STUDIES ON POPULATION DYNAMICS AND GROWTH OF A FEW WEEDS AS INFLUENCED BY DIFFERENT FARMING SYSTEMS

By

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IN MEMORY

OF MY

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CHAPTER I

GENERAL INTRODUCTION

Agriculture throughout the world is still man's single most important activity and is still the only reliable source of food and an important source of fibres and other products (Haines, 1982). With the increase in the population pressure the growing demand for food could not be met by the old traditional agricultural system and with this growing perception of the failure of mainstream agricultural research, the evolution of Farming Systems Research took place (Merrill Sands, 1986). Okigbo (1975) defines a farming system as a specific agricultural enterprise satisfying well defined objectives and involving various kinds of plant and/or animal inputs together with the practices of operations with which they are managed in a given environmental setting. Merrill Sands (1986) defines a farming system as a unique and reasonably stable arrangement of farming practices in response to physical, biological and socio-economic environments and in accordance with the household's goals, preferences and resources.

Diverse activities collectively described as Farming Systems Research (FSR) have become a prominent feature of the work of the International Agricultural Research Centres (IARCs) and also of many National Agricultural Research Systems (NARSs) in the past 10-15 years (Simmonds, 1986).

The evolution of Farming Systems Research dates back to the post "green revolution" era (Merrill Sands, 1982). The farming systems in the tropics and sub-tropics have evolved in response to particular agro-climatic, ecological and socio-economic conditions (Harwood, 1979; Hieldebrand, 1981; Hart, 1982a; Norman *et al.*, 1982; Collinson, 1983).

Pioneering works on FSR were of CIMMYT group in Mexico by Perrin *et al.* (1976) and Byerlee and Collinson (1980); Caqueza Project in Columbia (1971-75) by Zandstra *et al.* (1979); IRRI group in the Philippines by Gilbert *et al.* (1980) and Zandstra *et al.* (1981); in West Africa by Norman *et al.* (1982) and in East Africa by Collinson (1984). However, these works were mainly based on concepts and methodology for technology developments aimed at improving agricultural production.

In recent years, there has been considerable increase in agricultural activities in north-eastern region of India. Of the different land use practices prevalent in the region, slash and burn agriculture locally known as 'Jhum' is quite common. More than 80% of the total land area is under jhum cultivation. The practice consists of cutting down the forest at various stages of development on the hill slopes, allowing the slash to dry for a few months and burning it before cropping. Mixed cropping is a common feature of jhum cultivation. The jhum is carried out even on the hill slope of 20-40°.

Terrace cultivation has been introduced in the recent past as an alternative to jhum. This system is similar to jhum cultivation so far as mixed cropping is concerned, but here bench terraced lands are prepared for cultivation. In addition to this, valley cultivation of rice is also carried out on flat lands between mountain slopes. Valley land cultivation consists largely of rice monoculture and is a sedentary and settled form of agriculture.

The ICAR Research Complex for North-Eastern Hill region, Shillong has initiated a long term project on Farming Systems Researches, at its farm at Barapani. The Barapani farm of the ICAR is situated 22 Km north of Shillong, the capital of Meghalaya. The Farming Systems Research Project of the ICAR was initiated in 1984. It comprised evaluation of single and mixed land use systems by bringing 8 micro watersheds under different farming systems. These farming systems are livestock-based farming system, forestry, agro-forestry, agriculture system, agri-horti-silvi pastoral system, horticulture system, control (natural fallow) and jhum fallow. A large number of weedy species grow luxuriantly on these watersheds. It is an established fact that the weeds modify or suppress the growth of crop plants as a result of competition for nutrients, water and light etc. and cause tremendous loss to the crop yield. On account of their economic importance, the studies on weeds, especially the aspects directly related to their control measures, have engaged the attention of agricultural scientists during the past several decades.

'The studies on population dynamics and growth of exotic weeds in relation to burning, age of jhum fallows, associated vegetation and varied density, and light and soil conditions indicate that they are particularly successful on disturbed habitats. These weeds are very aggressive and spread fast posing serious threat to certain useful elements of native flora. Further, the disturbed habitats are being created at a much faster pace which brings the impending problems connected with rapid increase in populations of these weeds into sharp focus. Therefore, there is an urgent need to undertake intensive studies on exotic weeds with particular reference to their population dynamics, analysis of factors contributing to their remarkable success in the region, niche divergence, and possible impact on the native flora' (Tripathi, 1985).

A plant is assigned as a weed not only on the basis of its characteristics but its relative position with reference to other plants and man. Even a plant that is useful, is a weed when it grows where it is not wanted. Thus, all plant species may at one time or another, be classified as weeds. The intensive system of land management practices by man break down the natural equilibrium of plant communities and new habitats are continually created which offer fresh opportunities for colonization of unwanted plants and these frequently become serious weeds. Since weeds have unique characteristics for adaptation, they thrive well in any environment.

Weeds assume importance and pose problems because of their nuisance value (Tripathi, 1977). The significant losses to crop yield caused by these unsown and undesirable plant species reported by various workers justify worldwide efforts to control them. Although the economic importance and nuisance value of weeds in agriculture have resulted in numerous studies, the realization that they are also excellent material for addressing basic evolutionary and ecological issues have stimulated further interest in the study of weeds during recent years (Tripathi, 1985). Tripathi (1977) analysed the possible consequences of a complete eradication of the weed flora from agro-ecosystems. Mishra & Ramakrishnan (1984) suggested that the non-weed concept where weeds have a useful role to play, is an essential ingredient of traditional agro-ecosystems in different parts of the world and in the north-eastern India.

Each constituent species besides being characterised by its own ecological amplitude has a particular relationship with the environment and the associated species. Therefore, species composition of a given community may depend on the reaction of the species to the prevailing non-living and living environment of the system.

Species diversity and phytosociology of the Indian forest and grassland communities have been studied by several workers e.g., Pandeya (1952), Ramam (1966), Misra (1972), Choudhury (1974), Dagar & Mall (1980), Jain (1986), Khan et al. (1986), Singh & Verma (1986), Bihari & Lal (1989) and Rao et al. (1990). However, the agro-ecosystems have not been extensively analysed. Some of the earlier works on agricultural systems are those of Majumdar (1962), Roberts (1963), Tripathi (1964), Tripathi & Misra (1971), Patro (1971), Ambasht & Chakhaiyar (1979), Ayeni et al. (1984). Recent works relating to weed communities in different agricultural systems are those of Thomas (1985), Chancellor (1986), McIntyre et al. (1988), Pujadas Salva (1988), Wheeler (1988), Yeaton (1988), Hill et al. (1989), Marshall (1989), Saavedra et al. (1989) and Thompson & Shay (1989). The dynamics of weed communities can be satisfactorily quantified by determining various phytosociological attributes such as frequency, density and importance value indices of the constituent species at regular intervals. This approach has been adopted in the present study as well.

Since the introduction of the terms 'ecosystem' (Tansley, 1935) and 'biogeocoenose' (Sukachev, 1945) the ecologists have been actively engaged in studying the structural and functional aspects of various natural and man-modified ecosystems. Productivity being an important attribute of community function (Odum, 1960), has attracted much attention in recent years.

Studies on productivity of a number of ecosystems have been carried out by various workers (e.g. Singh & Yadava, 1974; Dwivedi, 1978; Falk, 1980; Ayeni et al., 1984; Khokhar, 1985; and Karunaichamy & Paliwal, 1989). Although some of these studies pertain to agro-ecosystems there is conspicuous lack of intensive and indepth analysis of productivity of weed communities in different farming systems.

Weedy species, in general, have a high biotic potential and their populations, therefore, tend to grow fast in spite of the fact that efforts are always made to keep them under control. Among the factors and environmental stresses that regulate the size of weed populations (e.g. resource competition, diseases, insect herbivory etc), weeding is the most important.

In the north-east, variations in rainfall, temperature and altitude create a variety of ecological habitats to promote invasion and colonization of a large number of weeds. Considerable studies have been made recently on weed-crop interference where competitive influences have been assessed not merely as an agronomic problem but more as an ecological problem (Harper & Gajic, 1961; Tripathi, 1967; 68 and 69; Ramakrishnan & Kumar, 1971; Roberts & Potter, 1980; Sen, 1981; Tripathi, 1985; Kushwaha, 1985; Marshall, 1989 and Saavedra et al., 1989).

The dynamics and growth of plant populations are generally studied by continuously monitoring the fate of individuals at short and regular intervals. Population dynamics of weedy species have been studied by several workers (e.g. Harper & White, 1971; Sarukhan & Harper, 1973; Hawthorn & Cavers, 1976; Mack, 1976; Watkinson & Harper, 1978; Kushwaha Ramakrishnan & Tripathi, 1981; Rai & Tripathi, 1984; Kotanen & Jefferies, 1987 and Pandey & Dubey, 1989). The mortality and plasticity of plant populations in pure and mixed stands have also been analysed by several workers (e.g. De Wit et al., 1966; Tripathi & Harper, 1973; Bazzaz & Harper, 1976; Tripathi & Gupta, 1980; Berendse, 1981; Ayeni et al., 1984; Ibrahim, 1984 and Beckett, 1988).

The survivorship and dynamics of several perennial grass and herb populations from different geographic regions have been studied by a number of workers (e.g. Williams, 1970; Antonovics, 1972; Sarukhan & Harper, 1973; Hawthorn & Cavers, 1976; Johnson & Thomas, 1978; Bishop *et al.*, 1978; Kushwaha *et al.*, 1981; Law, 1981; Yadav & Tripathi, 1981; Silvertown & Dickie, 1981; Schellner *et al.*, 1982; Zimmerman & Weiss, 1984; Tripathi, 1985; Fernandez-Quintanilla *et al.*, 1986; Tripathi & Yadav, 1987; Bradstock & Myerscough, 1988; and Pandey & Dubey, 1989). The population studies on biennials, however, have not engaged much attention although a few studies (Holt, 1972; Werner, 1977; and Klemow & Raynal, 1981) made on such species are both intensive and quite interesting. In view of the fact that population studies of annual plant species pose relatively lesser practical problems (Harper & White, 1974), extensive researches have been carried out on dynamics and regulation of their populations (Sharitz & McCormick, 1973; Watkinson & Harper, 1978; Regehr & Bazzaz, 1979; Weiss, 1981; Rai & Tripathi, 1984; Kelly, 1989 and Pandey & Dubey, 1989). Weiss (1981) studied population dynamics of *Emex australis* and reported heavy mortality during seedling stage especially in dense populations. The increase in the density may also reduce the reproductive potential of the species populations as reported by several workers (Palmblad, 1968a; Tripathi, 1968; Myerscough & Marshall, 1973; Williams & Ingber, 1977;

Tripathi & Gupta, 1980; Clay & Shaw, 1981; Trivedi & Tripathi, 1982a; Rai & Tripathi, 1982a).

The resource competition offered by the associated vegetation exercises a strong regulatory influence on plant populations (Harper & Gajic, 1961; Sagar, 1970; Putwain & Harper, 1970; Dwivedi & Tripathi, 1980; Yadav & Tripathi, 1981; Rai & Tripathi, 1985). Certain plant species have also been reported to inhibit the growth of neighbouring plants by producing allelochemics (Rice, 1974; 1979;Friedman *et al*., 1977; Hussain & Godoon, 1981; Rai & Tripathi, 1982b).

The success of an organism in a given environment is often determined by the allocation of limited available resources to diverse activities such as maintenance, growth and reproduction (Abrahamson & Gadgil, 1973). Plants respond to environmental variables and stresses in a complex manner, and these responses find expression in the rate as well as extent of growth. The growth of both weeds and crop plants has been analysed in relation to light & temperature and nutrients and in a variety of agricultural situations. Eagles (1973), Hughes (1973), Boston (1986), Chapin (1986), Petterson *et al*. (1988) and Harrington *et al*. (1989) carried out growth analysis in relation to light and temperature. The plant growth has been analysed in relation to nutrients by several workers (e.g. Clarkson, 1967; Boston, 1986; Chapin, 1986; Shipley & Keddy, 1988; and Konings *et al.*, 1989). Eze (1973), Bremester & Barnes (1981), Saxena & Ramakrishnan (1983), Banyikwa & Rulangaranga (1985), Bourdot *et al.* (1985), Swamy & Ramakrishnan (1988) and several others have analysed plant growth in agricultural situations.

Harper & Ogden (1970) studied the biomass allocation pattern in *Senecio vulgaris* expressing the dry matter stored in each organ type as a percentage of total biomass accumulated by the plant during its life time. They emphasized the significance of such studies in identification of distinct ecological strategies. Biomass allocation pattern has been extensively studied for gaining insight into the reproductive strategies of plants by a number of workers such as Harper & Ogden (1970), Tripathi & Harper (1973), Hickman (1977), Abrahamson (1979), Trivedi & Tripathi (1982), Bazzaz *et al.* (1987), Bittman & Simpson (1987).

The present investigation primarily aims at analysing the population dynamics and growth of two species of *Ageratum* (*A. conyzoides* and *A. houstonianum*) and *Bidens pilosa* as related to conditions prevailing in various watersheds. The study also examines the changes in structure of the weed communities and analyses the growth behaviour and dry matter allocation pattern of the above mentioned species under different farming systems.

Ageratum conyzoides L., *A. houstonianum* Mill. and *Bidens pilosa* L. occur abundantly in the local agricultural ecosystems. They also grow abundantly in roadsides, forests, wastelands, and disturbed places. Out of these three annual weeds, *A. conyzoides* and *A. houstonianum* are sympatric species and have synchronous growth. The growing period of *B. pilosa* also partly overlaps with that of *Ageratum* species. All of them are present in the crop fields together for most part of their life cycle. Thus, such species form an interesting and excellent group for population dynamics studies. *A. conyzoides* is reported to be a weed in 36 different crops in 46 different countries, whereas *B. pilosa* is a weed in 31 crops in more than 40 countries (Holm *et al*., 1977).

The watersheds under different farming systems are subjected to different cropping practices. The agricultural operations play a significant role not only in maintaining the structure of different farming systems, but may even decide the fate and success of the species composing the weed communities in different farming systems. Considering the above facts, the present study on the population dynamics and growth of *A. conyzoides*, *A. houstonianum* and *B. pilosa* has been made to cover the following aspects -

1. Weed community composition in relation to different farming systems.

2. Biomass and productivity of weeds and crops as affected by different farming systems.
3. Influence of farming systems on the population dynamics of A. conyzoides and A. houstonianum.
4. Influence of farming systems on the population dynamics of B. pilosa.
5. Dry matter allocation and growth of the three weeds as related to various farming systems.

