12)	103	13.9 (6)	103	12.7 (2)
O. crinita	3	3.1(13)	4	-	3	1.8(15)	-	
O corniculata	10	4.0(12)	12	4.2(11)	24	5.3(11)	7	2.5(14)
O. latifolia	5	2.5(14)	7	3.7(13)	3	1.5(16)	4	3.4(13)
P. alatum	204	29.8 (2)	221	34.2 (2)	11	4.6(12)	13	4.9(12)
S. glauca	11	5.0(11)	16	6.8 (8)	7	6.4 (9)	108	26.1 (3)
S. pallidefusca	40	12.8 (6)	48	14.8 (4)	36	16.3 (5)	17	9.9 (7)
S. arvensis	1911	161.4 (1)	1540	155.1 (1)	6	2.8(14)	21	6.2(11)

Dashes indicate species absence

Table 5.4 : Peak density (D = Plants m^{-2}) and mean importance value index (IVI) of weed species in cauliflower and radish fields under 'jhum' and terrace cultivation at Upper Shillong. Values in percentheses are species rank.

Species	'Jhum'								Terrace							
	Cauliflower				Radish				Cauliflower				Terrace			
	1988		1989		1989		1990		1988		1989		1989		1990	
	D	IVI	D	IVI	D	IVI	D	IVI	D	IVI	D	IVI	D	IVI	D	IVI
A. artemisiifolia	41	13.6 (4)	45	14.8 (4)	45	14.4 (4)	43	15.6 (4)	41	19.3 (5)	25	12.5 (7)	25	13.6 (7)	25	16.3 (6)
A. adnata	-		-		3	3.0(14)	9	5.1(11)	4	2.6(14)	5	3.8(13)	5	3.3(15)	5	3.0(16)
B. villosa	46	11.0 (7)	31	9.6 (9)	30	7.7(11)	58	10.6 (7)	54	14.9 (9)	30	11.4 (9)	30	10.7 (8)	42	12.1 (7)
D. adsendens	42	11.5 (6)	28	11.5 (8)	28	9.0 (6)	13	4.8(12)	46	16.0 (8)	38	14.9 (6)	38	14.1 (6)	9	7.5(12)
D. cordata	31	9.8 (9)	56	11.9 (7)	56	10.5 (5)	49	11.2 (6)	140	21.0 (4)	113	18.6 (5)	113	17.4 (5)	122	17.9 (5)
E. indica	-		-		-		-		33	14.2(10)	20	11.4 (8)	20	10.4 (9)	14	8.2(10)
F. complanata	16	4.0(13)	14	4.6(11)	14	7.8(10)	3	4.1(13)	-		-		5	4.5(14)	19	6.9(14)
G. ciliata	150	18.9 (3)	173	20.6 (3)	173	19.0 (3)	149	22.6 (3)	371	72.0 (1)	300	63.5 (2)	300	62.5 (2)	250	55.1 (2)
L. nummularifolia	35	10.4 (8)	41	11.9 (6)	41	8.2 (8)	47	11.9 (5)	92	19.2 (6)	96	20.4 (4)	90	19.7 (4)	113	23.0 (4)
O. corniculata	3	1.5(14)	-		3	2.1(15)	-		-		5	3.2(15)	5	3.1(16)	6	3.3(15)
O. latifolia	16	9.3(10)	-		4	3.5(13)	-		88	17.0 (7)	20	6.6(12)	13	6.8(13)	23	8.3 (9)
P. alatum	978	78.4 (2)	1457	108.4 (1)	1462	100.3 (1)	1256	97.7 (1)	72	21.3 (3)	123	31.7 (3)	123	31.1 (3)	155	34.3 (3)
P. latispicatus	14	4.7(12)	16	4.5(12)	16	6.5(12)	13	6.9(10)	7	6.1(12)	11	9.8(10)	11	7.8(11)	17	7.7(11)
S. glauca	35	6.9(11)	19	6.9(10)	17	8.0 (9)	19	8.8 (9)	11	4.6(13)	7	3.8(14)	17	9.1(10)	22	10.2 (8)
S. pallidefusca	45	11.9 (5)	39	12.6 (5)	27	8.8 (7)	19	9.2 (8)	32	11.9(11)	17	9.1(11)	7	6.9(12)	7	7.4(13)
S. arvensis	1494	108.8 (1)	1177	82.9 (2)	1422	91.9 (2)	1229	91.2 (2)	335	60.2 (2)	535	79.2 (1)	535	78.5 (1)	438	79.1 (1)

Dashes indicate species absence

conyzoides and *R. pilosa*. Such a pattern of dominance distribution was true for all the crops except linseed where *G. ciliata* shared major dominance (IVI-131) in the community. In this respect this community was similar to that found at high altitude site (Table 5.5).

Time series data of IVI of dominant weeds common to 'jhum' and terrace fields at Upper Shillong and terrace cultivation at Barapani are shown in Figs. 5.1-5.7. Under terrace cultivation, dominance of *G. ciliata* in maize field declined after 45 days of emergence at Upper Shillong, while it remained almost constant throughout the crop growth at Barapani (Fig. 5.1a). In radish fields it tended to increase with time at Upper Shillong but remained constant at Barapani (Fig. 5.1a). In potato and cauliflower fields at Upper Shillong (Fig 5.2 a, b, c) and groundnut and linseed fields at Barapani(Fig 5.2 d,e) dominance of *G. ciliata* remained almost unchanged throughout the crop duration. So far as the values of IVI are concerned, they were always higher at Upper Shillong than at Barapani except in linseed where this species attained highest value. Under 'jhum', IVI of *G. ciliata* gradually increased up to 45 days in all the four crops and then remained constant till crop maturity (Fig. 5.3).

Behaviour of *P. alatum* in 'jhum' and terrace fields at Upper Shillong is shown in Fig. 5.4. In all the fields its IVI was higher during early stage (15 days), thereafter it did not

Table 5.5. Peak density (D = Plants m^{-2}) and mean importance value index (IVI) of weed species in different crop fields under terrace cultivation at Barapani . Values in parentheses are species rank.

Species	Ground nut				Linseed				Maize				Radish			
	1989		1990		1988		1989		1989		1990		1988		1989	
	D	IVI	D	IVI	D	IVI	D	IVI	D	IVI	D	IVI	D	IVI	D	IVI
A. indicus	4	2.2(23)	4	2.2(23)					2	1.7(31)	3	1.7(24)			2	1.5(29)
A. conyzoides	68	26.6 (4)	48	22.3 (5)	9	15.0 (6)	12	15.4 (5)	53	23.9 (4)	64	22.4 (5)	35	24.7 (4)	54	28.7 (2)
A. houstonianum	92	27.7 (3)	76	27.4 (2)	17	27.9 (2)	22	22.7 (3)	70	31.8 (1)	87	35.0 (1)	108	50.9 (1)	94	48.9 (1)
A. philoxeroides	15	3.8(19)	12	2.3(22)	-		-		4	2.2(25)	4	2.2(22)	43	1.9(21)	4	2.5(24)
A. artemisiifolia	1	0.5(36)	4	1.9(25)	-		-		1	2.3(24)	-		-		-	
B. pilosa	64	22.4 (5)	53	23.9 (4)	11	15.4 (5)	8	14.8 (6)	47	22.3 (5)	68	26.6 (4)	29	22.1 (5)	24	19.9 (5)
B. articularis	19	10.2(11)	16	12.0(10)	-		-		16	11.3(11)	17	10.9(10)	-		5	4.4(16)
C. composita	1	0.7(35)	3	2.5(20)	-		-		4	1.9(20)	1	1.2(31)	-		-	
C. aciatica	1	1.4(30)	3	1.6(28)	2	2.7(17)	1	1.9(21)	3	1.8(29)	2	1.0(32)	-		3	3.5(21)
C. paludosa	2	2.0(25)	3	1.8(26)	-		-		3	1.6(32)	1	1.4(29)	3	1.2(26)	2	1.1(31)
C. crepidioides	17	11.5 (9)	27	17.0 (8)	10	18.7 (4)	8	16.9 (4)	17	14.9 (9)	12	11.7 (8)	9	20.1 (6)	12	14.7 (7)
C. dactylon	12	9.0(13)	7	5.3(14)	29	23.9 (3)	32	24.8 (2)	14	7.6(13)	19	9.6 (2)	22	11.8(10)	18	11.7(10)
C. tuberosus	2	1.6(27)	2	1.4(30)	-		2	1.6(22)	4	1.8(30)	-		1	1.3(24)	1	1.3(30)

Table 5.5 (contd.)

Species	**Ground nut**				**Linseed**				**Maize**				**Radish**			
	1989		**1990**		**1988**		**1989**		**1989**		**1990**		**1988**		**1989**	
	D	**IVI**	**D**	**IVI**	**D**	**IVI**	**D**	**IVI**	**D**	**IVI**	**D**	**IVI**	**D**	**IVI**	**D**	**IVI**
D. heterophyllum	2	0.7(35)	4	1.1(31)	3	1.9(19)	3	2.9(17)	2	1.4(34)	1	1.6(25)	22	1.3(25)	2	1.6(28)
D. cordata	4	1.7(26)	4	1.7(27)	-		-		12	2.5(20)	18	3.8(19)	-		12	3.6(19)
E. indica	17	10.9(10)	16	11.3(11)	5	5.7(11)	4	5.9(11)	16	12.0(10)	19	10.2(11)	12	16.4 (8)	15	13.1 (9)
E. sonchifolia	87	35.0 (1)	72	31.8 (1)	7	8.3 (8)	4	7.9 (8)	76	27.4 (2)	90	27.7 (3)	48	26.8 (3)	52	26.8 (3)
E. nigra	2	1.4(29)	1	1.4(30)	-		-		3	1.9(27)	2	1.6(27)	1	2.2(20)	2	2.3(25)
E. bonariensis	19	9.5(12)	14	7.5(13)	4	2.0(18)	2	2.7(18)	7	5.2(14)	12	8.9(13)	7	8.4(12)	8	8.4(12)
E. adenophorum	3	1.6(27)	4	2.4(22)	-		-		3	2.0(26)	2	2.0(23)	-		-	
E. odoratum	8	5.1(16)	7	4.9(17)	-		-		7	4.7(15)	12	5.3(15)	-		-	
F. complanata	2	2.0(24)	3	2.0(24)	2	1.7(20)	2	2.0(20)	4	2.4(22)	3	1.6(26)	5	4.0(17)	4	4.0(17)
G. ciliata	78	29.8 (2)	61	25.0 (3)	188	129.6 (1)	204	131.0 (1)	40	19.4 (6)	39	17.3 (7)	62	29.5 (2)	38	25.0 (4)
H. radicata	4	3.4(20)	2	2.4(23)	3	4.4(13)	4	5.2(12)	3	2.6(19)	2	1.4(30)	3	4.3(16)	3	3.6(20)
I. cylindrica	12	11.7 (8)	17	14.9 (9)	3	3.0(16)	2	2.7(19)	27	17.0 (8)	17	11.5 (9)	24	13.4 (9)	20	14.4 (8)
L. camara	-		2	0.8(33)	-		-		2	0.9(36)	-		-		-	

Table 5.5 (contd.)

Species	Ground nut				Linseed				Maize				Radish			
	1989		1990		1988		1989		1989		1990		1988		1989	
	D	IVI	D	IVI	D	IVI	D	IVI	D	IVI	D	IVI	D	IVI	D	IVI
M. pudica	2	1.4(31)	3	2.6(19)	2	1.3(21)	2	3.5(16)	2	2.4(23)	4	3.4(20)	4	2.9(19)	3	3.2(22)
O. crinita	5	2.8(22)	4	2.4(21)	-		-		1	1.5(33)	3	2.8(21)	-		-	
O. corniculata	12	5.3(15)	8	4.7(15)	11	5.7(10)	8	7.8 (9)	7	4.2(17)	8	5.2(16)	9	3.9(18)	7	3.1(23)
O. latifolia	2	1.0(33)	1	0.7(34)	2	3.5(15)	2	3.0(16)	1	0.8(37)	2	0.8(33)	2	1.8(23)	2	1.8(27)
P. montanum	3	2.8(21)	2	1.6(29)	-		-		4	2.4(21)	5	2.8(21)	7	4.8(15)	7	5.0(15)
P. alatum	1	1.0(32)	-		-		-		1	1.5(33)	-		-		-	
R. pilosa	38	17.3 (7)	40	19.5 (6)	-		-		58	25.0 (3)	77	29.8 (2)	14	6.0(13)	7	5.7(14)
R. moluccanus	1	0.7(34)	1	0.8(32)	-		-		1	0.6(38)	1	1.0(32)	-		-	
S. glauca	6	4.5(17)	20	10.9(12)	7	6.0(9)	3	6.0(10)	20	10.9(12)	19	6.5(14)	14	9.3(11)	14	9.9(11)
S. pallidefusca	19	6.5(17)	12	4.5(16)	2	4.1(14)	2	3.0(15)	6	4.5(16)	12	4.3(18)	6	3.9(18)	4	3.9(18)
S. oleraceous	20	4.3(18)	13	2.7(18)	5	5.5(12)	4	5.3(13)	4	2.7(18)	8	4.5(17)	7	5.9(14)	6	5.7(13)
S. paniculata	54	20.2 (6)	39	18.7 (7)	12	13.4 (7)	10	13.0 (7)	33	17.2 (7)	56	21.2 (6)	24	19.4 (7)	29	19.0 (6)
S. guianensis	2	1.6(28)	3	1.9(25)	-		-		1	1.4(35)	2	1.4(28)	4	1.8(22)	4	2.0(26)

Dashes indicate species absence

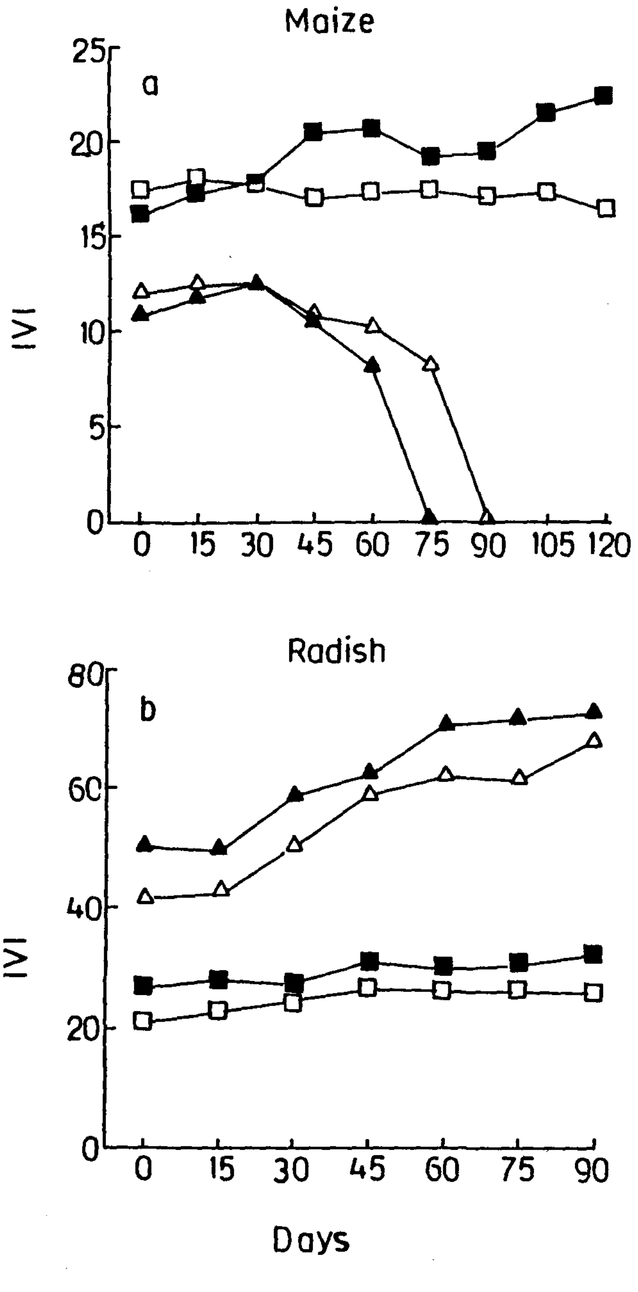

Fig. 5.1. Time series IVI data of *G. ciliata* in maize (a) and radish (b) crops in terrace fields at Upper Shillong (triangles) and Barapani (squares) for 1988-89 (open symbol) and 1989-90 (closed symbol).

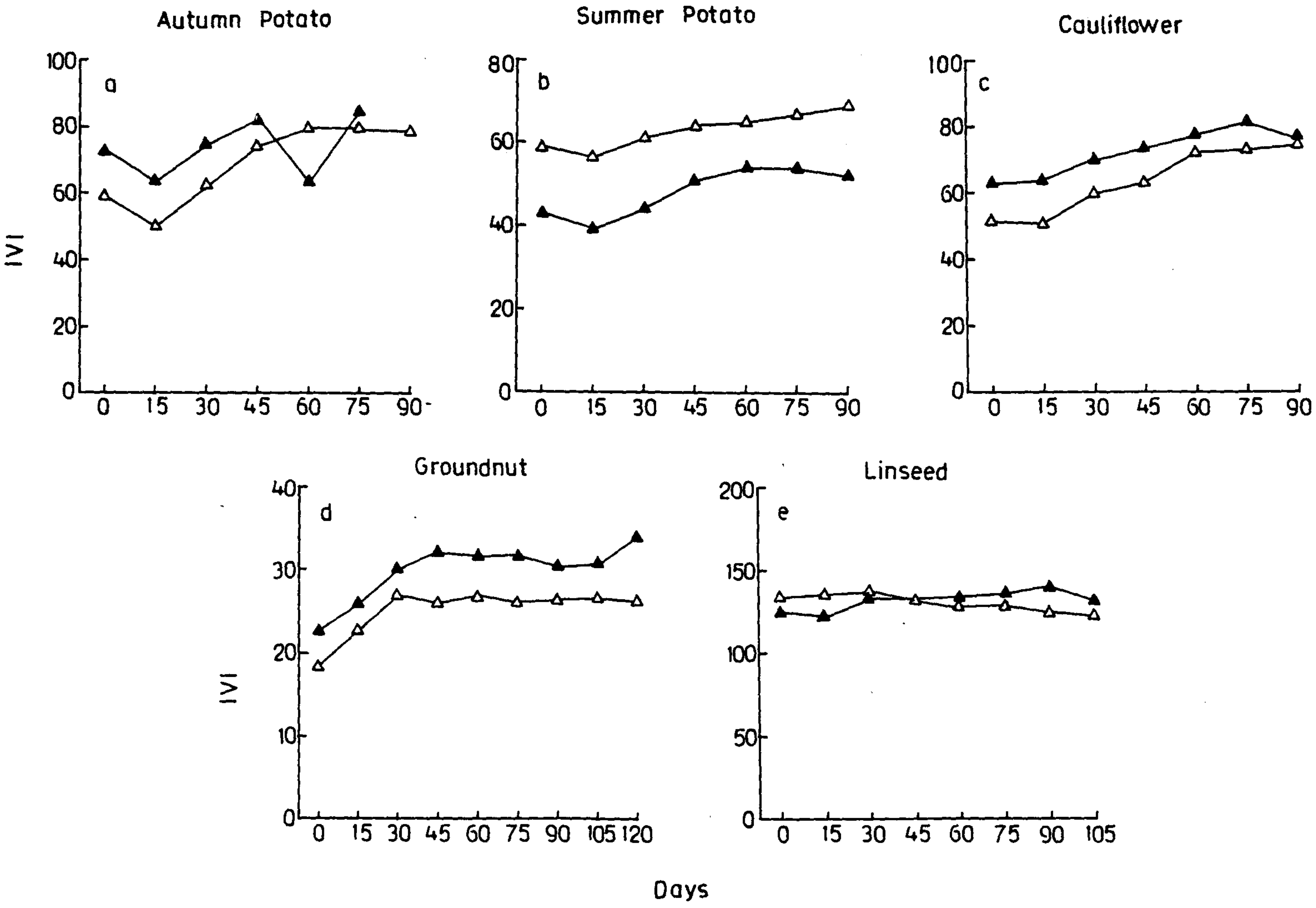

Fig. 5.2. Time series IVI data of G. ciliata in autumn potato (a), summer potato (b), cauliflower (c) at Upper Shillong and groundnut (d), linseed (e) crops at Barapani under terrace cultivation for 1988-1989 (▲) and 1989-1990 (△).

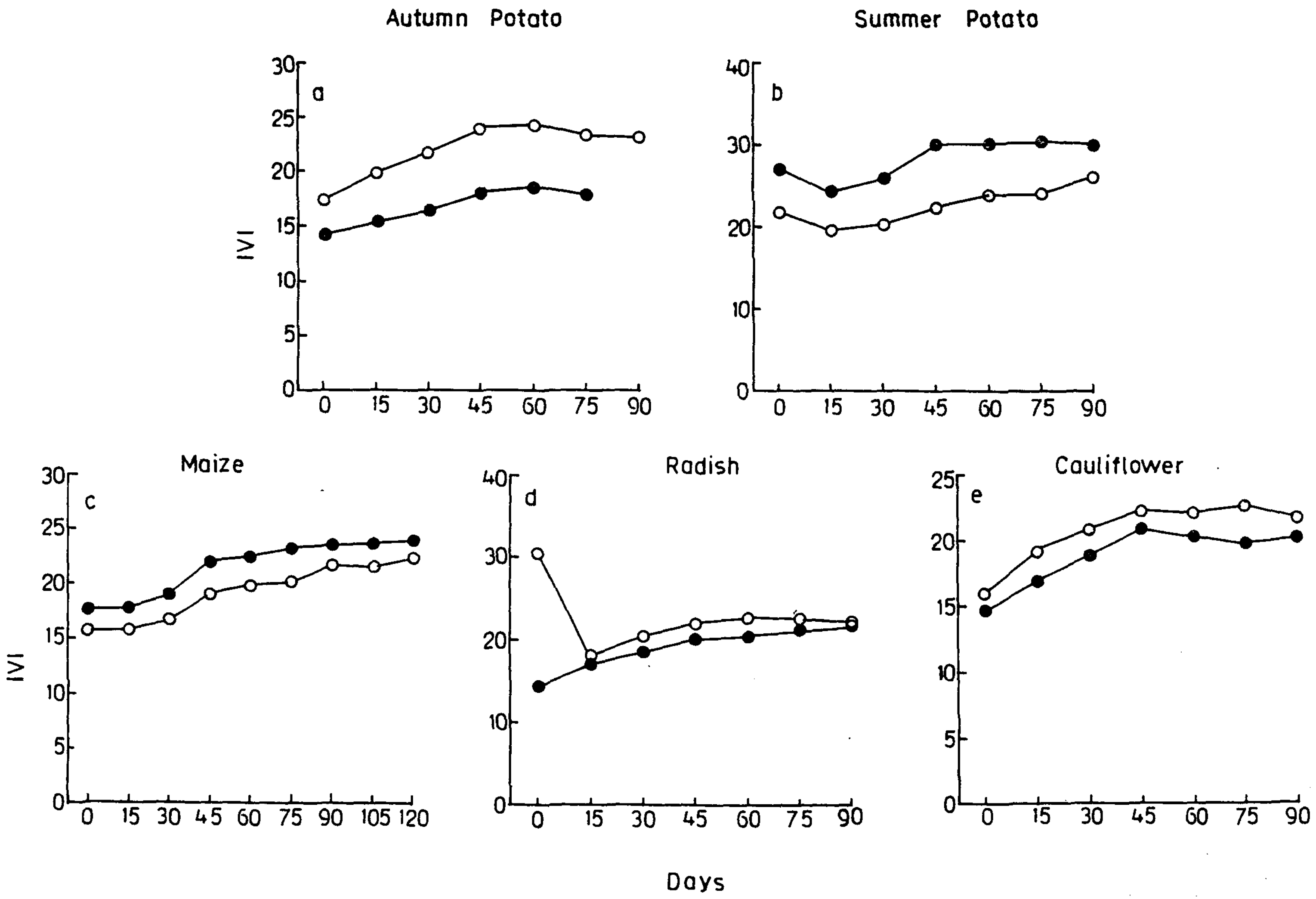

Fig. 5.3. Time series IVI data of <u>G</u>. <u>ciliata</u> in autumn potato (a), summer potato (b), maize (c), radish (d) and cauliflower (e) crops under 'jhum' cultivation at Upper Shillong for 1988-1989 (●) and 1989-1990 (o).

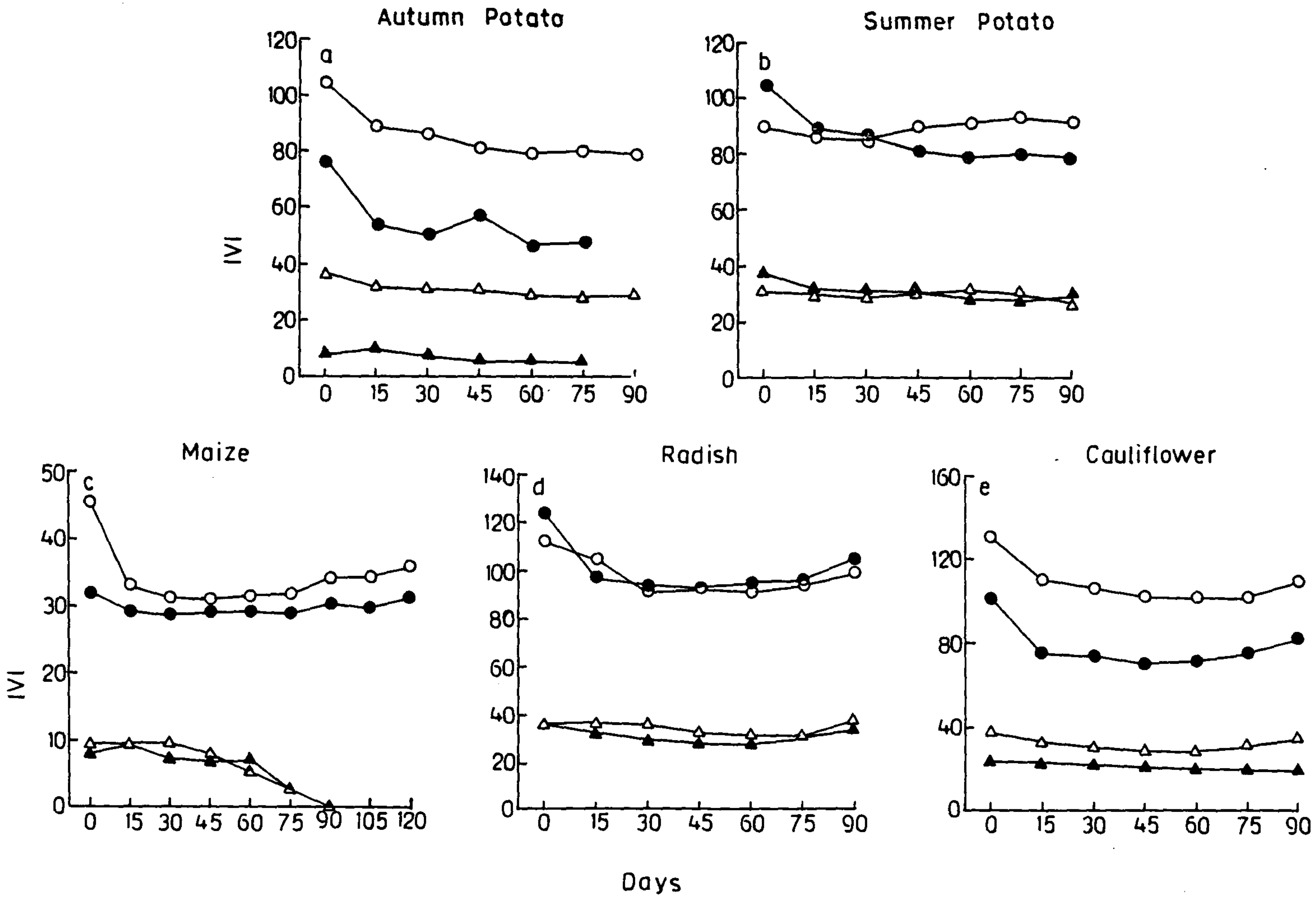

Fig. 5.4. Time series IVI data of *P. alatum* in different crops under 'jhum' (circles) and terrace (triangles) cultivation at Upper Shillong for 1988-1989 (closed symbols) and 1989-1990 (open symbols).

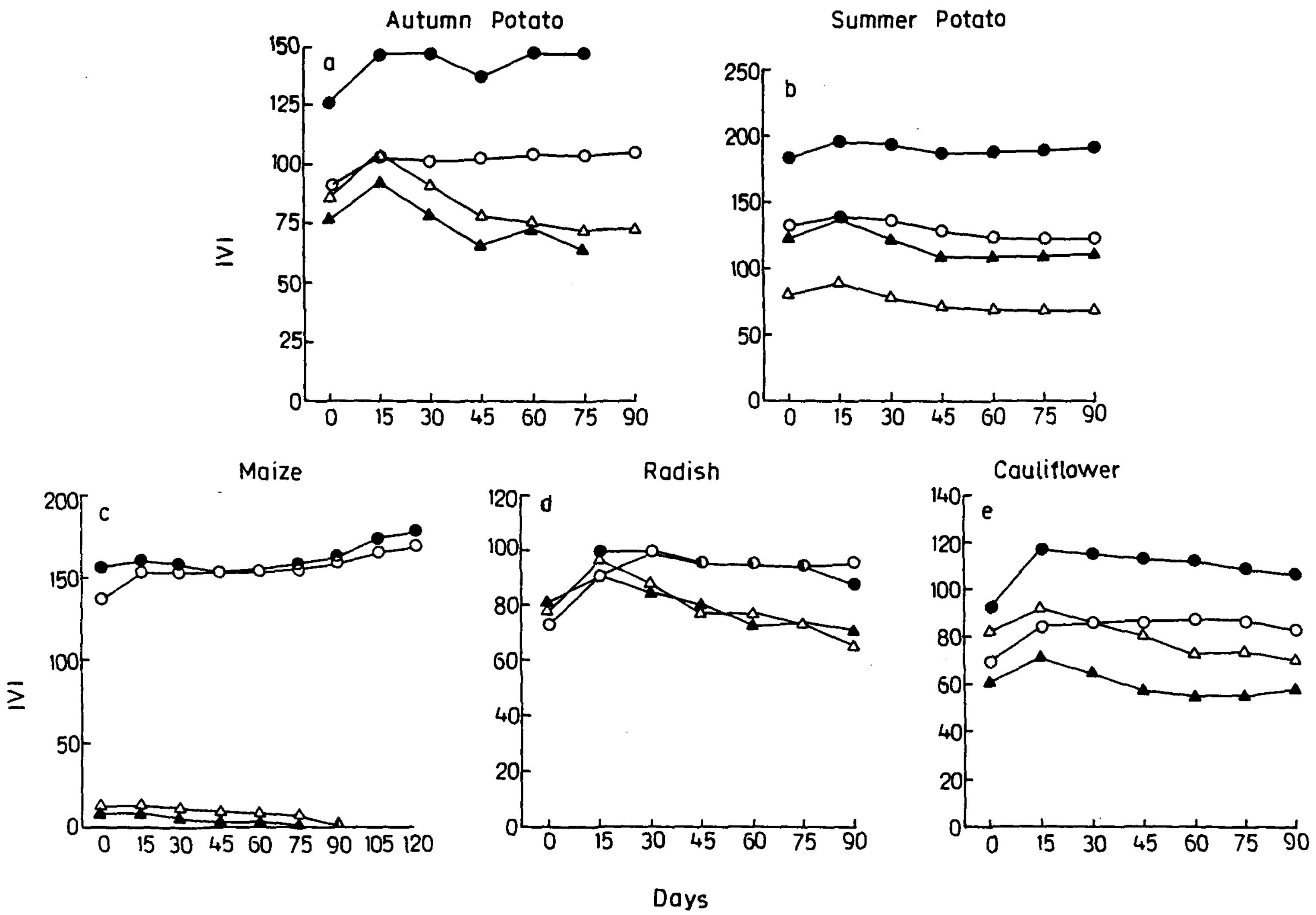

Fig. 5.5. Time series IVI data of S. arvensis in different crops under 'jhum' (circles) and terrace (triangles) cultivation at Upper Shillong for 1988-1989 (closed symbols) and 1989-1990 (open symbols).

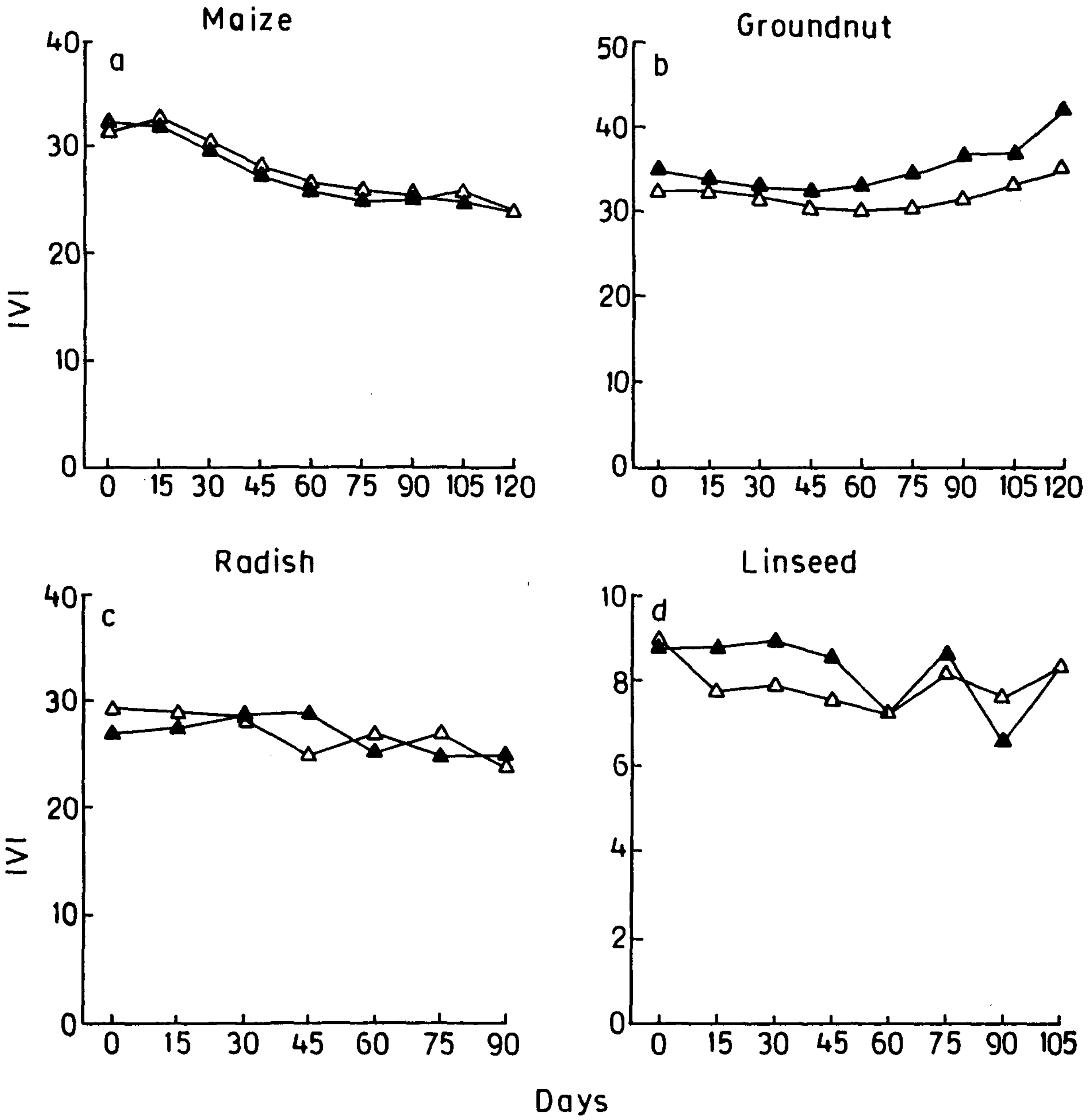

Fig. 5.6. Time series IVI data of E. sonchifolia in different crops under terrace cultivation at Barapani for 1988-89 (▲) and 1989-90 (△).

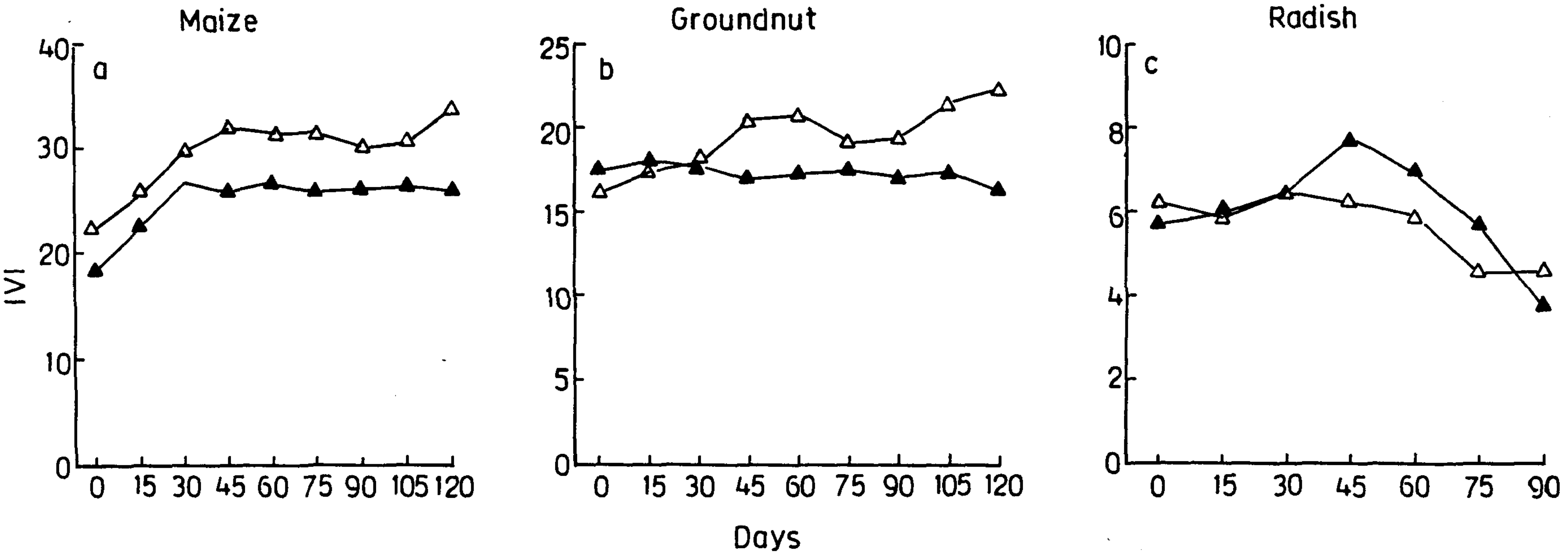

Fig. 5.7. Time series IVI data of R. pilosa in different crops under terrace cultivation at Barapani for 1988-89 (▲) and 1989-90 (△).

show any marked change, except in the maize field under terrace, where it gradually declined and became zero at 90 days (Fig. 5.4c). Its IVI was always high in 'jhum' than terrace fields.

Temporal changes in the dominance of *S. arvensis* in 'jhum' and terrace fields at Upper Shillong are depicted in Fig. 5.5. The species did not show any marked variation in IVI during crop duration and the difference between 'jhum' and terrace was also not prominent in cauliflower and summer potato. The most prominent difference was seen in maize, where IVI was many fold higher in 'jhum' than the terrace (Fig. 5.5c).

At Barapani, although IVI of *E. sonchifolia* did not vary markedly with time, the values were higher in maize, groundnut and radish than in the linseed crop (Fig. 5.6). Importance value of *R. pilosa* increased upto 60 days in maize, groundnut and radish fields, thereafter it remained almost unchanged in maize and groundnut but declined in radish fields (Fig. 5.7).