The experimental data on the above mentioned aspects have been presented in Chapter IV-VIII. These chapters are preceded by the 'General Introduction' (present chapter), which sets out the objectives of the thesis. Chapter II (Review of Literature) presents the state-of-art of the subject. A brief description of climate, soil and vegetation of the study area and biology and distribution of the three species are provided in Chapter III. The result of the individual chapters have been discussed separately in each chapter, however, an attempt has been made to integrate the results and discussions contained in various chapters under 'General Discussion'.

CHAPTER II

REVIEW OF LITERATURE

Vegetation constitutes the most important feature of land on which the existence of all animal life including man depends. The fact that vegetation is a dynamic entity with a progressive trend was realised at the turn of twentieth century (Warming, 1896; Cowles, 1901). Since then changes in structure and composition of vegetation with time has been a venerable and central concept in ecological thought (Clements, 1916; Tansley, 1939; Whittaker, 1953).

COMMUNITY COMPOSITION

Floristic composition is considered as one of the major distinguishing characters of a community (Danseareau, 1960). Studies on species diversity, frequency and density of the component species in the Indian forest and grassland communities have been made by Pandeya (1954), Bharucha & Shankarnarayan (1958), Ramam (1966), Singh & Misra (1969), Mishra (1972), Choudhury (1974), Shankar *et al*. (1975), Dagar & Mall (1980), Jain (1986), Singh & Verma (1986), Bihari & Lal (1989). However, the weed flora has not been so extensively studied.

Some of the early works on species composition on agricultural systems are those of Brenchley (1920), Singh *et al*. (1937), Thakur (1954), Majumdar (1962), Roberts

(1963), Tripathi (1964), Tripathi & Misra (1971) and Patro (1971). Recently Hernandez-Bermejo et al. (1984) studied the flora of irrigated crops. The studies of weed flora in orchards and horticultural crops have been carried out by Pujadas Salva & Hernandez-Bermejo (1986), that of cereals by Montegut (1974), of rape by Garcia Torres & Vazquez (1979), olive groves by Garcia Torres et al. (1983). Roberts & Potter (1980) studied the emergence pattern of weed seedlings in relation to cultivation and rainfall and found that the species composition of the seedling populations varied with the time of year at which the soil was disturbed and in each year there were periods when lack of soil moisture restricted emergence.

Pujadas Salva & Hernandez-Bermejo (1988) analysed the floristic composition and agricultural importance of weeds in Southern Spain and compared the richness of flora in the different ecosystems with that of other countries. Marshall (1989) found that bout 30% of the species recorded in the field boundary were found also at a varying distance into the crop. Hill et al. (1989) found the greatest abundance of summer annuals in spring sown faba beans and oats and after one cycle of the rotation weed cover in faba beans and winter wheat increased by more than 50%. Perennials increased in both crops as did weeds having life cycles similar to their respective crops.

BIOMASS AND PRODUCTIVITY

Primary producers in an ecosystem convert the solar energy into organic matter and accumulate it after respiratory utilization in the above and below ground parts. The accumulated organic matter, or the standing crop of the biomass serves as an important structural characteristic of the ecosystem (Golley, 1965; Odum, 1975) and regulates the overall energy flow and nutrient circulation within the ecosystem.

Net primary production has been defined as the photosynthesis of all the plants in an ecosystem in excess of respiratory processes (Pearson, 1965). Odum (1960) considers it to be apparent photosynthesis or total photosynthesis minus plant respiration. In the measurement of primary production through the 'harvest method' the apparent photosynthesis is taken into consideration. According to Ovington et al. (1963) annual productivity is not synonymous with plant biomass nor with gross changes in plant biomass from year to year, because of the fact that a plant community is normally composed of many different species, and individuals of the same species may not necessarily attain their greatest weights at the time of maximum community biomass. The primary productivity of the vegetation provides the basic energy for functioning of all the biotic components of the ecosystem (Pradhan & Dash, 1984).

Some of the well known studies on productivity of various ecosystems have been carried out by Ovington, Heitkamp & Lawrence (1963), Murphy (1975), Kummerow & Ellis (1984), Palmer (1988) and Liang *et al.* (1989). However, these do not relate to the agro-ecosystems.

In India, primary productivity and energetics of tropical ecosystems have been studied by Professor R. Misra and his associates. Plant biomass and productivity of grasslands have been studied by Misra & Gopal (1968), Singh & Yadava (1974), Sah *et al.* (1985), Khokhar (1985), Tiwari (1986), Dagar (1987), Pandya & Sidha (1987), Ramakrishnan & Ram (1988), Sah & Ram (1989) and many others.

Ovington *et al.* (1963) measured the plant biomass and productivity of prairie, savanna, oakwood and maize field ecosystems in central Minnesota and found that the weights of living vegetation in savanna and oakwood were much greater than those of the prairie or maize field.

Lal & Ambasht (1979) studied the effect of light intensity on biomass and productivity of *Scoparia dulcis* and found that plants showed highest biomass and productivity values in open sunlight than in partial or deep shade. Falk (1980) studied the annual net primary productivity of two lawns and compared with that of managed grasses such as maize and wheat. They reported that the NPP of lawns is comparable to that of managed grasses.

Ayeni _et al_. (1984) studied the weed interference in maize, cowpea and maize/cowpea intercrop and reported that maize monoculture produced the highest food energy yield. Khokhar (1985) reported that with the increase in age both shoot and root biomass and NPP of maize increased steadily and the maximum biomass was attained at 90 days. Pradhan & Dash (1984) studied the seasonal variation in plant biomass and NPP of a hill ecosystem at Sambalpur.

Dagar & Dagar (1986) studied the effect of density, time of emergence and removal of _Melilotus indica_ on biomass and grain yield of wheat. They reported that even 40 crop plants/m^2 gave more biomass and grain yield than 80 crop plants/m^2 in presence of competition with just 20 weed plants/m^2.

Pandey & Singh (1987) while studying the structure and function of early successional communities of an abandoned crop field at Varanasi concluded that grasses by virtue of their higher productivity and biomass were dominant component of the community especially in the 3-year old fallow.

DEMOGRAPHY AND POPULATION DYNAMICS

A major task in population studies is to accurately estimate, describe and explain the changes in plant numbers of a particular species population in relation to time and environmental factors. The plasticity of plants under different environmental conditions and the vegetative mode of reproduction are the two major difficulties often met with in population census (Harper, 1967).

The population of a species colonising a habitat passes through different growth phases with the passage of time. Initially the population grows exponentially till the resources become limiting. Later on, if the birth and death rates become equal, the population size gets stabilised showing fluctuations around a mean value. The growth of the species populations, however brings about certain changes in the environment as well. The modified environment may prove to be unsuitable for the early colonisers and their populations may disappear due to increased mortality. How long the species will continue to grow on a given habitat, of course, 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 these fluctuations in population size is referred to as population dynamics, a term for the first time proposed by Elton (1933).

The plant populations consist of two level of population organisation as suggested by Harper & White (1974), one, the number of individuals per unit area (colonies) and the other, the number of shoots or leaves or auxillary buds per plant. The early seedling phase of a plant's life is generally considered the most risky and this risk is exaggerated due to increasing density of the same or another species. When individuals of a species are released into a favourable environment, their number increases rapidly at first and then stabilizes, thus implying that it is the population size which itself in some way regulates the rate of population growth (Harper and Gajic, 1961).

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

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

In most of the plant population studies the survivorship curves have been found to be Deevey type II which implies constant death risk throughout the life span of the population. However, Williams (1970), Rai & Tripathi (1984) and Pandey & Dubey (1989) observed Deevey type III survivorship curve in *Danthonia caespilosa*, *Galinsoga* spp. and *Parthenium hysterophorus*, respectively with heaviest mortality in the young stage. In contrast, Canfield (1957) observed Deevey type I survivorship curve with less risk of death in young and middle periods of age and high mortality risk in old age in *Trichache californica*, *Boutelova hirsuta* and *B. chondrosoides*.

A lot of work has been done showing juvenile mortality in seedling populations of several plant-species (Williams, 1970; Sarukhan & Harper, 1973; Sharitz & McCormick, 1973; Hett & Loucks, 1976; Bazzaz & Harper, 1976; Yadav & Tripathi, 1981; Silvertown & Dickie, 1981; Weiss, 1981; Law, 1981; Rai & Tripathi, 1984; and Pandey & Dubey, 1989). Sharitz & McCormick (1973) argued that heavy mortality during seedling establishment is common in colonizing species which produce large number of seeds. Mack (1976) and Watkinson & Harper (1978) have also reported the occurrence of type

II and III survivorship curves (Deevey, 1947) in species capable of producing large number of seeds in contrast to those which produce lesser number of seeds and exhibit type I survivorship curve.

Besides being affected by competition from the individuals of their kind, the plants also have to face the hardships caused by the members of other species that might grow in their immediate vicinity. A number of workers have shown the effect of interspecific competition on the growth of various plant species (Sagar, 1959; Sagar & Harper, 1961; Harper & McNaughton, 1962; Harper & Clatworthy, 1963; Cavers & Harper, 1967; Bergh, 1968; Palmblad, 1968; Marshall & Jain, 1969; Tripathi & Harper, 1973; Pradhan & Tripathi, 1981). The distribution and abundance of a species are profoundly influenced by the associated vegetation in the community (Putwain & Harper, 1970; Peters & Wilson, 1983 and Rai & Tripathi, 1984). Poor seedling establishment has been reported in established communities by Tamm (1956) and Cavers & Harper (1967). Putwain & Harper (1970) and Dwivedi & Tripathi (1980) found that amongst the associated species grasses exercise the greater regulatory influence compared to dicots. Sagar (1970) noticed increased vegetative and reproductive growth of Plantago lanceolata when the associated vegetation was removed. Established plant populations also affect the survival and growth of the newly recruited individuals (Friedman, 1971; Andel & Rozema, 1974; Gupta & Tripathi, 1979; Singh, 1980; Yadav & Tripathi, 1981; Rai & Tripathi, 1984). There are reports that the species arriving late in already established vegetation show very low densities and survivorship as compared to the species arriving at an early period (Tamm, 1956; Sagar & Harper, 1960; Cavers & Harper, 1967; Putwain, Machin & Harper, 1968; Hawthorn & Cavers, 1976; Weaver & Cavers, 1979; Weiss, 1981; Rai & Tripathi, 1984; Kataoka et al., 1989 and Pandey & Dubey, 1989).

The lower temperature of environment has also been considered to be effective in population regulation. For example, Symonides (1974) found a mortality peak in pure population of Spergula vernalis in dunes of Poland due to frost. Yadav & Tripathi (1981) and Rai & Tripathi (1984) reported a severe mortality during winter for both seedlings as well as adult populations of Eupatorium odoratum and Galinsoga spp. respectively. While working on population dynamics of Erigeron canadensis - a successional winter annual in Illinois, Regehr & Bazzaz (1979) reported 16 to 86% mortality due to frost heaving.

The study of seed dynamics is also important in understanding the population behaviour of a plant species. This aspect assumes special significance for the secondary successional and early colonising plant species where the seed population plays a major role in the regulation of their actively growing populations. The development of secondary vegetation in many communities depends upon the viable buried seed populations existing before the disturbances were caused (Oosting & Humphreys, 1940; Johnson, 1975; Archibold, 1979; Fernandez-Quintanilla et al., 1986). The rapid development of the secondary vegetation following disturbance is due to the buried seed populations, which become active with the release of competition stress. Hayashi & Numata (1971) observed that in the grassland dominated by Zoysia stand, the natural regeneration of the vegetation is mainly dependent upon the viable buried seed populations. Similarly, the weed populations in pastures and agricultural lands are also regulated to a great extent by their soil seed populations. Thompson & Grime (1979) suggested four types of soil seed banks and emphasized the role of seed population in soil in the regeneration of the vegetation. Seed input to the soil and seed losses from the soil, thus become an essential consideration in the study of plant populations.

The seed input to the soil seed pool depends upon the seed production by the growing plant populations every year and on the environmental factors which affect the number of seeds reaching the soil seed bank. A large fraction of total seeds produced by the vegetation is carried away by wind and water to distant places. Predation and grazing also affect the number of seeds entering the seed pool (Harper, 1957; Sarukhan, 1974; Keeley & Hays, 1976; Keeley, 1977).

High buried seed populations have been reported in cultivated fields and grassland vegetation by various workers (Brenchley & Warrington, 1933; Roberts, 1958; Robinson & Kust, 1962; Wilson, 1985; Chauvel et al., 1989 and Hill et al., 1989). Roberts (1962, 1968) observed exponential decrease in buried seed populations of weeds in undisturbed areas when fresh input of seeds was stopped. Prolonged periods of weed-seedling emergence result from numerous environmental changes that are brought about by seasonal climatic changes, tillage, irrigation, and cropping (Chepil, 1946; Wilson, 1985). Thus, farming practices can contribute significantly to the complicated dynamics of buried weed seed populations and the control problems associated with them (Zorner et al., 1984; Wilson, 1985; Hill et al., 1989).

Agricultural soils usually contain large numbers of weed seeds which can remain viable for periods upto several decades (Kivilaan & Bandurski, 1981). Although among all plant parts the seed is least susceptible to the rigors of climate and other unfavourable conditions, a very large fraction of soil seed population fails to produce seedlings. Sagar (1959) found that only 11% of surface sown seeds of Plantago lanceolata and less than 3% of the seeds of P. major emerged as seedlings after one year period. A similar observation was made by Jefferies et al. (1981) with salt marsh annual Salicornia eurapaea. This indicates the death of large fraction of the soil seed population. The causes of death of such enormous population of seeds are numerous. A fraction of seed population may lose viability and degenerate due to unfavourable environmental conditions like fluctuating temperature and high humidity. A large number of weedy species studied by Roberts & Feast (1972) and Roberts (1979) lose seed viability rapidly and the seeds of only a few species could survive for more than five years. Further, a good percentage of seeds is also induced or enforced into dormancy (Sarukhan, 1974; Baskin & Baskin, 1975; Gorski et al., 1977; Yadav & Tripathi, 1981; Purvis et al., 1985; Wilson, 1985; and Chauvel et al., 1989).

ALLOCATION PATTERN AND REPRODUCTIVE STRATEGY

Recently, much attention has been focussed on the way in which organisms allocate their limited supply of energy and materials to diverse life functions (Hickman, 1975). The concept that organisms have certain limited energy available to expend for different life purposes was put forward by Cody (1966). Considering clutch size in birds, he argued that the way in which an organism allocates its energy to such ends as reproduction, competition and predator avoidance is a characteristic of ecological and evolutionary importance. Gadgil & Bossert (1970) viewed the life history strategies as attempts to optimize allocation of resources among maintenance, growth and reproduction.

Abrahamson & Gadgil (1973) suggested that reproductive effort should decrease under shaded condition as more emphasis is given for vegetative growth for survival of the plants under such situations. Similar pattern of resource allocation has been shown by a number of workers (Abrahamson & Gadgil, 1973; Gaines *et al*., 1974; Ross & Quinn, 1977).

Harper & Ogden (1970) described for the first time partitioning of dry matter and energy throughout the life cycle of different plant species. In annual plant species much of the energy is devoted to reproductive structures, whereas in perennials emphasis is laid on storage of energy for future growth and development by reducing reproductive budget (Harper & Ogden, 1970; Hickman, 1975; Peterson & Bazzaz, 1978; Bell *et al*., 1979). Clark & Burk (1980) attributed adaptive significance to such a strategy in the two annuals viz., *Canissonia boothi* and *Plantago insularis*. The former has a longer life cycle and it tends to maintain higher levels of non-structural carbohydrates for vegetative growth, whereas the latter starts its reproductive growth early and allocates greater proportion of energy to reproductive growth by reducing the allocation to vegetative organs.

A critical review of the methods for estimating reproductive efforts in plants has been given by Kawano & Nagai (1975). The most widely adopted method is that of Harper & Ogden (1970) where the ratio of reproductive growth to total biomass is considered as reproductive effort. While such an approach has yielded valuable information, little effort has been made in order to relate reproductive growth strategy with leaf growth (Bazzaz & Harper, 1977; Primack, 1977). This approach should have received more attention particularly in view of the fact that leaf as an organ is the chief region of photosynthetic activity.

Saxena & Ramakrishnan (1982) showed positive correlation of leaf area ratio with that of reproductive effort in early successional sprouting species. They (1983) also studied the growth, allocation pattern and nutritional status of some dominant annual weeds such as Borreria articularis, Cassia tora, Ageratum conyzoides and Erigeron linifolius in shifting agriculture (jhum) in north eastern India and observed differences in the allocations of biomass and nutrient. In all species, reproductive allocation of nitrogen and phosphorus was higher than that of biomass and potassium.

Abrahamson (1975a) is of the view that the distribution of biomass among plant organs is affected by the environment, habit of plant, life span of the plant and competitive interactions. Hawthorn & Cavers (1978) studied the growth patterns and biomass allocation to component plant parts in *P. major* and *P. rugelli* and reported that *P. major* with its early sustained diversion of biomass to seed production is distinctly adapted to frequently disturbed sites, while *P. rugelli* because of its more extensive root allocation and delayed seed production seems to be better adapted to less frequent disturbances.

Patterson (1980) studied the partitioning of plant biomass in *Imperata cylindrica* from shaded and exposed habitats and found that allocation to reproductive activities was greater under exposed situation. Fitters & Setters (1988), while working on *V. riviniana* and *V. tricolor* over one growing season at twelve sites, observed considerable variation in biomass allocation between species.

Plants grow by the progressive accumulation of elements in leaves, buds, internodes, branches and flowers which together make up modules. Plant growth analysis is widely used in the fields of agriculture and botany where the majority of species are annuals, biennials or short lived perennials (Evans, 1972; Hunt, 1982a; Brand *et al.*, 1987). Growth analysis is a useful tool in studying the complex interactions between plant growth and the environment. Growth analysis fills a gap in crop yield research between strictly mechanistic studies of plant physiology and strictly empirical studies of growth and yield.

Species that typically occur in fertile environments tend to have higher maximal relative growth rates than those that typically occur in infertile habitats (e.g. Clarkson, 1967; 1975; Grime, 1979; Boston, 1986; Chapin, 1986; Shipley & Kiddy, 1988). Relative growth rate provides a valuable overall index of plant growth. Patterson *et al.* (1988) found that interplant shading from greater leaf area tended to depress net assimilation rate (NAR) in a few weeds.

Early rapid weed growth is important in weed establishment and weed crop interactions, especially when nutrients and water become limiting in the growing season. Some of the studies on growth analysis in agricultural situations are those of Bremester & Barnes (1981), Bourdot *et al.* (1985). Bourdot, Sanille & Field (1984) have demonstrated that the low level of irradiance beneath cereal crops would be sufficient to reduce the RGR of *A. millefolium*.

The differences in RGR related to the nutrient supply in the natural habitat have been found by Higgs & James (1969), Veerkamp *et al*. (1980), Veerkamp & Kuiper (1982) and Konings *et al*. (1989).

Light has been recognised as a major factor influencing the replacement of species during secondary succession (Eagles, 1973; Marks, 1974; Bazzaz, 1979; Kushwaha & Ramakrishnan, 1982). In early succession, rapid growth, which depends upon abundant resources is advantageous. During the later stages of succession, the availability of such resources may be reduced and those plants with inherently high growth rates and high requirements of resources may not survive. Ruderal and competitive species have higher relative growth rates compared to stress tolerant species (Grime, 1976). This indicates slower relative growth rate in late succession, both due to high expenditure of carbon in maintenance of living but non-productive tissues and to decreased mineral availability to support further growth. Late successional species seldom exhibit high relative growth rate of early invaders. Their low RGR puts them at a disadvantage in early succession, but because of their higher tolerance limits of annual resources these species maintain a positive relative growth rate even in late succession and eventually become dominant (Grime, 1977).

Bittman & Simpson (1987) worked on growth pattern and net assimilation rate (NAR) of three forage grasses and suggested that NAR depends upon species and environment. Konings et al. (1989) working on Carex species, concluded that all growth parameters decreased during plant growth even under the controlled conditions of the experiment and the growth analysis at sequential harvest revealed that the species had no inherently different growth rates which could explain the difference in their productivity.

Pradhan (1981) reported that Trifolium repens shows substantial reduction in growth when grown mixed with Paspalum dilatatum, while the latter grew better in mixture than in monoculture. Saxena & Ramakrishnan (1983) observed that Eupatorium odoratum had the highest values for RGR and NAR, which may be due to its greater leaf area ratio which expresses the proportions of photosynthetic surface to respiratory mass. Swamy & Ramakrishnan (1988) observed that the growth functions of Mikania micrantha reached a maximum in 1 to 3 year old fallows, followed by a sharp decline in 6- and 12- year old fallows.

Leaf area ratio characterizes the relative size of the assimilatory apparatus and is a measure of the differences between plants and yield (Singh & Rao, 1987). They observed the steady decline of LAR with age of sugarcane crop and suggested that under low yielding environment, high leaf area ratio is necessary for better performance.

Review of work done on *Ageratum conyzoides* and *A. houstonianum*

The two species of Ageratum were originally imported from the American tropics as ornamentals, but they became wild many years ago in the Far East. Ageratum houstonianum was first used as a cover crop in the coffee and tea plantations in Indonesia, where it has been found to give excellent results as a soil stabilizer and source of mulch materials (Backer & Van Slooten, 1924; Planter, 1940). A. mexicanum Sims at present known as A. houstonianum Mill. is closely related to and can easily be mistaken for A. conyzoides.

Both species are prolific seeders often producing several thousand seeds per plant. Baker (1965) studied the autoecology of A. conyzoides and oserved that it can flower when as few as two pairs of leaves have been formed; and it may be seen as a plant upto 90 cm tall with hundreds of flower heads in favourable conditions, although it can also exist as a tiny plant with a single flower when it is crowded or when it is growing under extremely wet or dry conditions. A. conyzoides is not selective in its choice of soil. It prefers humid conditions rather than dry but it cannot stand marshy conditions (Baker & Van Slooten, 1924; Planter, 1940). Baker (1965) conducted experiment on *A. conyzoides* and concluded that it appears to have no specific photoperiodic requirement. It flowers at low or high night temperatures, produces an economical amount of pollen in its small seed heads, and is self pollinated. It may produce 40,000 seeds per plant and in some areas one-half of the seeds germinate shortly after they are shed. Christie (1971) studied the behaviour of seeds in *A. conyzoides* and reported that morphologically mature seeds show pronounced dormancy, with even less than 1% of freshly collected seeds germinating within three months.

Koul (1966) recognised the existence of two chromosomal races in *Ageratum conyzoides*, a diploid growing in colder regions and a tetraploid having spread to the warmer parts of India. According to him, two photoperiodic ecotypes exist within the tetraploid race of this species, one occurring during the monsoon period and the other in winter. He observed that the monsoon form could flower and fruit under a wide range of photoperiodic conditions and the winter form is a short day plant. This he could correlate with the natural day light conditions in which they grow.

Leela & Dhuria (1973) studied the effect of herbicide bromacil at different stages of development in *A. mexicanum* and found that *A. mexicanum* was susceptible at the germination stage and it was killed by 2 successive applications of 2 kg/ha. Sugha (1980) conducted experiments to assess the allelopathic potential of *A. conyzoides* on germination and growth of wheat and found that extracts of different plant parts caused an inhibition in the germination and growth of wheat seeds. Extracts of *Ageratum* (leaf, root) significantly inhibited the germination of wheat seeds and the extracts from leaf and stem caused statistically significant reduction in the length and dry weight of shoot and root of wheat seedlings. The extracts of seed also caused curling of roots and prevented normal root growth.

Banyikwa & Rulangaranga (1984) studied the competitive effects of *Ageratum conyzoides* on groundnut in relation to light and nutrients and found that full and shoot competition caused a significant decrease in the forage dry weight and RGR of groundnuts when the competition period exceeded 42 days. NAR remained unaffected, but the LAR of groundnut was significantly increased by competition.

The studies on the herbicidal control of these two weeds were made by Wettasinghe & Rajendram (1969) and Agarwala (1971) who argued that *Ageratum conyzoides* can be controlled in cereals and sugarcane with growth regulating herbicides such as 2,4-D, MCPA and 2,4,5-T. *Ageratum houstonianum*, however, can be relatively better controlled with various soil applied herbicides such as linuron, diuron, chloroxuron, lenacil, atrazine and prometryne.

Ochse *et al*. (1970) have ranked *A. conyzoides* to be one of the best non legumes now in use as soil binder and have recommended *A. conyzoides* carpet as an excellent protector of soil in newly planted areas of tea and other crops since the root system of this weed do not compete with the main crop (tea).

Besides being a severe weed in 36 different crops in 46 countries; *A. conyzoides* has been reported to be an alternate host of fungi *Cassytha filliformis* L. (Raabe, 1965), *Cercospora agerati* Stevens and *Puccinia conoclinii* Seym. (Stevens, 1925); of nematodes *Meloidogyne* sp. and *Practylenchus pratensis* (de Man) Filip. and of viruses which produce spotted wilt (Sakimura, 1937). *A. houstonianum* has been reported to be an alternate host of *Pseudomonas solanacearum* (Pegg & Moffett, 1971).

Review of work done on *Bidens pilosa*

Bidens pilosa which originated in tropical America has now spread throughout the warm region of the world. It is troublesome in both field and plantation crops and is reported to be a weed of 31 crops in more than 40 countries (Holm *et al*., 1977).

Single plant yields 3,000 to 6,000 seeds, but in some cases it can yield 12,000 seeds per plant (Stevens, 1932; Schwerzed, 1967; and Muniyappa *et al.*, 1973). Rochecouste & Vaughan (1959) studied the germination pattern of *Bidens pilosa* seeds and observed that many of the seeds germinate readily at maturity and it is possible to have three to four generations per year. They also concluded that seeds which are 3 to 5 years old may give 80% germination.

Valio *et al.* (1972) reported that germination of achenes of *B. pilosa* was enhanced by cold treatments and light, and brief exposures to blue, green, red and far-red light induced germination. Fenner (1980a) studied the effect of leaf canopy shade on *B. pilosa* under four vegetation types and found that germination of *B. pilosa* was almost completely prevented underneath the banana leaf and only one seed out of 150 germinated under the leaf. From this he suggested that leaf canopy shading may be an important step in limiting the distribution of this species. In the same year (1980b) Fenner, studied the induction of a light requirement in *B. pilosa* seeds by leaf canopy shade and concluded that exposure to leaf canopy shade clearly induces a light requirement in the seeds.

Santra *et al.* (1981) studied germination of *B. pilosa* seeds in relation to light, temperature and salt solutions. They found that seeds of *B. pilosa* are light and temperature sensitive. Continuous red light and low temperature are found to be favourable for germination. It was also revealed by them that ammonium nitrate (NH_4NO_3) has inhibitory effect on seed germination, whereas calcium nitrate ($Ca(NO_3)_2$) (at 0.5% concentration) stimulated germination.

Sherff (1937) used the morphological characters to separate B. pilosa into six varieties. Ballard (1986) made a detailed account of Bidens pilosa complex in north and central America and identified thirty flavonoid compounds occurring in the B. pilosa complex. Cytogenetic studies revealed that the chromosome counts of var. pilosa are n=36. Compatibility experiments have demonstrated that var. pilosa is self-fertile, a feature that has facilitated its pantropic spread (Ballard, 1986).

The study on the effect of herbicidal bromacil at different stages of development in B. pilosa has been carried out by Leela & Dhuria (1973). They found that B. pilosa was susceptible at the germination stage to bromacil at 2-3 kg/ha. Studies on the herbicidal control of B. pilosa has been also carried out by Padmanabhan (1967/68). He concluded that in sugarcane and cereals 2-4-D and MCPA application is effective and recommended a combined application with soil applied herbicides for longer residual action.