DISCUSSION

Composition of weed flora of the crop fields at high and low altitudes was dissimilar. Such a dissimilarity was also observed among the crop fields under 'jhum' and terrace cultivation at Upper Shillong. However, there was no difference in autumn and summer potato. Differences in the species richness in the weed community of agroecosystems at two elevations may be argued on the basis of differences in agro-climatic conditions prevailing at the two sites. Relatively lower temperature throughout the year and a long severe winter with occasional frost at Upper Shillong could be one of the important reason for lower species richness in the weed community as compared to Barapani. Minor variation in 'jhum' and terrace at Upper Shillong could be related to the differences in edaphic conditions due to adoption of different agricultural practices in the two fields (Table 3.2). Saavedra *et al.* (1989) observed similar difference between winter, summer and intermediate (spring-summer and winter-spring) weed floras in the Middle Valley of Guadalquivir, Spain. He attributed this difference to the crop type, crop cycle, soil management practices, irrigation types and a number of other edaphic factors. Several other workers (Thomas and Ivany 1990, Andreasen *et al.* 1991) also found these factors to be important in influencing the weed flora of crop fields.

In general, importance values of different weeds varied significantly among different crops cultivated under 'jhum' and terrace practices and between high and low altitudes. The difference in the abundance may be attributed to intra- and inter specific competition as well as to the microclimatic conditions within the community which changes markedly with time, growth and expansion of crop canopy. Large soil seed bank (Baskin and Baskin 1978, Grime 1979, Templeton and Levin 1979, and Cavers 1983) and poor weed control measures in 'jhum' than terrace fields are other important causes for greater abundance of weeds in the former fields. It is evident from the F values of discriminant analysis that 'jhum' and terrace fields at Upper Shillong irrespective of crop differed significantly (P<0.001) as far as the dominance of the different weeds was concerned. However, the species responsible for causing the differences between weed communities in 'jhum' and terrace fields varied from crop to crop (Fig. 5.8-5.10). In autumn and summer potato, *S. arvensis and P. alatum* were responsible for discrimination among the two fields during 1988, while it was due to *S. arvensis, P. alatum and G. ciliata* during 1989. In maize, *S. arvensis, S. pallidefusca, P. alatum* during 1989 and *S. arvensis, P. alatum, S. glauca* during 1990 were the important species (Fig. 5.9a). *F. complanata, D. adscendens, S. arvensis ,S. glauca, D. cordata* in radish (Fig. 5.9b) and *O. latifolia, S. pallidefusca, A. artemisiifolia S. arvensis, P. alatum, G. ciliata* in cauliflower (Fig. 5.10) were responsible for discrimination between 'jhum' and terrace. In general, growth and abundance of *S. arvensis, P. alatum and G. ciliata* were mostly responsible for discrimination between the two fields in most of the crops.

Since microenvironment prevailing within these crop fields is likely to influence the growth and abundance of weed species, four important microenvironmental variables were studied (Chapter 6) which undertaking a detailed study on population dynamics of dominant weed species as well as total weed population.

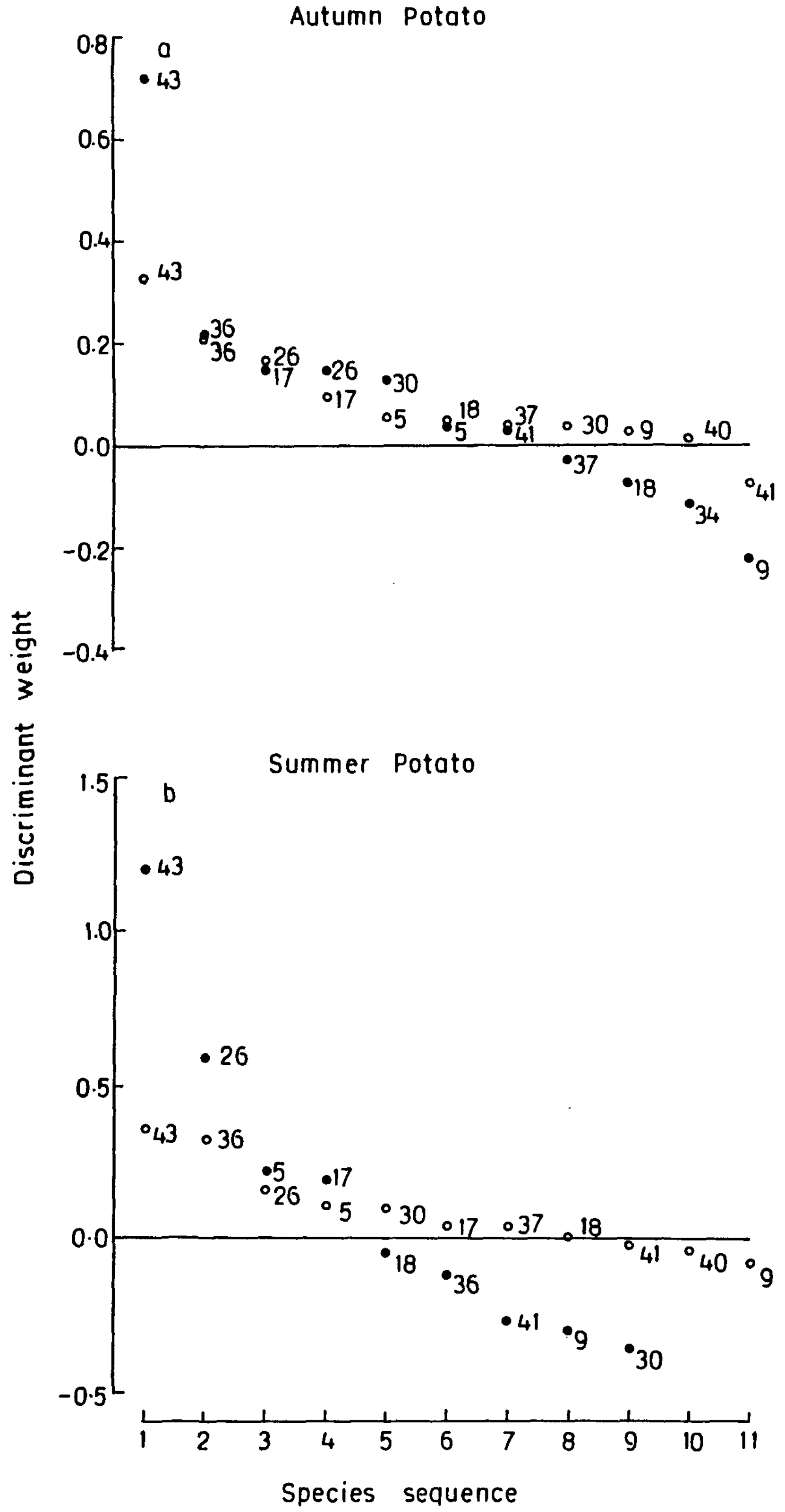

Fig. 5.8. Species ranked in order of importance for differentiating between the 'jhum' and terrace fields in potato fields as depicted from the discriminant weights of the linear discriminant function. Species number refers to the serial number mentioned in Table 5.1. ●,1988-89 ; O,1989-90.

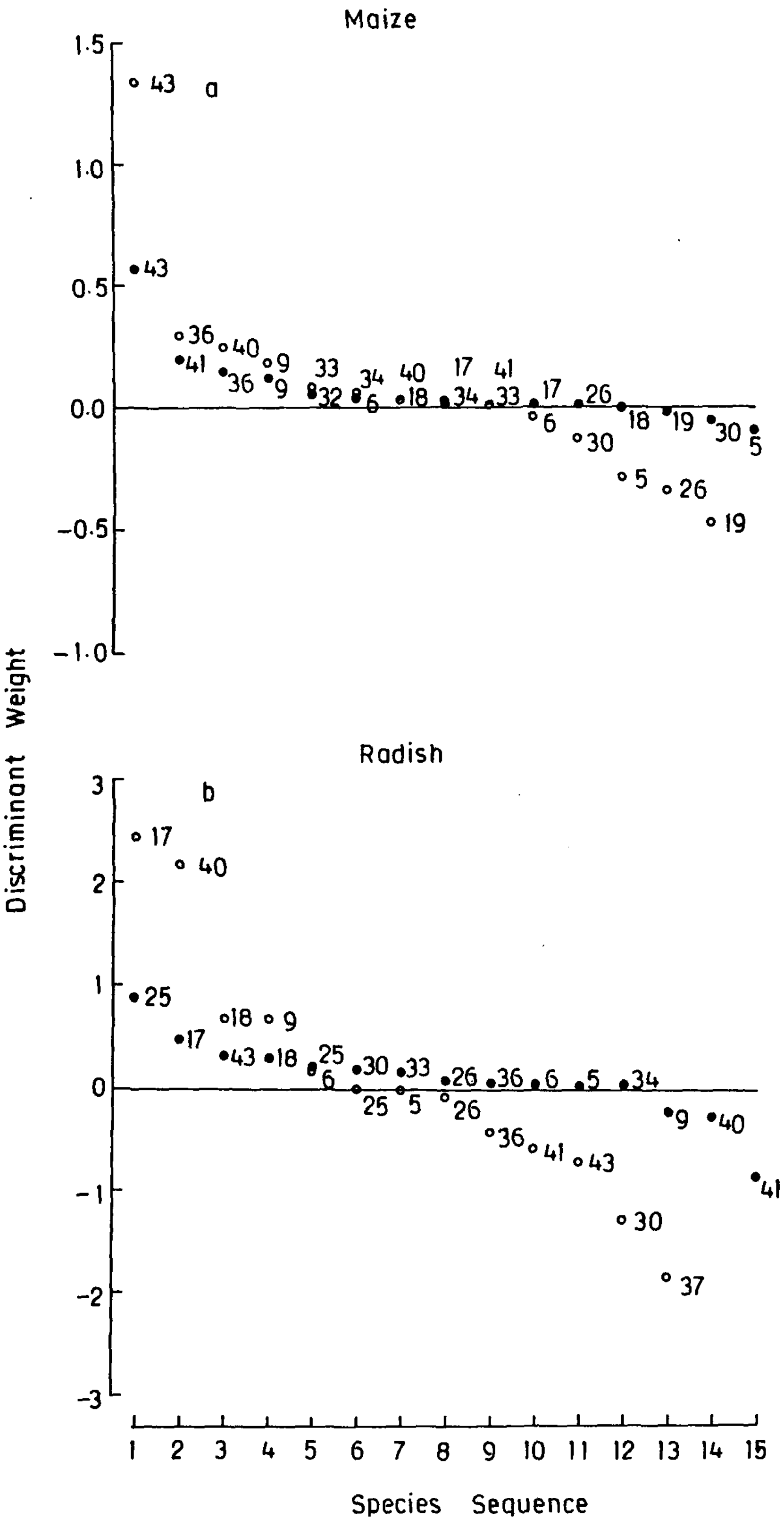

Fig. 5.9. Species ranked in order of importance for differentiating between the jhum and terrace fields in maize and radish fields as depicted from the discriminant weights of the linear discriminant function. Species number refers to the serial number mentioned in Table 5.1. ●, 1988-89; ○, 1989-90.

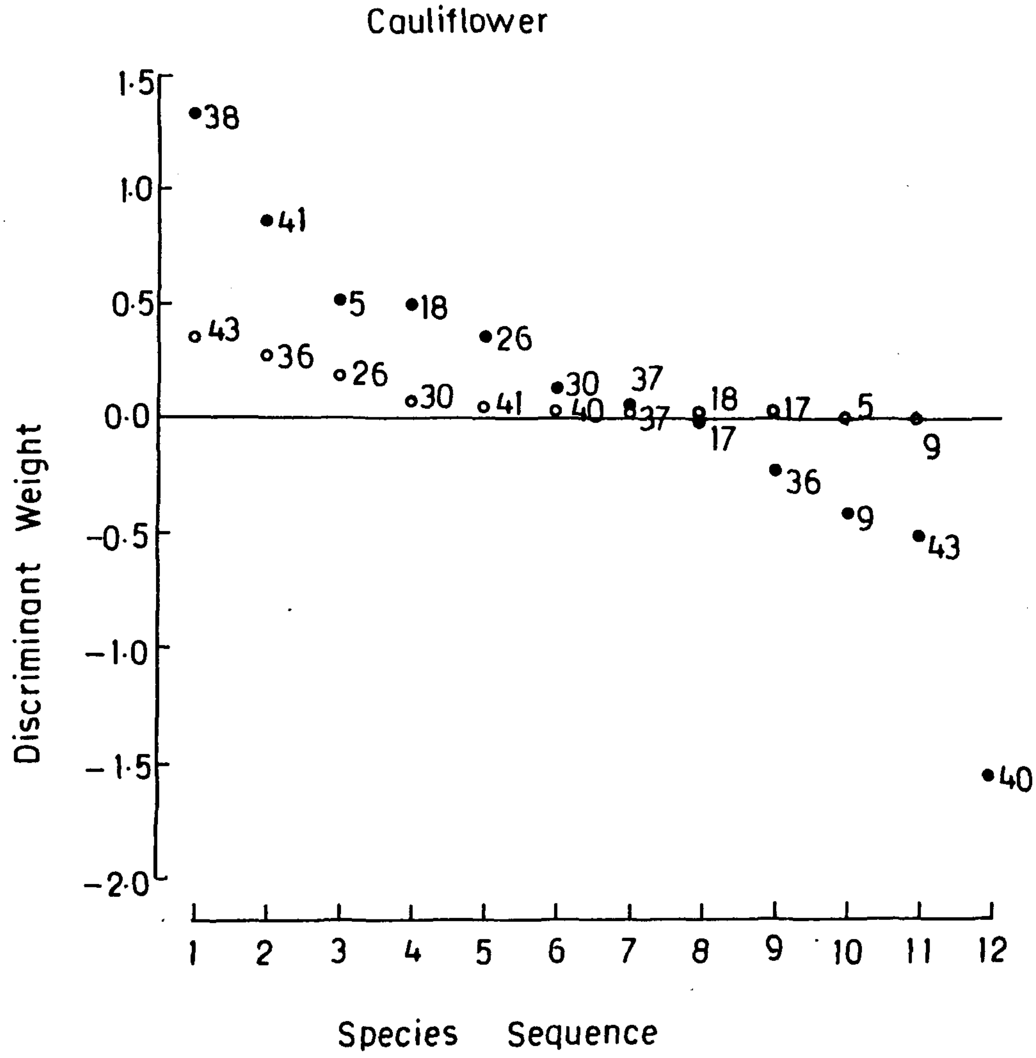

Fig. 5.10. Species ranked in order of importance for differentiating between the 'jhum' and terrace fields in cauliflower field as depicted from the discriminant weights of the linear discriminant function. Species number refers to the serial number mentioned in Table 5.1. ●,1988-89 ; O, 1989-90.

Chapter 6

MICROENVIRONMENT OF CROP FIELDS UNDER 'JHUM' AND TERRACE CULTIVATION

It has been repeatedly argued that environmental gradient, competitive interactions, mosaicness of disturbances and a number of other interactions between biotic and abiotic variables influence the distribution, growth and abundance of plant populations in time and space (Billington *et al.* 1990, Hobbs and Mooney 1991). A study of population behaviour along environmental gradients may help in understanding the ways in which habitat conditions limit the distribution of species (Slade and Hutchings 1989). The importance of different microenvironmental variables to plants in a community varies from species to species and from one growth stage to another (Harper 1977, Weiner 1982, Hartgerink and Bazzaz 1984, Schwaegerle and Levin 1990). Weeds in the crop field, although share a common habitat with crop plants, their immediate environment is markedly different from the associated crop plants. This is particularly true at the later stage of crop growth when crop canopy is fully expanded affecting the environment underneath. Therefore a satisfactory explanation of population behaviour of weeds would require a better understanding of microenvironment to which successively emerging cohorts of weed seedlings are exposed in different crop fields. It is also likely that individuals of a population, differing in age may differ in their responses to different environmental factors. Thus measurement of environmental factors along with the study of demography is helpful in the analysis of cause and effect for the observed pattern in the community (Mack and Pyke 1984). In view of the above and in order to study the effect of certain microclimatic and edaphic factors on weed population dynamics and growth in 'jhum' and terrace fields, photosynthetically active radiation (PAR), relative humidity and soil temperature were regularly measured over a period of two years in different crop fields under study and the results are discussed in this chapter.

RESULTS

Monthly variation in PAR over the crop canopy was highly significant. PAR declined from April onwards until October and then increased during ensuing winter and spring months (Fig. 6.1). The lowest value was recorded during September, which ranged between 470-530 μ mol m^{-2} s^{-1} at Barapani and 790-880 μ mol m^{-2} s^{-1} at Upper Shillong. The highest value of PAR was recorded during January-February, which varied between 1810 and 1850 μ mol $m^{-2}s^{-1}$ at Upper Shillong and Barapani, respectively. In comparison to Barapani, PAR was always higher at Upper Shillong. The yearly variation was insignificant at both the sites.

At Upper Shillong, PAR underneath the crop canopy showed similar temporal pattern of light interception in all the crops

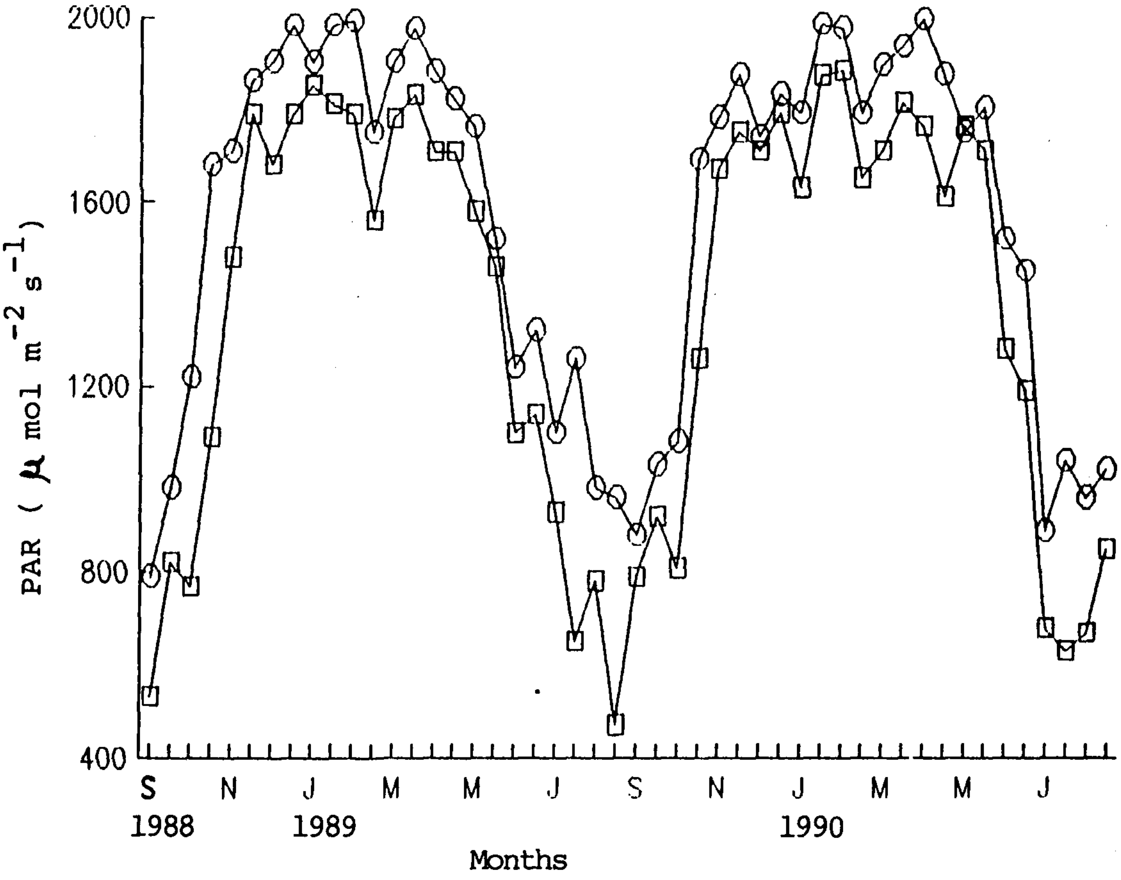

Fig. 6.1. Seasonal variation in photosynthetically active radiation (PAR) at Upper Shillong (-o-) and Barapani (-□-) during the study period.

studied (Fig. 6.2). Light interception through the canopy increased up to the age of 60 days, after which it decreased in all the crops both under 'jhum' and terrace. The percentage reduction in PAR under plant canopy was significantly ($P<0.01$) higher (56-68%) in 'jhum' than terrace (36-55%) fields. The percentage reduction in PAR was in the order potato > cauliflower > radish > maize.

At Barapani, maize and radish fields showed a similar trend of temporal variation in solar radiation near the ground (Fig. 6.3). This trend was also similar to the pattern observed in the crop fields at Upper Shillong.

Seasonal variation in relative humidity was significant ($P<0.01$) at both sites. It increased with setting of the rainy season and then declined during ensuing autumn and winter seasons. Relative humidity was around 93% at Upper Shillong and 82% at Barapani during August but during March-April it declined to 55-63% at Upper Shillong and 62-65% at Barapani (Fig. 6.4). Reduction in relative humidity under the canopy was very meager (0.5-1%) and it did not vary significantly between 'jhum' and terrace fields and among different crops.

At Upper Shillong, soil moisture content was lower in 'jhum' than terrace fields. Its seasonality was related to the rainfall pattern (Fig. 6.5 a). At Barapani, soil moisture content was more than that recorded at Upper Shillong. Soil moisture values at

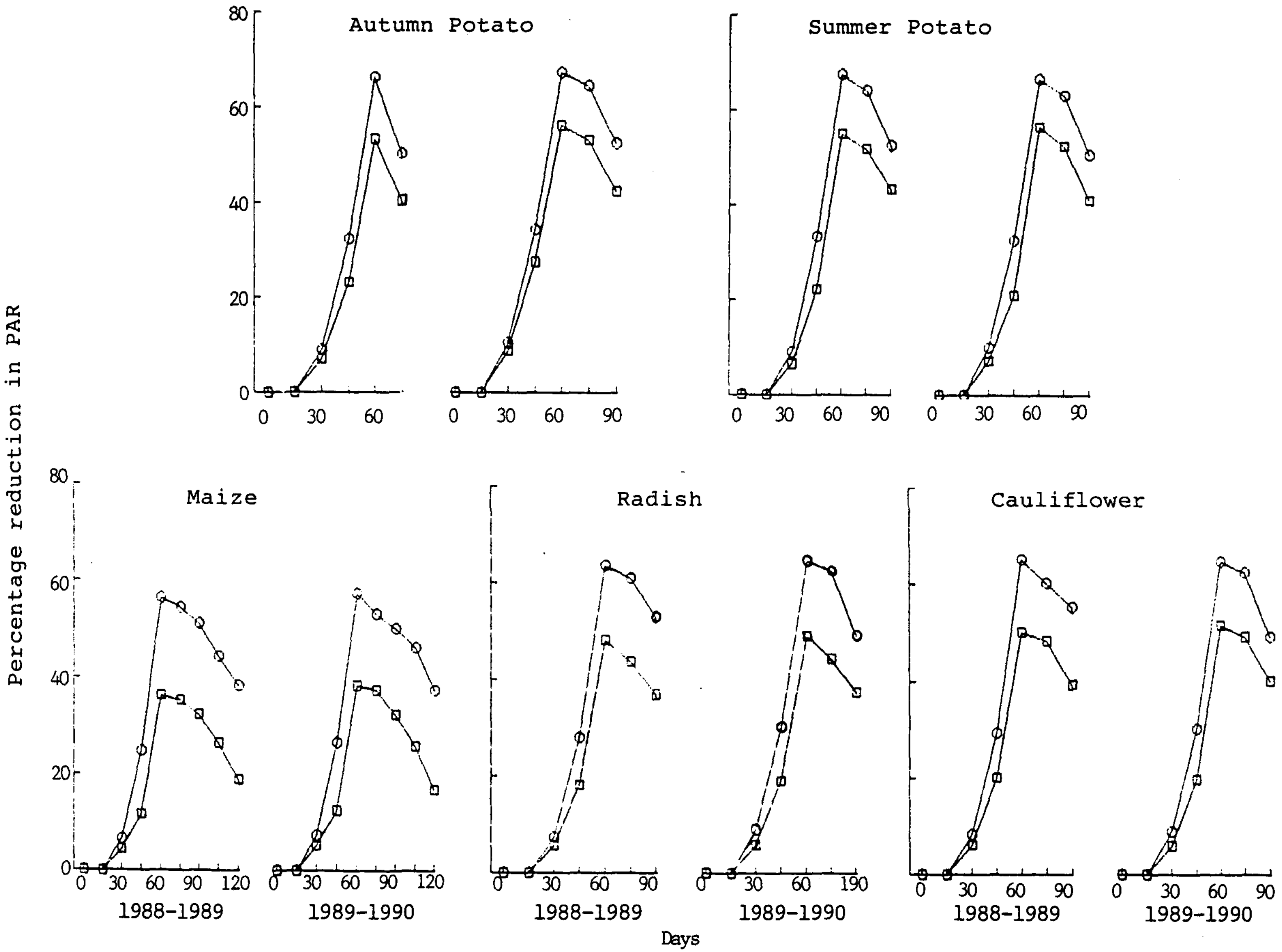

Fig. 6.2. Percentage reduction in photosynthetically active radiation (PAR) underneath the crop-weed canopy in different crop fields under 'jhum' (-o-) and terrace (-□-) cultivation at Upper Shillong.

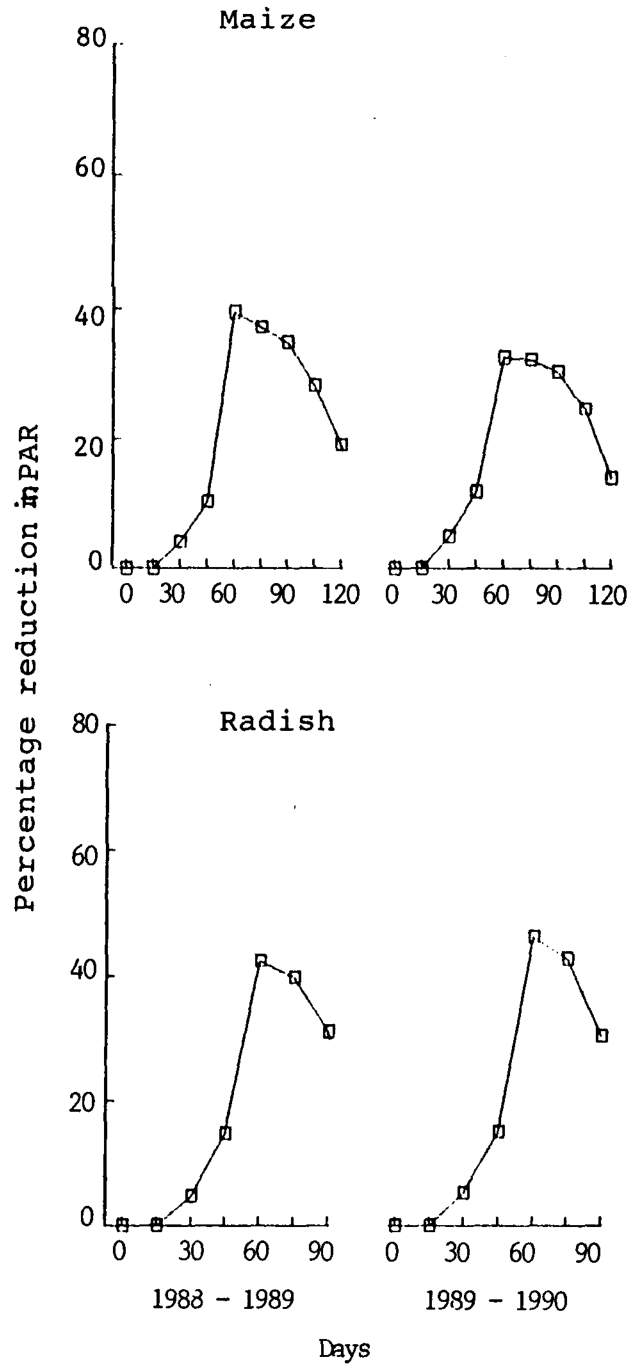

Fig. 6.3. Percentage reduction in photosynthetically active radiation (PAR) underneath crop-weed canopy in different crop fields under terrace cultivation at Barapani.

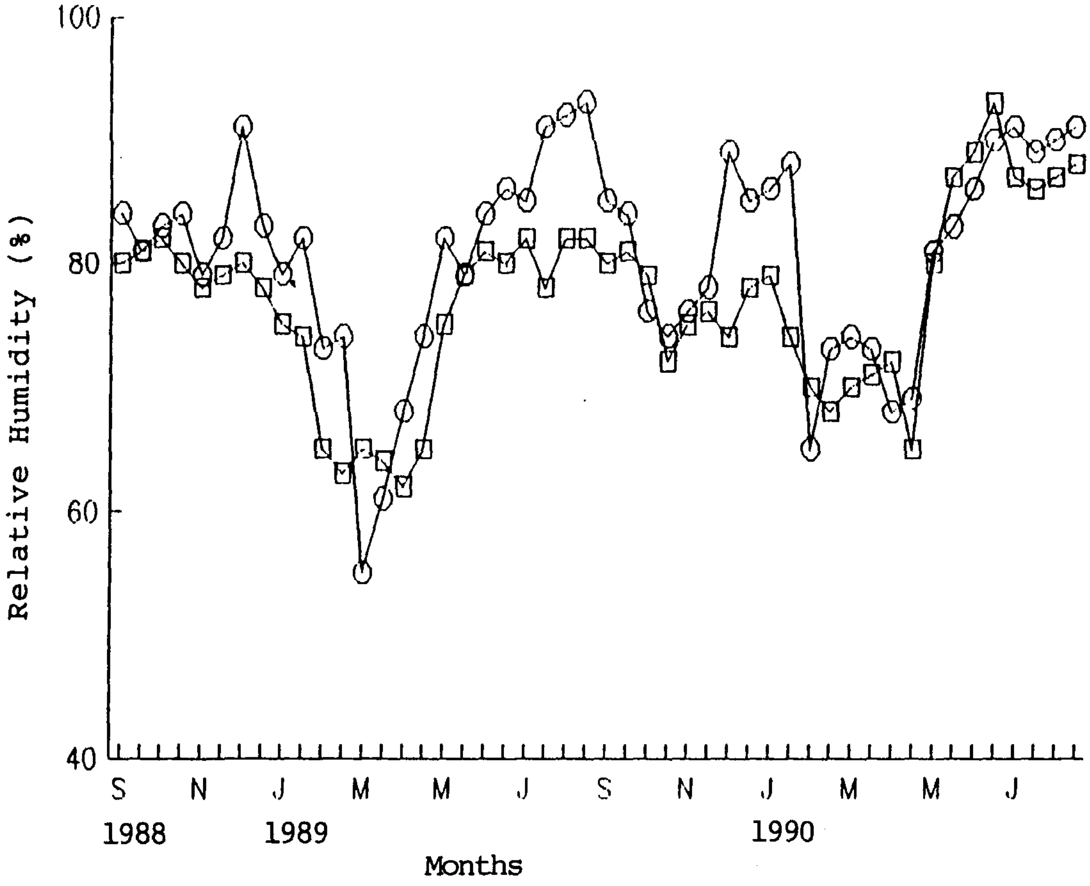

Fig. 6.4. Seasonal variation in relative humidity (%) at Upper Shillong (-o-) and Barapani (—□—) during the study period.

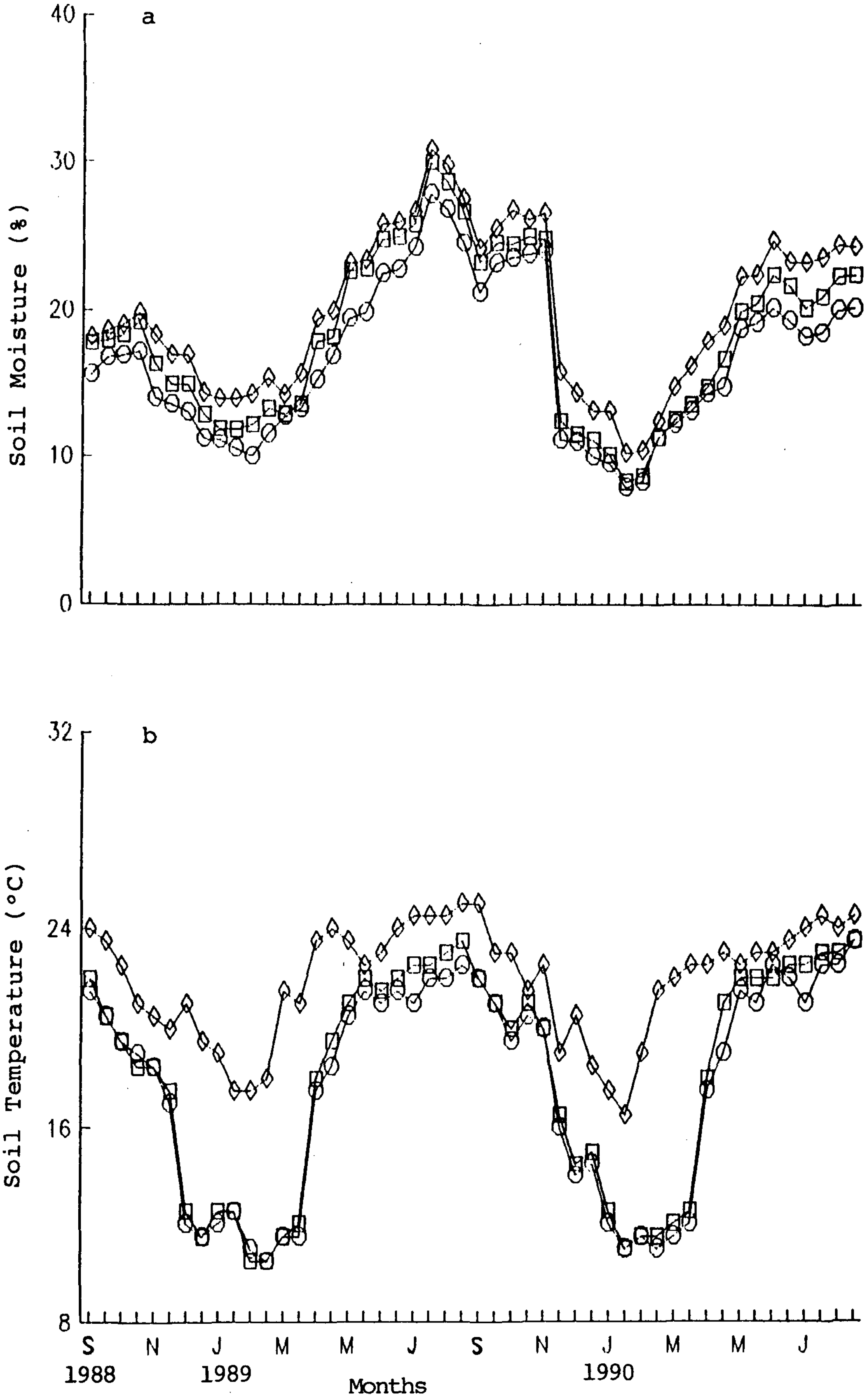

Fig. 6.5. Seasonal variation in (a) soil moisture (%) and (b) soil temperature in the crop fields under 'jhum' (-o-) and terrace (-□-) cultivation at Upper Shillong and under terrace (-◇-) cultivation at Barapani.

Upper Shillong ranged between 7.9-27.8% in 'jhum' fields, 8.3-29.9% in terraces while at Barapani it varied between 10.2 and 30.8%.

At Upper Shillong difference in soil temperature between 'jhum' and terrace fields was insignificant but seasonal variation was quite distinct. Yearly variation was insignificant. Highest soil moisture was recorded during April-August (Upper Shillong 'jhum'- 22.5°C, terrace- 23.5°C; Barapani- 23°C) and lowest during January-February (Upper Shillong-10.5°C, Barapani-17.5°C). Throughout the year, Barapani fields had higher temperature than Upper Shillong (Fig.6.5b). Like other microenvironmental factors yearwise variation in soil temperature was insignificant.

DISCUSSION

It is clearly evident from the results presented in the foregoing pages that the microenvironmental conditions within the crop-weed community of agroecosystem was considerably different from those prevailing outside. The factors which influenced these conditions included type of crop, age of plants and their density in the community. Available data suggest that with the growth of crop and weed plants in the field, solar radiation was reduced considerably near the ground. The percentage reduction in PAR by the foliage increased with time until 60 days in almost all crop fields. Significantly higher interception of PAR by foliage in 'jhum' than in terrace fields was mainly due to greater weed density in the former fields since density of a given crop was similar in the two fields. Temporal pattern as well as the magnitude of reduction in PAR below the canopy layer was similar in almost all the crops studied. However, in the maize field under terrace cultivation at Upper Shillong light interception by the canopy was much higher than any other field. Since this field was mainly infested with monocot weeds, greater interception could be related to the canopy architecture of the monocotyledonous species including the crop plants.

Rainfall influences the relative humidity and soil moisture of a particular site which in turn play a critical role in plant growth and dynamics of plant populations and communities (Hobbs and Moony 1991). So far as relative humidity is concerned, it was almost the same both above the plant canopy and near the ground in crop fields. It followed the trend of rainfall. Influence of plant growth on moisture content of the top soil layer was more prominent than on the relative humidity just above the soil. Growth of plants on one hand reduces evaporation loss from the soil by preventing direct exposure to sun but, on the other hand, it increases water loss from canopy through transpiration particularly after full expansion of foliage. Water loss through evapotranspiration plays an important role in influencing soil moisture, particularly during post-monsoon period. The net result of these two processes was a gradual reduction in soil moisture of both 'jhum' and terrace fields from seedling stage to crop maturity. Plant density seemed to have played an important role in this regard since 'jhum' fields having higher weed density than terraces at Upper Shillong had lower moisture content . Higher soil moisture content in terraces could also be due to better soil working than 'jhum' fields. Seif Eldin and Obeid (1979) reported that hoed soil had higher soil moisture content than the undisturbed soils. Another factor which influenced the moisture level of the soil, was its texture. At Barapani, where annual rainfall was same but temperature was relatively higher than Upper Shillong, possibility of greater evaporation losses from the surface soil was more than Upper Shillong. But the former showed higher soil moisture content than the latter. The most probable reason for such a difference between the two sites is clay loam texture of the soil at Barapani against sandy loam soil found at Upper Shillong. Higher soil temperature at Barapani than that at Upper Shillong was due to prevailing atmospheric temperature.

Thus, out of the four important environmental variables studied, two of them i.e., PAR and moisture content of the surface soil varied significantly between 'jhum' and terrace fields. In both fields these two factors showed a marked temporal variation during the crop growth . Role of these factors on population behaviour of dominant weeds in 'jhum' and terrace fields have been discussed in the ensuing chapters of the dissertation.

Chapter 7

POPULATION DYNAMICS AND GROWTH BEHAVIOUR OF TWO DOMINANT WEEDS IN DIFFERENT CROP FIELDS UNDER 'JHUM' AND TERRACE CULTIVATION

Dynamics of plant population is the outcome of summed performances or behaviour of all the individuals in a population (Hartnett and Bazzaz 1984). This can be studied through continuous monitoring of seedling emergence, mortality and fecundity of adult plants through time. In a plant population with overlapping generations, the study of the fates of successive cohorts is essential to explain the population behaviour under natural conditions. The present understanding of growth behaviour and dynamics of plant populations is based largely on the studies conducted on pure populations of individual species (Antonovics 1972, Lovett Doust 1981, Mack and Pyke 1984, Fernandez-Quintanilla *et al.* 1986). Similar information in a stand of multiple species is relatively meagre, probably due to complexity of interactions within and between the populations, on one hand, and between populations and abiotic environment, on the other. Weed communities in the crop fields offer an opportunity, wherein behaviour of individual cohorts as well as populations of different species can be studied simultaneously in the mixed stand. It is also not clear how growth and population behaviour of individual weed species differ in different crop fields under different modes of cultivation such as 'jhum' and terrace. Along with population parameters, continuous monitoring of various microenvironmental factors in crop fields and a critical analysis of their role in the emergence, survival pattern and growth of different weed populations may be helpful in evaluating their importance in population regulation and understanding the dynamics of entire weed community in the agroecosystems. Such studies are very much useful in assessing the long-term effects of various weed control measures on population behaviour of weeds in crop fields, although population studies are highly descriptive and have low predictive value.