B. pilosa besides being a severe weed in perennial crops, acts as an alternate host of fungi *Cassytha filliformis* L. (Raabe, 1965), *Cercospora megalopotamica* Speg.(Stevens, 1925); of nematodes *Meloidogyne* sp. (Raabe) and of viruses which cause spotted wilt (Sakimura, 1937) and ground rosette (Adams, 1967).

CHAPTER III

DESCRIPTION OF THE STUDY SITE, CLIMATE, VEGETATION OF THE AREA AND BIOLOGY OF THE SELECTED SPECIES

LOCATION

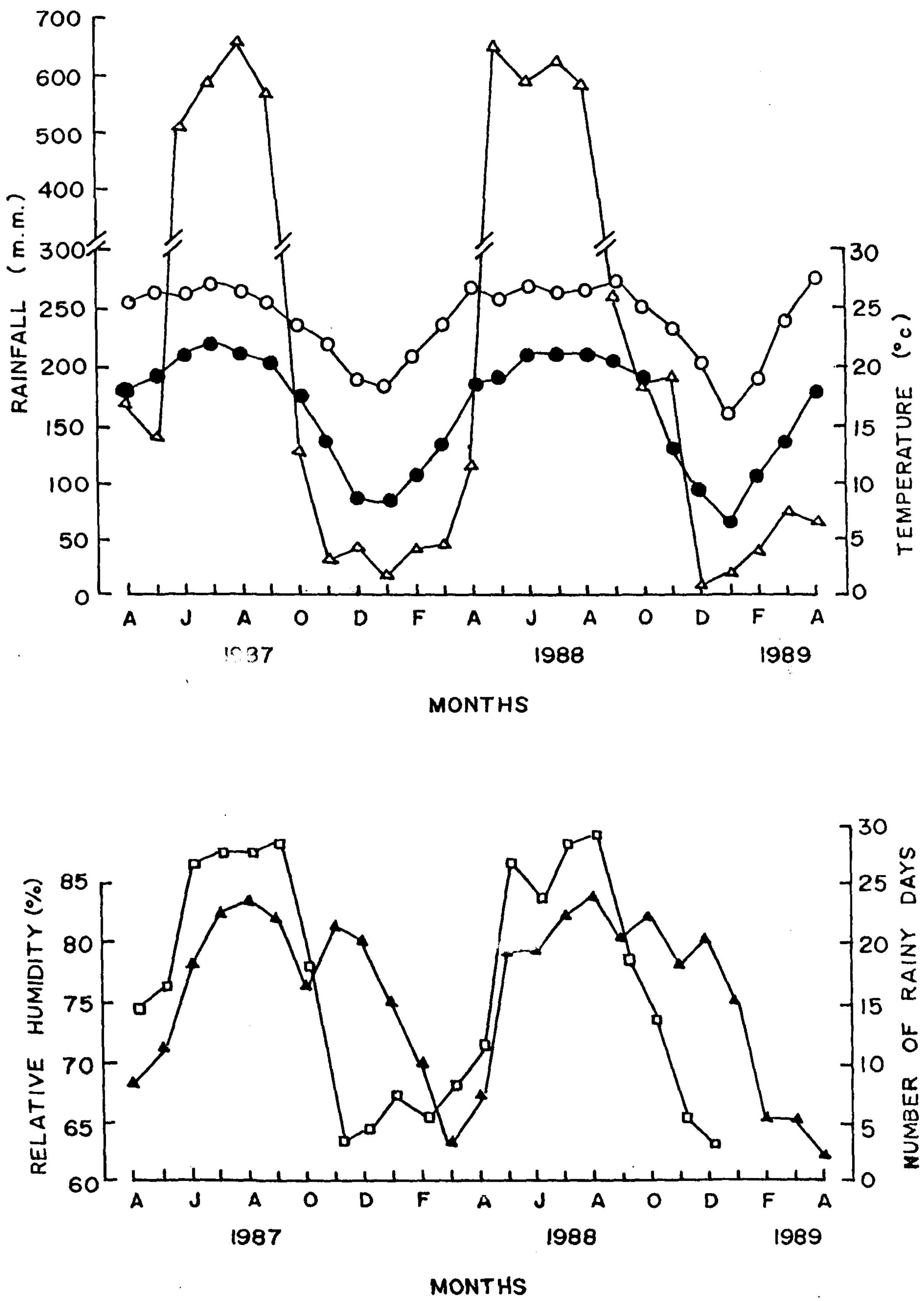
The study was carried out on eight experimental watersheds at the Farming Systems Research plot of ICAR Research Farm, Barapani (Plate 3.1) situated at a distance of 22 Km from Shillong. The Farming Systems Research at Barapani comprises evaluation of single and mixed landuse systems in micro watersheds. It was initiated in the year 1984. The land at the time of acquisition was under waste fallow. High hills were left fallow or maintained under upland crops without adopting any soil and water conservation measures (Prasad et al., 1987). The farm lies on 91°53' E longitude and 25°38' N latitude and is located at an average altitude of 950 msl. Details about the land use, crops grown in the experimental watersheds under different farming systems and area of various watersheds are given in Table 3.1.

CLIMATE

The climate is sub-tropical. The south-west monsoon and north-east winter winds influence the climate of Barapani. Data on average rainfall, temperature, relative humidity and number of rainy days are given in Fig. 3.1. The annual rainfall ranges between 2500-3200 mm. Most rainfall occurs between May to September. June, July and August are the wettest months. The rainy season is rather long (May to

Fig. 3.1(a) Rainfall and maximum and minimum temperature data for the study area during 1987 and 1988. Open triangles, rainfall; open circles, mean maximum temperature; closed circles, mean minimum temperature.

Fig. 3.1(b) Relative humidity and number of rainy days during 1987 and 1988. Squares, number of rainy days; closed triangles, relative humidity.



RAINFALL (m.m.)
TEMPERATURE (°c)
700
600
500
400
300
250
200
150
100
50
0
30
25
20
15
10
5
0
A J A O D F A J A O D F A
1987
1988
1989
MONTHS
RELATIVE HUMIDITY (%)
NUMBER OF RAINY DAYS
85
80
75
70
65
60
30
25
20
15
10
5
0
A J A O D F A J A O D F A
1987
1988
1989
MONTHS

Fig. 3·1

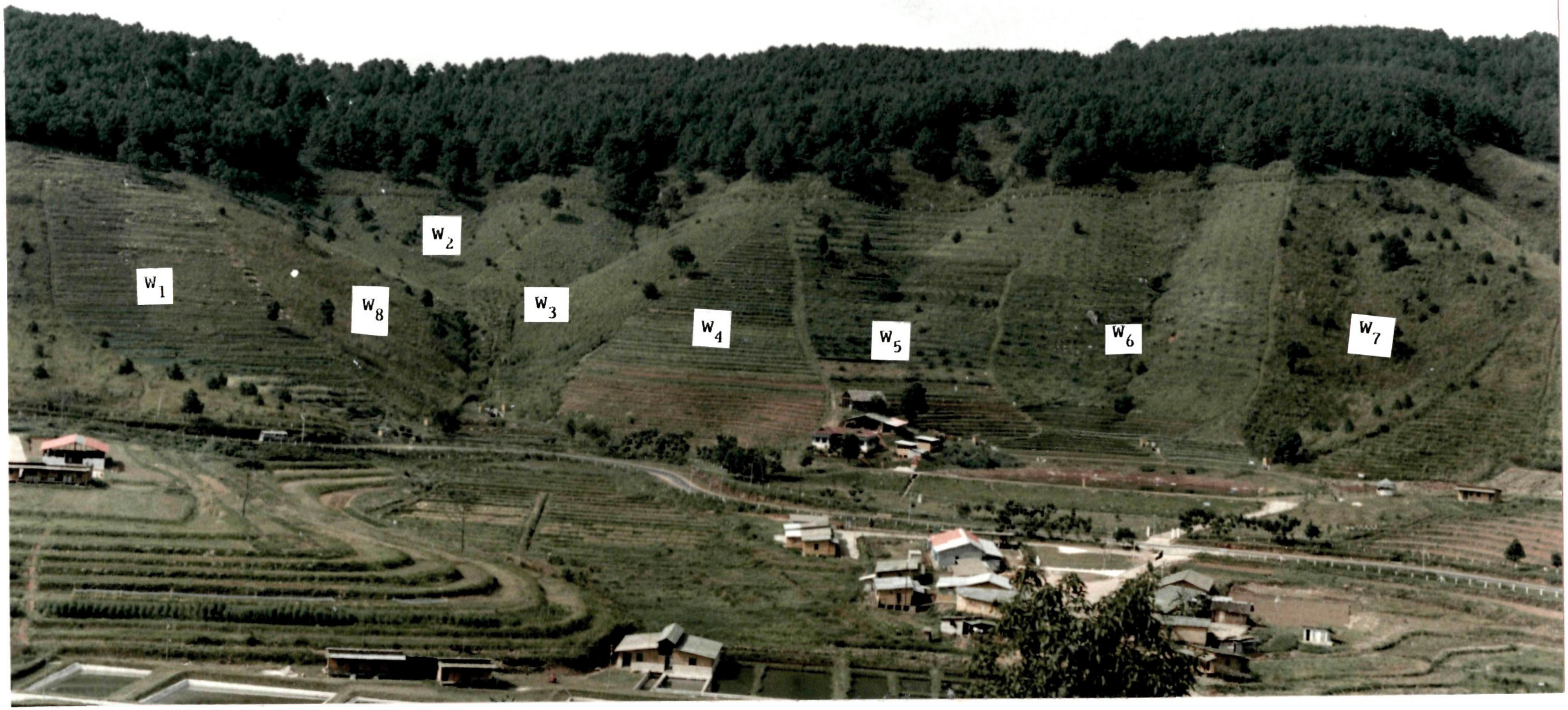


Plate 3.1 The watersheds ($FS\text{-}W_1$ - $FS\text{-}W_8$) under different farming systems at the ICAR farm, Barapani, Shillong.

September) in Meghalaya. The period between March to April is characterised by gradual increase in temperature. With the retreat of monsoon, the temperature starts dropping from October onwards. The period during December to February is characterised by low temperature, occasional showers and short photoperiods.

GEOLOGY AND SOIL

The Shillong plateau embracing the Garo, Khasi and Jaintia Hills of Meghalaya is made up largely of pre-cambrian rocks actively folded and steeply dipping with an overturned fringe of mesozoic and tertiary sediments. The rock types in Barapani area are quartzites, phyllites and metamorphosed conglomerates of Shillong series with metadolorit (green stone). There are pink to buff quartzite, hard black phyllite, medium hard reddish and greyish phyllite, sandstone etc.

Soils have been formed predominantly from the weathering of sedimentary and metamorphic rocks. The soil is somewhat degraded mainly because of continuous high intensity of denudation by slash and burn agriculture (locally called 'jhum'), which causes increased erosion losses. Physical and chemical properties of the soil at the Farming Systems Research Plot are given in Table 3.2. Textural analysis revealed that the soil is clay loam.

VEGETATION

The experimental watersheds comprise a steep hill slope with the hill top under pine forest plantation. The hill top bears a few scattered tree species of *Callicarpa arborea*, *Pinus kesiya*, *Schima wallichii*, *Symplocos* sp. and *Wendlandia wallichii*. The ground vegetation is composed of 93 different species. Of these, *Ageratum conyzoides*, *Ageratum houstonianum*, *Bidens pilosa*, *Imperata cylindrica*, *Arundinella benghalensis*, *Eupatorium adenophorum* and *Borreria hispida* were the dominant species in all the farming systems. Out of these weeds, *Ageratum conyzoides*, *Ageratum houstonianum* and *Bidens pilosa* were selected for detailed study. The population dynamics, growth, productivity and biomass allocation pattern of these three species were studied in relation to the agricultural practices operating in different farming systems on various experimental watersheds.

DISTRIBUTION, DESCRIPTION AND BIOLOGY OF THE SPECIES SELECTED FOR STUDY

1. *Ageratum conyzoides* L. (Plate 3.2)

Distribution

Ageratum conyzoides, a native of tropical America, belongs to family Asteraceae. Its common English name is 'Billy goat weed' (Beadle *et al.*, 1972). It is known as

Plate 3.2(A)

<u>Ageratum</u> <u>conyzoides</u> showing growth habit.

Plate 3.2(B)

<u>Ageratum</u> <u>conyzoides</u> growing in natural condition.

Mahakaua in Hindi in India (Holm *et al*., 1977; Thakur, 1984). Its range of distribution extends from Lat. 30° N to 30° S. It is reported from forty six countries representing all the six continents. It is a weed in 36 different crops. *A. conyzoides* and *A. houstonianum* are the two most important weeds in a genus of about 300 species (Holm *et al*., 1977). It is found throughout India, common everywhere in wastelands and on the roadsides; it ascends the Himalayas to an altitude of 5,000 feet (Caius, 1986). It is often a weed of plantation crops and pastures. It is a serious weed of corn in Ceylon and Ghana; peanuts, upland rice and chillies in Ceylon; sugarcane in Taiwan and Australia; tea in Ceylon, India, and Indonesia; potatoes in Malaysia and cocoa in Brazil (Holm *et al*., 1977).

Description

Ageratum conyzoides is an erect, branching annual herb that may be 60-120 cm tall at flowering, depending on environmental conditions. It is sometimes decumbent at the base with branches forming roots; roots shallow and fibrous; stems are erect, cylindric and the nodes enlarged. The leaves are opposite, soft, 2 to 10 cm long, 0.5 to 5 cm wide, petioles hairy, 0.5 to 5 cm long, sometimes broadly ovate, triangular ovate, or rhomboid-ovate with a sub cordate, rounded, or narrowed acute base. Leaf margins are toothed

Plate 3.3(A)

<u>Ageratum</u> <u>houstonianum</u> showing growth habit.

Plate 3.3(B)

<u>Ageratum</u> <u>houstonianum</u> growing in natural condition.

goat weed" (Beadle *et al.*, 1972) is reported as a weed of tea, cucumber and coffee plantations in Indonesia and is one of the most serious weeds of sugarcane in Australia (Young, 1962). It is a native of tropical America.