At Upper Shillong *Polygonum alatum* and *Spergula arvensis* (Plate 7.1) were the dominant weeds of the crop fields. By virtue of their high density and luxuriant growth, they shared *ca* 70% dominance in the weed community of 'jhum' and 40% in the terrace fields. *P. alatum* (Polygonaceae) is an annual herb with slender stem, branching freely at the base. Its ecological studies are lacking, albeit some work has been done on different species of this genus. For instance, seed germination in *P. aviculare* has been worked out by Courtney (1968) and Baskin and Baskin (1990). The seedling growth, physiology and survivorship of *P. newberryi* was studied by Chapin and Bliss(1989) and behaviour of buried seed population of *P. pencylvanicum* was analysed by Baskin and Baskin (1987). Resource allocation in *P. cascadens* in different habitats has been studied by Hickman (1975).

Plate 7.1. Dominant weeds (a) *Polygonum alatum* and (b) *Spergula arvensis* (b) at high altitude site.

S. arvensis (Caryophyllaceae), an erect annual herb, with thread-like bright green leaves appearing in whorls at each node, is a cosmopolitan exotic species (Godwin 1975). Distribution, biology, propagation and agricultural importance of this species have been described by Holm *et al.* (1977). Considering its pattern of seed dormancy, germination behaviour (Wesson and Wareing 1969, Jones and Hall 1979, Wagner 1988), seedling emergence pattern and high growth rate *S. arvensis* has been described as a successful weed of arable land (Fenner 1978). Besides, characters such as early flowering, high degree of developmental plasticity (Trivedi and Tripathi 1982a,b) and prolific seed production as exhibited by the species ensures its success on a wide range of habitats.

In this chapter, data pertaining to population dynamics and growth behaviour in terms of dry matter production of these two dominant weed species in different crop fields under 'jhum' and terrace cultivation at Upper Shillong have been presented and discussed in relation to the microenvironmental conditions in the respective crop fields.

RESULTS

SEEDLING EMERGENCE

Seedlings of *P. alatum* and *S. arvensis* emerged in three different groups giving rise to three distinct cohorts of seedlings. The time lag between crop sowing and emergence of the first cohort of seedlings was about 8-10 days in all the crop fields under both 'jhum' and terrace cultivation. Second cohort of seedlings emerged 15 days after the recruitment of the first cohort and the third cohort emerged one month after the emergence of the second cohort. The time lag between the cohorts was almost the same in all the crop fields during both years of study.

In general, seedling emergence declined in successive cohorts of both the species in all the crops studied. However, in summer potato highest recruitment of seedlings of *P. alatum* occurred in the third cohort during first year in both 'jhum' and terrace fields. In autumn potato and maize, recruitment was maximum in the second cohort in terraces during first year (Fig. 7.1). During second year, in summer potato, seedling emergence was lower in the second cohort than in the third cohort. In terraces, higher percentage of seedlings were recruited in the third cohort than in the second cohort in summer potato during first year. The same was true for the radish field during the second year (Fig. 7.2). Variation between different crop fields in seedling emergence pattern of *P. alatum* was significant ($P<0.01$) only during first year. Differences in the emergence of *S. arvensis* seedlings between different crop fields were insignificant. Variation among cohorts was significant ($P<0.01$) for both the species, however, the difference between 'jhum' and terrace fields with respect to seedling emergence was insignificant.

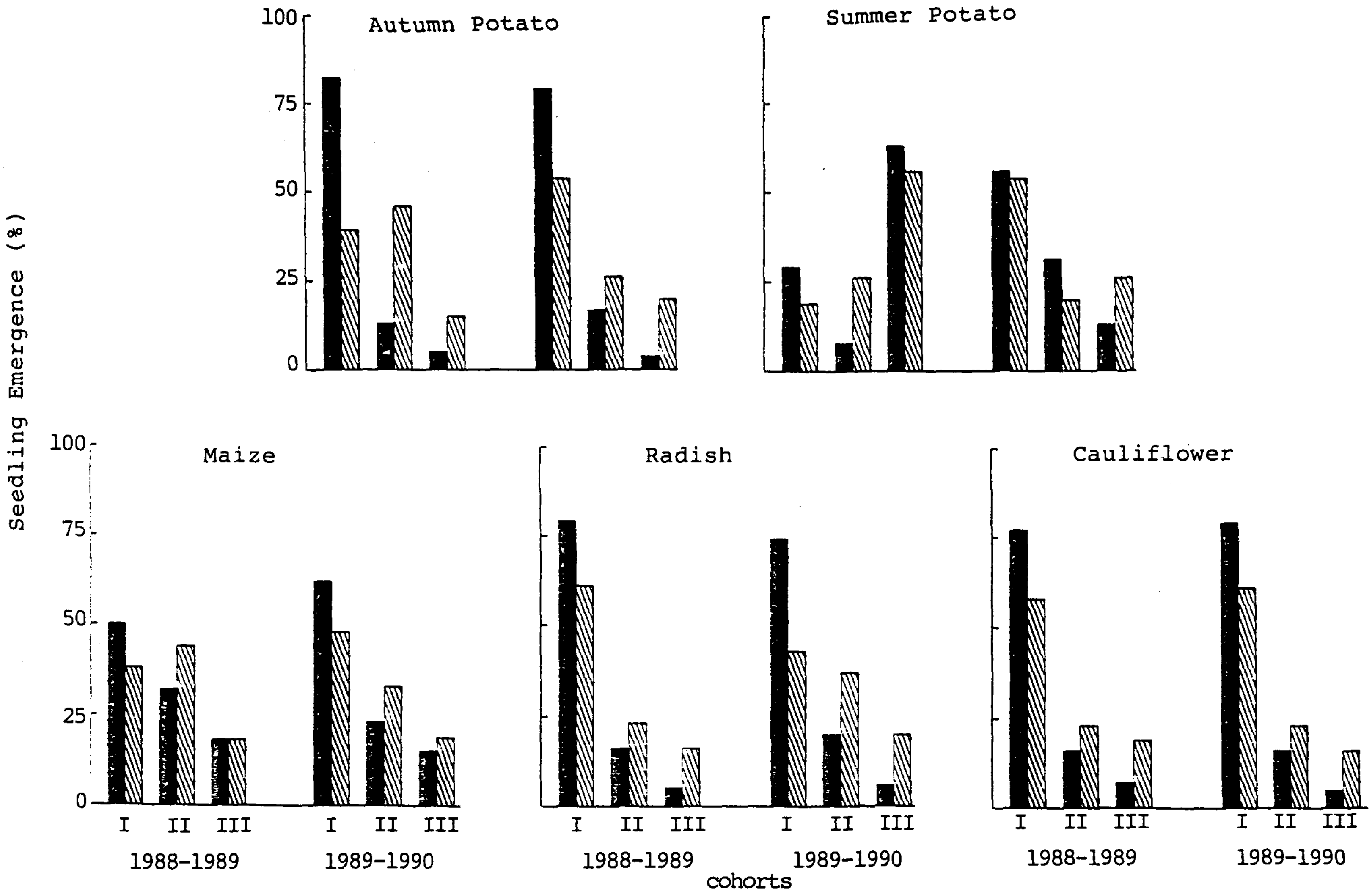

Fig. 7.1. Percentage emergence of P. alatum seedlings in three successive cohorts in different crops under 'jhum' (■) and terrace (▨) cultivation at Upper Shillong.

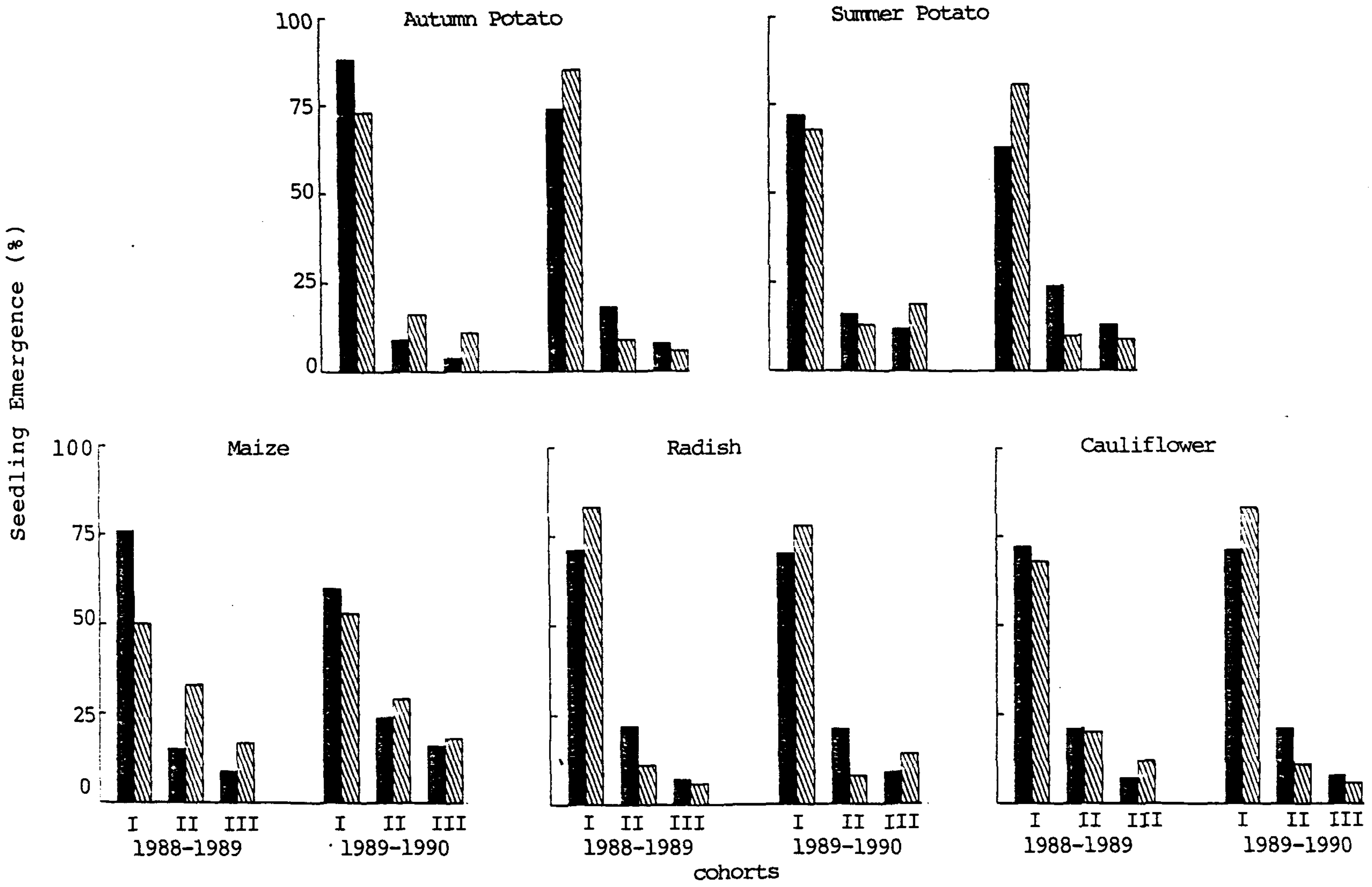

Fig. 7.2. Percentage emergence of *S. arvensis* seedlings in three successive cohorts in different crops under 'jhum' (■) and terrace (▨) cultivation at Upper Shillong.

Effects of various microenvironmental factors on seedling emergence were analysed using partial correlation coefficient (Table 7.1). Although all four factors viz., PAR, soil moisture, soil temperature and relative humidity influenced seedling emergence of both the species, importance of a given factor varied from one crop field to another and between 'jhum' and terrace fields. In general, soil temperature and PAR played a more important role in regulating seedling emergence of both *P. alatum* and *S. arvensis*.

SURVIVAL AND HALF-LIFE OF SEEDLING COHORTS

Total seedling recruitment of *P. alatum* and *S. arvensis* was higher in 'jhum' than terrace fields (Table 7.2). Especially in maize, the density of recruited seedlings was many fold higher in 'jhum' than terrace fields. Despite significant difference in density of first and second cohorts, their survivorship curves, showing high mortality at juvenile stage, were similar in all the crops. The third cohort showed a constant rate of mortality throughout its life (Fig. 7.3-7.8). In maize field under terrace cultivation, seedlings in all the three cohorts exhibited constant mortality throughout their life. The shape of the survivorship curves of *P. alatum* and *S. arvensis* was similar in all the fields.

In both the species half-lives of successive cohorts decreased in almost all the crops (Table 7.3). The first cohort

Table 7.1 Partial correlation coefficients between four micro-environmental variables (photosynthetically active radiation (PAR), relative humidity (RH), soil moisture (SM) and soil temperature (ST)) and seedling emergence (%) of *P. alatum* and *S. arvensis*.

Crop	Micro-environmental variables	*P. alatum*		*S. arvensis*		n
		'Jhum'	Terrace	'Jhum'	Terrace	
Autumn Potato	PAR	0.591*	0.470*	0.766**	0.806**	18
	RH	0.347	0.332	0.161	0.886**	18
	SM	0.456	0.281	0.677*	0.811**	18
	ST	0.395	0.314	0.645*	0.870**	18
Summer Potato	PAR	0.333	0.437*	0.809**	0.789**	18
	RH	0.483*	0.556*	0.531*	0.854**	18
	SM	0.708**	0.754**	0.744**	0.803**	18
	ST	0.391	0.506*	0.702**	0.855**	18
Cauliflower	PAR	0.619*	0.825**	0.576*	0.679**	18
	RH	0.698**	0.901**	0.686**	0.794**	18
	SM	0.691**	0.857**	0.677*	0.729**	18
	ST	0.798**	0.907**	0.711**	0.805**	18
Maize	PAR	0.905**	0.742**	0.621*	0.290	18
	RH	0.920**	0.369	0.570*	0.778**	18
	SM	0.936**	0.371	0.735**	0.683**	18
	ST	0.947**	0.413	0.766**	0.823**	18
Radish	PAR	0.565*	0.634*	0.695**	0.921**	18
	RH	0.657*	0.806**	0.752**	0.939**	18
	SM	0.667**	0.732**	0.782**	0.935**	18
	ST	0.700**	0.840**	0.806**	0.957**	18

* = Significant at $p<0.05$, ** = Significant at $p<0.01$

Table 7.2 Total recruitment of *P. alatum* and *S. arvensis* seedlings m^{-2} in different crop fields.

Crop	*P. alatum*				*S. arvensis*			
	'Jhum'		Terrace		'Jhum'		Terrace	
	1988-1989	1989-1990	1988-1989	1989-1990	1988-1989	1989-1990	1988-1989	1989-1990
Autumn Potato	856	1063	13	234	2485	1643	406	728
	(81)	(75)	(3)	(71)	(236)	(235)	(47)	(56)
Summer Potato	78	341	55	117	2726	2413	443	677
	(8)	(37)	(3)	(20)	(272)	(243)	(36)	(73)
Cauliflower	1275	1838	96	193	2064	1646	465	649
	(29)	(317)	(16)	(12)	(99)	(92)	(78)	(27)
Maize	320	355	16	21	2511	2333	12	34
	(41)	(38)	(2)	(2)	(138)	(248)	(3)	(5)
Radish	1843	1693	193	224	1934	1770	649	165
	(132)	(175)	(9)	(25)	(238)	(168)	(48)	(32)

Values in parentheses are ± S.E.

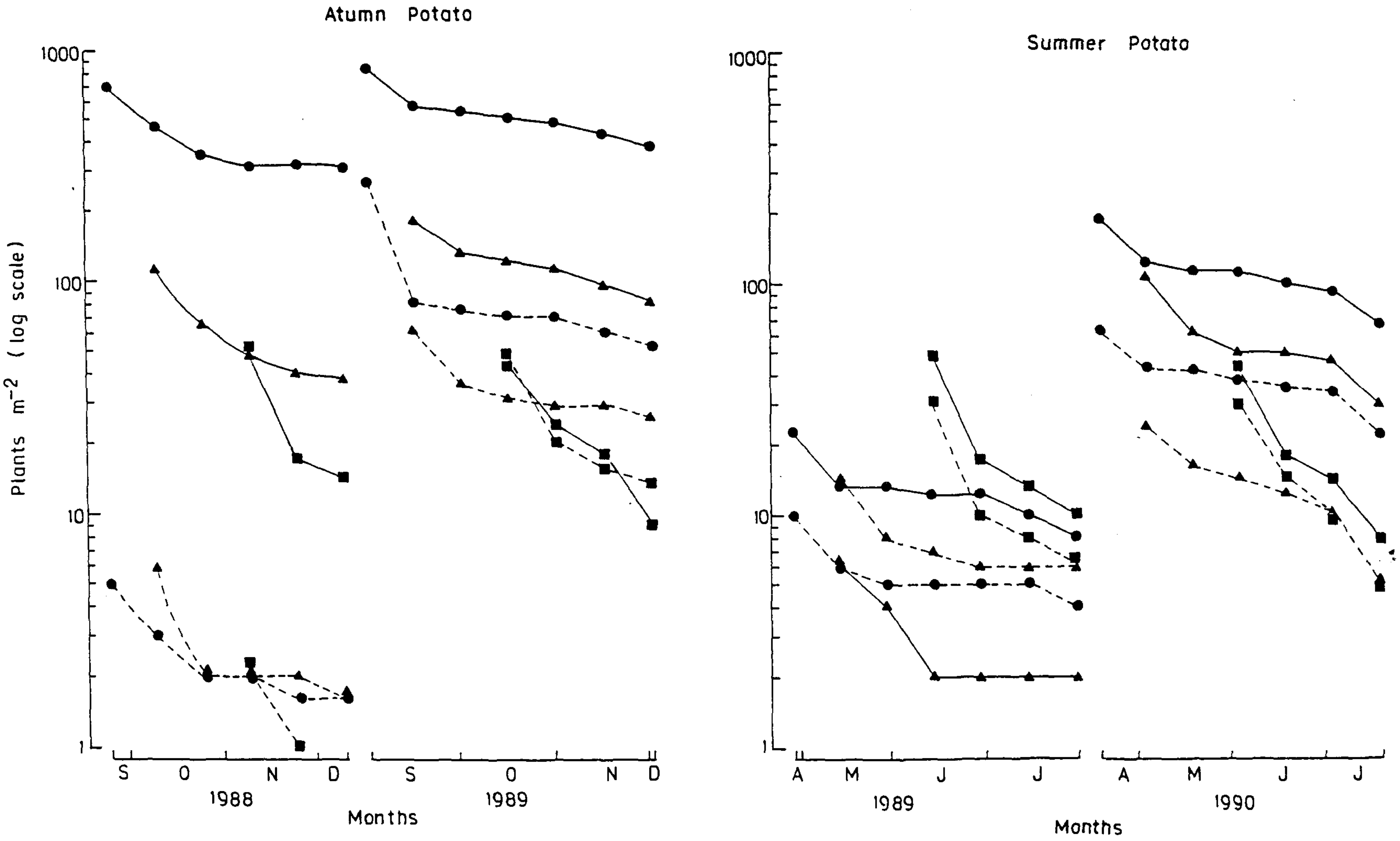

Fig. 7.3. Survivorship curves for seedling cohorts (cohort I, ● ; cohort II, ▲ and cohort III, ■) of *P. alatum* in potato fields under 'jhum' (——) and terrace (---) cultivation at Upper Shillong.

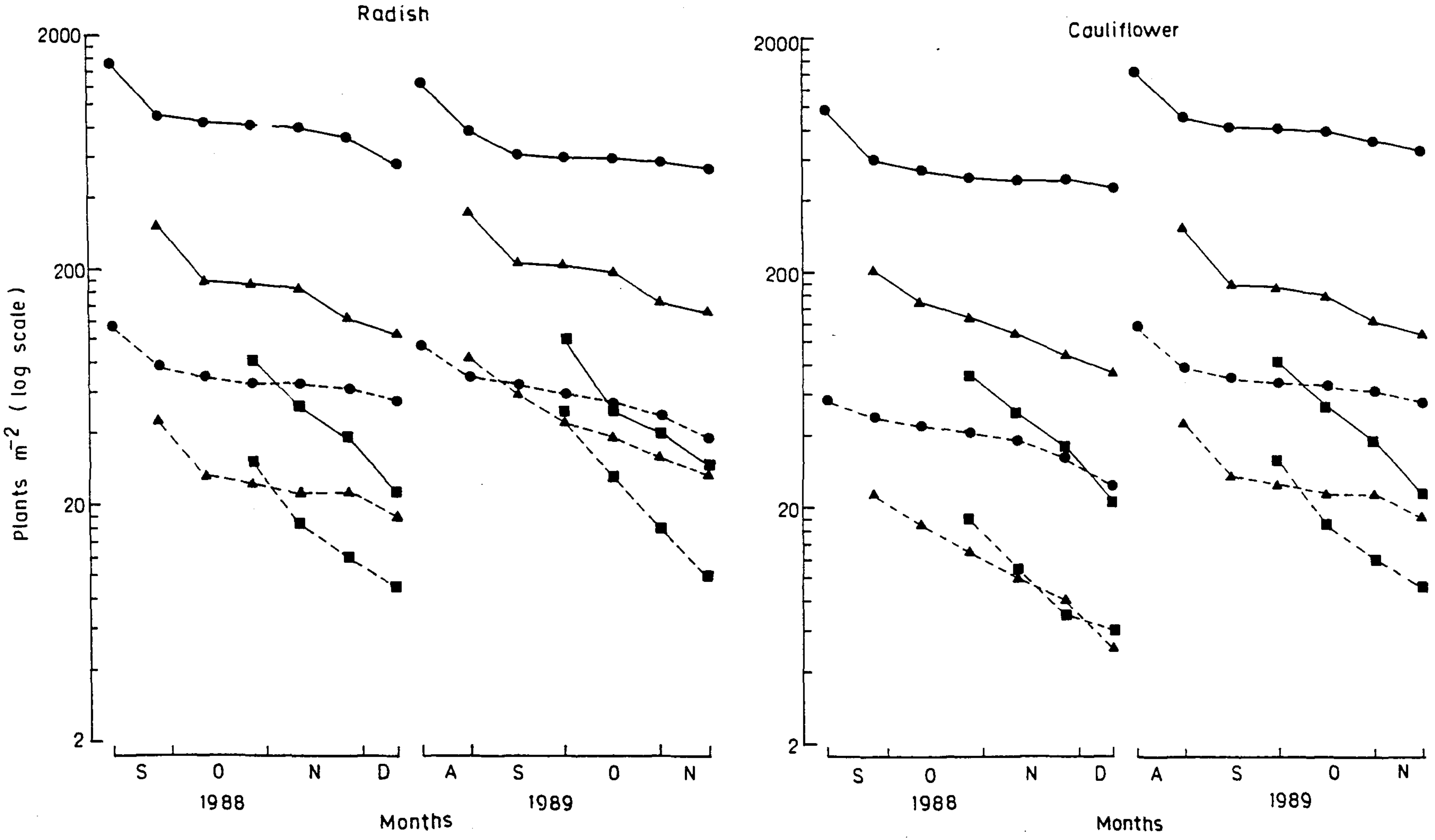

Fig. 7.4. Survivorship curves for seedling cohorts (cohort I, ● ; cohort II, ▲ and cohort III, ■) of P. alatum in radish and cauliflower fields under 'jhum' (——) and terrace (----) cultivation at Upper Shillong.

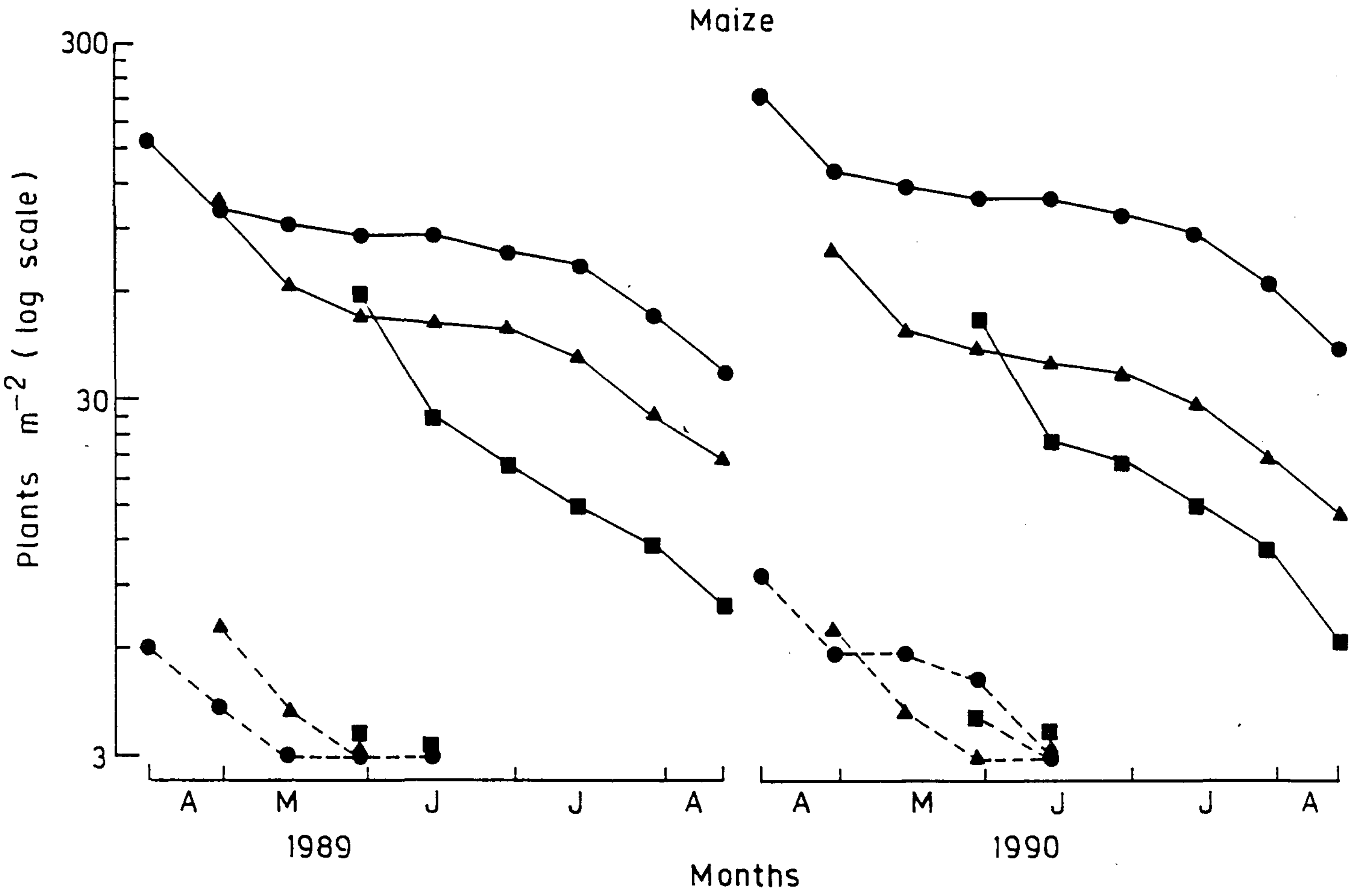

Fig. 7.5. Survivorship curves for seedling cohorts (cohort I , ● ; cohort II, ▲ and cohort III, ■) of P. alatum in maize field under 'jhum' (——) and terrace (---) cultivation at Upper Shillong.

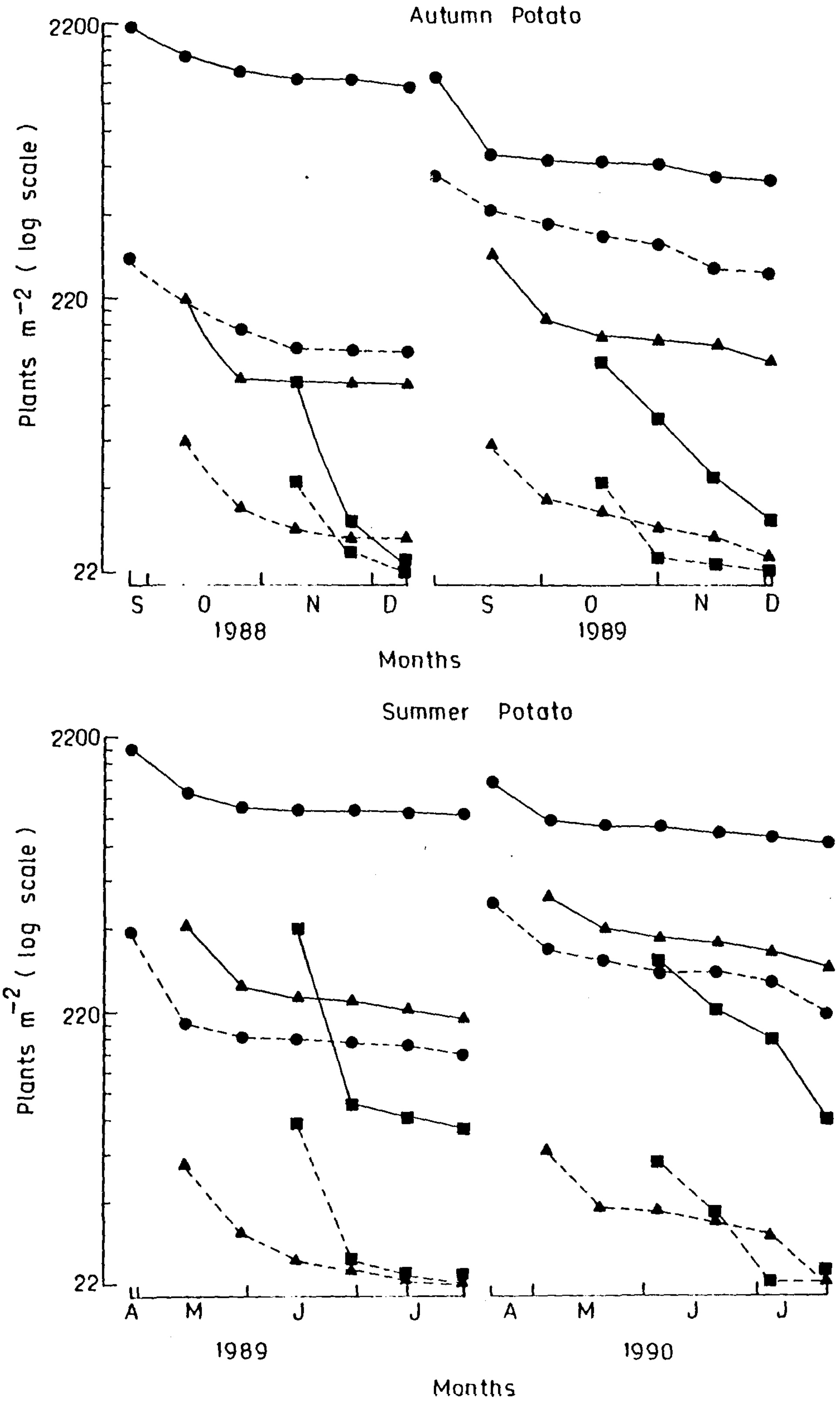

Fig. 7.6. Survivorship curves for seedling cohorts (cohort I, ●; cohort II, ▲ and cohort III, ■) of S. arvensis in potato fields under 'jhum' (——) and terrace (---) cultivation at Upper Shillong.

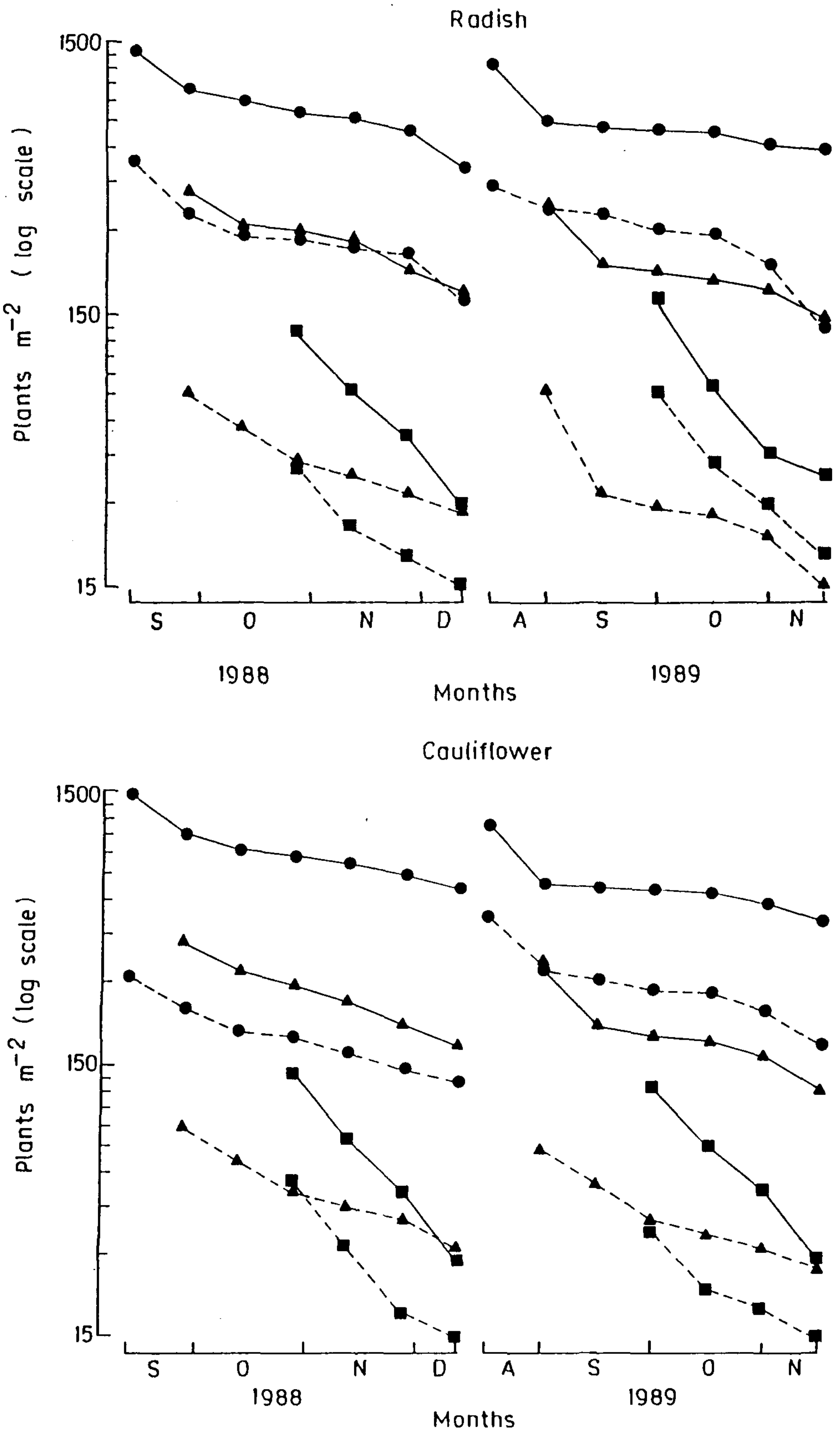

Fig. 7.7. Survivorship curves for seedling cohorts, (cohort I ● ; cohort II, ▲ and cohort III, ■) of S. arvensis in radish and cauliflower fields under 'jhum' (——) and terrace (---) cultivation at Upper Shillong.

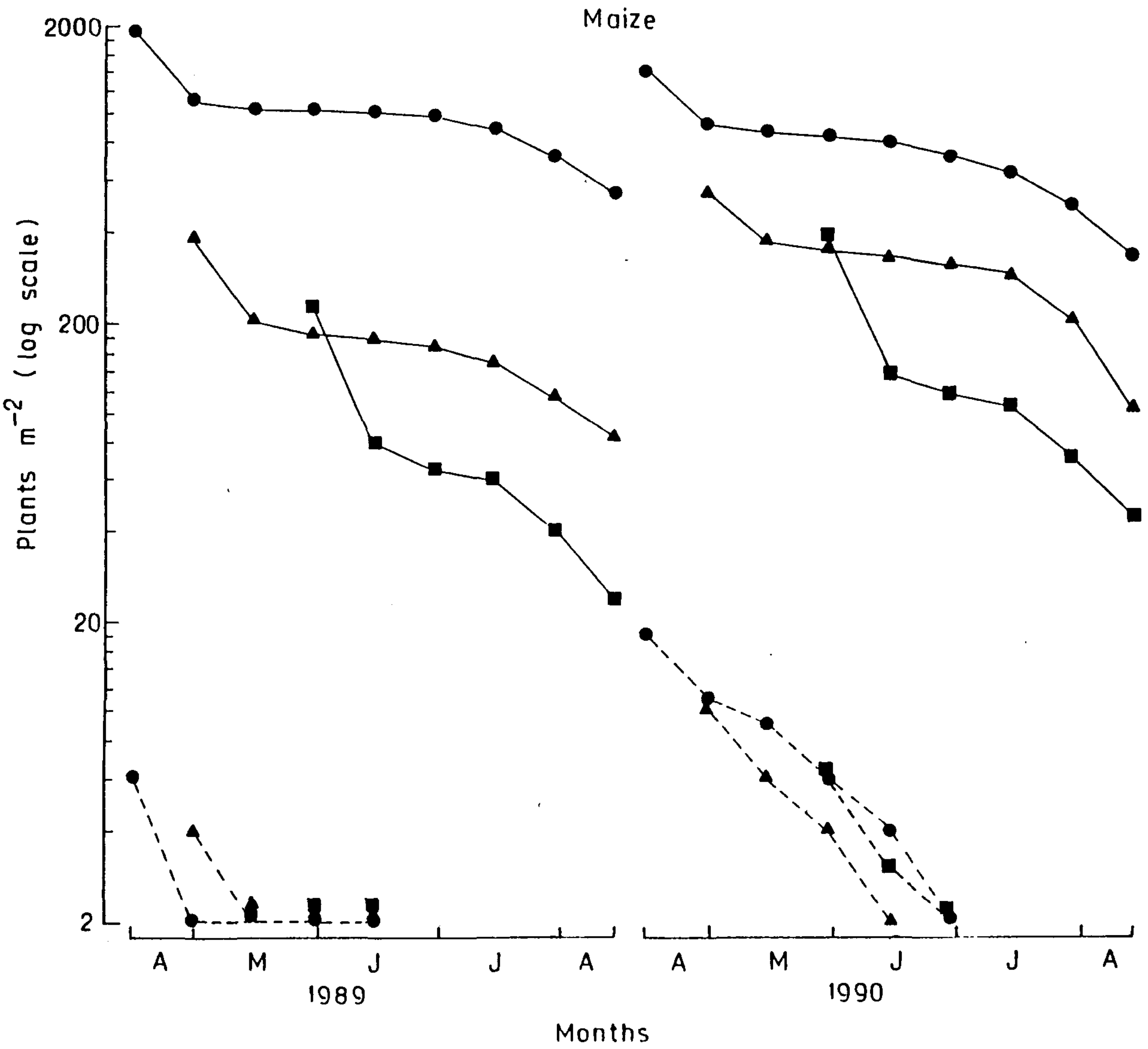

Fig. 7.8. Survivorship curves for seedling cohorts (cohort I, ●; cohort II, ▲ and cohort III, ■) of S. arvensis in maize field under 'jhum' (——) and terrace (---) cultivation at Upper Shillong.

Table 7.3 Half-life (weeks) of seedling cohorts of *P. alatum* and *S. arvensis* in different crop fields.

Crop	Cohort	*P. alatum*				*S. arvensis*			
		'Jhum'		Terrace		'Jhum'		Terrace	
		1988-1989	1989-1990	1988-1989	1989-1990	1988-1989	1989-1990	1988-1989	1989-1990
Autumn Potato	I	4.0	10.5	3.0	12.0	10.0	10.0	10.0	9.0
	II	3.0	8.5	1.0	4.0	2.0	8.0	3.0	6.0
	III	1.0	3.0	2.0	2.0	1.0	3.0	4.0	2.0
Summer Potato	I	6.0	9.0	4.0	10.5	12.0	12.0	12.0	10.0
	II	3.0	3.5	4.0	6.0	10.0	10.0	2.0	6.5
	III	1.0	1.5	1.0	2.0	1.5	4.0	1.0	3.0
Cauliflower	I	10.5	10.0	11.0	11.0	10.0	10.5	9.5	10.5
	II	6.5	6.5	5.0	5.5	8.0	7.5	6.0	6.0
	III	2.5	3.5	3.0	2.5	3.0	3.0	2.5	2.5
Maize	I	9.5	8.5	4.0	6.0	10.5	10.5	2.0	4.0
	II	5.0	5.0	2.5	2.5	4.0	3.0	2.0	3.0
	III	2.0	2.5	1.0	2.0	1.5	1.5	1.0	2.0
Radish	I	10.0	10.0	11.0	10.5	6.0	9.5	7.0	10.0
	II	6.5	7.0	6.0	5.0	8.0	6.5	6.0	7.5
	III	4.0	2.0	2.5	2.5	3.0	2.0	3.5	5.5

Table 7.3 (contd.)

Analysis of variance

Species	Source of variation	Degree of freedom		F Value	
		1988-1989	1989-1990	1988-1989	1989-1990
P. alatum	Crop	4	4	117.58**	29.13**
	Cultivation	1	1	18.90**	14.29**
	Cohort	2	2	368.53**	821.62**
S. arvensis	Crop	4	4	12.98**	359.76**
	Cultivation	1	1	22.90**	273.93**
	Cohort	2	2	151.24**	4627.70**

** = Significant at P<0.01

of *P. alatum* attained longest half-life in cauliflower and radish crops under terrace cultivation, while in *S. arvensis* it showed longest half-life in summer potato under 'jhum' cultivation. In both the species half-lives of the cohorts varied significantly ($P<0.01$) from one another. Half-lives of the cohorts also varied significantly ($P<0.01$) among the crops. Tukey's multiple comparison test revealed that the differences between first and second cohort, second and third cohort and first and third cohort was significant ($P<0.05$). Mode of cultivation also significantly ($P<0.01$) affected half-lives of the cohorts.

DRY MATTER PRODUCTION

Cohortwise as well as total dry matter production by the populations of both the species have been depicted in Figs. 7.9-7.12. In general, dry matter of cohort I and that of the total population followed a sigmoid curve until crop harvest in both 'jhum' and terrace fields; the shape of the curve gradually became linear from the second to third cohort. The first cohort attained peak between the age of 70-85 days after the crop sowing, while in the second and third cohorts highest biomass was recorded at the time of crop harvesting. The only exception was maize field under terrace cultivation where all the cohorts died much before the crop harvesting. The difference between 'jhum' and terrace fields was most prominent in cohort I and least clear in case of cohort III. Maximum difference in dry matter production between 'jhum' and terrace was recorded in maize

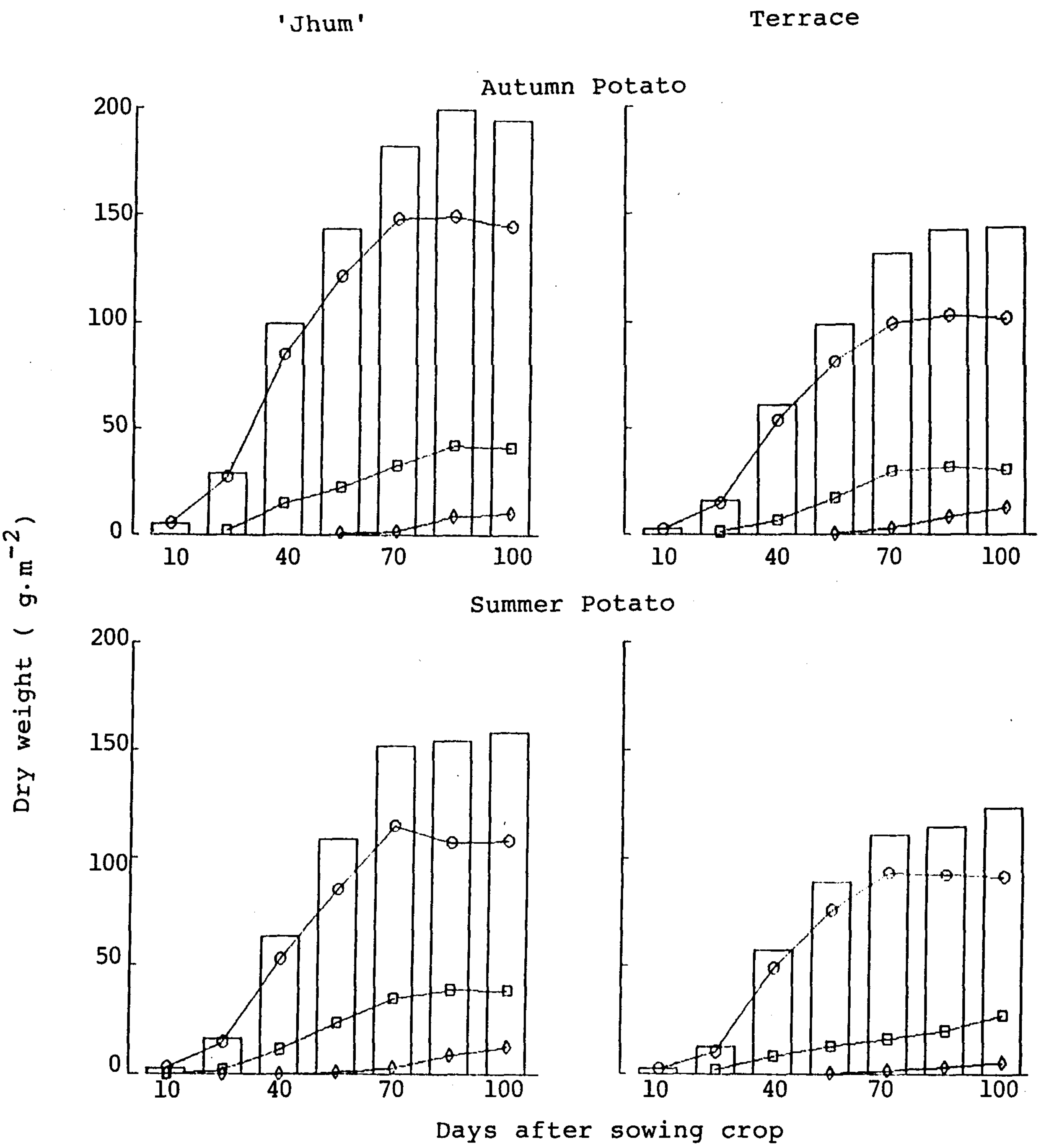

Fig. 7.9. Cohortwise (cohort I, -o-; cohort II, -□- and cohort III, -◊-) as well as total (□) dry matter production by P. alatum in potato fields under 'jhum' and terrace cultivation. The figure is based on the data of 1988-1989 and 1989-1990.

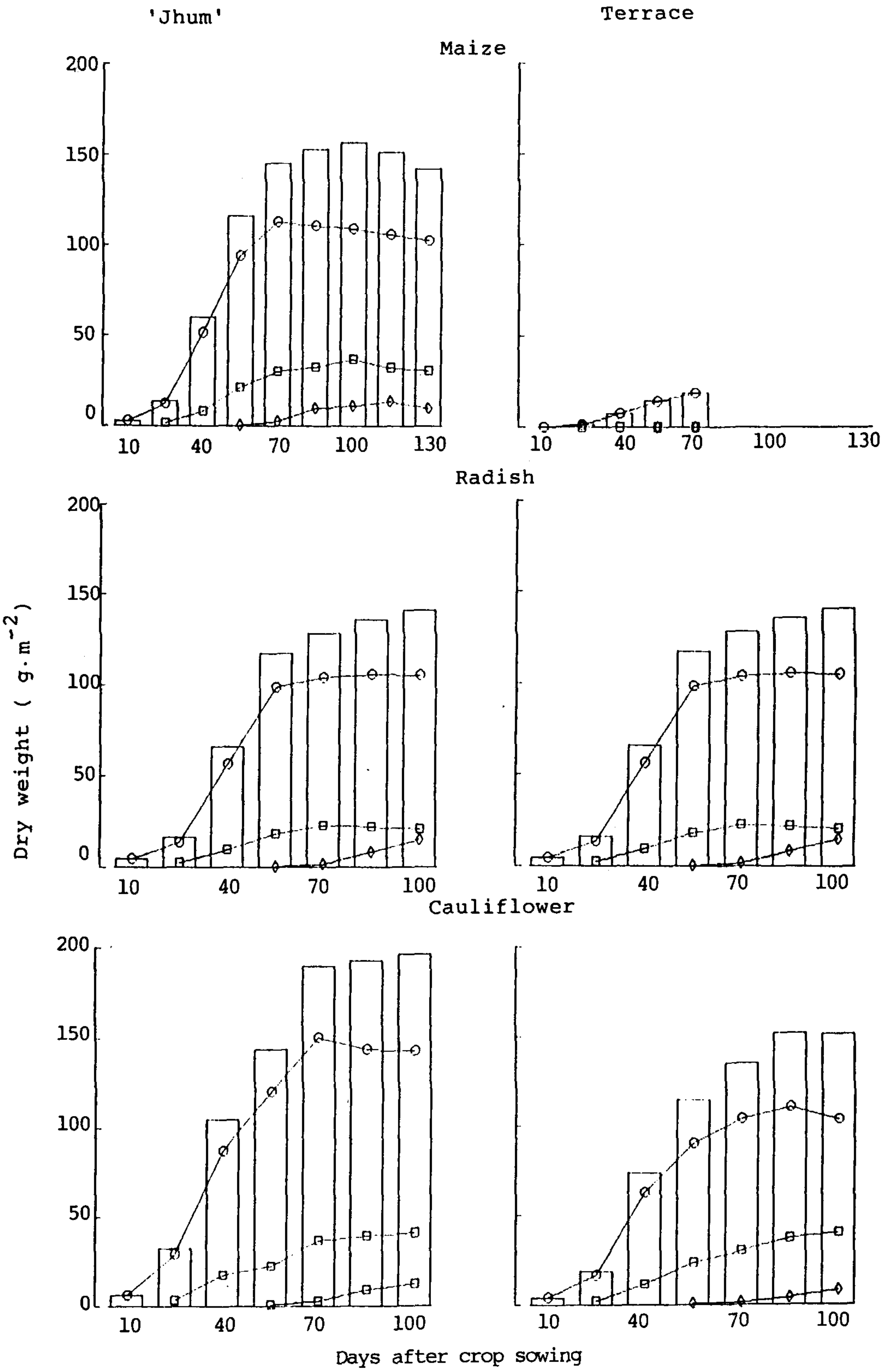

Fig. 7.10. Cohortwise (cohort I, -o-; cohort II, -□- and cohort III, -◊-) as well as total (□) dry matter production by P. alatum in maize, radish and cauliflower fields under 'jhum' and terrace cultivation. The figure is based on the data of 1988-1989 and 1989-1990.

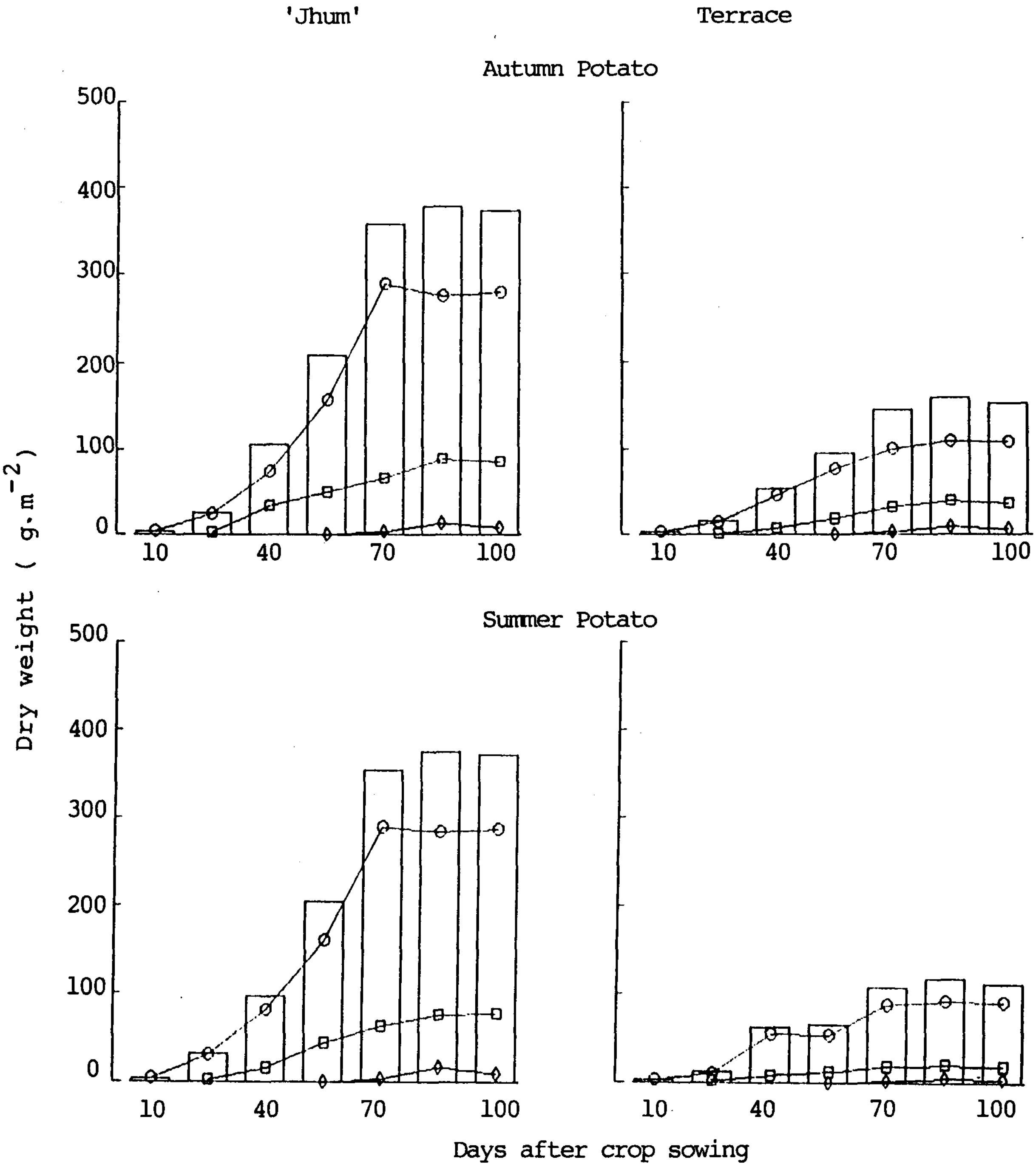

Fig. 7.11. Cohortwise (cohort I, -o-; cohort II, -□- and cohort III, -◊-) as well as total (□) dry matter production by S. arvensis in potato fields under 'jhum' and terrace cultivation. The figure is based on the data of 1988-1989 and 1989-1990.

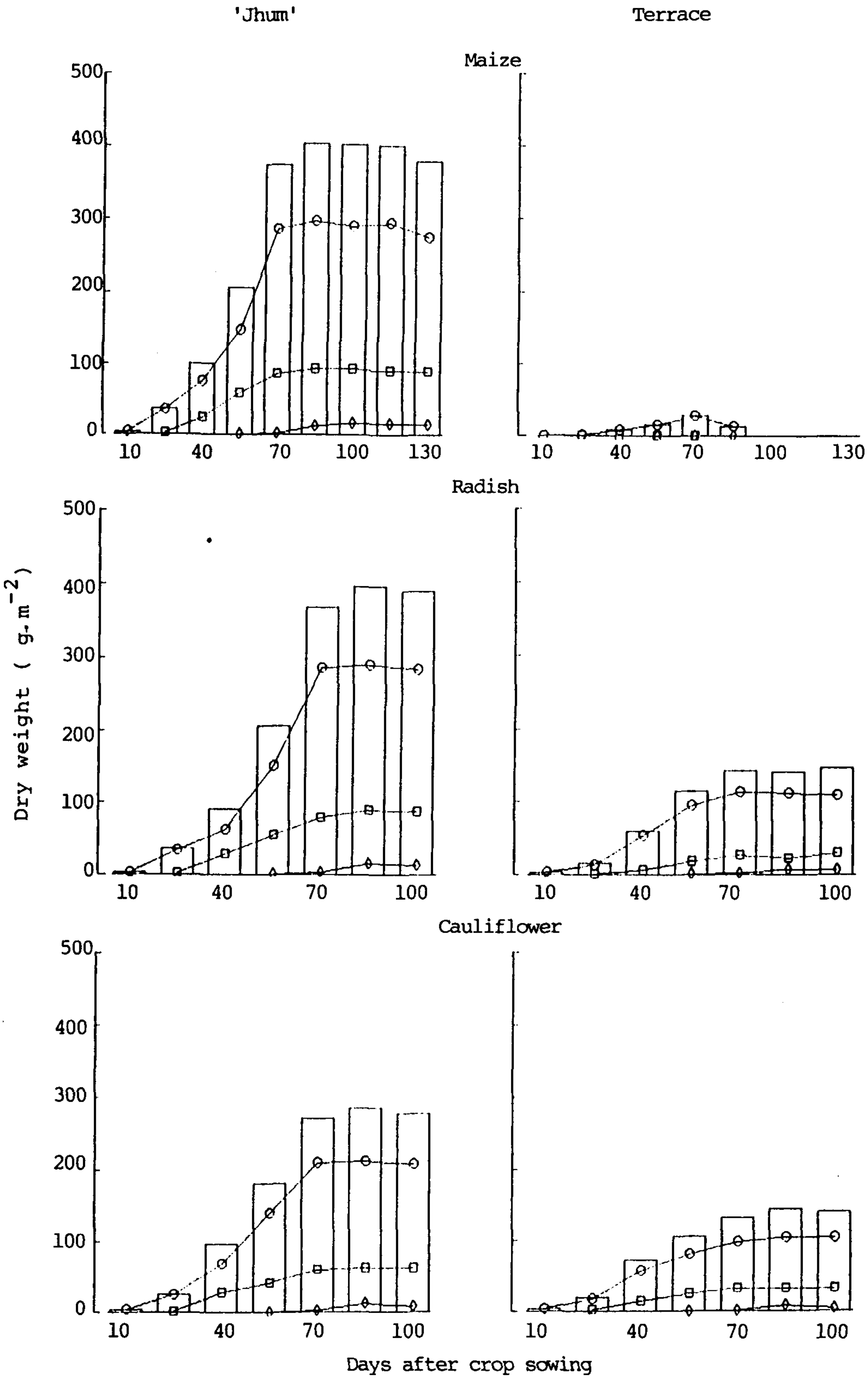

Fig. 7.12. Cohortwise (cohort I, -o-; cohort II, -▫- and cohort III, -◇-) as well as total dry matter(▯)production by S. arvensis in maize, radish and cauliflower fields under 'jhum' and terrace cultivation. The figure is based on the data of 1988-1989 and 1989-1990.

field (Figs. 7.10-7.12). In both the species, total biomass production was significantly higher ($P<0.01$) in 'jhum' than terrace fields but variation among different crops was insignificant. In general, dry matter of *S. arvensis* was higher than *P. alatum* in almost all the crops.

The study of allocation of dry matter among the three cohorts of a species reveals that *ca* 74% biomass was produced by the first cohort, the contribution of second and third cohorts was only 22% and 4%, respectively. In maize of terrace field, however, the first cohort contributed 97% in *P. alatum* and 90% in *S. arvensis*. This pattern of biomass partitioning among the cohorts was similar in both the species.

In order to assess the relative importance of PAR and soil moisture on dry matter production, partial correlation coefficients were computed. Results show that PAR more strongly influenced the growth of *P. alatum* and *S. arvensis* in all the crops in both 'jhum' and terrace fields, the only exception being *S. arvensis* in the maize field (Table 7.4). Regression models showing relationship between dry matter production (Y) and PAR (X_1) and soil moisture (X_2) are given in Table 7.5.

DISCUSSION

The seedlings of *P. alatum* and *S. arvensis* emerged in three successive cohorts. Variation in the time of seedling emergence

Table 7.4 Partial correlation coefficients between micro-environmental variables (photosynthetically active radiation (PAR) and soil moisture (SM)) and dry matter production (g.m^{-2}) of *P. alatum* and *S. arvensis*.

Crop	Micro-environmental variables	*P. alatum*				*S. arvensis*			
		'Jhum'	n	Terrace	n	'Jhum'	n	Terrace	n
Autumn Potato	PAR	0.967**	21	0.973**	21	0.956**	21	0.969**	21
	SM	0.180	21	0.379	21	0.454	21	0.459	21
Summer Potato	PAR	0.849**	21	0.829**	21	0.894**	21	0.815**	21
	SM	0.795**	21	0.790**	21	0.693**	21	0.782**	21
Cauliflower	PAR	0.790**	21	0.971**	21	0.971**	21	0.960**	21
	SM	0.477**	21	0.261	21	0.362	21	0.323	21
Maize	PAR	0.817**	27	0.795**	15	0.893**	27	0.227	18
	SM	0.535**	27	0.609**	15	0.556**	27	0.620**	18
Radish	PAR	0.976**	21	0.977**	21	0.953**	21	0.979*	21
	SM	0.018	21	0.069	21	0.500*	21	0.083	21

* = Significant at $P<0.05$, ** = Significant at $P<0.01$

Table 7.5 Regression models for growth (Y = dry matter $g.m^{-2}$) VS.PAR (X_1 = u mol $m^{-2}S^{-1}$) and soil moisture (X_2 = %) of *P. alatum* and *S. arvensis* in different crops under 'jhum' (J) and terrace (T) cultivation at Upper Shillong.

Crop	Cultivation	*P. alatum*	r2	n	*S. arvensis*	r2	n
Autumn Potato	J	$Y = -116.937+0.175X_1^{*}-0.793X_2$	0.95	21	$Y = -198.480+0.343X_1^{*}-5.058X_2^{*}$	0.94	21
	T	$Y = -77.944+0.128X_1^{*}-1.185X_2$	0.96	21	$Y = -78.031+0.139X_1^{*}-1.765X_2^{*}$	0.96	21
Summer Potato	J	$Y = 59.652-0.111X_1^{*}+10.543X_2^{*}$	0.94	21	$Y = 349.875-0.334X_1^{*}-18.782X_2^{*}$	0.94	21
	T	$Y = 37.624-0.081X_1^{*}+7.455X_2^{*}$	0.93	21	$Y = 32.405-0.076X_1^{*}+7.173X_2^{*}$	0.92	21
Cauliflower	J	$Y = 15.722+0.132X_1^{*}-5.259X_2^{*}$	0.76	21	$Y = -174.179+0.262X_1^{*}-2.366X_2$	0.96	21
	T	$Y = -85.581+0.135X_1^{*}-0.856X_2$	0.96	21	$Y = -70.018+0.126X_1-1.208X_2^{*}$	0.94	21
Maize	J	$Y = 165.739-0.120X_1^{*}+5.352X_2^{*}$	0.87	27	$Y = 518.305-0.361X_1^{*}+12.150X_2^{*}$	0.92	27
	T	$Y = 28.090-0.023X_1^{*}+0.925X_2^{*}$	0.92	15	$Y = -23.397-0.007X_1+2.192X_2^{*}$	0.65	18
Radish	J	$Y = -147.422+0.187X_1^{*}+0.071X_2^{*}$	0.96	21	$Y = -188.967+0.352X_1^{*}-6.082X_2^{*}$	0.94	21
	T	$Y = -108.135+0.133X_1^{*}+0.195X_2^{*}$	0.96	21	$Y = -107.890+0.139X_1^{*}-0.234X_2^{*}$	0.97	21

* = Significant at $P<0.05$

arises because it is the culmination of a large number of intrinsic processes whose rates may differ from individual to individual as well as by a large number of external environmental factors, especially the soil conditions. The decreasing size of successive cohorts conforms with the results of Rai and Tripathi (1984) on *Galinsoga ciliata* and *G. parviflora* and Pandey and Dubey (1989) on *Parthenium hysterophorus*. They attributed such a decline in density of successive cohorts to the depletion of germinable fraction of seeds in soil. Variation in seedling emergence could also be attributed to the microenvironmental conditions prevailing in the community. This is clearly evident from the partial correlation coefficient values between PAR, relative humidity, soil moisture, soil temperature and seedling emergence given in Table 7.1. All these factors significantly influenced seedling recruitment in the population, however, their relative importance varied from crop to crop and from one season to another in the same crop field. The importance of these factors on seed germination and emergence of seedlings of other species has been discussed by several workers (Singh 1973, Toole 1973, Baskin and Baskin 1977, Bobstock 1978, Fenner 1980, Manthey and Nalewaja 1987, Rai 1987, Baskin and Baskin 1988, Eddleman and Romo 1988, Egley 1990). It is difficult to give the precise reasons for the differential influence of different microenvironmental factors on seedling emergence with the available data because a large number of other factors such as nature of species, composition of soil seed bank, depth of seed burial and edaphic conditions also play important role in the seedling emergence under field conditions.

By exhibiting high mortality rate at juvenile stage, most of the species behaved like pioneer and colonizing species which show low juvenile survival (Harper 1965) and short life cycle (Bazzaz 1986). High and constant risk of mortality in the third cohort may be due to keen competition for resources with already established plants of older cohorts as well as the crop plants. Results of a large number of studies carried out on different species provide conclusive evidence in favour of competitive advantage of early emerging seedling cohorts over the late emerging cohorts (Sarukhan and Harper 1973, Cook 1979, Weiss 1981, Rai and Tripathi 1984, Kelly 1989a, Pandey and Dubey 1989, Misra *et al.* 1992). This might be the reason for longer half-life of the early recruited cohort than those which were recruited late in the community. This finding does not agree with the results of other workers (Gross 1980, Klemow and Raynal 1981, Marks and Prince 1981, Mack and Pyke 1983), who have reported lower survival rates for early cohorts. In this respect difference between 'jhum' and terrace did not exhibit any definite trend.

Lower dry matter production by the late emerging cohorts clearly reveals that along with survival their growth was also adversely affected. Rai and Tripathi (1985) in two species of *Galinsoga* and Pandey and Dubey (1989) in *Parthenium hysterophorus* have reported that the species responded to the competition from older cohorts through reduced vegetative and reproductive growth. Spread in the time of seedling emergence is a main cause of variation in mature plant weight, probably because differences in emergence timing affect seedling size at that point of time when plants start to compete with one another for growth resources (Benjamin 1990). Among the environmental factors, PAR significantly influenced the dry matter yield of both *P. alatum* and *S. arvensis*. However, in case of the latter species soil moisture also significantly affected dry matter production in 'jhum' fields. The total biomass production ($g.m^{-2}$) of the two weeds in 'jhum' field was much higher than the terrace field (Figs.7.9-&.12). This was obviously related to the higher density in the former field. However, dry weight of individual plants, was higher in terrace field than in 'jhum' field mainly because of lower density and application of fertilizers in the former. Considering the density and biomass production of *S. arvensis* and *P. alatum* it may be concluded that the former was more successful than the latter in almost all the fields.

Chapter 8

POPULATION DYNAMICS AND GROWTH BEHAVIOUR OF TWO DOMINANT WEEDS IN DIFFERENT CROP FIELDS UNDER TERRACE CULTIVATION AT BARAPANI

The community structure is an important determinant as well as the consequence of various demographic events that govern population size. Phytosociological analysis of weed community in the crop fields at Upper Shillong and Barapani revealed that the floristic composition and dominance distribution pattern among the species markedly varied at the two sites. These differences in the structure of weed community at the two altitudes could be due to variations in climatic and edaphic conditions. Since the probability of recruitment and mortality of individuals in the population is influenced by a large number of potential physical variables, most of which are affected by the structure of community itself (Powell 1990), it is logical to conclude that population behaviour and growth performance of weed species in the crop fields at the low altitude would be different from those found at the high altitude. Therefore, the objectives of this chapter are to discuss the demographic and growth behaviour of the dominant weed species in different crop fields at the low altitude study site.

The two dominant species selected for study were *Emilia sonchifolia* and *Richardsonia pilosa* (Plate 8.1). *E. sonchifolia*

Plate 8.1. Dominant weeds (a) *Emilia sonchifolia* and (b) *Richardsonia pilosa* (b) at low altitude site.

(Asteraceae) is an erect annual herb with slender stem, attaining a height of 10-35 cm. Its lower leaves are lyrate-pinnatifid or sinuate, toothed, narrowed at the base, while the upper ones are alternate with acute apex. *R. pilosa* (Rubiaceae) is an erect annual weed with slender stem of 10-30 cm height. Its sub-sessile, oval leaves with entire margin show opposite phyllotaxy. These species although grow abundantly in agricultural fields, often found in ruderal habitats. They show best growth during rainy season, emerging simultaneously with the crop plants and attaining maturity at the time of crop harvest. They also infest winter crops but their growth and abundance is relatively less in these crops. Population dynamics and growth behaviour of these species were studied for two years in two common summer and winter crops viz. maize and radish and the results are discussed in relation to the microenvironmental conditions measured during the cropping period in the two fields.

RESULTS

SEEDLING EMERGENCE

The seedlings of *E. sonchifolia* emerged in three successive cohorts in the maize field, while in the radish field only two cohorts could be identified. In maize field, about 60% of the total recruited seedlings emerged in the first cohort. In radish field, the seedling recruitment in the first cohort during the first and second year were *ca* 70% and 90% respectively (Fig.

8.1). The seedling recruitment pattern was similar during both the years of study. The statistical analysis of seedling emergence data showed significant difference (P<0.01) between the cohorts and the crops.

In maize field, seedling emergence pattern of *R. pilosa* was similar to *E. sonchifolia*. More than 50% of the total seedlings were recruited in the first cohort followed by a significant decrease in emergence (P<0.01) in successive cohorts. In radish field, more than 80% of the seedlings were recruited in the first cohort during the first year. In the second year, all the seedlings emerged in a single cohort. The difference in seedling emergence between crop fields was highly significant (P<0.01).

The effect of PAR, relative humidity, soil moisture and soil temperature on seedlings emergence was analysed using partial correlation analysis. Soil moisture and soil temperature were found to be important in the maize field, while PAR and soil temperature were of great importance in the radish field (Table 8.1).

SURVIVAL AND HALF-LIFE OF SEEDLING COHORTS

The total number of seedlings of *E. sonchifolia* and *R. pilosa* recruited in the maize field was significantly higher (P< 0.01) than the radish field. The yearly variation in total recruitment was insignificant (Table 8.2). The mortality pattern

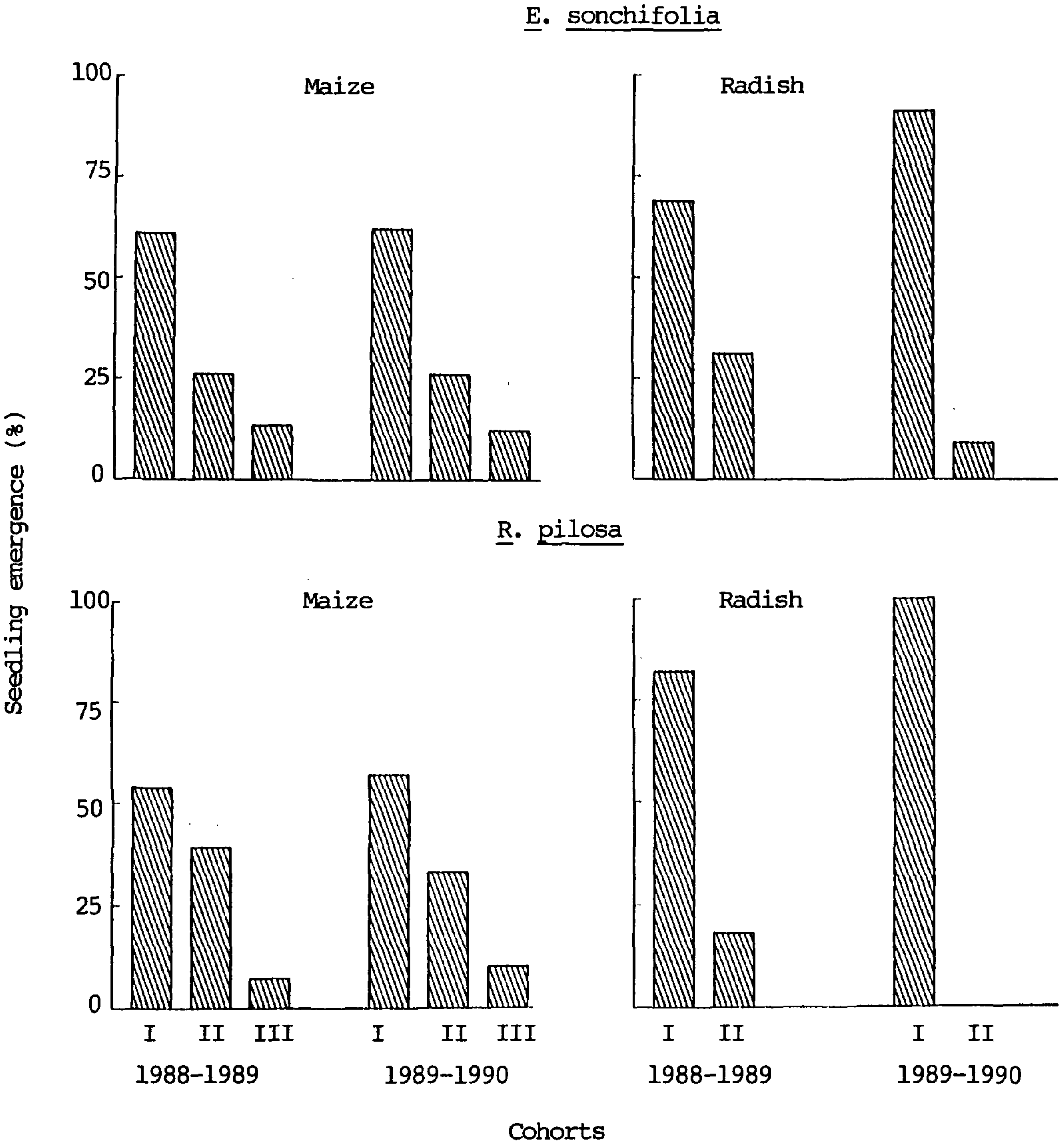

Fig. 8.1. Percentage emergence of E. sonchifolia and R. pilosa seedlings in three successive cohorts in maize and radish fields under terrace cultivation at Barapani.

Table 8.1 Partial Correlation coefficients between four microenvironmental variables (photosynthetically active radiation (PAR), relative humidity (RH), and moisture (SM), soil temperature (ST) and seedling emergence (%) of *E. sonchifolia* and *R. pilosa*.

Crop	Micro-Environmental variable	*E. sonchifolia*	n	*R. pilosa*	n
Maize	PAR	0.612*	18	0.310	18
	RH	0.577**	18	0.085	18
	SM	0.938**	18	0.927**	18
	ST	0.776**	18	0.345	18
Radish	PAR	0.759*	12	0.981**	9
	RH	0.312	12	0.282	9
	SM	0.323	12	0.709	9
	ST	0.978**	12	0.856*	9

* = Significant at $P<0.05$, ** = Significant at $P<0.01$

Table 8.2 Total recruitment of *E. sonchifolia* and *R. pilosa* seedlings m^{-2} in maize and radish fields.

Crop	*E. sonchifolia*		*R. pilosa*	
	1988-1989	1989-1990	1988-1989	1989-1990
Maize	111 (13)	120 (19)	69 (12)	94 (11)
Radish	70 (8)	57 (9)	17 (3)	7 (3)

Values in parentheses are ± S.E.

of the cohorts of seedlings for both *E. sonchifolia* and *R. pilosa* was essentially similar (Figs. 8.2-8.3). The first cohort in the radish field and the first and second cohorts in the maize field depicted Deevey's type III survivorship curve where mortality was higher in the beginning and at the end of the life cycle. Similarly the behaviour of the second cohort in the radish field and the third cohort in the maize field was almost alike. The shape of the curves in these cases was like Deevey's type II survivorship curve, which indicates continuous mortality risk throughout the life-span. In case of *E. sonchifolia* major difference between radish and maize fields was lower seedling recruitment and absence of the third cohort in the former field. In case of *R. pilosa*, although recruitment was higher in the maize field, the slope of the survivorship curves of the first cohort was more steep in the radish field than the maize field.

Similar to other weed species, as discussed in chapter 7, the half-lives of *E. sonchifolia* and *R. pilosa* seedlings decreased in the successive cohorts in both the crop fields (Table 8.3). The half-lives of the cohorts of both the species were generally higher in the maize than the radish field. In maize field, half-lives of the first and second cohorts of *R. pilosa* was higher than the corresponding cohorts of *E. sonchifolia*, but this trend was reversed in the radish field. Difference in half-life between the cohorts was significant ($P<0.01$), while yearwise variation was insignificant.

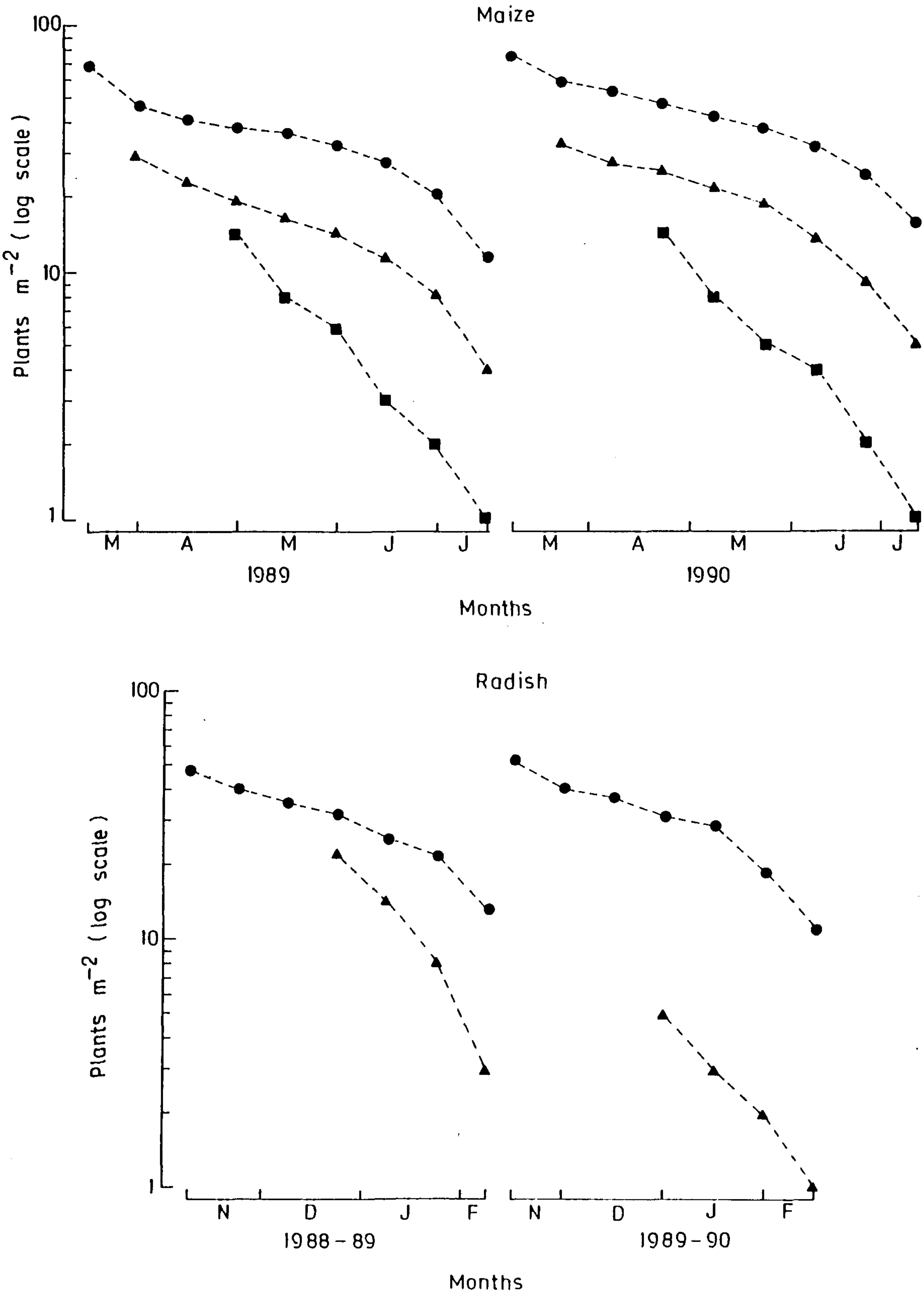

Fig. 8.2. Survivorship curves for seedling cohorts (cohort I, ●; cohort II, ▲ and cohort III,■)of E. sonchifolia in maize and radish fields at Barapani.