Description

A. houstonianum is an erect or creeping-at-base and rooting annual or short-lived perennial herb. It can grow upto a height of 90 cm. The stems are cylindric, sometimes branched, covered with white hairs which spread or open at an angle from the stem, slightly purple-tinged; leaves are opposite, on 0.5 to 6.5 cm long petioles subtriangular or deltoid, top leaves ovate, with a notched (sub-cordate), flattened or rounded base passing acutely into the petiole, obtuse or almost acute at the apex, both surfaces with hairs which spread at an angle from the surface, 2 to 10 cm long, 1.5 to 5.5 cm wide. Inflorescence is terminal or often axillary, head clusters small, dense to very dense, peduncles 2 to 10 cm long; flower heads blue or violet, 5.5 to 7 mm long with 75 to 100 flowers, bracts surrounding the flower head very hairy; fruit an achene, angled, covered with hairs, but not densely hairy, 1.5 to 2 mm long and pappus is shorter than the corolla.

Biology

Although very little is known about the biology of *A. houstonianum* there is a feeling that it probably is similar to *A. conyzoides* (Holm *et al.*, 1977) as the two species are often found growing in the same habitat.

III. *Bidens pilosa* L. (Plate 3.4)

Distribution

Bidens pilosa is a widely distributed sub-tropical and tropical weed with its centre of diversification in Mexico (Ballard, 1986). It is commonly known as 'black jack', 'hairy beggar stick', 'spanish needle' (Kranz *et al.*, 1977). It is found throughout India (Caius, 1986) where it is known as 'cobbler's peg' (Holm *et al.*, 1977). It can usually be seen at all seasons in the tropics, but it grows most actively in the warmer and wetter parts of the year (Holm *et al.*, 1977). It is troublesome in both field and plantation crops and is reported to be a weed of 31 crops in more than 40 countries (Holm *et al.*, 1977). It is one of the most successful genera occurring in different natural forests of Eastern Himalayas, growing even at margins of cultivated lands (Santra *et al.*, 1981).

Description

Bidens pilosa is an erect, annual herb, growing to a height of 150 cm. The stems are four angled, variably hairy, leaves opposite, petioled, pinnate, usually with

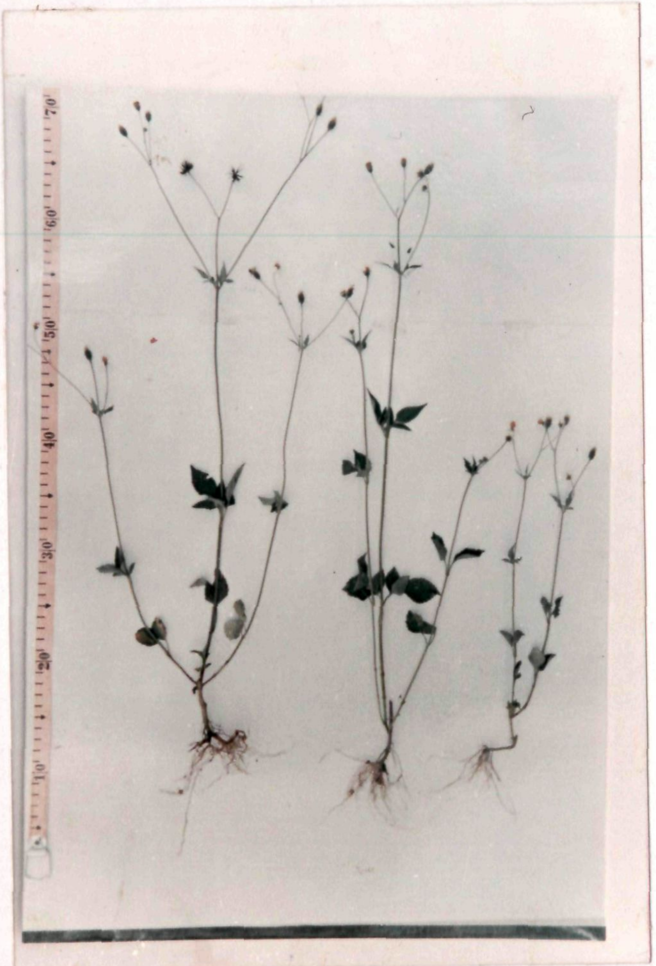


Plate 3.4(A)

Bidens pilosa showing growth habit.

Plate 3.4(B)

Bidens pilosa growing in natural condition.

three (sometimes five) ovate, acute leaflets, the upper leaflet usually largest (upto 9 cm long and 3 cm broad), margins sharply serrate, sparsely hairy to smooth on both sides. Inflorescence is a capitulum, yellow, terminal, 7 mm in diameter, on peduncles 5 cm long, outer involucral bracts oblong or more or less spoon shaped; fruit (achene) blackish, about 11 mm long, narrow, ribbed, sparsely bristled to smooth. Pappus is a ring of awns (two to four) with recurved barbs, 3 mm long.

Biology

The spread and colonization of areas by B. pilosa can be attributed in part to very effective pollination arrangements and to special adaptations which allow the distribution of its fruits by workers, animals, wind and water. This weed is reported in crops at higher elevations in several countries (Holm et al., 1977). The young plants of B. pilosa have strap-shaped cotyledons and purple tinged hypocotyles. A single plant may produce as many as 3,000 to 6,000 seeds, many of them germinating readily at maturity. In some areas, the seedling recruitment takes place three to four times in a year (Holm et al., 1977). Light and good aeration are required for germination. Seeds which are three to five years old may give 80% germination (Rochecouste & Vaughan, 1959).

Table 3.1. Details of land use and crops grown in different experimental watersheds along with their area and dimension.

Particulars	Experimental Watersheds							
Land use	Agriculture (fodder)	Forestry (fuel and fodder)	Agro-forestry	Agriculture (food crops)	Agri-horti-silvi-pastoral	Horticulture	Natural fallow (control)	Jhum fallow
Land use notations	$FS\text{-}W_1$	$FS\text{-}W_2$	$FS\text{-}W_3$	$FS\text{-}W_4$	$FS\text{-}W_5$	$FS\text{-}W_6$	$FS\text{-}W_7$	$FS\text{-}W_8$
Area under planned land use (ha)	0.94	0.84	0.90	0.58	1.03	0.96	0.95	0.50
Average slope (%)	32.02	38.60	32.18	32.42	41.77	53.18	45.87	41.35
Maximum length (m)	301.00	320.00	295.00	240.00	260.00	515.00	250.00	185.00
Maximum width (m)	65.00	230.00	175.00	65.00	85.00	85.00	70.00	48.00
Crops grown	Love grass, Stylosanthes, Setaria sphaculata, maize, cabbage, tapioca, cauliflower.	Alnus nepalensis, Exbucklandia, cherry, Betula.	Pumpkin, Cucumber, bitter-gourd, mango, Albezzia, cherry, Exbucklandia, Betula, Cassia fistula.	Paddy, maize, linseed, groundnut, green pea, mustard, lentil, soyabean.	Paddy, maize soyabean, green pea, groundnut, guava, cucumber, pineapple, lemon, pumpkin, love grass, Alnus nepalensis, Stylosanthes guianensis.	Guava, pineapple, lemon, pumpkin, cucumber.	Control with well fenced boundary	The land lying fallow for 4 years

Table 3.2. Soil characteristics under different farming systems from the forest on the top hill to the bottom portion of the watershed.

	FS-W_1	FS-W_2	FS-W_3	FS-W_4	FS-W_5	FS-W_6	FS-W_7	FS-W_8
pH								
Forest	5.55	5.12	5.36	5.42	5.45	5.40	5.50	5.48
Top	5.76	5.66	5.79	5.60	5.55	5.37	5.59	5.48
Middle	5.55	5.52	5.67	5.47	5.44	5.42	5.49	5.38
Bottom	5.36	5.27	5.90	5.38	5.42	5.08	5.62	5.28
Organic Carbon (%)								
Forest	2.26	2.40	2.00	1.65	1.88	2.32	1.87	2.59
Top	1.72	2.40	1.98	1.74	1.82	1.83	1.74	2.40
Middle	2.04	2.37	1.61	1.55	1.70	1.42	2.72	1.00
Bottom	1.72	2.10	1.92	1.65	1.56	1.12	1.35	2.10
Available P(PPM)								
Forest	0.92	0.88	0.60	0.50	0.50	0.95	0.55	0.42
Top	0.56	0.65	0.56	0.30	0.45	0.81	0.43	0.32
Middle	0.64	1.06	0.47	0.46	0.60	0.79	0.58	0.56
Bottom	0.92	0.82	0.56	1.26	1.65	1.35	0.77	0.90
Available K(PPM)								
Forest	127.0	76.0	68.0	55.0	55.0	80.0	65.0	78.0
Top	34.0	41.0	47.0	49.0	45.9	46.0	43.0	68.8
Middle	36.0	55.0	53.0	29.0	49.9	43.0	63.0	70.8
Bottom	41.0	58.0	36.0	134.0	76.3	137.0	55.0	82.5

CHAPTER IV

WEED COMMUNITY STRUCTURE IN DIFFERENT FARMING SYSTEMS

Plant community is a dynamic entity which shows both spatial and temporal changes. It can be analysed in terms of phytosociological attributes such as species composition, diversity, frequency, density etc. (Hanson & Churchill, 1961 and Kershaw, 1964). Each constituent species has its own ecological amplitude and a particular relationship with the environment and the associate species. The nature of a plant community at a place is therefore, determined by the species that grow and develop in such environments (Bliss, 1962). The degree of diversity depends upon the adaptability of a species to a particular micro habitat (Singh & Verma, 1986). Diversity indices are an additional tool for measuring the quality of the environment and the effect of induced stress on the structure of a community. Many forms of stress tend to reduce diversity by making the environment unsuitable for some species or by giving other species a competitive advantage. Temporal and spatial changes in environmental stress may be assessed through the comparison of the structural changes of two or more communities. Similarity indices therefore, have been developed by plant ecologists in order to distinguish community organization in space or successional time (Sheehan, 1984).

Although the forest and grassland communities of

India have been extensively analysed for species diversity and phytosociology, the agro-ecosystems have not been adequately studied. Some of the earlier phytosociological works on Indian agro-ecosystems are those of Majumdar (1962), Tripathi (1964), Singh (1969), Singh et al. (1969), Tripathi & Misra (1971), Singh & Bhan (1975), Ambasht & Chakhaiyar (1979) and Mishra & Ramakrishnan (1983).

Some of the recent works on floristics of weeds in different agricultural systems are those of Chancellor (1986), McIntyre et al. (1988), Pujadas Salva et al. (1988), Wheeler (1988), Yeaton (1988), Hill et al. (1989), Saavedra et al. (1989) and Thompson & Shay (1989).

Although studies on weed floras of vegetable crops (Roberts, 1963), cereals (Montegut, 1974), rape (Garcia Torres & Vazquez, 1979), olive groves (Garcia Torres et al., 1983), irrigated crops (Hernandez-Bermejo et al., 1984) and orchards and horticultural crops (Pujadas Salva & Hernandez Bermejo, 1986) have been carried out, no attempt has been made to study the weed communities in different farming systems as a whole.

MATERIALS AND METHODS

The studies were carried out in eight watersheds under different farming systems during 1987 and 1988. Ten permanent quadrats of 1 m^2 were randomly laid in each watershed. The weeds growing in different watersheds were identified. Density, frequency and basal cover of different species were determined at monthly intervals in the permanent quadrats. Importance value indices (IVI) of different species were computed as described by Misra (1968). The data on relative abundance was used to calculate the Shannon diversity index ($\bar{d}$). the machine formula as proposed by Lloyd, Zar & Karr (1968) has been used for calculating $\bar{d}$. In order to find out the similarity between different farming systems in terms of species composition Sørensen's similarity index was applied (Sørensen, 1948).

a) Species composition: The species identified during the study period were placed under the following groups:

i) Grasses - members of Poaceae

ii) Legumes - members of Leguminosae

iii) Other forbs - non Poaceae and non Leguminous herbs

b) Density:

$$= \frac{\text{Total no. of individuals of each species}}{\text{Total no. of quadrats studied}} \times 100$$

c) Frequency:

$$= \frac{\text{No. of quadrats in which species occurs}}{\text{Total no. of quadrats sampled}} \times 100$$

d) Basal area:

$$= \pi r^2, \text{ where r (radius)} = \frac{\text{average diameter}}{2}$$

e) Importance value index (IVI):

= Sum of Relative dominance, Relative density and Relative frequency.

i) Relative dominance

$$= \frac{\text{Total basal area of the species}}{\text{Total basal area of all species}} \times 100$$

ii) Relative density

$$= \frac{\text{Number of individuals of the species}}{\text{Number of individuals of all species}} \times 100$$

iii) Relative frequency

$$= \frac{\text{Number of occurrences of the species}}{\text{Number of occurrences of all species}} \times 100$$

f) Shannon diversity index ($\bar{d}$):

$$\bar{d} = \frac{C}{N} (N \log_{10} N - \Sigma n_1 \log_{10} n_i)$$

where, C = 3.32 (converts base 10 log to base 2 (bits)

N = total number of individuals

n_i = total number of individuals in the ith species.

g) Sørensen's similarity index: or Co-efficient of community index CC

$$= \frac{2C}{A+B} \times 100$$

Where, C = number of species common to both communities

A = number of species in community 1

B = number of species in community 2

RESULTS

Species composition

During 1987, a total of 89 weed species were found growing on the watersheds under study. A list of the species recorded in these watersheds is given (Table 4.1). Out of these 89 species, 14 were grasses, 5 legumes and 70 other forbs. The highest number of weed species (61) during 1987 was recorded in FS-W_1 (Table 4.2). Some weeds such as Cannabis sativa, Gentiana sp., Hypericum sp., Plantago major and Solanum khasianum were exclusively present in this watershed. Other exclusive weed species are Mikania micrantha in FS-W_4, Rungia pectinata in FS-W_5 and Guinea panicummaximum in FS-W_8 (Table 4.4).

During 1988, a total of 93 weeds were recorded in different farming systems compared to 89 weeds in the previous year (Table 4.1). The new arrivals during 1988 are Indigofera sp., Digitaria sanguinalis, Echinochloa crusgalli and Paspalum dilatatum. Out of these four new arrivals, 3 were grasses and 1 legume. During 1988 also, the highest number of weed species (53) was recorded in FS-W_1 followed by FS-W_2 (52),

$FS\text{-}W_3$ and $FS\text{-}W_8$ (51), $FS\text{-}W_5$ (48), $FS\text{-}W_7$ (46), $FS\text{-}W_4$ (45) and $FS\text{-}W_6$ (42) (Table 4.3).