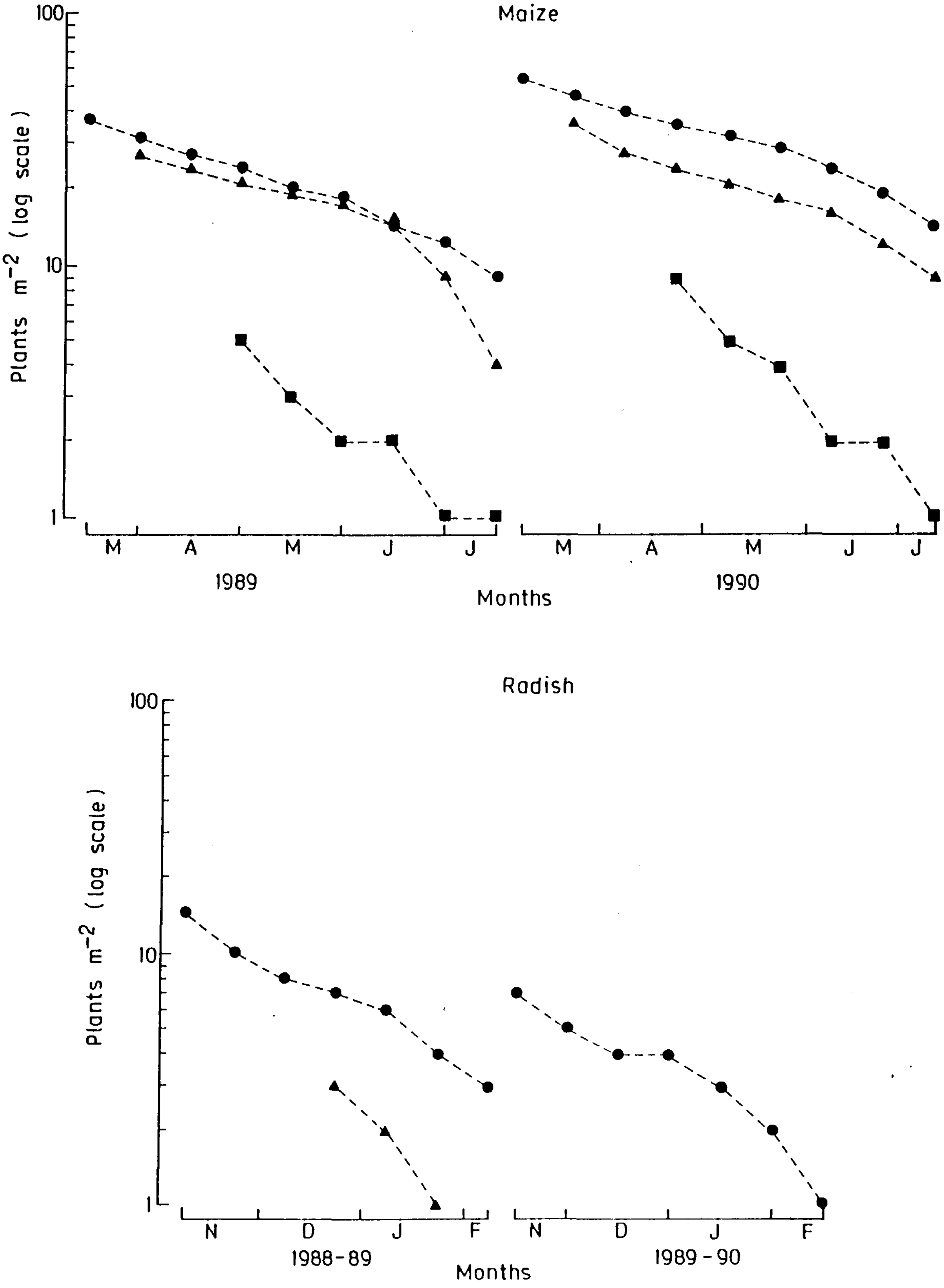

Fig. 8.3. Survivorship curves for seedling cohorts (cohort I, ●; cohort II, ▲ and cohort III, ■) of R. pilosa in maize and radish fields at Barapani.

Table 8.3 Half-life (weeks) of seedlings cohorts of *E. sonchifolia* and *R. pilosa* m^{-2} in maize and radish fields.

Crop	Cohort	*E. sonchifolia*		*R. pilosa*	
		1988-1989	1989-1990	1988-1989	1989-1990
Maize	I	9.0	10.0	12.0	11.0
	II	7.0	8.5	10.0	10.0
	III	3.0	2.5	3.0	3.0
Radish	I	9.0	8.5	6.0	7.0
	II	3.0	3.0	3.0	-
	III	-	-	-	-

DRY MATTER PRODUCTION

In radish field, dry matter production of *R. pilosa* was very low as compared to *E. sonchifolia*. Temporal variation in dry matter production was similar both for total and for the cohorts (Fig. 8.4). The unimodal curve showed a peak at 85 days after crop sowing in maize and at 70 days in radish for both first and second cohorts. In cohort III, the peak was observed after 100 days of crop sowing. After attaining the peak, biomass declined till the time of crop harvest.

In order to assess the relative importance of PAR and soil moisture on dry matter production, partial correlation coefficients were computed. Results showed that, in maize field, PAR and soil moisture were most influential factors while in the radish field only soil moisture was important in this respect (Table 8.4). The regression models showing relationship between dry matter production (Y), and PAR (X_1) and soil moisture (X_2) are given in Table 8.5.

DISCUSSION

The decrease in size of successive cohorts of *E. sonchifolia* and *R. pilosa*, the two dominant weed species in the low altitude crop fields was essentially similar to the dominant weeds of high altitude crop fields. In other words, the cultivation methods viz., 'jhum' and terrace and the difference in the

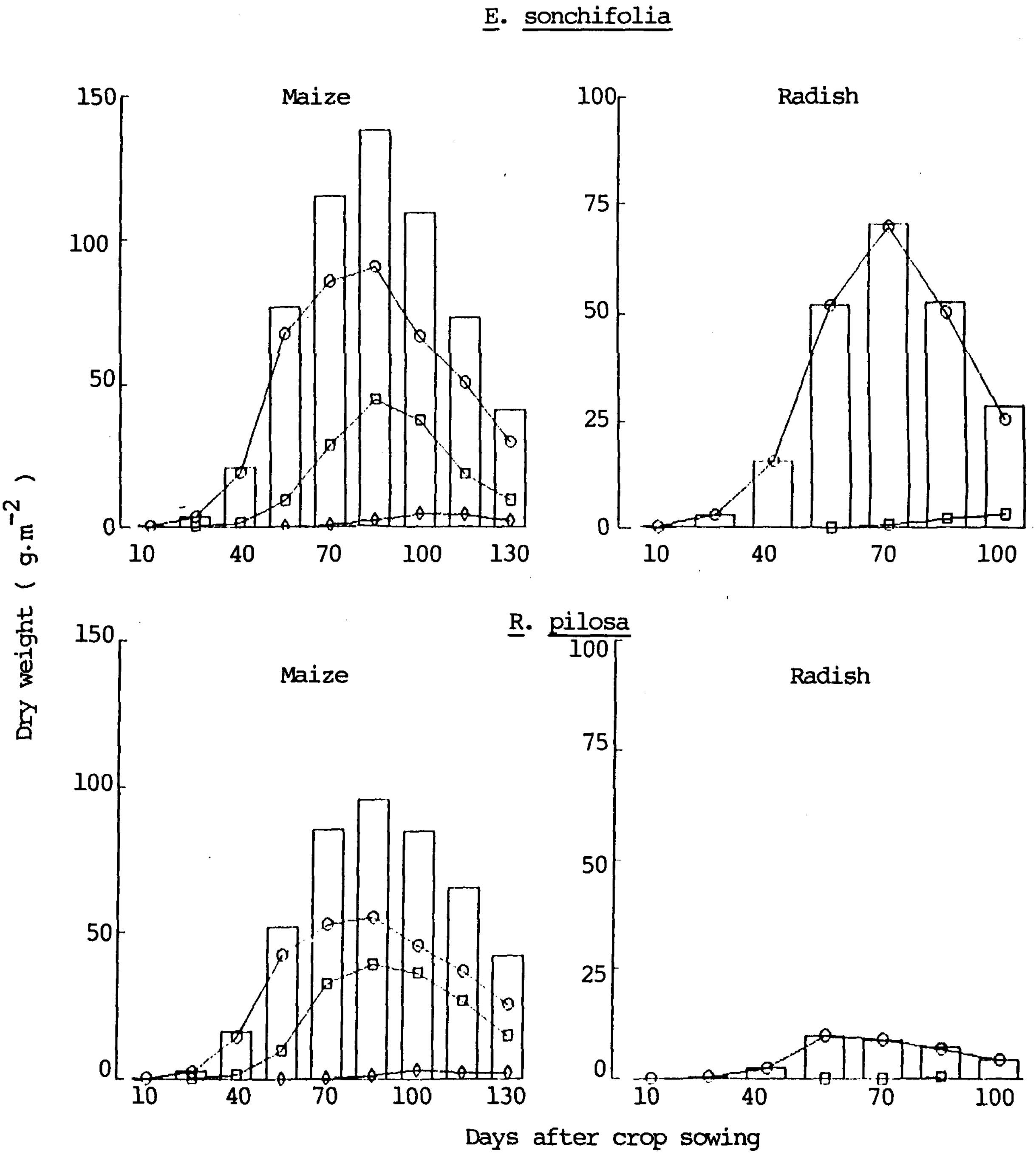

Fig. 8.4. Cohortwise (cohort I, -o- ; cohort II, -□- and cohort III, -◇-) as well as total (□) dry matter production by E. sonchifolia and R. pilosa in maize and radish fields at Barapani. The figure is based on the data of 1988-1989 and 1989-1990.

Table 8.4 Partial correlation coefficients between microenvironmental variables (photosynthetically active radiation (PAR) and soil moisture (SM) and dry matter production $g.m^{-2}$) of *E. sonchifolia* and *R. pilosa*.

Crop	Micro-Environ-mental variable	*E. sonchifolia*	*R. pilosa*	n
Maize	PAR	0.723**	0.690**	27
	SM	0.867**	0.888**	27
Radish	PAR	0.114	0.981	
	SM	0.685	0.649**	21

** = Significant at P<0.01

Table 8.5 Regression models for growth (Y = dry matter $g.m^{-2}$) vs. PAR (X_1 = u mol $m^{-2}s^{-1}$) and soi moisture (X_2 = %) relation with of *E. sonchifolia* and *R. pilosa*) in maize and radish fields.

Crop	*E. sonchifolia*		*R. pilosa*		n
		R2		R2	
Maize	$Y = -440.163+0.112X_1+16.158X_2^*$	0.76	$Y = -228.438+0.065X_1^*+11.517X_2^*$	0.81	27
Radish	$Y = 124.641+0.024X_1^*-9.768X_2^*$	0.54	$Y = 24.213+0.00004X_1-1.404X_2^*$	0.47	21

* = Significant at $P < 0.05$

microenvironmental conditions between the altitudes seems to have little effect on the proportion of seedling emergence in different cohorts in the crop fields. At Barapani, differences in seedling emergence between the crop fields was mainly due to variation in the cropping season. In maize, which is grown during monsoon period, frequent rains immediately after crop sowing were responsible for the recruitment of a large number of seedlings in three successive cohorts. Whereas, in radish which is a winter crop, higher soil moisture content and favourable temperature in the beginning of cropping period i.e., between last week of October and first week of November, favoured the emergence of a large proportion of seedlings in the form of the first cohort. As soil moisture level and soil and air temperature declined with time, conditions became unfavourable for seed germination and emergence of seedling cohorts in the field. Moisture stress suppresses the seedling emergence from soil (Sharitz and McCormick 1973, Mack 1976, Cook 1980 and Tayalla *et al.* 1988). Baskin and Baskin (1978) reported that the timing of seedling emergence in the field is often closely related to the temperature requirement of the seeds.

The decreasing size of successive cohorts could be attributed to the depletion of germinable fraction of seeds in the soil seed bank as reported by Rai and Tripathi (1984), Pandey and Dubey (1989). Competition with the already established associated vegetation may be another cause of the reduced size of the late emerging seedling cohorts. Tamm (1956), Antonovics and

Levin (1980), Singh (1980) and Rai and Tripathi (1984) also observed poor recruitment and establishment of seedlings in established community and attributed it to the resource competition within the community. Therefore, the variation in seedling population density in maize and radish fields could be the effect of several factors such as physiological state of seed and their population density in soil seed bank, cropping season, soil conditions, competition etc.

The first and second cohorts by showing high mortality at their early ages behaved like pioneer and colonizing species, which are characterised by low juvenile survival (Harper 1965, Sharitz and McCormick 1973) and short life cycle (Bazzaz 1986). Generally long-lived species show Deevey's type III survivorship curve (Fenner 1987). *E. sonchifolia* and *R. pilosa* being annuals were somewhat unusual in having this type of curve. Albeit earlier workers (Antonovics 1972, Harper 1977, Johnson and Thomas 1978, Rai and Tripathi 1984) have demonstrated that survival of herbaceous plants is generally a linear function of time. The present study illustrates the occurrence of both linear (type II) as well as concave (type III) survivorship curves, therefore conforming the view of Mack and Pyke (1983) who reported that different cohorts of the same species may show markedly different survivorship curves in different places or at different times.

The variation in the shape of survivorship curves of early and late emerging cohorts indicates that the probability of seedling survival within the cohort is influenced by the age of the cohort (Pyke and Thompson 1986). An analysis of the survivorship curves of the cohorts over a particular period of time revealed a marked variation in mortality rate between the cohorts. Such a differential response of cohorts could also be due to differences in microenvironmental conditions in different crop fields.

Almost identical growth pattern in terms of dry matter production, indicates similarity in functional niches of both the weed species in the crop fields. However, lower biomass production by *R. pilosa* in radish field seems to be the effect of resource competition with different weed species as well as with associated crop plants. The difference in the time of peak biomass production between the cohorts could be due to competitive advantage of early emerging cohorts over the late emerging ones (Sarukhan and Harper 1973, Cook 1979, Weiss 1981, Cousens *et al.* 1991).

A comparison of population behaviour of these species with the dominant weeds at high altitude revealed similarity in survivorship curves of all the cohorts except that at Upper Shillong, where the mortality rate of early emerging cohorts was low towards the end of the life-cycle as compared to Barapani. The major difference between the two sites was wide variation in population density of the dominant species, the value being much higher at Upper Shillong. A slight variation in seedling emergence pattern was also noticed. Unlike Upper Shillong, where seedlings of all the weeds studied emerged in three successive cohorts, at Barapani only one or two seedling cohorts were observed in the radish field.

Chapter 9

POPULATION DYNAMICS AND GROWTH BEHAVIOUR OF GALINSOGA CILIATA - A DOMINANT WEED AT HIGH AND LOW ALTITUDE CROP FIELDS

Galinsoga ciliata (Rafin.) Blake (Plate 9.1) is a common ruderal and agrestal weed of Meghalaya. It is an erect annual herb and attains a moderate height, which ranges from 15 to 170 cm. The stem is profusely branched at the upper portion and the leaves are ovate or elliptic oblong with cuncate base, acute or rather accuminate and thickly hairy.

The plants of the genus *Galinsoga* prefer moist habitats and therefore, are abundantly found in the irrigated crop fields in the humid tropics. Lack of dormancy in the seeds (Ivany and Sweet 1973) ensures its immediate emergence whenever temperature and moisture conditions become favourable (Usami 1976) and within a short life-cycle several cohorts of seedlings keep on appearing in nature at different time intervals.

Shontz and Shontz (1970, 1972) studied the introduction and spread of *G. ciliata* in north-eastern United States and recognized two ecological races in the population growing in

Plate 9.1. *Galinsoga ciliata* - a dominant weed of high and low altitude sites.

western Massachusetts. Control measures of *G. ciliata* were studied by Ivany and Sweet (1973), who concluded that control of this species by herbicide application is difficult. But findings of Stilwell and Sweet (1975) indicate that post-emergence treatment with ammonium nitrate may check the growth of this weed.

In India, Rai and Tripathi (1984) studied the population regulation of *G. ciliata* and *G. parviflora* and reported that the density of *G. ciliata* in crop fields is much higher than that in the wastelands of Meghalaya. A study on the food reserves in the seeds of these species revealed a significant difference in protein and carbohydrate contents of ray and disc achenes (Rai and Tripathi 1982). Ray achenes having high energy content exhibited better germination behaviour irrespective of sowing depth than disc achenes. The seedlings emerging from the ray achenes also showed better growth performance than those of disc achenes even under nutrient deficient conditions. In order to understand the population dynamics and growth behaviour of this species in different crop fields under 'jhum' and terrace cultivation and at different altitudes, a study was undertaken in potato, cauliflower, maize and radish fields at Upper Shillong and in maize and radish fields at Barapani. The data on recruitment, mortality and dry matter production were collected for a period of two years, which have been discussed in this chapter.

RESULTS

SEEDLING EMERGENCE

Galinsoga seedlings were recruited in three successive cohorts. At Upper Shillong, 50-75% of the seedlings were recruited in the first cohort, 20-35% in the second cohort and 7-25% in the third cohort (Fig 9.1). The difference among cohort emergence was significant ($P<0.01$) during both the years, however, variation among crops and between 'jhum' and terrace fields were insignificant.

At Barapani, the percentage emergence of seedlings in the first cohort was significantly higher than Upper Shillong. In the maize field, seedlings emerged in three cohorts but in the radish field only two cohorts could be recognized (Fig. 9.2). In both the fields seedlings emergence in the first cohort was significantly higher than the second cohort. The difference between first and second cohort was much higher in the maize field than that noticed at Upper Shillong.

Seedling emergence in almost all fields was influence by PAR, relative humidity, soil moisture and soil temperature (Table 9.1). However, the importance of a given factor varied from crop to crop and between 'jhum' and terrace fields. In general, soil temperature and PAR more strongly influenced the seedling emergence of *G. ciliata* than other two variables.

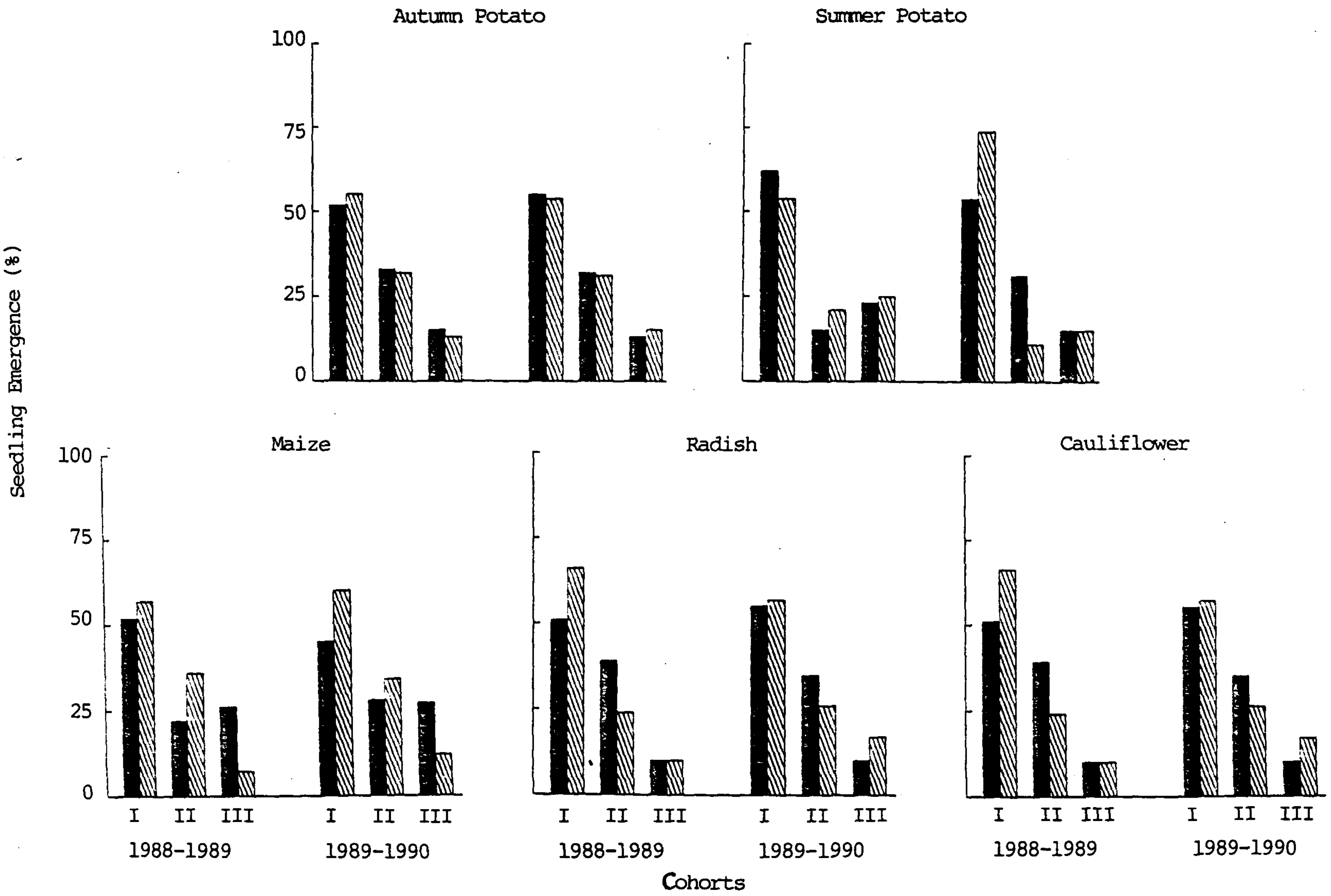

Fig. 9.1. Percentage emergence of G. ciliata seedlings in three successive cohorts in different crop fields under 'jhum' (■) and terrace (▨) cultivation at Upper Shillong.

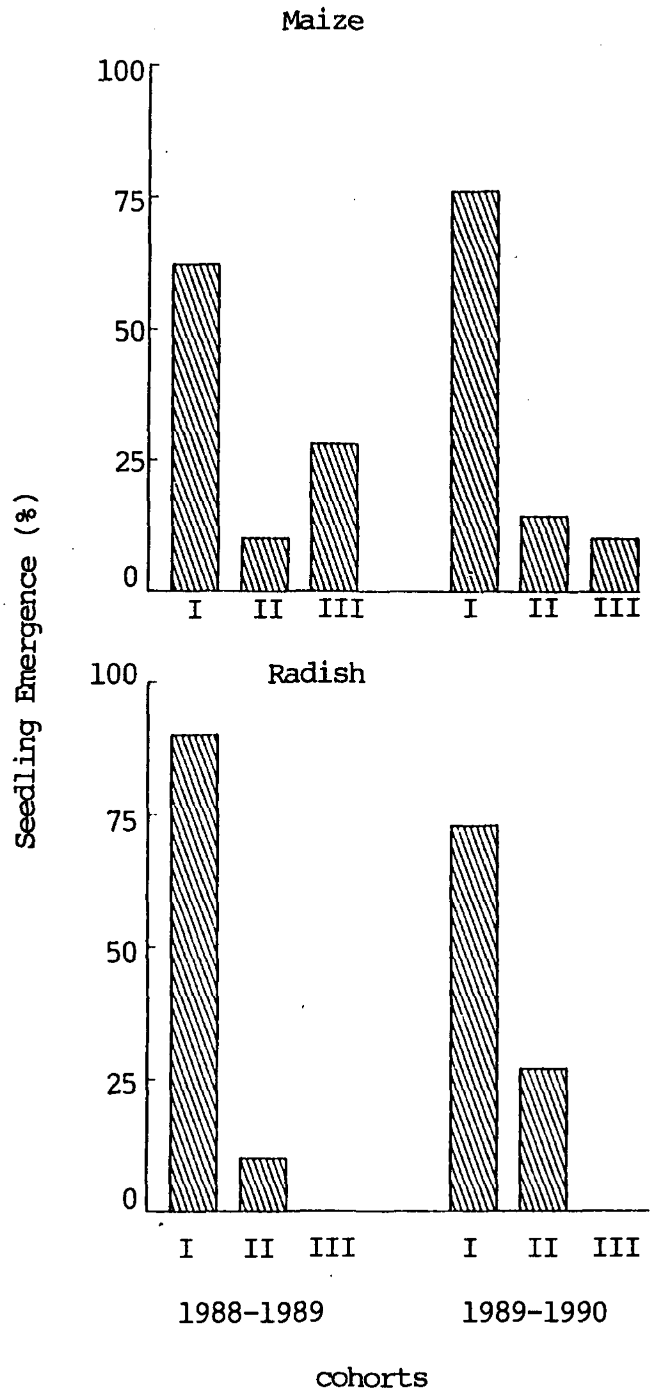

Fig. 9.2. Percentage emergence of <u>G. ciliata</u> seedlings in three successive cohorts in maize and radish fields at Barapani.

Table 9.1 Partial correlation coefficients between four micro-environmental vairable (photosynthetically active radiation (PAR), relative humidity (RH), soil moisture (SM) and soil temperature (ST)) and seedling emergence (%) of *G. ciliata*.

Crop	Micro-environmental variables	Upper Shillong			Barapani	
		'Jhum'	Terrace	n	Terrace	n
Autumn Potato	PAR	0.059	0.970**	18	Not grown	
	RH	0.713**	0.980**	18		
	SM	0.721**	0.969**	18		
	ST	0.875**	0.987**	18		
Summer Potato	PAR	0.827**	0.985**	18	Not grown	
	RH	0.889**	0.966**	18		
	SM	0.778**	0.969**	18		
	ST	0.627**	0.737**	18		
Cauliflower	PAR	0.866**	0.764**	18	Not grown	
	RH	0.895**	0.913**	18		
	SM	0.113	0.838**	18		
	ST	0.751**	0.934**	18		
Maize	PAR	0.881**	0.393	18	0.504*	18
	RH	0.831**	0.387	18	0.538*	18
	SM	0.475*	0.678*	18	0.879**	18
	ST	0.825**	0.532*	18	0.781**	18
Radish	PAR	0.751**	0.977**	18	0.980**	12
	RH	0.464*	0.989**	18	0.451	12
	SM	0.409	0.987**	18	0.599	12
	ST	0.691**	0.995**	18	0.901**	12

* = Significant at $P<0.05$, ** = Significant at $P<0.01$

SURVIVAL AND HALF-LIFE OF SEEDLING COHORTS

At Upper Shillong, recruitment of *G. ciliata* seedlings in potato, radish and cauliflower fields under terrace cultivation was much higher than their 'jhum' counterparts. This trend was reversed in maize field (Table 9.2). The survivorship curves of the first and second cohorts showed high mortality at the juvenile stage. This was true for all the crop fields except maize. The third cohort showed constant mortality throughout its life (Fig. 9.3 and 9.4). In the maize field, seedlings in all three cohorts exhibited constant mortality throughout their life (Fig 9.5). The survivorship curves for seedling cohorts in radish and maize fields at Barapani was similar to the maize field at Upper Shillong (Fig 9.6).

The half-life of *G. ciliata* declined in successive cohorts in almost all the fields (Table 9.3-9.4). In potato and cauliflower fields the cohorts had longer half-lives in terraces than in 'jhum' fields at Upper Shillong. This was not true for maize and radish fields where such a difference was indistinct. A comparison of half-life of different cohorts in the maize field at Upper Shillong and Barapani showed higher values at the latter site. Such a trend was not observed in the radish field. Tukey's multiple comparison test revealed that difference between the first and second cohort, second and third cohort and first and third cohort was significant ($P<0.01$). Difference between 'jhum' and terrace fields and among different crops was also significant ($P<0.01$).

Table 9.2 Total seedling recruitment of *G. ciliata* (plants m^{-2}) in different crop fields.

Crop	Upper Shillong				Barapani	
	'Jhum'		Terrace		Terrace	
	1988-1989	1989-1990	1988-1989	1989-1990	1988-1989	1989-1990
Autumn Potato	168 (31)	191 (29)	345 (41)	557 (43)	Not grown	
Summer Potato	209 (34)	122 (31)	138 (19)	416 (21)	Not grown	
Cauliflower	206 (26)	222 (39)	498 (21)	440 (28)	Not grown	
Maize	191 (18)	151 (6)	28 (3)	35 (7)	50 (4)	50 (5)
Radish	222 (36)	198 (27)	440 (24)	347 (33)	69 (9)	52 (6)

Values in parentheses are ± S.E.

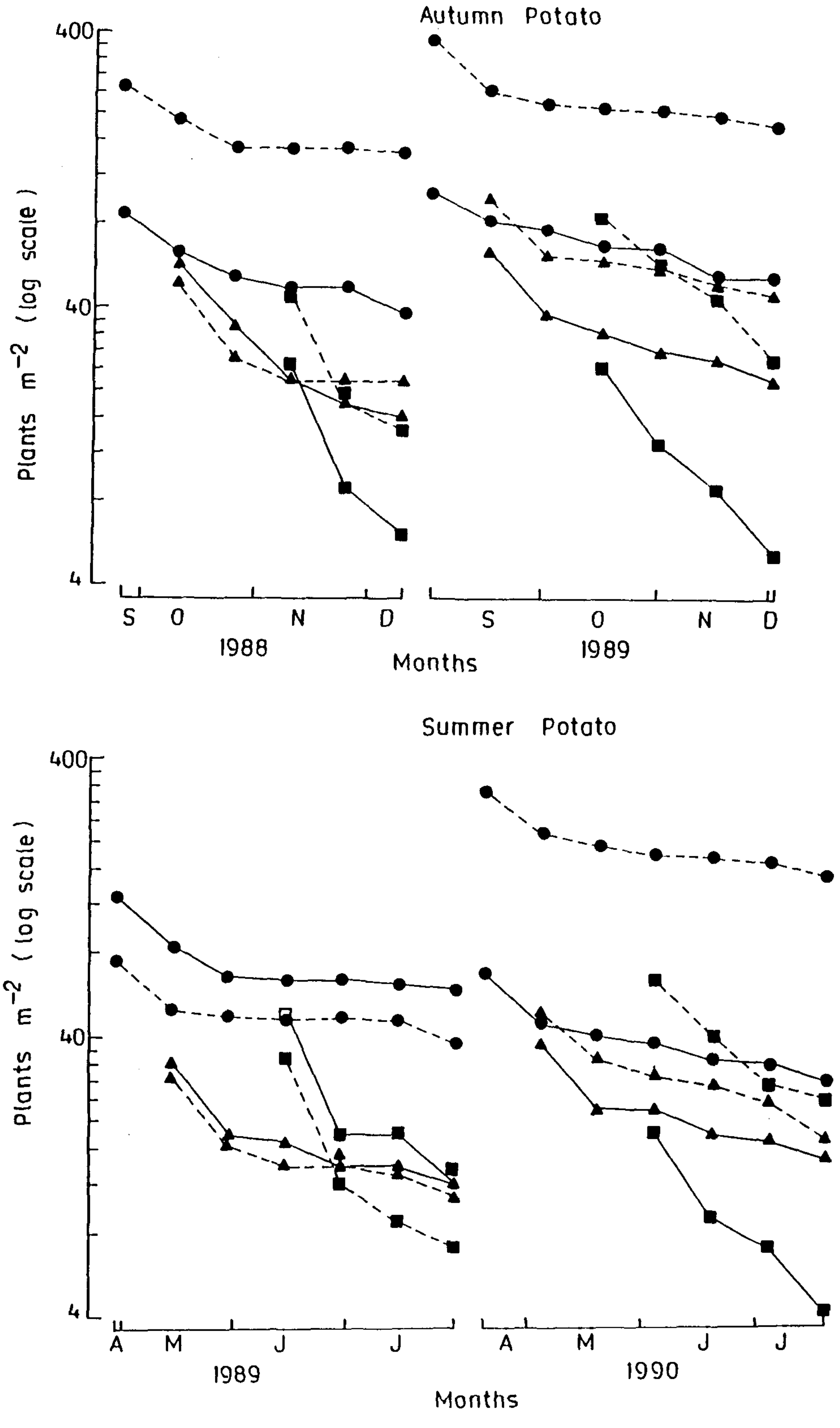

Fig. 9.3. Survivorship curves for seedling cohorts (cohort I, ●; cohort II, ▲ and cohort III, ■) of G. ciliata in potato fields under 'jhum' (——) and terrace (---) cultivation at Upper Shillong.

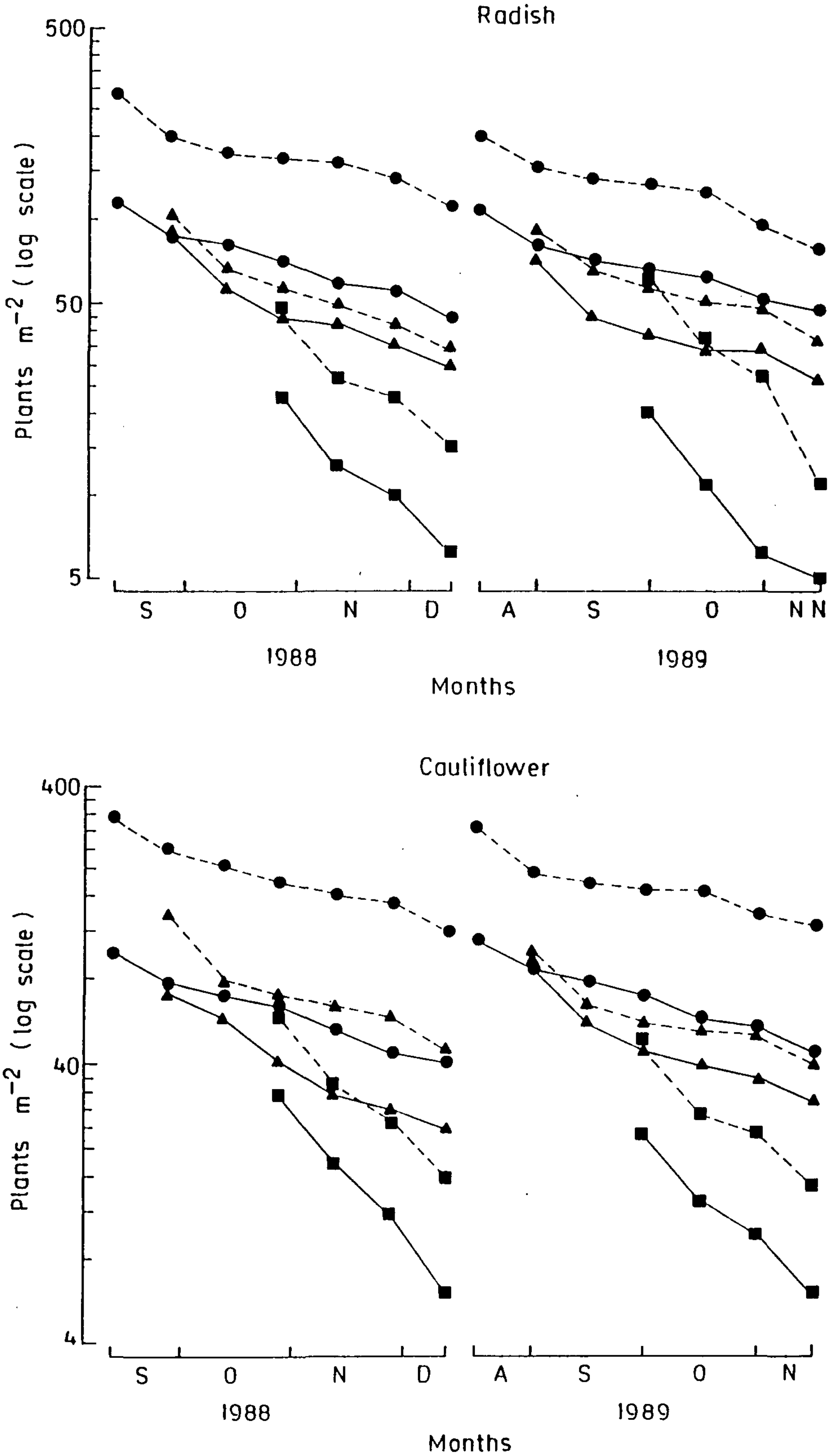

Fig. 9.4. Survivorship curves for seedling cohorts (cohort I, ●; cohort II, ▲ and cohort III, ■) of G. ciliata in radish and cauliflower fields under 'jhum' (——) and terrace (---) cultivation at Upper Shillong.

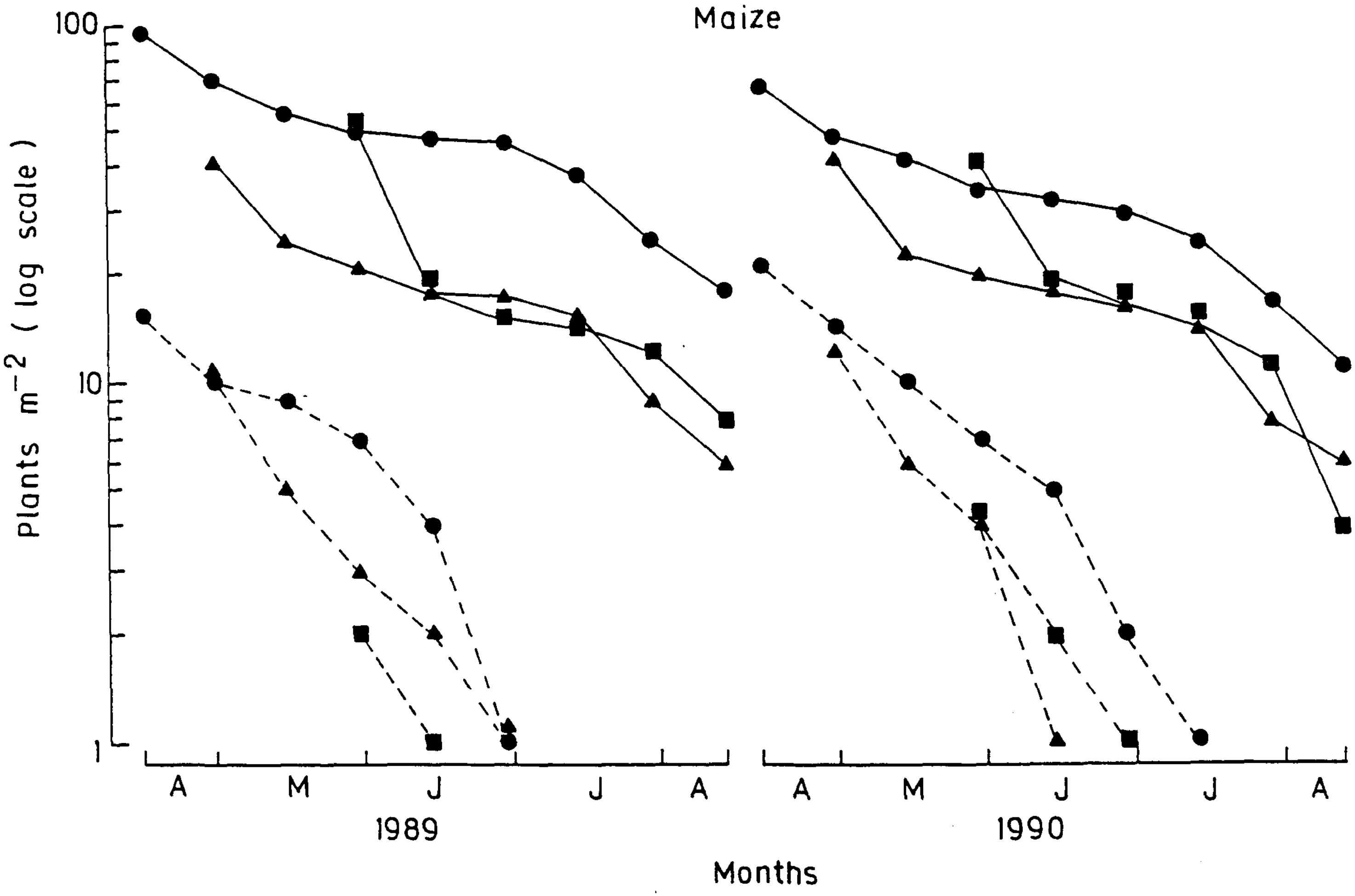

Fig. 9.5. Survivorship curves for seedling cohorts (cohort I, ●; cohort II, ▲ and cohort III, ■) of *G. ciliata* in maize fields under 'jhum' (——) and terrace (---) cultivation at Upper Shillong.

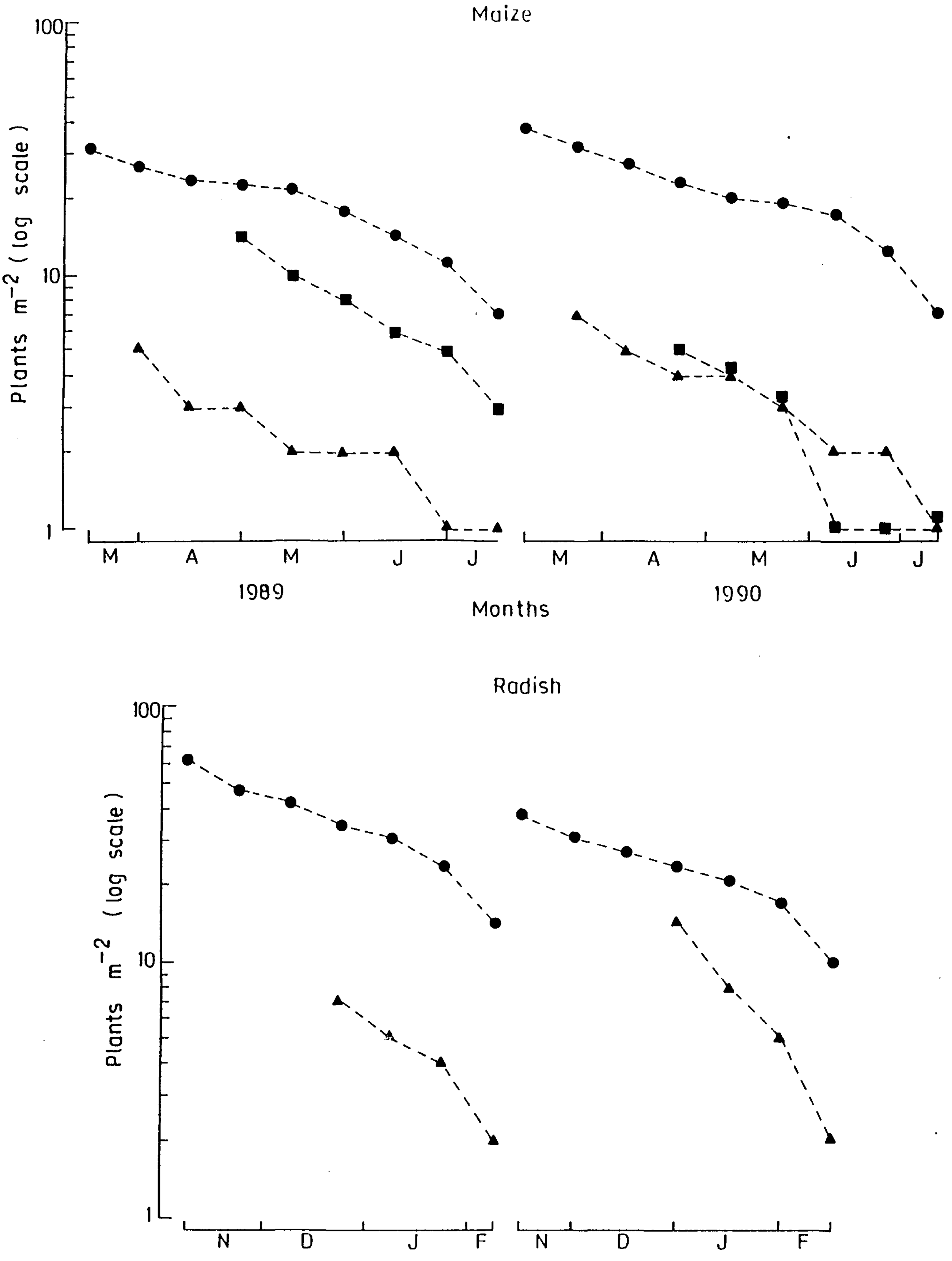

Fig. 9.6. Survivorship curves for seedling cohorts (cohort I, o; cohort II, ▲ and cohort III, ■) of G. ciliata in radish and maize fields under terrace cultivation at Barapani.

Table 9.3 Half-life (weeks) of seedling cohorts of *G. ciliata* in different crop fields under 'jhum' and terrace cultivation at Upper Shillong.

Crop	Cohort	'Jhum'		Terrace	
		1988-1989	1989-1990	1988-1989	1989-1990
Autumn Potato	I	2.5	8.5	10.0	11.0
	II	3.0	4.5	6.0	7.0
	III	1.5	2.5	1.5	4.0
Summer Potato	I	4.0	8.0	12.0	12.0
	II	4.0	5.5	8.0	8.0
	III	1.5	2.0	1.5	3.0
Cauliflower	I	8.5	8.0	10.0	9.5
	II	5.0	5.0	6.0	6.0
	III	2.5	3.0	3.5	4.0
Maize	I	8.0	7.0	5.0	3.5
	II	4.0	3.0	2.0	2.0
	III	1.5	2.0	2.0	2.0
Radish	I	9.5	9.5	9.5	3.5
	II	7.5	5.5	5.0	2.0
	III	2.5	2.5	4.0	2.0

Table 9.3 (contd.)

Analysis of variance

Source of variation	Degree of freedom		F Value	
	1988-1989	1989-1990	1988-1989	1989-1990
Crop	4	4	38.74**	34.82**
Cultivation	1	1	65.97**	44.64**
Cohort	2	2	408.15**	325.48**

** = Significant at P<0.01

Table 9.4 Half-life (weeks) of seedling cohorts of *G. ciliata* in maize and radish crop fields under terrace cultivation at Barapani.

Crop	Cohort	1988-1989	1989-1990
Maize	I	11.0	9.5
	II	5.0	7.0
	III	5.0	4.5
Radish	I	8.0	9.0
	II	4.5	2.5
	III	-	-

DRY MATTER PRODUCTION

Cohortwise as well as total dry matter production by *G. ciliata* in different crop fields at Upper Shillong have been depicted in (Fig 9.7 and 9.8). In general, dry matter production in terrace was significantly higher ($P<0.01$) than in 'jhum' fields in almost all the crops, the only exception being maize where the values were higher in 'jhum' than terrace fields. The first cohort attained peak between 70-85 days after the crop sowing, while the second and third cohorts peaked at the time of crop maturity. In the potato field, dry matter production by *G. ciliata* was more during autumn than during summer. In both the seasons, after attaining peak, biomass remained more or less unchanged (Fig. 9.7). This trend was unlike other crop fields where it declined sharply after attaining the peak. This was most prominent in the maize field (Fig. 9.8). The growth of *G. ciliata* in radish fields under terrace cultivation at Barapani was very poor as compared to Upper Shillong, however, in the maize field the difference was insignificant (Fig. 9.9).

Partial correlation coefficients showed that at Upper Shillong PAR more strongly influenced dry matter production than soil moisture, while the effect of soil moisture was more important at Barapani (Table 9.5). Multiple regression equations showing relationship between dry matter production (Y) and PAR (X_1) and soil moisture (X_2) are given in Table 9.6.

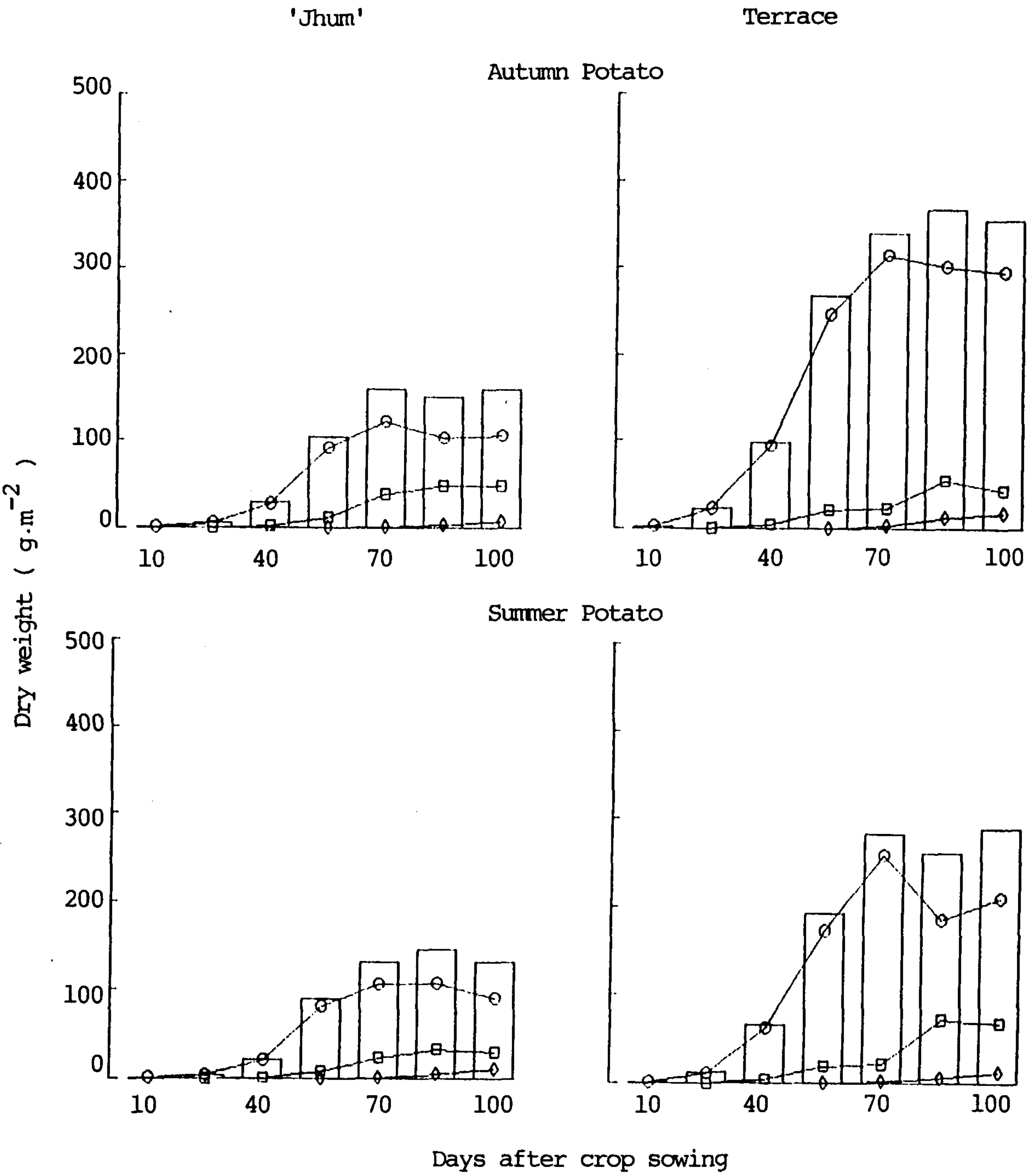

Fig. 9.7. Cohortwise (cohort I, -o-; cohort II, -□- and cohort III, -◊-) as well as total (□) dry matter production by G. ciliata in potato fields under 'jhum' and terrace cultivation at Upper Shillong. The figure is based on the data of 1988-1989 and 1989-1990.

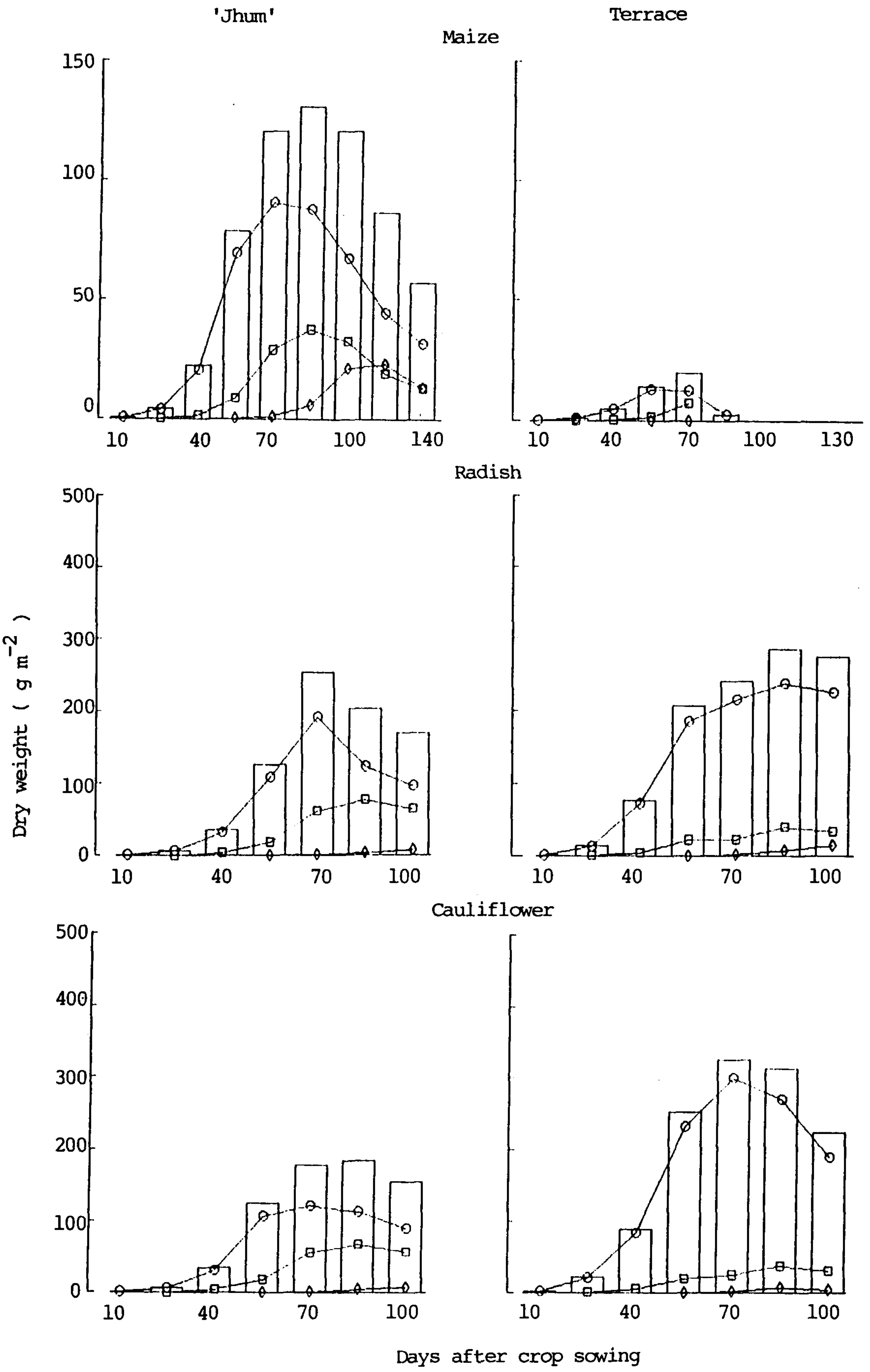

Fig. 9.8. Cohortwise (cohort I, -o-; cohort II, -□- and cohort III, -◊-) as well as total (□) dry matter production by G. ciliata in maize, radish and cauliflower fields under 'jhum' and terrace cultivation at Upper Shillong. The figure is based on the data of 1988-1989 and 1989-1990.

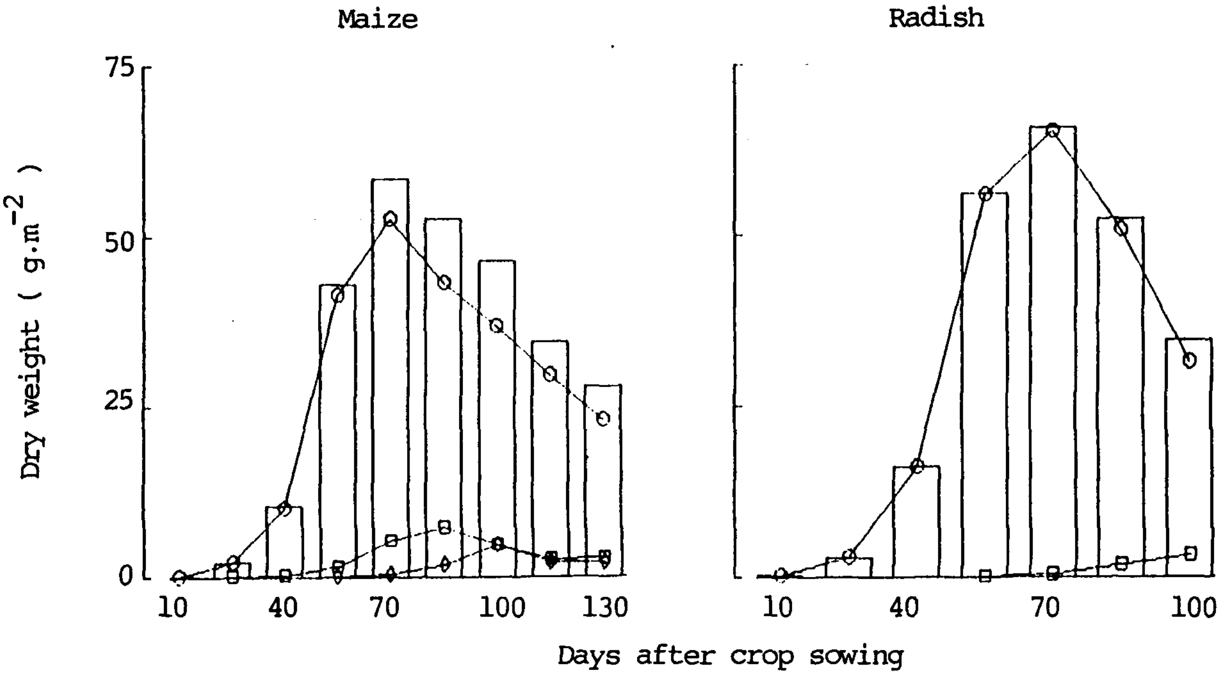

Fig. 9.9. Cohortwise (cohort I, -o-; cohort II, -□- and cohort III, -◊-) as well as total (□) dry matter production by G. ciliata in maize and radish fields under terrace cultivation at Barapani. The figure is based on the data of 1988-1989 and 1989-1990.

Table 9.5 Partial correlation coefficients between micro-environmental variables (photosynthetically active radiation (PAR) and soil moisture (SM)) and dry matter production ($g.m^{-2}$) of *G. ciliata*.

Crop	Micro-environmental variables	Upper Shillong				Barapani	
		'Jhum'	n	Terrace	n	Terrace	n
Autumn potato	PAR	0.965**	21	0.987**	21	Not grown	
	SM	0.297	21	0.380	21		
Summer potato potato	PAR	0.870**	21	0.810**	21	Not grown	
	SM	0.644**	21	0.647**	21		
Cauliflower	PAR	0.969**	21	0.955**	21	Not grown	
	SM	0.149	21	0.341	21		
Maize	PAR	0.624**	21	0.112	18	0.653**	27
	SM	0.174	27	0.534*	18	0.849**	27
Radish	PAR	0.908**	21	0.989**	21	0.011	21
	SM	0.046	21	0.544**	21	0.705**	21

* = Significant at $P<0.05$, **Significant at $P<0.01$

Table 9.6 Regression models for growth (Y = dry matter $g^{-2}.m$) VS. PAR (X_1 = u mol $m^{-2}.s^{-1}$) and soil moisture (X_2 = %)) of *G. ciliata* in different crops fields under 'jhum' (HJ) and terrace (HT) cultivation at Upper Shillong and terrace cultivation (LT) at Barapani.

Crop	Cultivation		r^2	n
Autumn Potato	HJ	$Y=-119.263+0.156X_1^*-1.264X_2$	0.95	21
	HT	$Y=-263.828+0.357X_1^*-2.328X_2$	0.98	21
Summer Potato	HJ	$Y=131.080-0.128X_1^*+7.174X_2^*$	0.92	21
	HT	$Y=192.688-0.241X_1^*+15.750X_2^*$	0.89	21
Cauliflower	HJ	$Y=-150.005+0.179X_1^*-0.649X_2$	0.95	21
	HT	$Y=-347.792+0.318X_1^*+3.436X_2$	0.92	21
Maize	HJ	$Y=159.735-0.095X_1^*+2.090X_2^*$	0.61	27
	HT	$Y=-33.320+0.003X_1^*+1.724X_2$	0.39	18
	LT	$Y=-171.545+0.041X_1^*+6.720X_2^*$	0.74	27
Radish	HJ	$Y=-206.459+0.216X_1^*+0.429X_2$	0.85	21
	HT	$Y=-182.203+0.266X_1^*-2.432X_2^*$	0.98	21
	LT	$Y=177.701-0.002X_1^*-10.169X_2^*$	0.54	21

* = Significant at $P<0.05$

DISCUSSION

The decreasing size of successive cohorts in *G. ciliata* conforms with the result of Rai and Tripathi (1984) on two species of *Galinsoga*, Ballare *et al.* (1987) on *Datura ferox* and Pandey and Dubey (1989) on *Parthenium hysterophorus*. They attributed decline in the population density of successive cohorts to the depletion of germinable fraction of seeds in soil. Variation in seedling emergence could also be related to the microenvironmental conditions prevailing in the crop fields. At Barapani for instance, comparatively high rainfall during pre-sowing period, which influences the soil moisture content is an important factor regulating weed seedling emergence in the crop fields, therefore, the soil moisture level seems to be conducive to weed seed germination only during crop sowing period resulting in a large number of seedling recruitment in the first cohort. Relatively low rainfall during post-emergence period either reduced the number of cohorts or inhibited the seedling emergence in the late emerging cohorts. The differential seedling emergence pattern in different crop fields could also be attributed to the cropping season and crop canopy architecture. Benjamin (1990) concluded that the difference in the time of seedling emergence may be the result of a large number of factors such as water and temperature regimes, sowing depth and seed attributes. So far as emergence of *G. ciliata* seedlings is concerned all the four factors viz. PAR, relative humidity, soil moisture, soil temperature played important role both in 'jhum' and terrace agroecosystems. However, their relative importance varied in different crop fields in autumn and summer cropping seasons. Significance of individual factors such as light (Rai 1987, Van der Toorns and Pons 1988, Baskin and Baskin 1990), soil moisture (Thurston and Phillipson 1976, Aibar 1988, Eddleman and Romo 1988, Fernandez-Quintanilla *et al.* 1990) soil temperature (Baskin and Baskin 1977, 1988, 1990, Fenner 1980, Benech Arnold *et al.* 1988, Eddleman and Romo 1988, Egley 1990) and their direct and indirect interactions (Schwaegerle and Levin 1990) have been discussed by these workers in great detail.

Higher population density of *G. ciliata* at Upper Shillong could also be related to the sandy loam texture of the soil, since increased proportion of sand in soil has been reported to enhance the seed germination of this species (Rai and Tripathi 1982). High mortality during juvenile phase is in conformity with the findings of Harper (1965), Sarukhan and Harper (1973), Sharitz and McCormick (1973), Hawthorn and Cavers (1976) and Yadav and Tripathi (1981). They have concluded that high juvenile mortality is a common phenomenon in most of the colonizing species due to keen competition for resources during active growth phase. The greater survival of early emerging cohorts of *G. ciliata* than the late recruited ones conforms with the population behaviour of certain other species studied by Sarukhan and Harper (1973), Hawthorn and Cavers (1976), Cook (1979), Gross (1980), Weiss (1981), Kelly (1989a), Pandey and Dubey (1989) and Misra *et al.* (1992).

The longer half-life of cohorts and higher dry matter by this species in terrace than 'jhum' fields indicates the prevalence of favourable conditions for plant growth in the former field due to adoption of improved cultural operations, and better nutrient availability on account of fertilizer application and lower population density. Gross (1980), Weiner (1982) Rai and Tripathi (1985), Swamy and Ramakrishnan (1988) and Pandey and Dubey (1989) have reported that the species responded to competition from older cohorts or neighbours by showing reduced vegetative and reproductive growth. Schwaegerle and Levin (1990) opined that the interaction between plant and environment differ between sites and the environmental factors that had a greater impact on plant performance at one site were often unimportant at the other site.

In a nutshell, the results of the study reveals that the moist and cool climate at high altitude which favoured population growth and dry matter yield of *G. ciliata* made it a highly successful species of crop fields. PAR most strongly influenced the growth and abundance of the species at Upper Shillong, while soil moisture regulated the growth performance at Barapani. Improved cultural practices also helped in the success of this species in the terrace fields.

Chapter 10

GROWTH AND POPULATION DYNAMICS OF WEEDS AND THEIR INFLUENCE ON CROP YIELD IN 'JHUM' AND TERRACE CULTIVATION

Weeds are the integral component of the agroecosystems. In spite of the best efforts to check infestation and growth of weeds by adopting various control measures, they often grow abundantly and interfere with the growth and yield of crop plants by sharing essential environmental resources. Populations of different weed species are recruited in the crop field at different times and most of them complete their life-cycle during the crop duration. This is possible on account of their enormous ability to adapt to varied edaphic and microclimatic conditions, which differs in different crop fields depending on the cultural operations and growth form of the crop plants. Studies dealing with population behaviour of some dominant weeds have been discussed in the preceding chapters. This chapter analyses the dynamics of entire weed community in different crop fields. Such a study is important because the crop plants in the agroecosystem have to compete with the successive populations of different weed species during their life-cycle and their ultimate yield performance depends on the interactions with the entire weed community in the crop field.

Survey of literature reveals that the studies on the plant population dynamics during the past decades were directed mostly to elucidate the phenomenon of ecological succession (Sharitz and McCormick 1973), to compare the life history characteristics of closely related species (Sarukhan and Harper 1973, Newell *et al.* 1981, Kelly 1989a,b) and to understand the differences between species populations on contrasting habitats (Bishop *et al.* 1978, Lovett Doust 1981). More specifically works on population dynamics of weeds in crop fields have been done either on a single or two weed species (Naylor 1972, Snaydon 1980, Weavers and Lechowiez 1982, Peters and Arc 1983, Smith 1983, Rai and Tripathi 1984, Zimmerman and Weiss 1984, Fernandez-Quintanilla *et al.* 1986, Gonzalez- Anduzar and Fernandez Quintanilla 1991).

The analysis of the dynamics of entire weed community presented in this chapter is based on the continuous monitoring of recruitment, mortality and population density of all the weed species in a given crop field. Apart from the demographic analysis, viable weed seed population in soil, weed seed production and net gain or loss of viable seeds in soil during cropping and fallow period were estimated to explain the population dynamics of weeds in the crop fields. Total weed growth in terms of dry matter production as well as its effect on crop yield have also been discussed.

RESULTS

DYNAMICS OF WEED POPULATIONS IN CROP FIELDS

Cauliflower:

At Upper Shillong about 4000 seedlings m^{-2} were recruited in 'jhum' fields, while it was about half of this value in the terrace field (Table 10.1). Out of these, monocots were 3-4% in 'jhum' and 6-8% in the terrace. The mortality percentage for dicot weeds was higher in 'jhum' than terrace field. However, total mortality, did not vary significantly between the fields. Net weed density, the resultant of cumulative gains and losses has been shown in Fig. 10.1. It is clearly evident from the figure that despite large difference in the density, the recruitment and mortality pattern and temporal fluctuation in net population was remarkably similar in 'jhum' and terrace fields during both the years.

Population dynamics of weeds as well as weed seeds in 'jhum' and terrace fields have been summarised in Fig. 10.2. Population density of viable seeds in soil seed bank and the recruited seedlings were higher in 'jhum' than terrace both during cropping and fallow periods. About 40% of the recruited seedlings could attain adulthood and produce seeds. Their number per unit area was about 2.2 times higher in 'jhum' than terrace. The seedling recruitment rate (K) and fecundity (F) were more in terrace than 'jhum' field, while survivorship (p) was higher in the latter

Table 10.1 Total recruitment (R=plants·m^{-2}) and mortality (M=%) of weeds in different crop fields under 'jhum and terrace cultivation.

Crop	Weed	'Jhum'				Terrace							
		Upper Shillong				Upper Shillong				Barapani			
		1988-1989		1989-1990		1988-1989		1989-1990		1988-1989		1989-1990	
		R	M	R	M	R	M	R	M	R	M	R	M
Cauliflower	Dicots	3722 (178)	59	3911 (257)	58	1535 (97)	63	1645 (104)	63	-	-	-	-
	Monocots	215 (14)	38	170 (17)	44	205 (22)	35	144 (16)	49	-	-	-	-
	Total	3937 (964)	58	4081 (236)	58	1740 (89)	59	1789 (153)	62	-	-	-	-
Autumn potato	Dicots	3676 (173)	49	3079 (175)	54	1170 (17)	53	1878 (153)	58	-	-	-	-
	Monocots	114 (12)	16	134 (15)	19	104 (12)	13	126 (12)	16	-	-	-	-
	Total	3790 (27)	48	3213 (87)	53	1224 (19)	47	2004 (102)	55	-	-	-	-
Summer potato	Dicots	3105 (48)	49	2945 (70)	46	805 (41)	57	1513 (165)	62	-	-	-	-
	Monocots	53 (7)	30	2945 (70)	31	52 (8)	31	139 (16)	29	-	-	-	-
	Total	3158 (31)	48	3063 (75)	49	857 (39)	57	1652 (164)	57	-	-	-	-
Maize	Dicots	3169 (87)	76	2946 (217)	81	334 (12)	98	330 (17)	98	597 (52)	82	733 (69)	80
	Monocots	242 (17)	71	273 (16)	74	984 (58)	46	985 (49)	45	121 (17)	62	96 (21)	61
	Total	3411 (80)	76	3219 (221)	80	1318 (35)	41	1315 (65)	42	718 (46)	79	829 (92)	78

Table 10.1 (Contd.)

Crop	Weed	‘Jhum’				Terrace							
		Upper Shillong				Upper Shillong				Barapani			
		1988-1989		1989-1990		1988-1989		1989-1990		1988-1989		1989-1990	
		R	M	R	M	R	M	R	M	R	M	R	M
Radish	Dicots	4214	64	3874	49	1638	65	1544	68	473	76	463	78
		(211)		(174		(66)		(81)		(61)		(51)	
	Monocots	150	47	149	58	149	50	169	66	118	64	106	64
		(11)		(9)		(8)		(12)		(22)		(15)	
	Total	4346	63	4923	58	1787	64	1718	68	591	73	569	76
		(102)		(179)		(58)		(75)		(49)		(61)	

Values in parentheses are ± S.E., Dashes represent crop not grown.

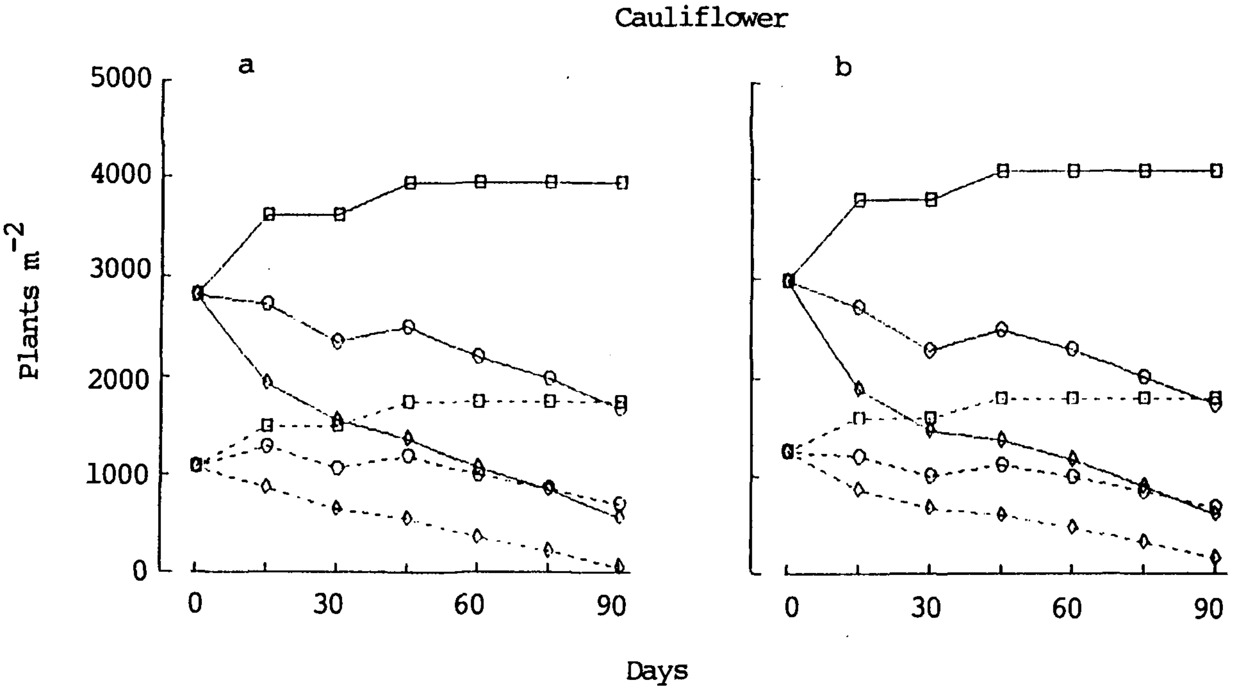

Fig. 10.1. Cumulative gains (□), cumulative losses (◊) and net populations (o) of weeds in cauliflower crop under 'jhum' (——) and terrace (---) cultivation during 1988 (a) and 1989 (b).

Cauliflower

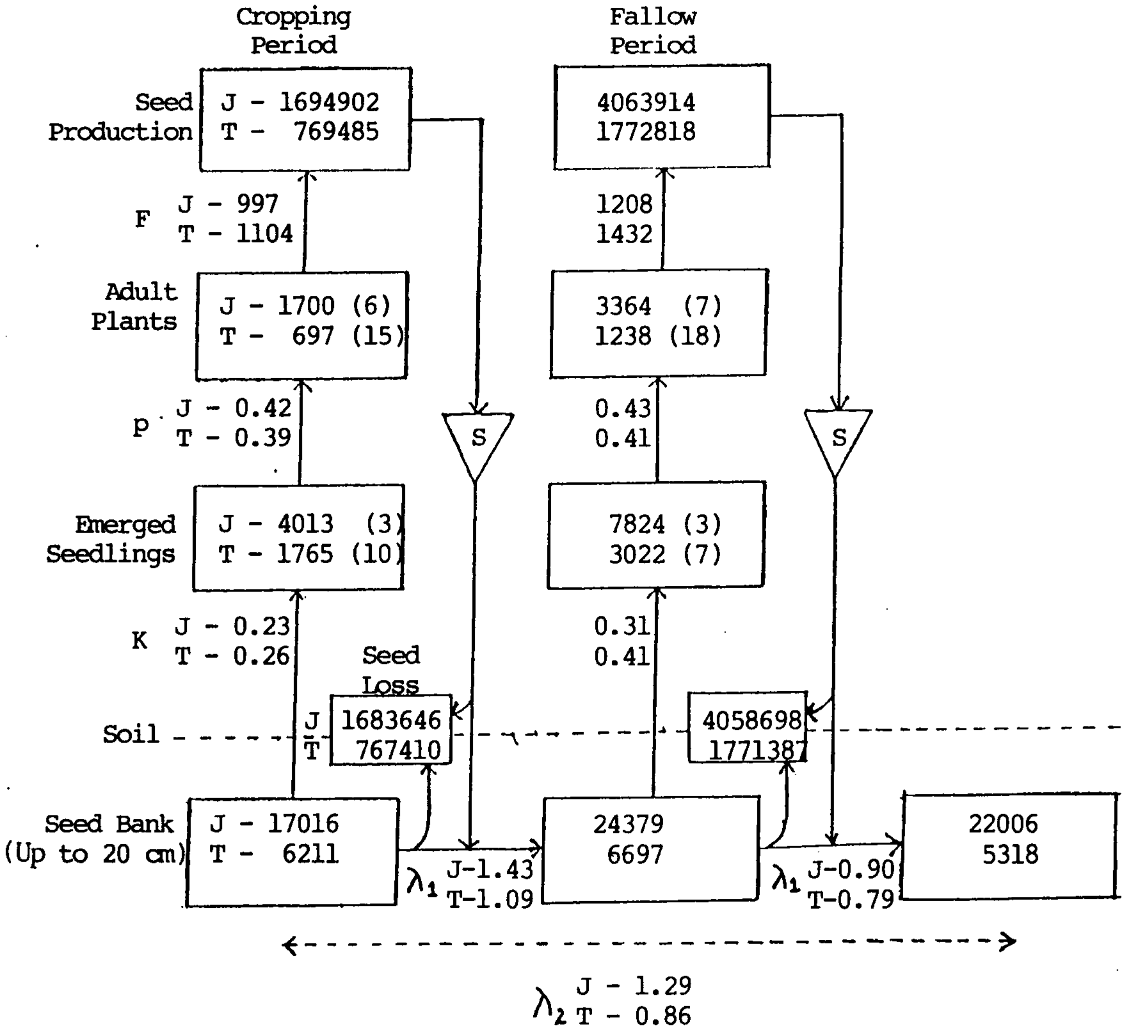

Fig. 10.2. Total weed population flux (average of two years) in cauliflower field during cropping and fallow period at Upper Shillong. Figures in boxes are average numbers of viable seeds in soil and plants m^{-2} in 'jhum' (J) and terrace (T) fields. Values in parentheses indicate the percentage of plants arising from vegetative parts. Seedling recruitment (K), survivorship (p), fecundity (F) and growth rate of seed population (seasonal value, λ_1; annual value, λ_2) in soil are shown along the lines. 'S' indicates seed rain.

field. The rate of increase of viable seed population in soil at the end of the cropping period (λ_1) and annual rate (λ_2) were more in 'jhum' than terrace.