In both years, the highest number of weed species belonged to the family Asteraceae followed by Poaceae and Fabaceae. Other families viz. Labiatae, Cyperaceae, Verbenaceae, Rubiaceae, Melastomaceae and Oxalidaceae were also well represented. During 1988 also same exclusive species were recorded in $FS\text{-}W_1$, whereas Mikania micrantha which was exclusively present in $FS\text{-}W_4$ during 1987 was not recorded in that watershed during 1988, however, it was recorded as an exclusive species in $FS\text{-}W_5$. Other exclusive species in $FS\text{-}W_5$ during 1988 were Nelsonia canescens and Rungia pectinata. During 1988 Sonerila maculata, was recorded as an exclusive species in $FS\text{-}W_6$. Guinea panicummaximum was exclusively present in $FS\text{-}W_8$ in both years. Many weed species were present in all the farming systems. The number of such species was 30 (4 grasses, 2 legumes and 24 other forbs) during 1987, while the number of such common species decreased to 21 (3 grasses, 2 legumes and 16 other forbs) during 1988 (Table 4.5). During 1987, there were 9 grass species, 3 legumes and 39 other forbs common to more than one watershed (but not in all) (Table 4.6), however during 1988 the number increased to 13 grass species, 4 legumes and 45 other forbs (Table 4.7). The highest number of weed species occurred during rainy season (May to September) in both years (Table 4.2 & 4.3).

During 1987 the ratio of annual to perennial species (A/P ratio) was greater in the watersheds which were subjected to a variety of agricultural operations (e.g. FS-W_1, FS-W_3, FS-W_4, FS-W_5 and FS-W_6) compared to the farming systems where agricultural operations were not carried out (FS-W_2, FS-W_7 and FS-W_8). However, during 1988 FS-W_1, FS-W_5 and FS-W_6 showed lesser A/P ratio while the ratio in FS-W_4, and FS-W_7 remained unchanged (Table 4.8). It is interesting to note that FS-W_7 had the least and unchanged A/P ratio (0.7) in both years, thus showing the dominance of perennial plant species (Table 4.8).

Table 4.8. The ratio of annual to perennial weed species under different farming systems during 1987 and 1988.

Year	Watersheds							
	FS-W_1	FS-W_2	FS-W_3	FS-W_4	FS-W_5	FS-W_6	FS-W_7	FS-W_8
1987	1.09	0.75	1.06	1.08	1.20	0.93	0.7	0.87
1988	0.87	0.81	0.78	1.08	0.96	0.92	0.7	0.86

DENSITY

Analysis of data presented in Table 4.2 reveals that in all the watersheds the period during August to November

(1987) is characterised by high weed density and greater weed diversity. In spite of the high weed diversity in December the total density tended to decrease and this trend continued until March/April. From May onwards population of weeds and number of weed species that occured in different watersheds showed an increasing trend. During peak growth period of weeds (August to November) as also in other months total weed density was generally much lower in FS-W_2, FS-W_4, FS-W_5 and FS-W_6 compared to the other watersheds.

During 1988, the weed density showed decreasing trend from January onwards until March. From April onwards number of weed species and population densities of various weeds showed an increasing trend in different watersheds. The period between July to October is characterised by a high weed density and greater weed diversity (Table 4.3). The total weed density declined from November onwards. The total weed density during peak growing period (July to October), was much lower in FS-W_1, FS-W_4, FS-W_5 and FS-W_6 compared to the other watersheds.

In both years, the highest density values were recorded for <u>Bidens pilosa</u> in agriculture-based farming system (FS-W_4). A list of weed species with their peak density values and phenology in different farming systems have been given (Table 4.9). The period between April to August was characterised by the highest density values in both years. The herbaceous annuals in all the watersheds recorded the highest density values in both years except in FS-W_7 where Arundinella benghalensis (perennial grass) showed its dominance. During 1988, Imperata cylindrica showed the highest density in FS-W_6 (Table 4.9). The rainy season weeds were more dominant showing higher density values than the post rainy season weeds. The grasses showed greater density at the peak growing period (August) in 1988 than in 1987 whereas the legumes showed a lesser density in 1988 except for Desmodium microphyllum which showed greater density in almost all the watersheds during 1988. Most of the forbs showed lesser density during 1988 compared to 1987. Among other forbs, increase in the density was noticed in Cyperus tuberosa, Eusteralis stellata, Galinsoga parviflora and Stachytorpheta dichotoma in almost all the watersheds.

FREQUENCY

Table 4.10 shows the variation in frequency of the species at the peak growing period (August) in different farming systems. The frequency of the grass species during 1988 either remained constant or increased in most of the cases. Among the grass species, Arundinella benghalensis, Bothriochloa intermedia, Imperata cylindrica, Panicum montanum and Setaria glauca were quite frequent. Among the legumes, Desmodium microphyllum and Mimosa pudica showed high frequency in both years.

The frequency percentages for almost all the forbs were higher during 1987 compared to 1988. The percentage frequency ranged between 10-100%. During peak growth period in 1988, four new species with frequency range of 30-80% appeared in different farming systems and many species which were observed in 1987 did not occur in 1988.

IMPORTANCE VALUE INDEX (IVI)

Among the grasses, Imperata cylindrica showed the highest IVI value (25.8) during 1987 in FS-W_6 closely followed by Arundinella benghalensis (24.4) in FS-W_7 and (22.9) in FS-W_8 (Table 4.11). Among legumes, Desmodium microphyllum showed highest IVI value in all the farming systems. The highest IVI (31.0), among the forbs, was recorded for Ageratum houstonianum in FS-W_4, closely followed by Borreria hispida (29.8) in FS-W_1. Other species which showed their highest IVI values in agriculture-based farming system (FS-W_4) are Ageratum conyzoides (19.1), Bidens pilosa (19.6), Cosmos bipinnatus (13.3) and Galinsoga parviflora (24.0).

During 1988, Imperata cylindrica and Arundinella benghalensis were the only grasses showing high IVI values compared to the other grasses. Imperata cylindrica recorded its highest IVI value (72.2) in FS-W_6 and *Arundinella benghalensis* (46.4) in FS-W_7. *Desmodium microphyllum* however, remained the most dominant legume in both years. *Bidens pilosa* among the forbs showed the highest IVI value (50.1) in FS-W_4.

Diversity Index

The species diversity in all the farming systems were quite low during January-February, however, there was a sudden rise in diversity in the month of March in all the farming systems. With the advent of rainy season the diversity showed an increasing trend from May onwards (Table 4.12). The period between September to December was marked with the highest diversity indices. Among all the farming systems the highest diversity index (5.91) was observed in the agriculture-based farming systems (FS-W_4) in the month of November.

Compared to 1987, the diversity index values during 1988 were lesser in all the farming systems. It followed an increasing trend from May onwards except for a sudden decrease in August, the month of peak growth period (Table 4.12). During 1988, the period between September to October was marked by high diversity values whereas in 1987 the species diversity remained high over a longer period. During 1988, the highest diversity value (4.97) was recorded for the control systems - (FS-W_7) and Jhum fallow (FS-W_8).

Similarity index

Table 4.13 shows the similarity index values of weed communities growing in different farming systems during peak growth period. During 1987, the similarity index between different farming systems in terms of species composition ranged between 64.5-89.3%. The watershed under forestry-based farming system (FS-W_2) and agro-forestry system (FS-W_3) showed the highest similarity (89.3%) during 1987 (Table 4.13). The least similarity (64.5%) was observed between agriculture-based system (FS-W_4) and the control (FS-W_7).

Similar trend was observed during 1988 too. The maximum similarity (87.4%) was recorded between FS-W_2 and FS-W_3 and minimum (53.9%) between FS-W_4 and FS-W_7. However, both maximum and minimum similarity percentages during 1988 were lower than 1987.

DISCUSSION

The results show that the weed communities in various farming systems differ in floristic composition and phytosociological attributes. The watershed under livestock-based farming system (FS-W_1) which recorded the highest number of weed species (61) with 5 exclusive species viz. <u>Cannabis sativa</u>, <u>Gentiana quadrifaria</u>, <u>Hypericum japonicum</u>, <u>Plantago major</u> and <u>Solanum khasianum</u>, appears to differ markedly from the rest of the watersheds.

The difference in composition of weed flora in various watersheds could be attributed to the difference in farming operations, types of crop grown, crop canopy, soil characteristics, differential competitive ability of crops, variation in micro climatic conditions, crop density and physiographic features of different watersheds. The difference in composition of weed flora due to difference in farming operations as observed in the present study is in conformity with the findings of Montegut (1974), Garcia Torres & Vazquez (1979), Garcia Torres et al. (1983), Hernandez Bermejo et al. (1984), Pujadas Salva & Hernandez Bermejo (1986), Dagar (1987), Pujadas Salva & Hernandez Bermejo (1988) and Saavedra et al. (1989).

Barralis (1976) mentions that the crop cycle greatly influences weeds. The variation in species composition and dynamics of weed communities on different watersheds may be due to difference in the type of crops grown and in edapho-climatic conditions (Saavedra et al., 1989).

The increase in number of weed species to 93 during 1988 from 89 in 1987 is in agreement with the findings of Odum (1960) who observed progressive increase in species diversity over a 3 year study period in an old field.

The dominance of perennials in the control system

($FS-W_7$) could be attributed to the protection of the vegetation against various disturbances including agricultural operations. The ability of a perennial plant to develop in a crop yield depends on its capacity to regenerate after the soil tillage that is associated with the cultivation of the crop and its ability to compete with crop (Hakansson, 1982). Thus, as could be expected, the number of perennials was lesser in the watersheds where various agricultural operations were carried out compared to the other watersheds such as $FS-W_2$, $FS-W_7$ and $FS-W_8$ where agricultural operations were absent.

The period during August to November (1987) is characterised by high weed density and greater weed diversity. Although in December too, weed diversity was fairly high, the total weed density tended to decrease due to the prevailing low temperature and soil moisture stress. This finding is in conformity with that of Saavedra et al. (1989). From April onwards population of weeds and number of weed species showed an increasing trend. During peak growth period of weeds as also in other months, total weed density was generally much lower in $FS-W_2$, $FS-W_4$ and $FS-W_5$ and $FS-W_6$ compared to the other watersheds. Such a behaviour of weed population may be attributed to frequent agricultural operations and resource competition offered by the crops in $FS-W_4$, $FS-W_5$

and FS-W_6. The crop growth cycle and the timing of tillage operation clearly determines the weed flora (Saavedra et al., 1989). The better growth of weedy species in the livestock-based farming system (FS-W_1), Jhum fallow (FS-W_8) and control system (FS-W_7) during 1987 indicates that the conditions prevailing in these watersheds were more conducive for the weed growth. Low diversity of weeds in forestry-based farming system (FS-W_2) could be attributed to the absence of certain agricultural practices which tend to create favourable habitat for weeds.

There was a sudden increase in the number of weed species during rainy season due to prevailing favourable growth conditions. This is in conformity with the findings of Misra & Mall (1975), Glyphis, Moll & Campbell (1975) and Danin (1978). Thus, change in species composition appears to be controlled by forces originating from within the community through competition and interaction and by external factors related to climate and soil (Spatz, 1975; Zubereva, 1975; Werner, 1977; and VanHulst, 1979).

The frequency, density and abundance of grasses, legumes and forbs showed variations at the peak growing period in both years. Among the grasses, Arundinella benghalensis, Bothriochloa intermedia, Imperata cylindrica, Panicum montanum and Setaria glauca seem to be more dominant particularly in the control system (FS-W_7) and Jhum fallow (FS-W_8). Among the legumes, Desmodium microphyllum showed 100% frequency in FS-W_8. The grasses and legumes were much more frequent and abundant in FS-W_8 than in the rest of the watersheds. In all the farming systems forbs were more abundant than the grasses. There seems to be a strong impact of different farming systems on the distribution and abundance of the weed species.

It is apparent from Table 4.11 that Imperata cylindrica had the highest IVI followed by Arundinella benghalensis in FS-W_6, FS-W_7 and FS-W_8 compared to other weed species. The minimum agricultural operations in these systems favoured the growth of grasses as they showed their dominance over legumes and other forbs in these systems. Dominance of grass species in this system may be attributed to the phenomenon of interacting soil and plant complex, however, FS-W_4 was dominated by other annual forbs. FS-W_4 which recorded maximum number of dominant species seems to differ markedly in terms of agricultural practice, crops and other ecological factors from the rest of the farming systems, as it is always in the state of disturbance and agricultural manipulations.

There was a definite influence of climatic seasonality on species diversity, rainy season being most conducive for the growth of a large number of weeds, which is in agreement with the findings of Sinha et al. (1988) who also found maximum diversity in rainy season. $FS-W_4$ had maximum number of dominant species in 1987 and it also showed a high species diversity. The same was true in case of $FS-W_7$ during 1988. This may be attributed to the availability of suitable niche and resource apportionment in a community (Whittaker, 1972; Saxena & Singh, 1982). Species diversity was high in $FS-W_4$, $FS-W_7$ and $FS-W_8$ which shows the ability of the component species to withstand the high disturbance due to frequent agricultural operations ($FS-W_4$), and the stresses imposed by the already established plant communities in undisturbed and control systems. The low diversity communities mainly tend to share the resources in accordance with the availability. The dominant species presumably use as its share a major fraction of the available resources of the community, leaving in turn a rather small fraction of resources to be pre-empted successively by other species (Sinha et al., 1988). Thus, sharing of some limiting resources by the member species is proportionately related with the dominance of the species, which becomes more distinct with low diversity (Yodzis, 1978).

From the data of Sørensens index of similarity it is observed that no two watersheds are identical in species composition. Low indices of similarity between communities of the different watersheds are indicative of important role of farming systems in changing the weed flora. Relatively higher similarity between FS-W_2 and FS-W_3 is due to the growth of only a few highly dominant species on these watersheds. The most notable difference was observed in the similarity index between FS-W_4 and FS-W_7 as these systems showed the least similarity of species. The two most disturbed sites viz. FS-W_4 and FS-W_5 which appeared similar showed considerable dissimilarity. The greater similarity between FS-W_2 and FS-W_3 may be attributed to almost equal degree (mild) of agricultural operations and similar type of tree canopy in these watersheds. It is concluded that the various kinds of manipulations created in various farming systems brought about the observed differences in weed species content and phytosociological attributes of weed communities developing on different watersheds.