Potato :

Weed seedling recruitment was much greater in the 'jhum' than terrace in both autumn and summer crops at Upper Shillong. The proportion of monocots in the whole population ranged between 2-4% and 6-8% in 'jhum' and terrace field, respectively. Dicot weeds suffered greater mortality (49-60%) than the monocots (13-31%). In both fields mortality of monocot weeds was higher during summer than in autumn. Dicot weeds showed this trend only in terrace. Total seedling mortality was more in terrace than 'jhum' during summer. In both autumn and summer potato, cumulative gains and net population of weeds were always higher in 'jhum' than terrace but temporal changes in net populations was similar in both the fields (Fig. 10.3).

Majority of weeds in potato field were recruited from seeds and the proportion of those emerged from the vegetative parts was very low (2-17%) (Fig. 10.4). Like cauliflower field, population density of viable seeds in soil seed bank and the recruited seedlings were higher in 'jhum' than terrace both during cropping and fallow periods. In the former field 48-50% seedlings attained adulthood, while in the latter the value ranged between 39-47%. During summer fallow the survival rate was minimum (25-28%) both in 'jhum' and terrace. The rate of seedling recruitment from soil

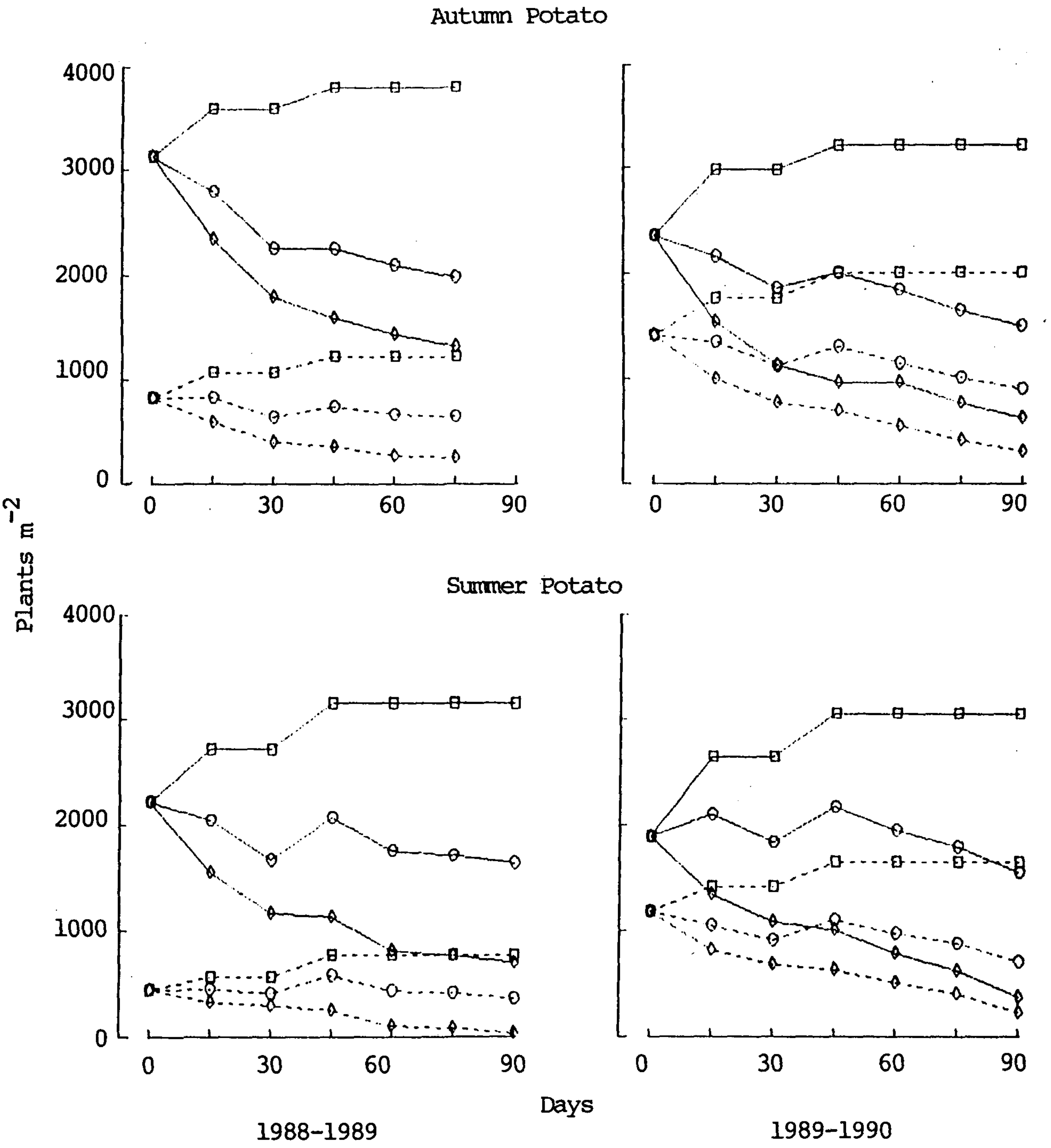

Fig. 10.3. Cumulative gains (□), cumulative losses (◊) and net populations (o) of weeds in potato crops under 'jhum' (——) and terrace (---) cultivation during 1988-1989 and 1989-1990.

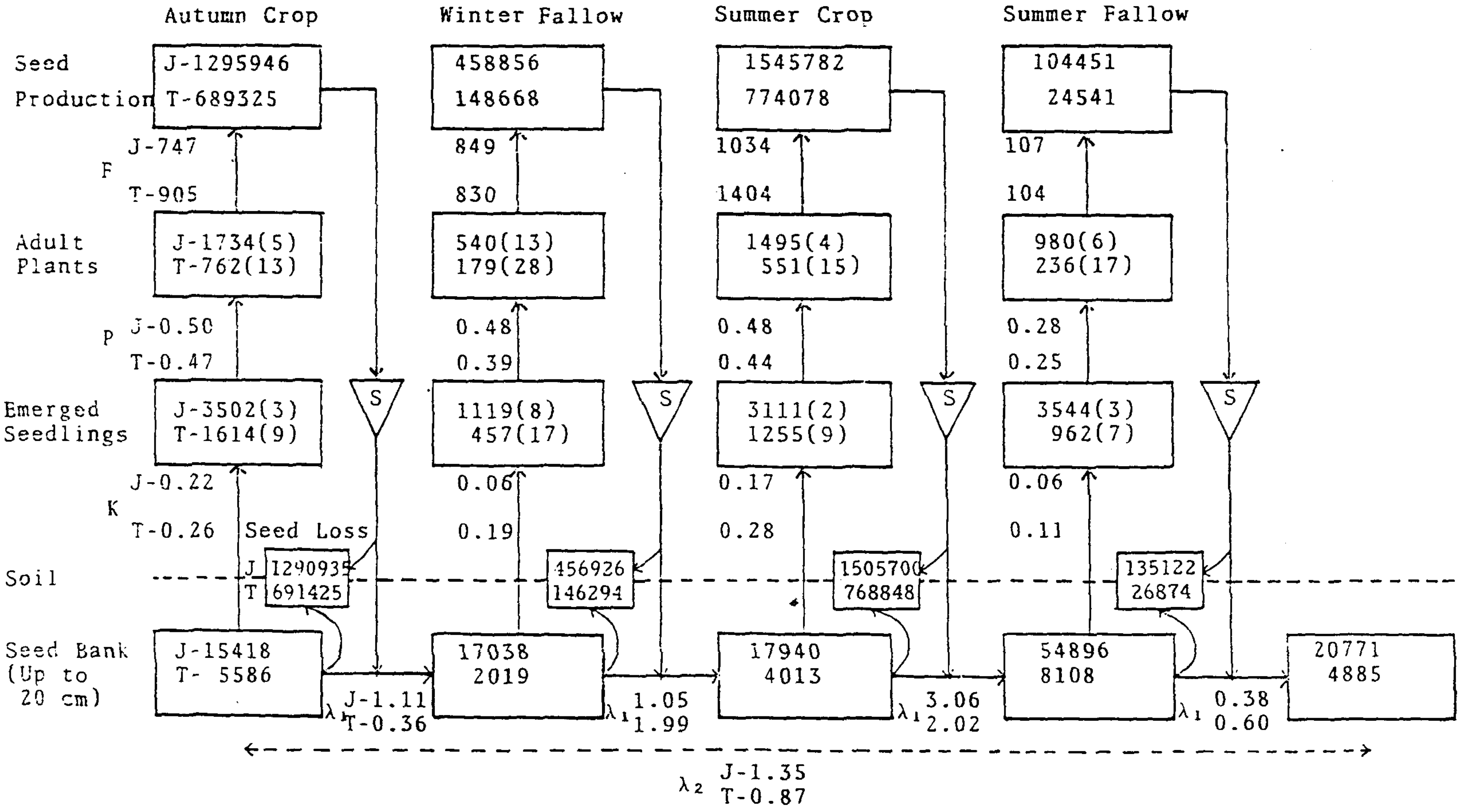

Fig. 10.4. Total weed population flux (average of two years) in potato field under 'jhum' and terrace cultivation at Upper Shillong. Other details are same as Fig. 10.2.

seed bank (K) was greater in terrace than in 'jhum'. However, survivorship (p) was more in 'jhum'. Fecundity (F) was higher in terrace during the cropping period. The rate of increase in viable seeds in soil during cropping period (λ_1) and annual rate (λ_2) were higher in 'jhum' than in terrace.

Maize :

In maize field, significantly higher ($P<0.05$) number of weed seedlings were recruited in 'jhum' than terrace at Upper Shillong. The recruitment of weeds in the terrace field at Upper Shillong was significantly higher ($P<0.05$) than that at Barapani. At Upper Shillong, the proportion of monocots in the weed community of 'jhum' field was *ca* 8%, while in the terrace field it was *ca* 75%. The mortality of dicots (98%) was significantly higher ($P<0.05$) than the monocots (45-46%) in the terrace field, while this difference was insignificant in the 'jhum' field. At Barapani, the mortality pattern of monocots and dicots was similar to the 'jhum' field at Upper Shillong. The total mortality was greater in 'jhum' than terrace field (Table 10.1). The cumulative gains, losses and net population of weeds in 'jhum' and terrace fields at Upper Shillong followed a similar trend during both the years. In both the places, the relatively low recruitment and high rate of mortality resulted into a continuous decline in net population density during cropping period. However, the cumulative losses in the terrace field at Upper Shillong was less compared to the 'jhum' field as well as the terrace field at Barapani (Fig. 10.5).

The weed population dynamics during cropping and fallow periods have been summarized using flux diagram (Figs. 10.6-10.7). The proportion of plants from vegetative parts were very low as compared to seed borne plants in the 'jhum' field (6%), while in the terrace 63% individuals originated from the ramets. During cropping period seedling recruitment rate (K) was higher in 'jhum' than terrace but survivorship (p) and fecundity (F) were more in terrace. The rate of increase in viable seed population in soil was more during cropping period (λ_1) than the fallow period. In general, the growth rate of seeds in soil seed bank was higher in 'jhum' than terrace fields (Fig 10.6). In terrace field, K and F were lower at Barapani than at Upper Shillong, while p and λ were higher at Barapani (Fig. 10.7).

Radish

Like other crops, weed seedling recruitment was significantly higher in 'jhum' than in terrace field. The proportion of monocot was 3-4% in 'jhum' and 8-10% in the terrace field at Upper Shillong and 19-20% at Barapani (Table 10.1). The mortality percentage of dicots (59-78%) was higher than the monocots (47-66%). Total mortality was higher in terrace (64-68%) than in 'jhum' (58-63%). Mortality pattern at Barapani was similar to that at Upper Shillong. Despite significant variation in density between 'jhum' and terrace, cumulative gains, cumulative losses and net population of weeds showed similar

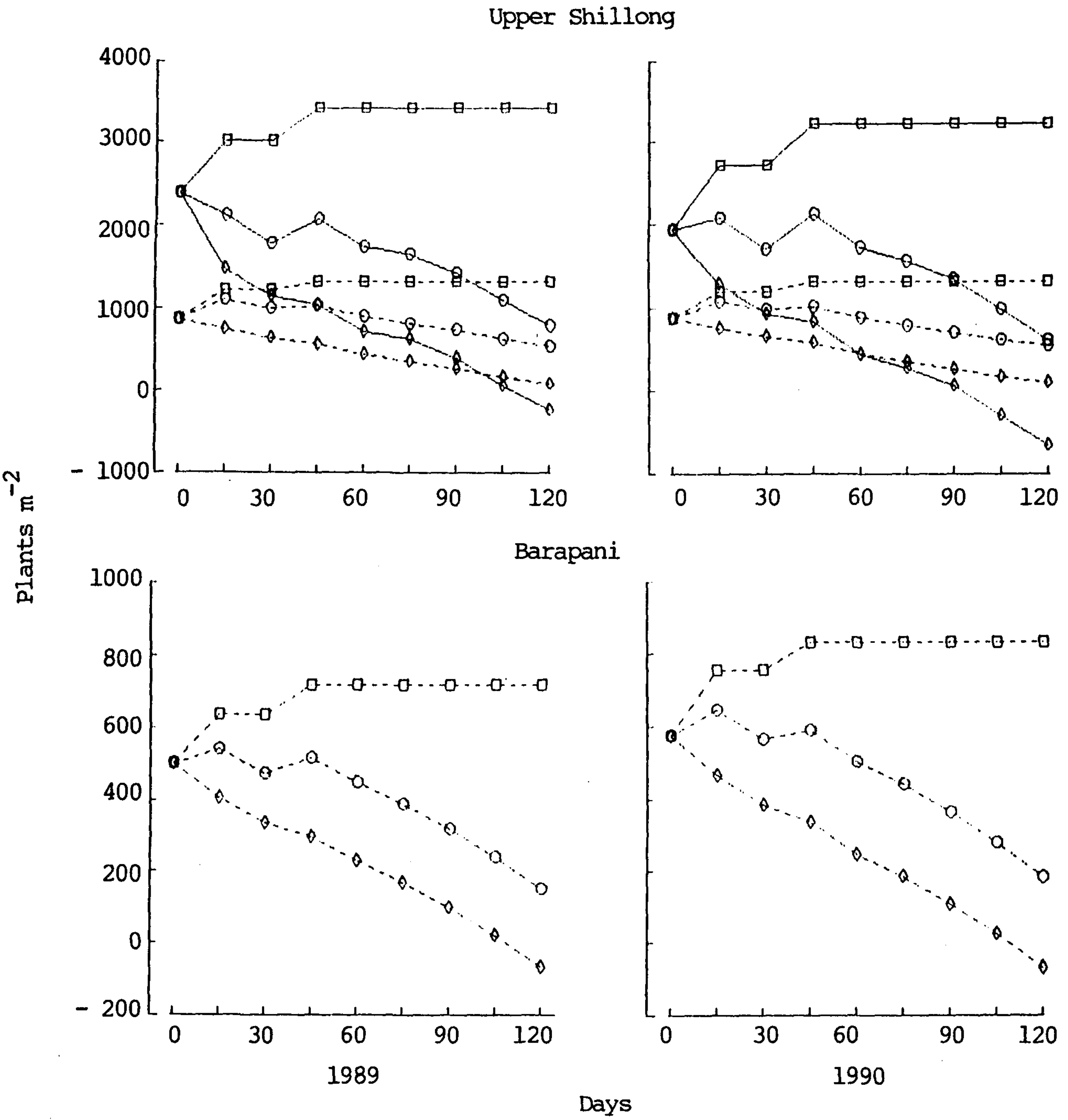

Fig. 10.5. Cumulative gains (□), cumulative losses (◊) and net populations (o) of weeds in maize crop under 'jhum' (——) and terrace (----) cultivation at Upper Shillong and Barapani during 1989 and 1990.

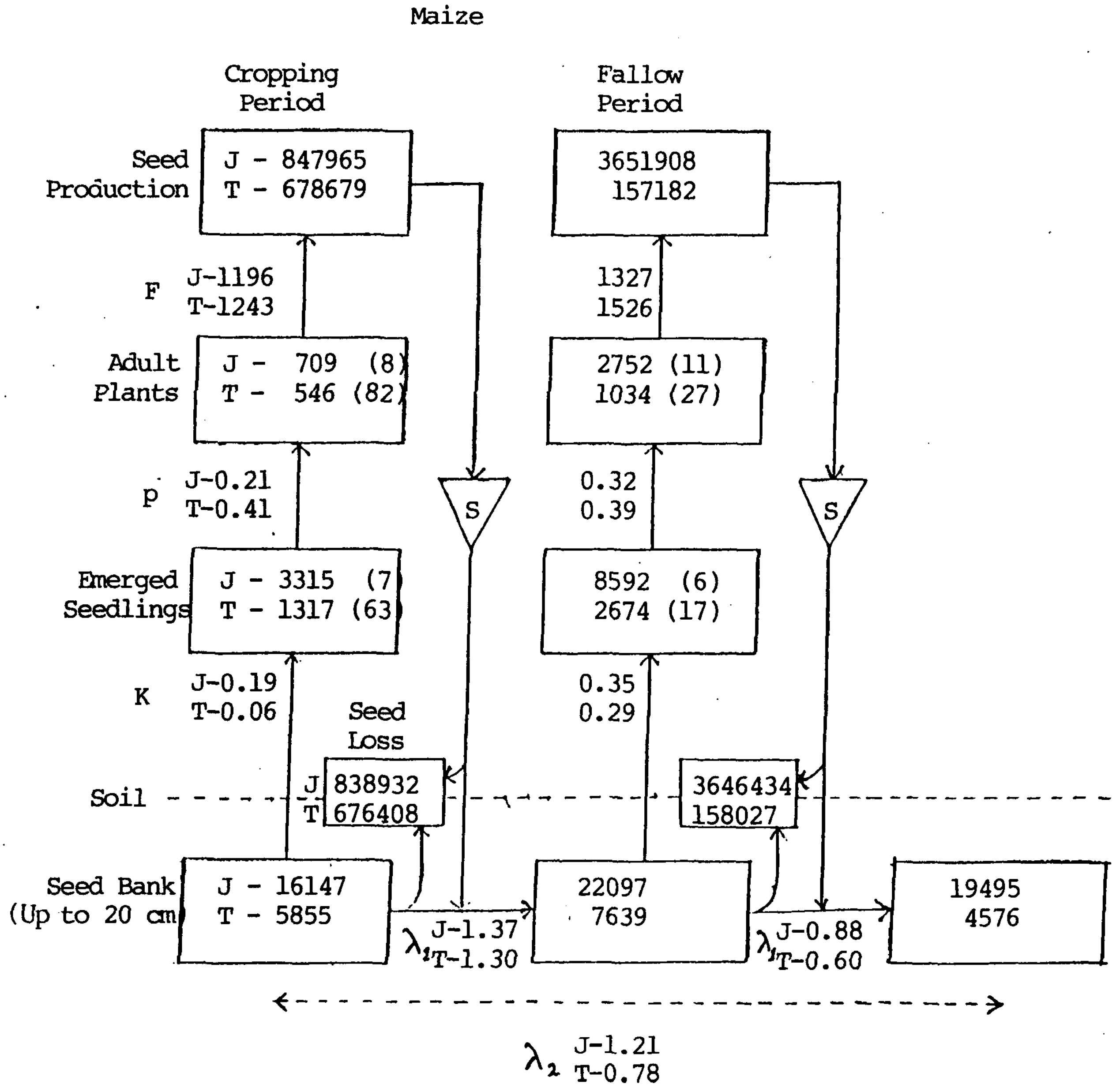

Fig. 10.6. Total weed population flux (average of two years) in maize field under 'jhum' and terrace cultivation at Upper Shillong. Other details are same as Fig. 10.2.

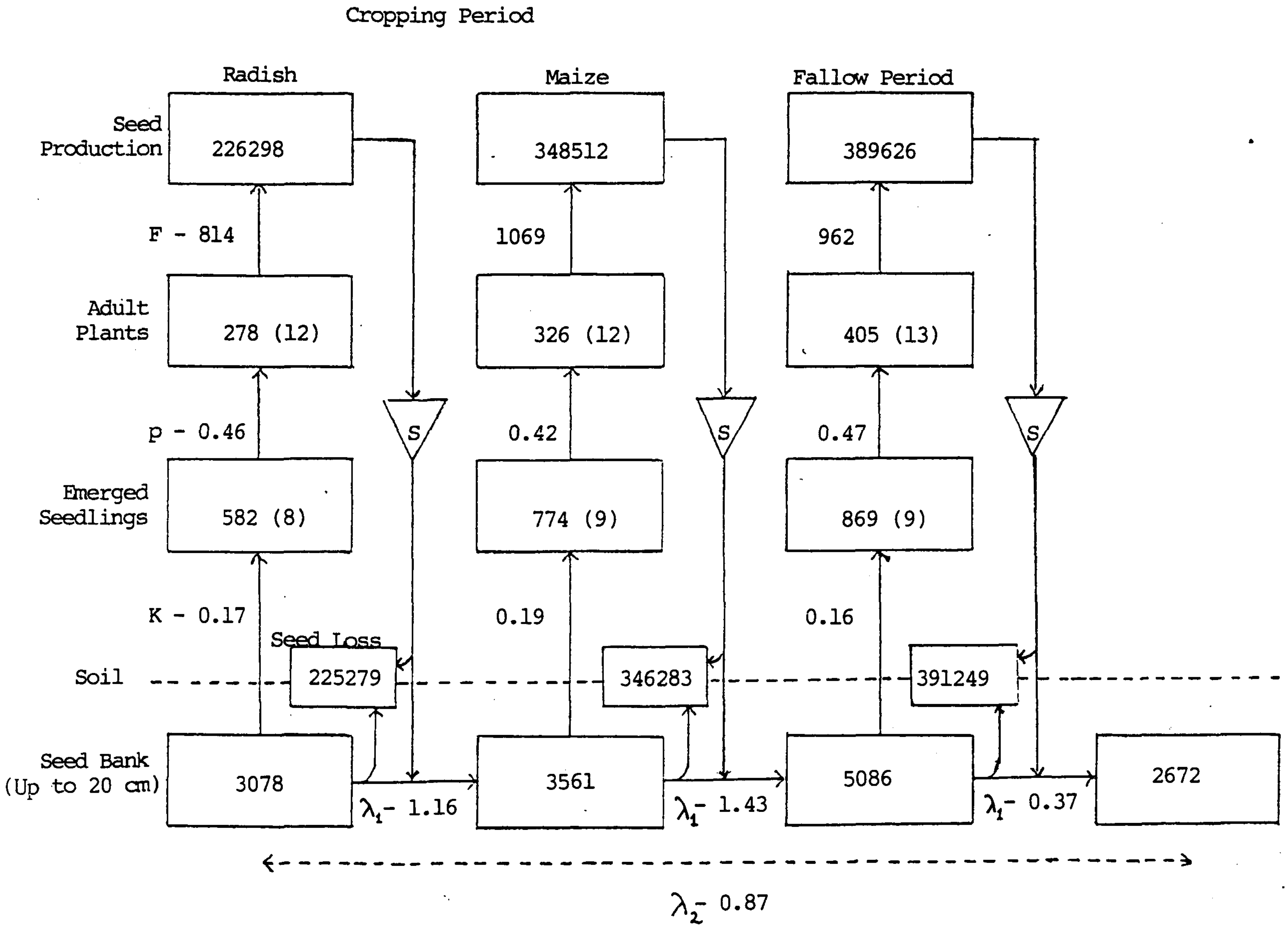

Fig. 10.7. Total weed population flux (average of two years) in radish and maize field under terrace cultivation at Barapani. Other details are same as Fig. 10.2.

trend at Upper Shillong (Fig. 10.8). At Barapani, after initial recruitment there was no gain upto 30 days. Like maize field, cumulative loss was much higher than the recruitment thereby causing a continuous decrease in net population throughout the cropping period.

Like cauliflower and potato fields, the proportion of seedlings emerging from the parent ramets was very low (3-9%) as compared to the seed borne plants at both the sites. The population density of viable weed seeds in soil, the number of recruited seedlings and adult plants and the seed production per unit area were higher in'jhum' than terrace (Fig. 10.9). In 'jhum' field, 38-39% seedlings could attain adulthood, while in terrace the values were 33% at Upper Shillong (Fig. 10.9) and 46% at Barapani (Fig. 10.7). K and F were more in terrace, while p and λ were more in the 'jhum' field. In the terrace field at Barapani, the seedling recruitment rate (K) was lower than that at Upper Shillong.

DRY MATTER PRODUCTION OF WEEDS IN CROP FIELDS

Cauliflower

The weed biomass increased with time and attained a peak of 998.7 g. m^{-2} in 'jhum' and 949.6 g. m^{-2} in the terrace field at 75 days and then declined (Fig. 10.10). Major portion of this in the 'jhum' field was due to *S. arvensis*, whose contribution was 28.6%. This was followed by *P. alatum* (19.3%) and *G. ciliata*

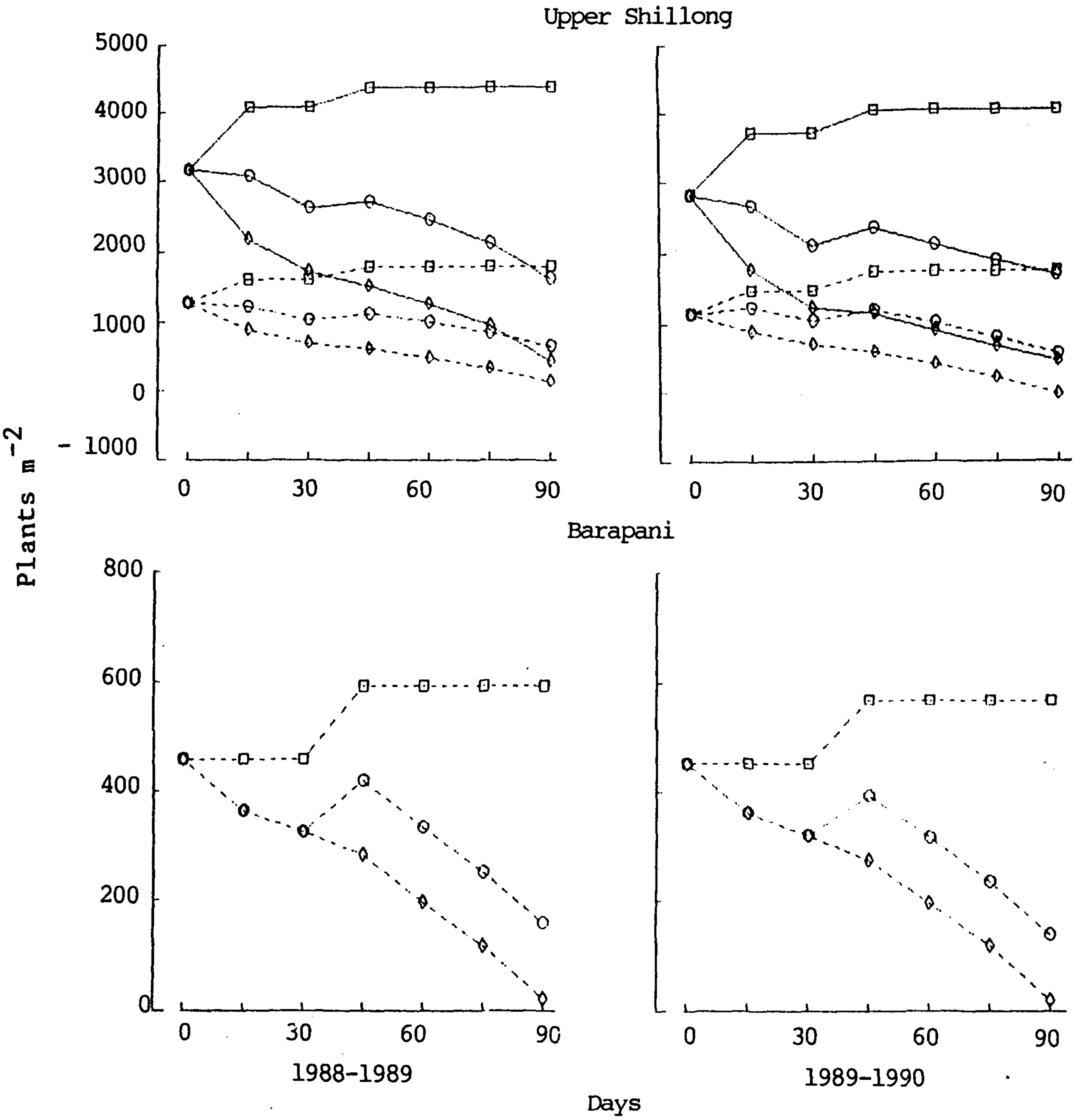

Fig. 10.8. Cumulative gains (□), cumulative losses (◊) and net populations (o) of weeds in radish crop under 'jhum' (——) and terrace (---) cultivation at Upper Shillong and Barapani during 1988-1989 and 1989-1990.

Radish

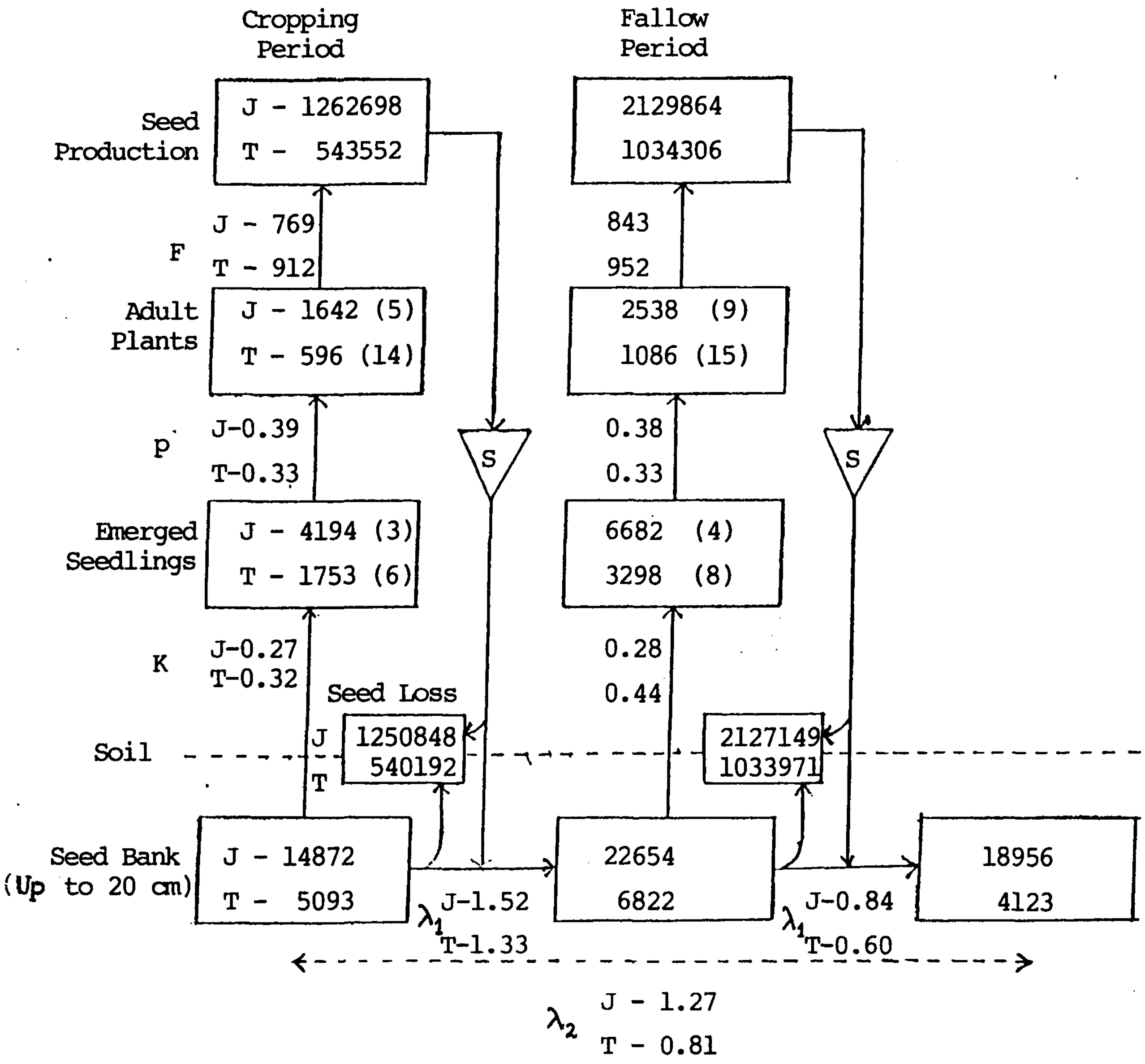

Fig. 10.9. Total weed population flux (average of two years) in radish fields under 'jhum' and terrace cultivation at Upper Shillong. Other details are same as Fig. 10.2.

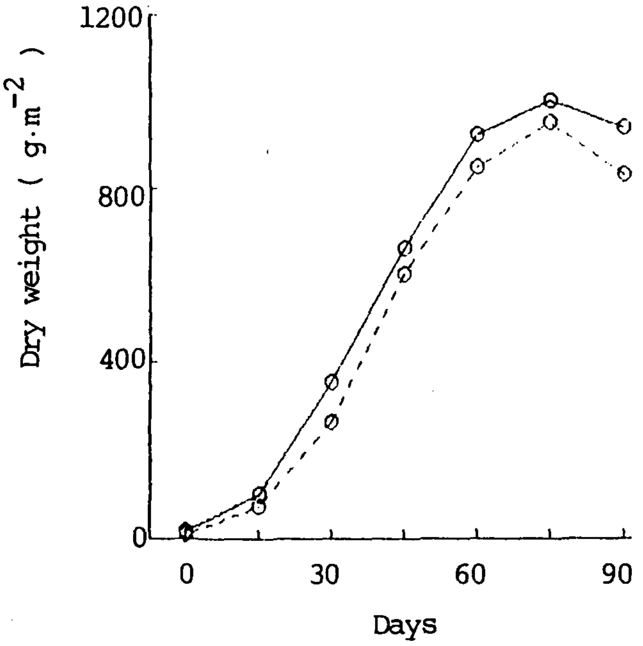

Fig. 10.10. Total dry matter production by weeds in cauliflower field under 'jhum' (——) and terrace (---) cultivation at Upper Shillong. The figure is based on data pooled for 1988 and 1989.

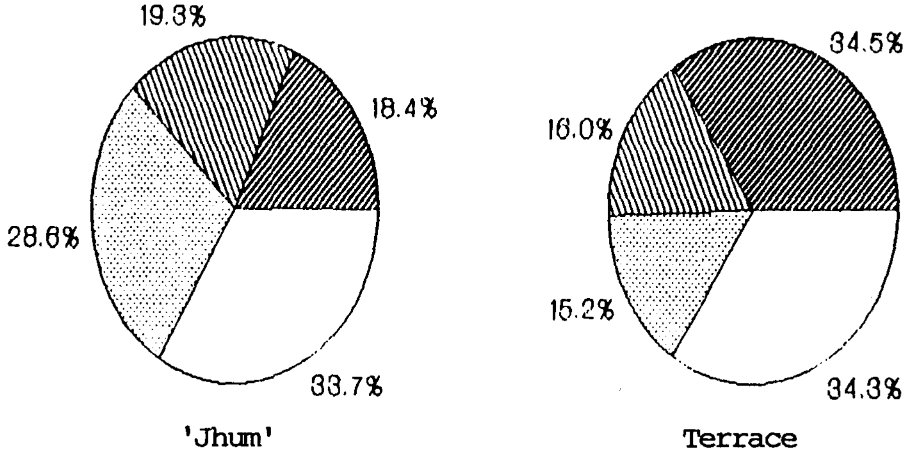

Fig. 10.11. Percentage contribution of *G. ciliata* (▨), *P. alatum*(▧)*S. arvensis* (▤) and other weeds (□) at the time of peak biomass in potato field under 'jhum' and terrace cultivation at Upper Shillong.

(18.4%). In terrace field, *G. ciliata* had the largest share (34.5%) followed by *P. alatum* (16%) and *S. arvensis* (15.2%). The contribution of other weeds was about 34% in both fields (Fig. 10.11).

Potato

Weed biomass followed a sigmoid curve with time both in 'jhum' and terrace fields and attained a peak of 1032.3 g.m^{-2} in autumn and 901.3 g.m^{-2} in summer crop in'jhum' field and 951.2 g.m^{-2} and 691.4 g.m^{-2} in the terrace field, respectively (Fig. 10.12). In both autumn and summer, biomass was much higher in 'jhum' than terrace field. This difference was particularly more prominent in the summer crop. In both the seasons peak occurred at the age of 75 days and then the curve declined. *S. arvensis* was the dominant contributor to the weed biomass in the 'jhum' fields, while *G. ciliata* attained this distinction in the terrace fields (Fig. 10.13). Contribution of *P. alatum* was almost same in both the fields. Other weeds shared about 29% in the autumn crop and about 23% in the summer crop.

Maize

Like other crop fields, the total weed biomass was higher in 'jhum' than terrace field at Upper Shillong. At Barapani, though the density of weeds was lower than the terrace field at Upper Shillong, the biomass was higher (Fig. 10.14). The peak values were 890.9 g.m^{-2}, 523.8 g.m^{-2} and 752.4 g.m^{-2} in 'jhum' and terrace fields at Upper Shillong and terrace field at Barapani,

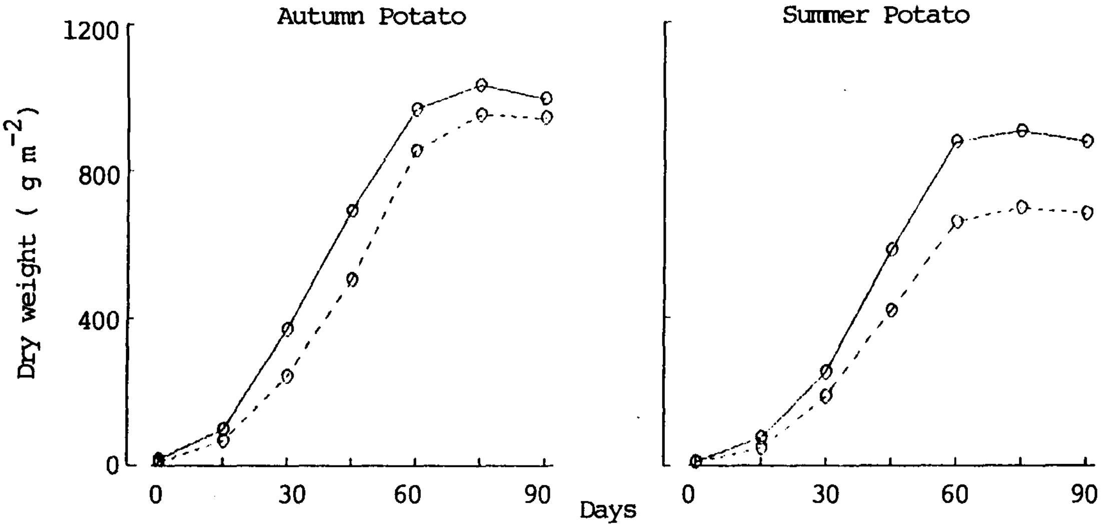

Fig. 10.12. Total dry matter production by weeds in potato fields under 'jhum' (——) and terrace (---) cultivation at Upper Shillong. The figure is based on pooled data for 1988-1989 and 1989-1990.

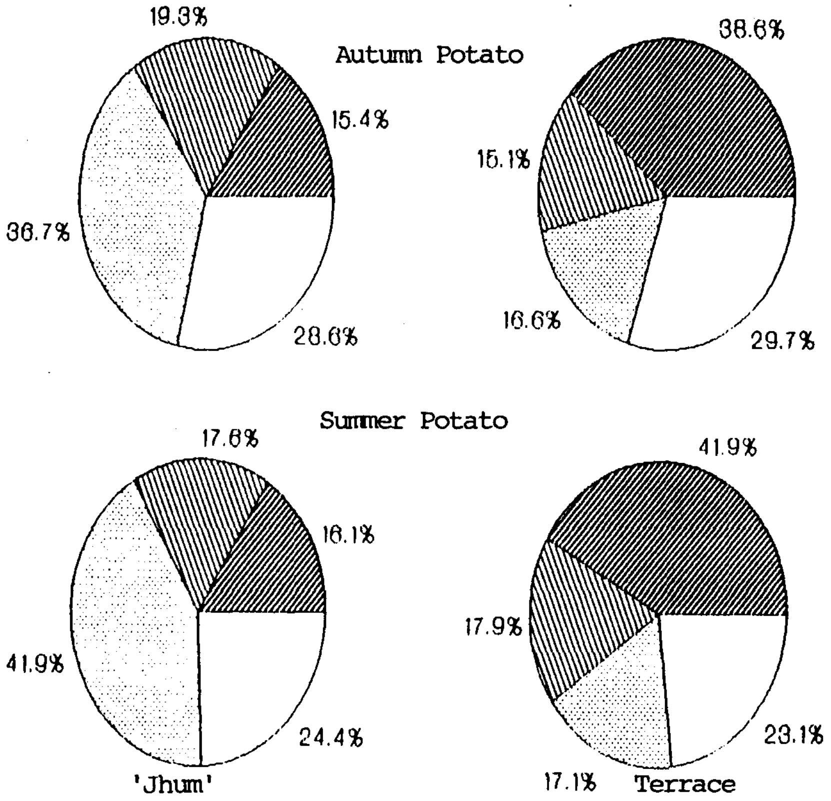

Fig. 10.13. Dry matter distribution pattern at the time of peak biomass of G. ciliata (▨), P. alatum (▧), S. arvensis (▒) and other weeds (□) in potato fields under 'jhum' and terrace cultivation at Upper Shillong.

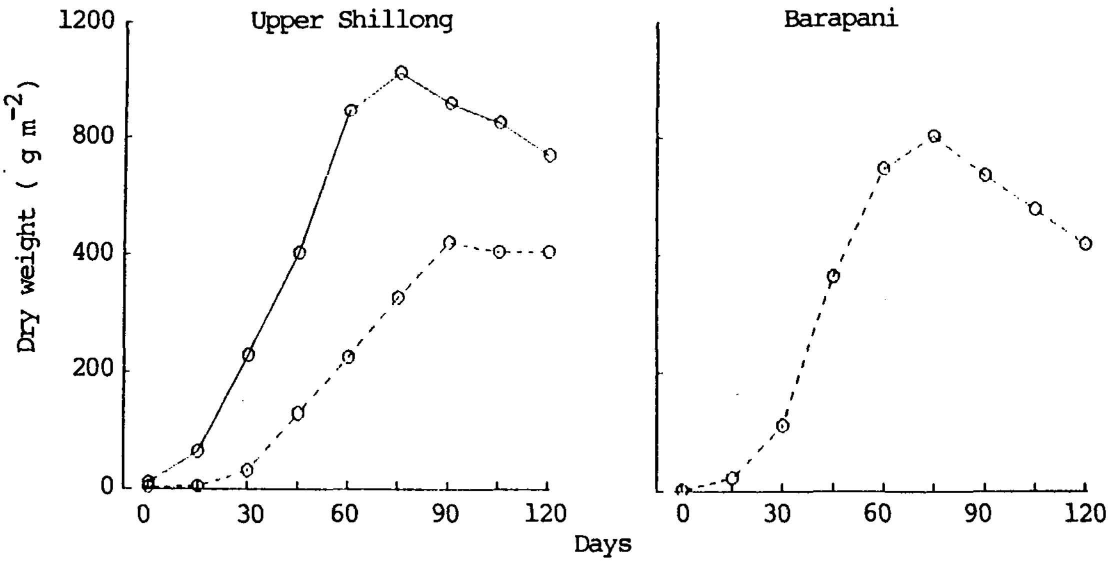

Fig. 10.14. Total dry matter production by weeds along a time gradient in maize crop under 'jhum' (——) and terrace (---) cultivation at Upper Shillong and Barapani. The data are pooled for 1989 and 1990

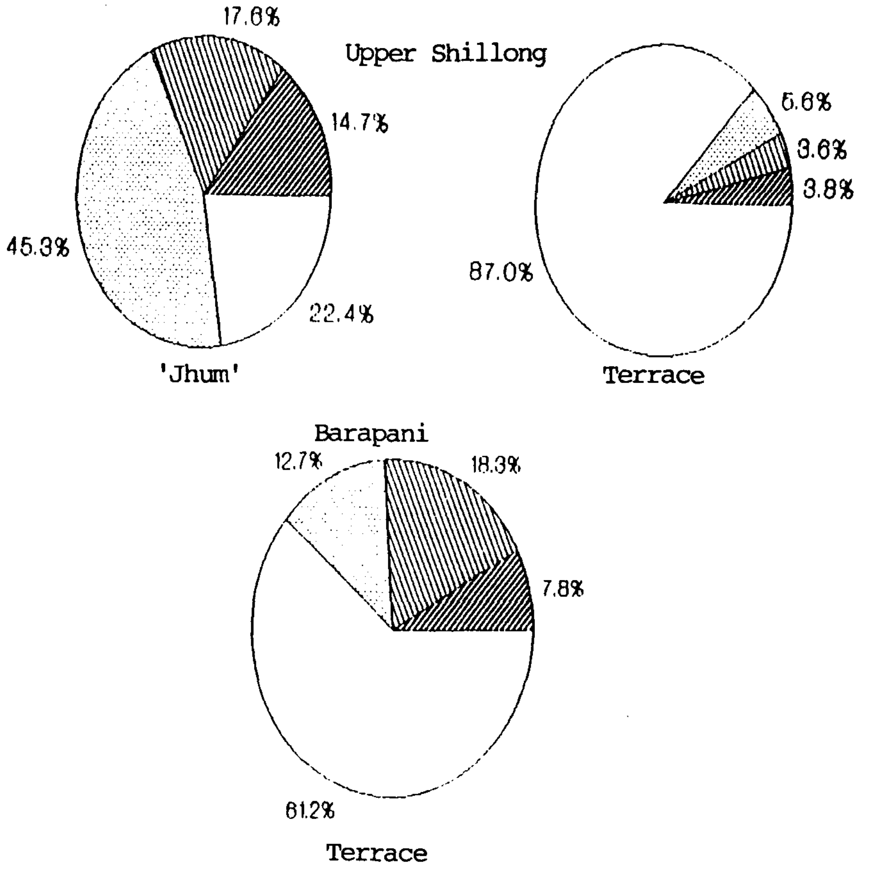

Fig. 10.15. Percentage contribution of dry matter production at peak by G. ciliata (▨), P. alatum (▧) S. arvensis (▤) and other weeds (☐) in maize crops under 'jhum' and terrace cultivation at Upper Shillong and by G. ciliata (▨), E. sonchifolia (▧), R. pilosa (▤) and other weeds (☐) at Barapani.

respectively. The three dominant weeds shared 77.6% biomass in 'jhum' and only 13% in the terrace field at Upper Shillong (Fig. 10.15). At Barapani, the distribution of biomass in three dominant species and other weeds was 38.8% and 61.2%, respectively.

Radish

At Upper Shillong, total biomass showed a peak at 75 days in both the fields, while at Barapani, it showed the peak at 60 days and then declined (Fig. 10.16). At Upper Shillong, among the three dominant weeds, *S. arvensis* was the major contributor (31.9%) to the total biomass. This was followed by *G. ciliata* (20.4%) and *P. alatum* (16%) in 'jhum'. In terrace, *G. ciliata* had the largest share of 33.9% followed by *P. alatum* (16.8%) and *S. arvensis* (14.2%) (Fig. 10.17). At Barapani, *E. sonchifolia* contributed 14.5%, while *G. ciliata* and *R. pilosa* contributed 13.6% and 2%, respectively. The other species in the community contributed about 32-35% at Upper Shillong and about 70% at Barapani.

CROP YIELD

The crop yield in weed-free and unweeded plots has been given in Table. 10.2. Analysis of variance of the data reveals that the crop yield in the weed-free plots was significantly higher ($P<0.01$) than the unweeded plots in all the cases. The difference in crop yield between 'jhum' and terrace was also

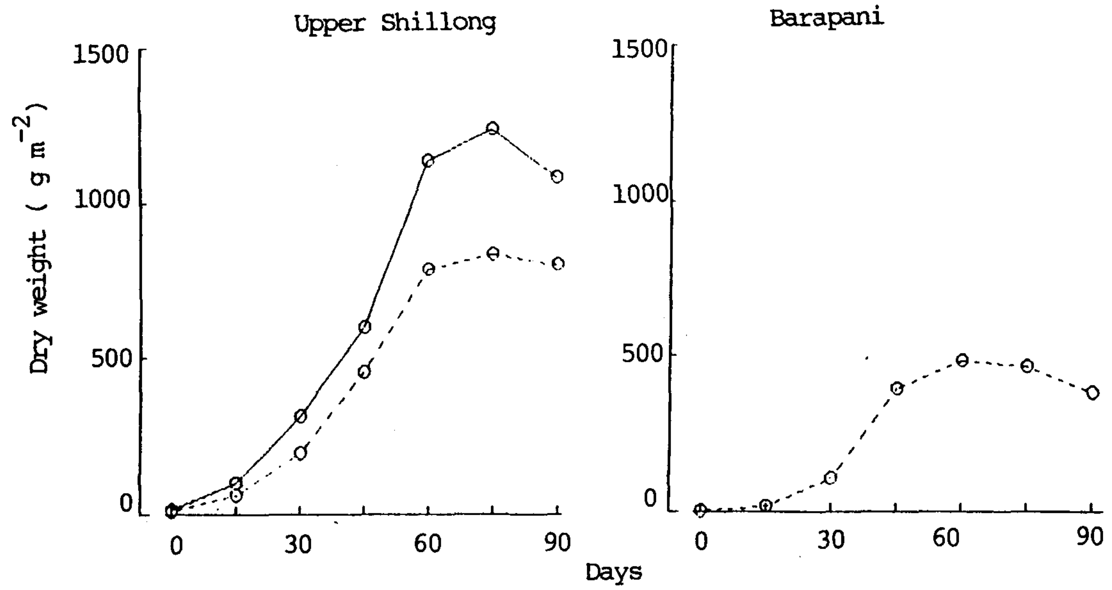

Fig. 10.16. Total dry matter production by weeds along a time gradient in radish crop under 'jhum' (——) and terrace (---) cultivation at Upper Shillong and Barapani. The data are pooled for 1988-1989 and 1989-1990.

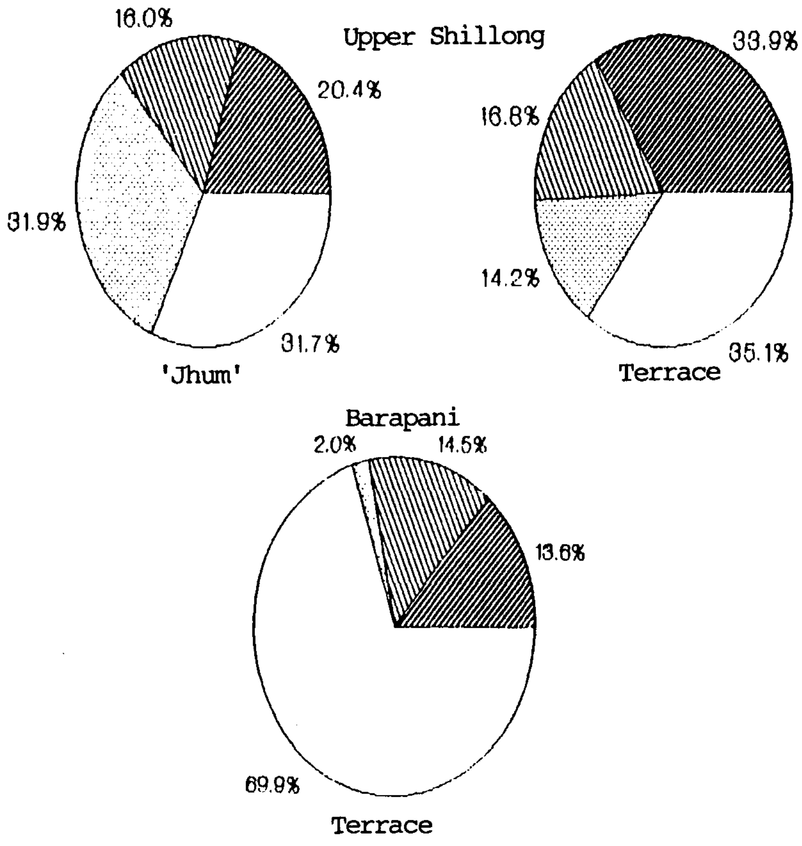

Fig. 10.17. Dry matter distribution pattern at the time of peak biomass of G. ciliata (▨), P. alatum (▧), S. arvensis (▦) and other weeds (□) in radish field at Upper Shillong and G. ciliata (▨), E. sonchifolia (▧), R. pilosa (▦) and other weeds (□) at Barapani.

Table 10.2 Yield ($kg \cdot m^{-2}$) in different crops fields under 'jhum' and terrace cultivation.

		'Jhum'		Terrace			
		Upper Shillong		Upper Shillong		Barapani	
Crop	Weed	1988-1989	1989-1990	1988-1989	1989-1990	1988-1989	1989-1990
Cauliflower	Unweeded	3.94 (0.118)	3.89 (0.119)	5.04 (0.142)	4.66 (0.099)	-	-
	Weed free	6.21 (0.176)	5.98 (0.181)	7.62 (0.211)	6.94 (0.124)	-	-
Autumn Potato	Unweeded	1.48 (0.106)	1.36 (0.092)	1.86 (0.115)	1.96 (0.113)	-	-
	Weed free	2.37 (0.101)	2.41 (0.118)	2.71 (0.144)	2.68 (0.123)	-	-
Summer Potato	Unweeded	1.23 (0.093)	1.33 (0.104)	1.82 (0.142)	1.74 (0.151)	-	-
	Weed free	2.31 (0.118)	2.29 (0.116)	2.53 (0.165)	2.49 (0.112)	-	-
Maize	Unweeded	1.27 (0.141)	1.32 (0.131)	1.69 (0.141)	1.62 (0.093)	1.74 (0.076)	1.58 (0.102)
	Weed free	1.79 (0.122)	1.65 (0.114)	2.08 (0.086)	1.99 (0.108)	2.12 (0.104)	2.05 (0.094)
Radish	Unweeded	2.86 (0.154)	3.15 (0.148)	3.81 (0.131)	3.76 (0.184)	3.72 (0.142)	3.64 (0.126)
	Weed free	4.42 (0.126)	4.21 (0.145)	5.25 (0.208)	5.08 (0.218)	4.90 (0.132)	4.78 (0.141)

Values in parenthess are ± S.E., Dashes represent crop not grown.

significant ($P<0.01$) in all the crops. At Upper Shillong the magnitude of reduction in crop yield in unweeded plots under 'jhum' was 20-48% and in terrace 19-34%. In this regard altitudinal difference did not show any definite trend.

DISCUSSION

'Jhum' and terrace fields showed a large difference in the density of recruited weed seedling populations; the values being always higher in the former. But the seedling recruitment rate (K) was higher in the terrace than in 'jhum'. Favourable soil conditions created by frequent ploughing in the former seems to be the main reason for such a difference in the seedling emergence because in spite of large buried seed population in the 'jhum' fields seedling recruitment was low. Findings of Seif El Din and Obeid (1979) and Roberts and Potter (1980) supports this hypothesis that buried seeds show better germination and emergence in disturbed soil.

The weed mortality pattern at Upper Shillong was influenced more by the type of crop than mode of cultivation, but a comparison of mortality in terrace fields at Upper Shillong and Barapani indicates a strong influence of altitudinal difference. Relatively high mean temperature and low rainfall at Barapani could be considered responsible for higher weed mortality in the crop fields located at this altitude.

Considering the mortality and recruitment patterns of the weed populations, it was found that there was a rapid flux of births and deaths at the early stage of crop growth. As the density of the population increase with the addition of new cohorts of seedlings, competition starts in the multiaged population leading to poor growth and higher mortality of late emerging cohorts. The severe resource competition among the populations of different species also lead to mortality throughout the life of the crop plants. Consequently the population declined with an increase in age of crop plants. Similar observations in grasslands, wastelands and woodlands habitats on individual weed species have been recorded by Sarukhan and Harper (1973) in *Ranunculus repens*, Weiss (1981) in *Emex australis*, Rai and Tripathi (1984) in *Galinsoga ciliata* and *G. parviflora*, Kelly (1989a) in *Euphrasia psuedokerneri, Linum catharticum* and *Gentianella amarella* and Pandey and Dubey in *Parthenium hysterophorus*.

The population behaviour of weeds was similar in the two farming systems. This trend is similar to the findings of Lovett Doust (1981), who studied the population dynamics of *Ranunculus repens* in different habitats. Among-site differences in seedling size, growth and survival have been attributed to environmental factors rather to the population differences (Hickman 1975, Clarke 1980, Fowler and Antonovics 1981, Antonovics and Primack 1982, Schmidt and Levin 1985, Kranniz and Carey 1988).

Higher fecundity rate in the terrace than in the 'jhum' fields could be the result of lower competition and better nutrient availability due to application of chemical fertilizers and frequent soil working.

The chief cause of net increase in buried seed population in 'jhum' field is the traditional weed control measure in which the uprooted weeds, some of which with a large number of mature seeds, are buried in the field. On the contrary, removal of uprooted weeds from the field and regular use of herbicides are main causes of reduction in the total buried weed seed population in the terrace field.

Higher dry matter production by weeds in different 'jhum' fields was mostly due to greater density, dominance pattern and competitive ability of the constituent weeds. Wells (1979) showed a negative linear relationship between crop yield and weed density i.e., as the weed density increased, crop yield decreased. Similar observations were made by Spitter (1983), Cousens *et al.* (1985), Hakannson (1988) and Wilson and Wright (1990). However, results of Cousens *et al.* (1988), reveals that low density of weed had a relatively greater effect on crop yield, than the high weed density.

Chapter 11

GENERAL DISCUSSION

The characteristics of weedy vegetation in a crop field largely depend on the disturbance induced by different kinds of agricultural practices (Bazzaz 1983, Saavedra *et al.* 1989, Mohler and Calloway 1992). The effect of these practices on weed populations is likely to vary depending on the disturbance regime and nature of the concerned weed species. In the traditional form of agriculture in northeast India i.e., slash and burn or 'jhum', where soil disturbance is minimum due to adoption of primitive methods of cultivation and chemical weed control measure is hardly applied, crop fields are overgrown with a large variety of weeds. In crop fields under terrace cultivation, a method relatively recently introduced in northeast India to check various environmental problems generated by the age old practice of 'jhum' and to develop a suitable agroecosystem for sustainable yield, weed infestation is also a serious problem. Abundant weed growth in both 'jhum' and terrace fields in this part of the country occurs due to favourable climatic conditions particularly suitable temperature and high precipitation for about eight months during a year.

The weed floras in different 'jhum' and terrace fields at low and high altitudes of Meghalaya are composed of both annual and perennial weeds. The composition of weed flora varied between 'jhum' and terrace fields and also among the fields located at each of the two elevations. The altitudinal variation in floral composition was more prominent than the difference between 'jhum' and terrace fields.

Species content in the weed community at low altitude was more than that at the high altitude. Such a difference in species richness of the weed community may be attributed to the differences in agro-climatic conditions - more specifically, differences in temperature and soil moisture conditions at the two altitudes. Low altitude site was characterised by comparatively higher soil (low altitude 16.5°C-25°C, high altitude 10.5°C-23.5°C) and air temperature (low altitude 16.4°C-24.2°C, high altitude 12.9°C- 20.5°C) throughout the year and relatively less annual precipitation at low altitude (2673 mm/year) than the high altitude site (2800 mm/year). Apart from these differences, variations in soil texture i.e. clay loam at low altitude and sandy loam at high altitude might have also contributed to the variation in the floristic composition of weeds at the two sites. Dagar (1987) and Saavedra *et al.* (1989, 1990) have also emphasized that the variation in weed flora composition may occur due to a large number of factors such as diversity and density of crops, their growth cycle and competitive ability, timing of tillage operation, soil characteristics and variation in microclimatic conditions.

Abundance of annuals in the weed community at both the altitudes was related to the composition of the weed seed bank in soil. This is evident from the data on soil seed bank collected from the same crop fields by Sahoo (1992). His findings support this hypothesis, since major portion of soil seed bank was composed of viable seeds of annual species. Kropac (1966), Roberts and Stokes (1966), Sarkany (1975), Lockett and Roberts (1976), Leguizamon and Cruz (1980) and Roberts (1981) have also reported that the annual weeds are the main contributors to the seed bank in soil. They also attributed abundance of annuals in the weed flora to the composition of soil seed bank.

At high altitude, all the crop fields except maize, under 'jhum' and terrace were dominated by *S. arvensis, P. alatum* and *G. ciliata*, which together shared more than 70% dominance. In maize field however, *S. arvensis* and *P. alatum* were dominant in 'jhum' and *E. indica* and *D. adscendens* in terrace. At low altitude on the other hand, dominance was shared by many species and three species viz., *G. ciliata, E. sonchifolia* and *R. pilosa* could be identified as dominants, which together shared *ca* 30-35% dominance. The peak density and IVI of dominant species were much higher at the high altitude as compared to the low altitude site and the values were higher in 'jhum' than terrace fields. The species, whose dominance markedly varied in 'jhum' and terrace fields were *S. arvensis, P. alatum* and *G. ciliata*. Their performance was mainly responsible for the differences in the community characteristics in the 'jhum' and terrace fields. Such a differential response of weed species in the two fields could be due to microenvironmental conditions within the crop-weed community and competition for essential growth resources. *S. arvensis*, which prefers soil of low pH (Schamaiifuss 1935, Streibig *et al.* 1984, Andreasen *et al.* 1991), was dominant in 'jhum' fields at high altitude, where soil was relatively more acidic (pH 5.1) than the terrace fields (pH 5.6). *E. sonchifolia* and *R. pilosa* seemed to be better adopted to high temperature regimes and grew well at low altitude where mean temperature was relatively higher than the high altitude site. This is further confirmed by the fact that both the species were relatively more abundant in summer crop (IVI for *E. sonchifolia* 27.6, and for *R. pilosa* 27.4 in maize crop) than in the winter crop (IVI for *E. sonchifolia* 26.8 and for *R. pilosa* 5.9 in radish crop).

Species diversity was higher in terrace than 'jhum' fields (Fig. 11.1). Better soil management which helps emergence of seedlings from buried viable seed population and their subsequent growth appear to be the main reasons for higher species diversity in the terrace fields. Thus the species composition and their overall dominance pattern in different crop fields was influenced by composition of soil seed bank, seasonal nature of the buried seed population, differences in temperature and rainfall, soil texture and moisture that varied in 'jhum' and terrace field at the two altitude. Similar reasons were assigned for the site-specific variation in weed community by Simpson (1978), Karssen (1982) and Post (1988). Apart from these reasons,

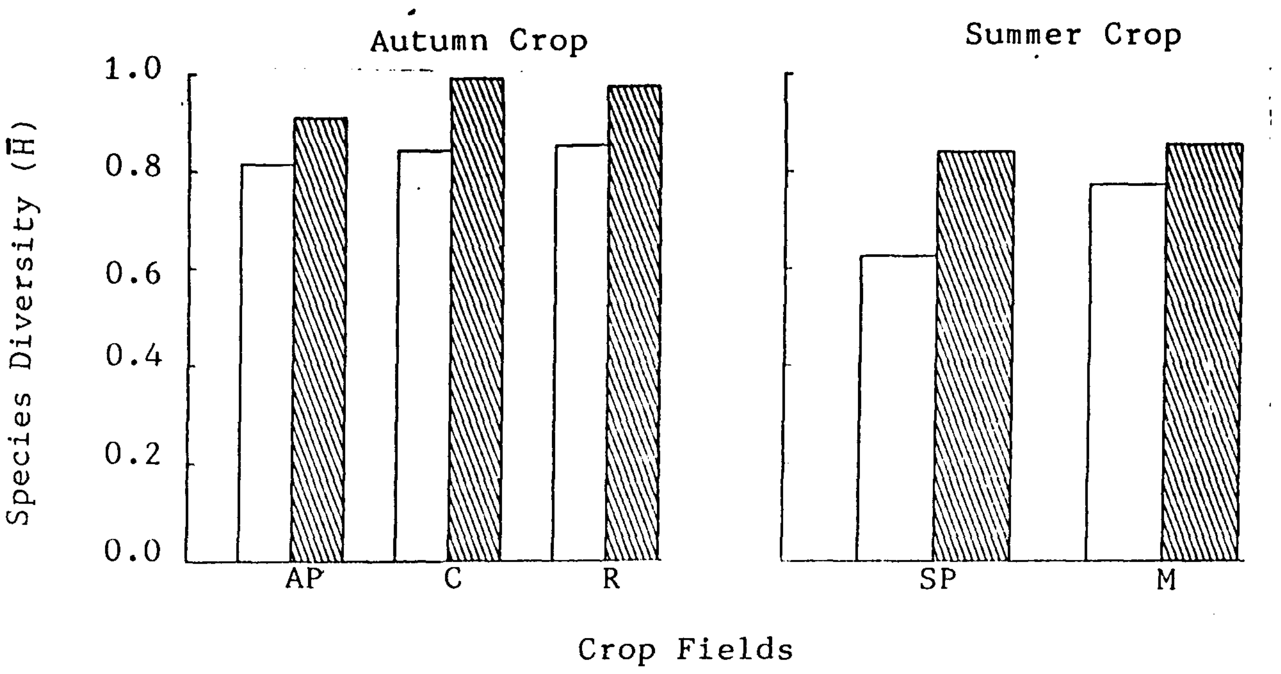

Fig. 11.1. Species diversity of weeds in different crop fields viz., autumn potato (AP), cauliflower (C), radish (R), summer potato (SP), and maize (M) under 'jhum' and terrace cultivation at Upper Shillong.

application of fertilizer and herbicide also affect the composition of weed community in the crop fields (Thomas and Ivany 1990, Andreasen *et al.* 1991).

Microclimate not only affects crop growth, but also influences weeds, pests and pathogens which are often associated with the crop plants. The role of some of the microclimatic and edaphic variables on emergence, population dynamics and growth of weeds have been analysed in this study. In all the fields, interception of photosynthetically active radiation (PAR) by the crop-weed canopy increased up to the age of 60 days, and then declined until harvest. Interception of radiation by the canopy varied between 56-68% in 'jhum' and 36-56% in terrace fields. Greater interception in the former occurred due to higher plant population density. Another factor which influenced the light environment in the crop fields was canopy architecture of the crops, for instance, minimum (36-57%) light interception occurred in the maize field and maximum 53-68% in the potato field. The influence of plant density was also seen on soil moisture, which was lower (16.9%) in 'jhum' having an average density of 3014 plants/m^2 than the terrace field (18.5%) with a mean density of 1541 plants/m^2. Low soil moisture in the field having high plant population density could be the result of greater transpiration losses. Altitudinal difference in soil moisture i.e., relatively higher value at low altitude (23.5% at low altitude and 21.4% at high altitude during the period of peak rainfall) despite low rainfall, seems to be related to the texture of the soil, which at low altitude site was a clay loam and at high altitude a sandy loam. Higher soil temperature at Barapani was related to air temperature which was higher throughout the year at this site. As expected, seasonality in soil temperature was also distinct here.

The importance of microenvironmental factors in weed seedling emergence was clearly evident from the significant partial correlation coefficients between PAR, relative humidity, soil moisture, soil temperature and seedling emergence of different weed species. Although all of them significantly affected seedling recruitment, their relative importance varied from species to species. The importance of these factors on seedling emergence of various other species has been discussed by Thurston and Phillipson (1976), Baskin and Baskin (1977, 1988, 1989, 1990), Fenner (1980), Rai (1987), Eddleman and Romo (1988), Egley (1990) and Gonzalez-Anduzar and Fernandez-Quintanilla (1991).

The population behaviour of dominant weeds as well as the dynamics of total weeds were studied in detail considering their emergence, recruitment and survival pattern in relation to the type of cultivational practice and altitudinal variation. Weed seedlings appeared within 10 days of crop sowing and three cohorts of seedlings emerged until 45 days. Their percentage emergence varied significantly between altitude, but the difference between 'jhum' and terrace was insignificant.
Generally emergence percentage decreased in successive cohorts,

which is in conformity with the findings of Rai and Tripathi (1984), Ballare *et al.* (1987) and Pandey and Dubey (1989). They have attributed it to the depletion of germinable fraction of seeds in soil. This may be true in this case as well. Apart from this, microenvironmental conditions also influenced seedling emergence as discussed above.

Survivorship curves of *S. arvensis, P. alatum, G. ciliata, E. sonchifolia* and *R. pilosa* were similar in different crop fields. The first two cohorts exhibited high juvenile mortality and their survivorship curves were similar to Deevey's type III curve. The third cohort on the other hand, was characterised by a constant rate of mortality throughout its life and the survivorship curve was similar to Deevey's type II curve. High juvenile mortality indicates pioneer nature of the species which are usually successful on disturbed habitats (Harper 1965) and are characterised by low juvenile survival. Constantly high mortality in the third cohort may be attributed to keen resource competition with early recruited cohort of different weed species as well as with the crop plants. This conforms the conclusion drawn by a number of workers that early emerging cohorts have competitive advantage over late emerging cohorts and competition adversely affected their recruitment and both vegetative and reproductive growth (Sarukhan and Harper 1973, Hawthorn and Cavers 1976, Cook 1979, Gross 1980, Weiss 1981, Kelly 1989a, Pandey and Dubey 1989, Misra *et al.* 1992). This might also be the reason for relatively longer half-life of the early recruited cohorts than those recruited late in the population and community. The variation in half-lives of seedling cohorts between 'jhum' and terrace was significant and terrace fields had higher half-lives than 'jhum'. This might be due to the differences in the management practices adopted in two fields.

Analysis of weed population flux in different crop fields under 'jhum' and terrace cultivation shows that seedling recruitment rate (K) was higher in terrace than 'jhum' fields, but seedling population density was lower in terrace than 'jhum'. Frequent ploughing, which helps in seedling emergence by breaking the dormancy of the viable buried seed population hitherto under the state of enforced dormancy might be responsible for the higher recruitment rate in the terrace field. Higher fecundity rate in the terrace than in 'jhum' was probably due to lower competition stress in the former, where the density of adult plants was lower than the latter. The main cause of annual rate of increase in buried seed population in 'jhum' was greater seed input into the soil, since in the traditional method of weed control the uprooted weeds, some of which bearing a large number of seeds are buried in the field. Conversely, better weed control by regularly removing the uprooted weeds from the field and use of herbicides in the terrace fields were responsible for reduction in weed seed input and consequently causing decline in the rate of increase in weed seed population in the soil seed bank. Since the rate of seedling recruitment in 'jhum' was lower than terrace, checking of weed seed input into soil through adoption of efficient weed control measures may reduce weed population growth in 'jhum' field. Weeding between 30 and 45 days, when majority of plants are at their peak vegetative growth stage will be helpful in reducing weed seed input into the soil. Discontinuance of the prevalent practice of *in situ* burial of uprooted mature weed plants will greatly reduced the weed problem in 'jhum' fields.

Dry matter production of weeds in different crops was highly variable and it was significantly influenced by the type of species, crop and cultivation practice. Except in a few crop fields, biomass of weeds declined after attaining peak which occurred between 70-85 days after crop sowing depending on crop and weed species. Dry matter production by weeds in general was directly proportional to their population density. Lower dry matter production by the cohort III than cohort I and II clearly reveals that like survival, the growth of the late recruited cohorts was also adversely affected by competition. PAR and soil moisture significantly influenced dry matter production of weeds. At low altitude, soil moisture was more influential than PAR while at high altitude PAR was more important than the soil moisture. Species-specific variation in growth behaviour was evident from the fact that for some species PAR, while for others soil moisture was more important for the dry matter production.

The significant reduction in crop yield due to weed infestation in all the crop fields was in conformity with the results of Wells (1979), Spitters (1983), Cousens *et al.* (1985), Hakannson (1988) and Wilson and Wright (1990), who established a negative linear relationship between crop yield and weed density. The reduction in crop yield was more in 'jhum'(20-48%) than terrace (19-34%).

The foregoing discussion shows that the pattern of seedling emergence, survivorship and half-lives of dominant weed species as well as dynamics of total weed community was broadly similar in 'jhum' and terrace agroecosystems. But they differed from one another in respect of dominance distribution pattern in weed community, rates of seedling emergence and fecundity, population density of recruited seedlings and buried weed seed population in soil. Some of these population attributes were strongly influenced by altitudinal variation and microenvironmental conditions within the crop fields. Nevertheless, since the dominant weeds in different crop fields behaved more or less in a similar fashion, a single model of weed control measure may be applicable both in 'jhum' and terrace agroecosystems of Meghalaya.

Summary

The crop fields under 'jhum' (slash and burn agriculture) and terrace cultivation in north-eastern India are heavily infested with a large variety of native and exotic weeds due to favourable climatic conditions of the region. In absence of any effective weed control measure, weeds pose a serious threat to the crop growth and yield under both the systems of cultivation. Since an understanding of their population and growth behaviour is important both from agronomic and ecological view points, a study of the population behaviour of the dominant weeds in different fields under 'jhum' and terrace agroecosystems was undertaken. The study was carried out during 1988-1990 in the 'jhum' and terrace fields located at Upper Shillong (high altitude site) and in terrace fields at Barapani (low altitude site) near Shillong. At high altitude site, the experimental fields of Central Potato Research Station, representing the terrace system and nearby crop fields of a farmer under 'jhum' system were selected for the study. At low altitude the study was conducted in the Research Complex of Indian Council of Agricultural Research for North-Eastern Hill Region. The study was carried out in potato, maize, radish and cauliflower crops at Upper Shillong and in maize, radish, groundnut and linseed crops at Barapani.

The composition of weed flora varied between 'jhum' and terrace fields and also between high and low altitudes. The altitudinal variation in composition was more prominent than the difference between 'jhum' and terrace fields. At high altitude, the number of weeds was much lower (16) than the low altitude fields (39). In 'jhum', the number of weeds identified in potato, maize, radish and cauliflower fields was 14, 15, 14 and 14, respectively, while the corresponding number in terrace was 14, 16, 16 and 15, respectively. At low altitude, in both maize and groundnut fields 39 species were recorded, while 31 and 22 weed species were identified in radish and linseed fields, respectively. The number of annual species was more than the perennials in all the fields at both the altitudes but the relative proportion of perennials was more at the low altitude.

At Upper Shillong, almost all fields under 'jhum' and terrace were dominated by *S. arvensis, P. alatum* and *G. ciliata*, which together shared more than 70% dominance. At Barapani on the other hand, dominance was shared by many species and three dominant species *E. sonchifolia, G. ciliata* and *R. pilosa*, selected for study shared *ca* 30-35% dominance. Peak density and mean IVI values of dominant weeds were always higher at Upper Shillong than Barapani and 'jhum' fields showed higher values than the terrace fields. The abundance of individual species varied from one crop field to another. Species diversity was higher in terrace fields than in 'jhum'.

In order to explain the population behaviour of the dominant weeds in different crop fields, four microenvironmental variables viz. photosynthetically active radiation (PAR), relative humidity, soil moisture and soil temperature were regularly measured at fortnightly interval during the study period. PAR was consistently higher at high altitude throughout the year. In all the crop fields, light interception by the crop-weed canopy increased up to 60 days of the crop age and then declined until harvest. Interception was significantly higher (56-68%) in 'jhum' than terrace fields (36-58%). Cropwise interception was 53-68% in potato, 50-65% in cauliflower, 49-65% in radish and 36-57% in maize field. Greater light interception in the 'jhum' fields was attributed to the plant population density, which was about two fold higher in 'jhum' than terrace fields. Seasonal variation in relative humidity was prominent at both the sites; the values were higher in rainy season than autumn and winter. Altitudinal difference in soil moisture i.e., relatively higher value at low altitude (23.5% at Barapani vs. 21.4% at Upper Shillong during peak rainfall period) despite low rainfall seemed to be related to soil texture, which was clay loam at Barapani and sandy loam at Upper Shillong. Higher mean soil temperature at Barapani (21.5°C) than Upper Shillong (17.5°C) was related to air temperature which was higher throughout the year at the former site.

In most of the crop fields weed seedlings were recruited in three distinct cohorts. The first cohort was recruited within 10 days of crop sowing, second and third cohorts emerged after about 15 and 45 days of emergence of the first cohort. In general, the emergence percentage decreased in successive cohorts, the value was much higher in the first cohort than the second and third cohorts. Emergence percentage in different cohorts of the dominant weed species varied significantly between the two altitudes among different crops, but the variation between 'jhum' and terrace was insignificant. The cohortwise seedling emergence was significantly influenced by PAR, relative humidity, soil moisture and soil temperature. The relative importance of these factors, however, varied from crop to crop and also from species to species.

The mean population density of total recruited seedlings of all the weed species, was significantly higher in 'jhum' (3014 plants/m^2) than the terrace fields (1541 plants/m^2) at high altitude. Low altitude site had much lower mean density (677 plants/m^2). The density of *G. ciliata* was higher in terrace, while that of *P. alatum* and *S. arvensis* was higher in 'jhum' fields. *G. ciliata* which was present at both the altitudes showed higher population density at the high altitude.

The survivorship curves of *P. alatum, S. arvensis, G. ciliata, E. sonchifolia* and *R. pilosa* were similar. The first and second seedling cohorts exhibited high juvenile mortality, while the third cohort was characterised by constant rate of mortality throughout the life. Half-lives of the early recruiting cohorts were significantly higher than the late recruiting cohorts.

In order to characterise the weed population flux in different crop fields, seedling recruitment (K), survivorship (p) and fecundity (F) rates and rate of increase in the viable buried weed seed population in soil (λ) were computed. The seedling recruitment rate ranged between 6-44% in terrace and 6-31% in 'jhum' depending on the crop. The survivorship rate ranged between 21-50% in 'jhum' and 25-47% in terrace. The fecundity rate was more in terrace than 'jhum' and was related to the population density of adult plants which was two fold higher in the latter than the former. The chief cause of higher annual rate of increase in viable buried seed population in 'jhum' than terrace was the traditional method of weed control in 'jhum' wherein the uprooted weeds, some of which bearing a large number of seeds are buried in the field it self. On the other hand, removal of uprooted weeds from the field and use of herbicides were responsible for the reduction in the total buried weed seed population in the terrace fields.

The growth of weeds was assessed on the basis of dry matter production, which varied between the two agroecosystems. Total average dry matter production of weeds was 1012 $g.m^{-2}$ in 'jhum' fields and 790 $g.m^{-2}$in terrace fields. At Upper Shillong major portions of dry matter production (66-78%) was contributed by *S. arvensis, P. alatum* and *G. ciliata* while that at Barapani (30-

39%) was contributed by *E. sonchifolia, G. ciliata* and *R. pilosa*. In all the species, first cohort contributed about 75%, while the share of second and third cohort was 20% and 5%, respectively. This clearly indicates that along with survival, growth of the late emerging cohorts was also adversely affected by the early recruited cohorts of different weed species as well as by the established crop plants in the field. PAR and soil moisture were the two most important environmental variables, which influenced the dry matter yield of different weeds. At low altitude, however, influence of soil moisture was stronger than PAR. The reduction in crop yield was more in 'jhum' (20-48%) than terrace fields (19-34%).

In a nutshell, the seedling emergence, survivorship and half-lives of dominant weeds as well as the dynamics of total weed population was broadly similar in 'jhum' and terrace agroecosystems. However, the dominance distribution pattern in the weed community, rates of seedling emergence and fecundity, population density of recruited seedlings and buried weed seed populations were different in the two agroecosystems and were also influenced by the altitudinal variation in the study sites.

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