Table 4.1. Species composition of weed communities in different farming systems during 1987 and 1988. + = Present, – = Absent, A = Annual, P = Perennial.

Weed Species		1987								1988							
		W_1	W_2	W_3	W_4	W_5	W_6	W_7	W_8	W_1	W_2	W_3	W_4	W_5	W_6	W_7	W_8
GRASSES																	
Arundinella benghalensis (Spreng) Druce	P	–	+	+	–	+	+	+	+	–	+	+	–	+	+	+	+
Bothriochloa intermedia (R. Br.) A. Camus	P	–	+	+	–	–	–	+	+	–	+	+	–	–	–	+	+
Cynodon dactylon Pers.	P	+	–	–	+	+	–	–	–	+	–	+	+	+	–	–	–
Digitaria sanguinalis Scop.	A	–	–	–	–	–	–	–	–	–	+	+	–	+	+	–	+
Echinochloa crusgalli Beauv.	A	–	–	–	–	–	–	–	–	–	–	–	+	+	–	–	–
Eleusine indica Gaertn.	A	–	–	–	+	+	–	–	–	–	–	–	+	+	–	–	–
Eragrostis rubra	A	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Eulalia fustigiata (Nees) Haines	A	+	+	+	+	+	+	+	+	–	+	–	–	–	+	–	+
Guinea panicummaximum	P	–	–	–	–	–	–	–	+	–	–	–	–	–	–	–	+
Imperata cylindrica Beauv.	P	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Panicum montanum Roxb.	P	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Paspalum dilatatum Poir.	P	–	–	–	–	–	–	–	–	–	+	+	+	+	+	–	–
Pannisetum polystachyon Schult.	A	–	–	–	+	+	–	–	–	–	–	–	+	+	+	–	+
Phragmites karka Trin.	P	–	+	–	–	–	+	+	–	–	+	–	–	–	–	+	+

Table 4.1. (Contd.)

Weed Species		1987								1988							
		W_1	W_2	W_3	W_4	W_5	W_6	W_7	W_8	W_1	W_2	W_3	W_4	W_5	W_6	W_7	W_8
Saccharum spontaneum L.	P	+	-	-	-	-	-	+	+	+	+	-	-	-	-	+	+
Setaria glauca Beauv.	A	+	+	+	+	+	-	-	+	+	+	+	+	+	-	-	+
Setaria palmifolia (Koen.) Stapf.	A	-	-	+	-	-	-	+	-	-	-	+	+	-	-	+	+
LEGUMES																	
Crotolaria striata DC.	A	-	-	+	-	-	+	+	-	-	-	-	-	-	-	+	+
Desmodium heterophyllum DC.	P	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Desmodium microphyllum Miq.	A	+	+	+	-	-	+	+	+	+	+	+	-	+	+	+	+
Indigofera sp.	P	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	+
Mimosa pudica L.	P	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Stylosanthes guianensis SW.	P	-	-	+	-	-	-	-	-	-	-	+	-	-	-	-	+
OTHER FORBS																	
Acrocephalus indicus (Burm. f.) Ktze.	A	+	+	+	+	+	+	+	+	-	+	-	+	-	-	-	-
Ageratum conyzoides L.	A	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Ageratum houstonianum Mill.	A	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Ajuga macrosperma Wall.	A	+	-	+	-	-	+	-	+	-	-	-	-	+	+	-	-
Alectra indica Benth.	A	+	+	+	+	-	+	-	+	+	+	+	-	-	+	+	-

Table 4.1. (Contd.)

Weed Species		1987								1988							
		W_1	W_2	W_3	W_4	W_5	W_6	W_7	W_8	W_1	W_2	W_3	W_4	W_5	W_6	W_7	W_8
Alternanthera philaxeroides Griseb.	A	+	–	–	+	+	–	–	–	+	+	+	–	–	+	+	–
Alternanthera sessilis Br.	A	–	–	–	–	+	–	–	+	–	–	–	–	+	–	+	–
Anaphilis adnata DC.	A	+	+	+	–	–	–	–	+	+	+	+	–	–	–	–	+
Argostemma khasianum Cl.	A	–	–	+	–	+	+	+	+	–	–	+	–	+	–	–	+
Aristolochia tagala Chem.	P	+	+	+	+	+	+	+	+	+	+	+	–	+	+	+	+
Artemisia vulgaris L.	P	+	–	–	+	–	–	–	–	+	–	–	+	–	–	–	–
Bidens pilosa L.	A	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Biophytum sensitivum DC.	A	+	+	+	+	+	+	–	+	+	–	–	+	+	–	–	–
Blumea sp.	A	+	+	+	–	–	+	+	+	+	+	+	–	–	+	+	+
Borreria hispida (L.) Schum	A	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Buddleja asiatica Lour.	P	+	+	+	–	–	+	+	+	+	+	+	–	–	+	+	+
Callicarpa rubella Lindl.	P	+	+	+	+	–	–	–	+	+	+	+	–	–	–	+	–
Cannabis sativa L.	A	+	–	–	–	–	–	–	–	+	–	–	–	–	–	–	–
Carex composita Bott.	P	+	+	+	+	+	+	+	+	–	+	+	+	+	+	+	–
Centella asiatica (L.) Urb.	P	+	+	+	+	+	+	–	+	+	+	+	+	–	–	–	–
Commelina paludosa Bl.	A	–	–	+	+	+	–	–	–	+	–	+	+	+	–	–	–
Cosmos bipinnatus Cav.	A	+	+	+	+	+	+	+	+	+	+	+	+	+	–	+	+

Table 4.1. (Contd.)

Weed Species		1987								1988							
		W_1	W_2	W_3	W_4	W_5	W_6	W_7	W_8	W_1	W_2	W_3	W_4	W_5	W_6	W_7	W_8
Crassocephalum crepidioides (Benth) S. Moore	A	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Cyanotis vaga Schultes f.	A	+	+	+	+	+	+	+	+	-	+	+	-	-	+	+	+
Cyclea sp.	A	+	-	-	-	+	+	-	-	-	+	-	-	-	+	-	+
Cyperus tuberosa Rottb.	P	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Drymeria cordata Willd.	A	+	-	-	+	-	-	-	-	-	-	-	+	-	-	-	-
Dysophylla linearis Benth.	A	+	+	+	-	-	-	-	+	+	+	+	-	-	-	+	+
Elephantopus scaber L.	P	+	+	-	-	-	+	-	-	+	+	+	-	+	+	+	+
Elsholtzia blanda Benth.	P	+	+	+	-	+	+	+	+	+	+	+	-	+	-	+	+
Emilia sonchifolia DC.	A	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Eupatorium adenophorum Spreng.	P	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Eupatorium odoratum L.	P	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Eusteralis stellata (Lour.) Balak.	P	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Erigeron bonariansis L.	A	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Fimbristylis complanata Benth.	A	+	+	+	-	+	+	-	+	+	+	+	-	+	+	-	+
Galinsoga parviflora Cav.	A	+	-	-	+	+	+	-	-	+	-	-	+	+	+	-	-
Gentiana quadrifaria Bl.	A	+	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-
Gleichenia dichotoma Willd.	P	-	+	+	-	-	+	-	-	-	+	+	-	-	+	+	+

Table 4.1. (Contd.)

Weed Species		1987								1988							
		W_1	W_2	W_3	W_4	W_5	W_6	W_7	W_8	W_1	W_2	W_3	W_4	W_5	W_6	W_7	W_8
Hypericum japonicum Thumb.	A	+	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-
Hypochaeris radicata L.	A	+	-	+	-	-	-	-	-	-	-	-	+	-	-	-	+
Inula cappa DC.	P	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Kyllinga melanosperma Nees	P	+	+	+	+	+	+	+	+	+	+	-	+	+	-	-	-
Lantana camara L.	P	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Lygodium sp.	P	+	+	+	+	-	+	+	+	+	+	+	+	-	+	+	+
Melastoma normale Don.	P	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Mikania micrantha HBK	P	-	-	-	+	-	-	-	-	-	-	-	-	+	-	-	-
Nelsonia canescens Nees	P	-	-	-	-	+	-	-	+	-	-	-	-	+	-	-	-
Osbeckia crinita Benth.	P	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Oxalis corniculata L.	P	+	-	-	+	+	-	-	-	+	-	-	+	-	-	-	-
Oxalis latifolia HBK	P	+	+	+	+	+	+	+	+	+	+	+	+	+	-	-	-
Phyllanthes urinaria L.	A	-	+	+	-	-	-	-	-	-	+	+	-	-	-	-	+
Plantago major L.	P	+	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-
Plectranthus ternifolius Don.	P	-	-	-	-	-	+	-	+	-	-	-	-	-	-	+	-
Polygala persicariaefolia DC.	A	+	+	+	-	+	+	+	+	+	+	-	-	-	-	-	-
Pteridium aquilinum (L.)	P	+	+	+	-	-	+	+	+	+	+	+	+	-	+	+	+

Table 4.1. (Contd.)

Weed Species		1987								1988							
		W_1	W_2	W_3	W_4	W_5	W_6	W_7	W_8	W_1	W_2	W_3	W_4	W_5	W_6	W_7	W_8
Richardsonia sp.	A	+	+	+	+	+	+	+	+	+	+	-	+	+	-	+	-
Rubus ellipticus Sm.	P	+	+	-	-	-	+	+	+	+	+	+	-	-	+	+	+
Rubus moluccanus L.	P	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Rungia pectinata Nees	A	-	-	-	-	+	-	-	-	-	-	-	-	+	-	-	-
Salmonia cantoniensis Low.	A	+	+	+	+	+	-	+	+	+	+	-	+	-	-	-	-
Sida rhomboidea Roxb.	P	-	+	+	-	+	-	+	+	+	-	-	-	+	+	-	+
Solanum khasianum Cl.	P	+	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-
Sonchus oleraceus L.	A	-	-	+	+	-	-	-	-	-	-	+	+	-	-	+	-
Sonerila maculata Roxb.	A	+	-	-	+	-	+	-	-	-	-	-	-	-	+	-	-
Spilanthes paniculata DC.	A	-	-	-	+	+	-	-	-	+	-	-	+	+	-	-	-
Stachytorpheta dichotoma Vahl.	P	+	+	+	+	-	-	+	-	+	+	+	+	-	-	+	-
Triumfetta rhomboidea Jacq.	A	-	-	+	-	-	+	-	+	-	-	+	-	-	+	-	+
Urena lobata L.	P	+	+	+	-	-	+	+	+	+	+	+	-	+	+	+	+
Verbena vinosa	A	+	-	-	-	+	+	+	+	-	+	-	-	+	+	+	-

Table 4.2. Monthly variation in total number of weed species growing in different watersheds during 1987. The values in parentheses refer to total weed density per m^2.

Month	Watersheds							
	$FS\text{-}W_1$	$FS\text{-}W_2$	$FS\text{-}W_3$	$FS\text{-}W_4$	$FS\text{-}W_5$	$FS\text{-}W_6$	$FS\text{-}W_7$	$FS\text{-}W_8$
January	29 (96)	27 (93)	36 (159)	26 (113)	31 (78)	31 (107)	27 (116)	35 (149)
February	29 (92)	29 (93)	37 (155)	26 (110)	34 (86)	32 (103)	28 (119)	35 (149)
March	33 (112)	32 (109)	40 (174)	30 (127)	37 (99)	34 (117)	31 (124)	37 (156)
April	36 (100)	31 (101)	39 (163)	32 (125)	37 (99)	34 (104)	32 (119)	38 (150)
May	37 (112)	36 (106)	41 (172)	31 (126)	34 (97)	35 (113)	34 (131)	39 (158)
June	42 (135)	39 (117)	43 (193)	33 (130)	34 (110)	36 (131)	36 (151)	39 (173)
July	44 (145)	39 (121)	44 (193)	35 (130)	33 (110)	36 (126)	36 (163)	39 (184)
August	60 (161)	54 (145)	58 (219)	45 (139)	44 (127)	49 (142)	48 (188)	55 (214)
September	61 (156)	55 (144)	59 (221)	46 (140)	45 (130)	50 (145)	49 (184)	56 (210)
October	60 (154)	55 (147)	59 (217)	46 (136)	45 (126)	50 (145)	49 (182)	56 (204)
November	60 (148)	55 (142)	58 (211)	46 (144)	45 (124)	50 (141)	49 (177)	55 (208)
December	58 (129)	55 (141)	57 (188)	42 (119)	43 (115)	50 (127)	49 (162)	54 (176)

Table 4.3. **Monthly variation in total number of weed species growing in different watersheds during 1988. The values in parentheses refer to total weed density per m^2.**

Month	Watersheds							
	$FS\text{-}W_1$	$FS\text{-}W_2$	$FS\text{-}W_3$	$FS\text{-}W_4$	$FS\text{-}W_5$	$FS\text{-}W_6$	$FS\text{-}W_7$	$FS\text{-}W_8$
January	44 (95)	47 (111)	49 (153)	34 (102)	33 (94)	37 (97)	37 (143)	38 (131)
February	28 (77)	33 (92)	36 (135)	24 (78)	22 (67)	25 (82)	32 (128)	34 (120)
March	34 (72)	31 (86)	29 (115)	19 (49)	20 (47)	21 (65)	29 (142)	27 (128)
April	35 (99)	34 (124)	35 (152)	22 (108)	24 (83)	25 (102)	31 (150)	28 (143)
May	46 (177)	48 (191)	49 (226)	38 (217)	38 (169)	33 (153)	42 (195)	37 (212)
June	51 (186)	52 (201)	50 (230)	44 (221)	45 (173)	37 (157)	44 (197)	44 (224)
July	52 (155)	52 (181)	51 (206)	45 (183)	48 (149)	41 (138)	45 (192)	51 (216)
August	53 (162)	52 (186)	50 (209)	45 (199)	48 (166)	41 (137)	44 (186)	50 (219)
September	52 (137)	51 (167)	50 (189)	43 (158)	48 (140)	42 (121)	45 (178)	50 (203)
October	52 (127)	51 (164)	50 (177)	42 (126)	48 (125)	42 (112)	46 (173)	51 (193)
November	43 (114)	45 (161)	45 (173)	35 (123)	43 (123)	33 (109)	41 (173)	45 (188)
December	33 (91)	37 (143)	37 (156)	29 (119)	34 (117)	27 (105)	37 (156)	39 (164)

Table 4.4. Species exclusively present in different farming systems during 1987 and 1988.

Watersheds	Exclusive species
	1987
FS-W_1	Cannabis sativa, Gentiana quadrifaria, Hypericum japonicum, Plantago major, Solanum khasianum.
FS-W_2	None
FS-W_3	None
FS-W_4	Mikania micrantha
FS-W_5	Rungia pectinata
FS-W_6	None
FS-W_7	None
FS-W_8	Guinea panicummaximum
	1988
FS-W_1	Cannabis sativa, Gentiana quadrifaria, Hypericum japonicum, Plantago major, Solanum khasianum.
FS-W_2	None
FS-W_3	None
FS-W_4	Drymeria cordata
FS-W_5	Mikania micrantha, Nelsonia canescens, Rungia pectinata.
FS-W_6	Sonerila maculata
FS-W_7	None
FS-W_8	Guinea panicummaximum

Table 4.5. List of species common to all the eight watersheds under different farming systems during 1987 and 1988.

1987	1988
Grasses	**Grasses**
Eragrostis rubra	Eragrostis rubra
Eulalia fustigiata	Imperata cylindrica
Imperata cylindrica	Panicum montanum
Panicum montanum	
Legumes	**Legumes**
Desmodium heterophyllum	Desmodium heterophyllum
Mimosa pudica	Mimosa pudica
Other Forbs	**Other Forbs**
Acrocephalus indicus	Ageratum conyzoides
Ageratum conyzoides	Ageratum houstonianum
Ageratum houstonianum	Bidens pilosa
Aristolochia tagala	Borreria hispida
Bidens pilosa	Crassocephalum crepidioides
Borreria hispida	Cyperus tuberosa
Carex composita	Emelia sonchifolia
Cosmos bipinnatus	Eupatorium adenophorum
Crassocephalum crepidioides	Eupatorium odoratum
Cyanotis vaga	Eusteralis stellata
Cyperus tuberosa	Erigeron bonariansis
Emelia sonchifolia	Inula cappa
Eupatorium adenophorum	Lantana camara
Eupatorium odoratum	Melastoma normale
Eusteralis stellata	Osbeckia crinita
Erigeron bonariansis	Rubus moluccanus
Inula cappa	
Kyllinga melanosperma	
Lantana camara	
Melastoma normale	
Osbeckia crinita	
Oxalis latifolia	
Richarsonia sp.	
Rubus moluccanus	

Table 4.6. List of species common to more than one watershed (but not to all watersheds) during 1987.

Species	Watersheds							
	FS-W_1	FS-W_2	FS-W_3	FS-W_4	FS-W_5	FS-W_6	FS-W_7	FS-W_8
GRASSES								
Arundinella benghalensis	–	+	+	–	+	+	+	+
Bothriochloa intermedia	–	+	+	–	–	–	+	+
Cynodon dactylon	+	–	–	+	+	–	–	–
Eleusine indica	–	–	–	+	+	–	–	–
Pennisetum polystachyon	–	–	–	+	+	–	–	–
Phragmites karka	–	+	–	–	–	+	+	–
Saccharum spontaneum	+	–	–	–	–	–	+	+
Setaria glauca	+	+	+	+	+	–	–	+
Setaria palmifolia	–	–	+	–	–	–	+	–
LEGUMES								
Crotolaria striata	–	–	+	–	–	+	+	–
Desmodium microphyllum	+	+	+	–	–	+	+	+
Stylosanthes guianensis	–	–	+	+	–	–	–	–
OTHER FORBS								
Ajuga macrosperma	+	–	+	–	–	+	–	+
Alectra indica	+	+	+	+	–	+	–	+
Alternanthera sessilis	–	–	–	–	+	–	–	+
Amaranthes sessilis	+	–	–	+	+	–	–	–
Anaphilis adnata	+	+	+	–	–	–	–	+
Artemisia vulgaris	+	–	–	+	–	–	–	–
Biophytum sensitivum	+	+	+	+	+	+	–	+
Blumea sp.	+	+	+	–	–	+	+	+
Borreria stricta	–	–	+	–	+	+	+	+
Buddleja asiatica	+	+	+	–	–	+	+	+
Callicarpa rubella	+	+	+	+	–	–	–	+

Table 4.6.(Contd.)

Species	Watersheds							
	FS-W_1	FS-W_2	FS-W_3	FS-W_4	FS-W_5	FS-W_6	FS-W_7	FS-W_8
Centella asiatica	+	+	+	+	+	+	–	+
Commelina paludosa	–	–	+	+	+	–	–	–
Cyclea sp.	+	–	–	–	+	+	–	–
Drymeria cordata	+	–	–	+	–	–	–	–
Dysophylla linearis	+	+	+	–	–	–	–	+
Elephantopus scaber	+	+	–	–	–	+	–	–
Elsholtzia blanda	+	+	+	–	+	+	+	+
Fimbristylis complanata	+	+	+	–	+	+	–	+
Galinsoga parviflora	+	–	–	+	+	+	–	–
Gleichenia dichotoma	–	+	+	–	–	+	–	–
Hypochaeris radicata	+	–	+	–	–	–	–	–
Lygodium sp.	+	+	+	+	–	+	+	+
Nelsonia canescens	–	–	–	–	+	–	–	+
Oxalis corniculata	+	–	–	+	+	–	–	–
Phyllanthes urinaria	–	+	+	–	–	–	–	–
Plectranthus ternifolius	–	–	–	–	–	+	–	+
Polygala persicariaefolia	+	+	+	–	+	+	+	+
Pteridium aquilinum	+	+	+	–	–	+	+	+
Rubus ellipticus	+	+	–	–	–	+	+	+
Salmonia cantoniensis	+	+	+	+	+	–	+	+
Sida rhomboidea	–	+	+	–	+	–	+	+
Sonchus oleraceus	–	–	+	+	–	–	–	–
Sonerilia sp.	+	–	–	+	–	+	–	–
Spilanthes paniculata	–	–	–	+	+	–	–	–
Stachytorpheta dichotoma	+	+	+	+	–	–	+	–
Triumfetta rhomboidea	–	–	+	–	–	+	–	+
Urena lobata	+	+	+	–	–	+	+	+
Verbena vinosa	+	–	–	–	+	+	+	+

Table 4.7. List of species common to more than one watershed (but not to all watersheds) during 1988.

Species	Watersheds							
	FS-W_1	FS-W_2	FS-W_3	FS-W_4	FS-W_5	FS-W_6	FS-W_7	FS-W_8
GRASSES								
Arundinella benghalensis	-	+	+	-	+	+	+	+
Bothriochloa intermedia	-	+	+	-	-	-	+	+
Cynodon dactylon	+	-	+	+	+	-	-	-
Digitaria sanguinalis	-	+	+	-	+	+	-	+
Echinochloa crusgalli	-	-	-	+	+	-	-	-
Eleusine indica	-	-	-	+	+	-	-	-
Eulalia fustigiata	-	+	-	-	-	+	-	+
Paspalum dilatatum	-	+	+	+	+	+	-	-
Pennisetum polystachyon	-	-	-	+	+	+	-	+
Phragmites karka	-	+	-	-	-	-	+	+
Saccharum spontaneum	+	+	-	-	-	-	+	+
Setaria glauca	+	+	+	+	+	-	-	+
Setaria palmifolia	-	-	+	+	-	-	+	+
LEGUMES								
Crotolaria striata	-	-	-	-	-	-	+	+
Desmodium microphyllum	+	+	+	-	+	+	+	+
Indigofera sp.	-	-	-	-	+	-	-	+
Stylosanthes guianensis	-	-	+	-	-	-	-	+
OTHER FORBS								
Acrocephalus indicus	-	+	-	+	-	-	-	-
Ajuga macrosperma	-	-	-	-	+	+	-	-
Alectra indica	+	+	+	-	-	+	+	-
Alternanthera sessilis	-	-	-	-	+	-	+	-
Amaranthes sessilis	+	+	+	-	-	+	+	-
Anaphilis adnata	+	+	+	-	-	-	-	+
Aristolochia tagala	+	+	+	-	+	+	+	+
Artemisia vulgaris	+	-	-	+	-	-	-	-
Biophytum sensitivum	+	-	-	+	+	-	-	-
Blumes sp.	+	+	+	-	-	+	+	+
Borreria stricta	-	-	+	-	+	-	-	+

Table 4.7. (Contd.)

Species	Watersheds							
	FS-W_1	FS-W_2	FS-W_3	FS-W_4	FS-W_5	FS-W_6	FS-W_7	FS-W_8
Buddleja asiatica	+	+	+	−	−	+	+	+
Callicarpa rubella	+	+	+	−	−	−	+	−
Carex composita	−	+	+	+	+	+	+	−
Centella asiatica	+	+	+	+	−	−	−	−
Commelina paludosa	+	−	+	+	+	−	−	−
Cosmos bipinnatus	+	+	+	+	+	−	+	+
Cyanotis vaga	−	+	+	−	−	+	+	+
Cyclea sp.	−	+	−	−	−	+	−	+
Dysophylla linearis	+	+	+	−	−	−	+	+
Elephantopus scaber	+	+	+	−	+	+	+	+
Elsholtzia blanda	+	+	+	−	+	−	+	+
Fimbristylis complanata	+	+	+	−	+	+	−	+
Galinsoga parviflora	+	−	−	+	+	+	−	−
Gleichenia dichotoma	−	+	+	−	−	+	+	+
Hypochaeris radicata	−	−	−	+	−	−	−	+
Kyllinga melanosperma	+	+	−	+	+	−	−	−
Lygodium sp.	+	+	+	+	−	+	+	+
Oxalis corniculata	+	−	−	+	−	−	−	−
Oxalis latifolia	+	+	+	+	+	−	−	−
Phyllanthes urinaria	−	+	+	−	−	−	−	+
Plectranthes ternifolius	−	−	−	−	−	−	+	+
Polygala persicariaefolia	+	+	−	−	−	−	−	−
Pteridium aquilinum	+	+	+	+	−	+	+	+
Richardsonia sp.	+	+	−	+	+	−	+	−
Rubus ellipticus	+	+	+	−	−	+	+	+
Salmonia cantoniensis	+	+	−	+	−	−	−	−
Sida rhomboidea	+	−	−	−	+	+	−	+
Sonchus oleraceus	−	−	+	+	−	−	+	−
Spilanthes paniculata	+	−	−	+	+	−	−	−
Stachytorpheta dichotoma	+	+	+	+	−	−	+	−
Triumfetta rhomboidea	−	−	+	−	−	+	−	+
Urena lobata	+	+	+	−	+	+	+	+
Verbena vinosa	−	+	−	−	+	+	+	−

Table 4.9. The weed species showing highest density values in different farming systems during 1987 and 1988. The months in which they show peak density along with the details of their growth phase are also indicated. Data based on 10 quadrats of 1 m^2 area. Sg = Seedling, Veg. = Vegetative, Fl. = Flowering, Fr. = Fruiting.

Watersheds	1987				1988			
	Species	Density (m^2)	Month	Phenology	Species	Density (m^2)	Month	Phenology
FS-W_1	*Bidens pilosa*	28.2	April	Sg.	*Ageratum houstonianum*	30.0	May	Sg., Veg.
FS-W_2	*Bidens pilosa*	24.8	May	Sg., Veg.	*Ageratum houstonianum*	29.0	May	Sg.
FS-W_3	*Ageratum houstonianum*	31.0	August	Sg., Veg., Fl., Fr.	*Bidens pilosa*	33.0	April	Sg., Veg.
FS-W_4	*Bidens pilosa*	62.2	May	Sg., Veg.	*Bidens pilosa*	54.2	April	Sg., Veg.
FS-W_5	*Bidens pilosa*	30.2	May	Sg., Veg.	*Bidens pilosa*	36.0	April	Sg., Veg.
FS-W_6	*Bidens pilosa*	27.6	May	Sg., Veg.	*Imperata cylindrica*	33.0	June	Veg., Fr.
FS-W_7	*Arundinella benghalensis*	19.1	May	Veg., Fl.	*Arundinella benghalensis*	19.2	June	Veg., Fl., Fr.
FS-W_8	*Ageratum houstonianum*	23.4	August	Sg., Veg.	*Ageratum conyzoides*	25.0	April	Sg.

Table 4.10. Frequency (%) of weed species in August (the peak growing period) in different farming sytems during 1987 and 1988.

Species	1987								1988							
	W_1	W_2	W_3	W_4	W_5	W_6	W_7	W_8	W_1	W_2	W_3	W_4	W_5	W_6	W_7	W_8
GRASSES																
Arundinella benghalensis	-	80	80	-	50	80	100	100	-	80	80	-	50	90	100	100
Bothriochloa intermedia	-	50	60	-	-	-	100	80	-	60	80	-	-	-	100	80
Cynodon dactylon	20	-	-	40	20	-	-	-	70	-	40	80	60	-	-	-
Digitaria sanguinalis	-	-	-	-	-	-	-	-	-	70	-	-	50	60	-	80
Echinochloa crusgalli	-	-	-	-	-	-	-	-	-	-	-	40	30	-	-	-
Eleusine indica	-	-	-	20	20	-	-	-	-	-	-	60	50	-	-	-
Eragrostis rubra	50	50	40	40	50	40	60	40	30	30	50	30	50	40	70	40
Eulalia fustigiata	20	30	10	10	20	30	30	50	-	-	-	-	-	50	-	-
Guinea panicummaximum	-	-	-	-	-	-	-	50	-	-	-	-	-	-	-	50
Imperata cylindrica	70	80	100	60	60	100	70	90	70	100	100	60	80	100	80	100
Panicum montanum	-	100	70	40	40	40	70	50	50	100	70	40	60	50	70	80
Paspalum dilatatum	-	-	-	-	-	-	-	-	-	40	60	50	30	30	-	-
Pennisetum polystachyon	-	-	-	30	-	-	-	-	-	-	-	30	30	30	-	60
Phragmites karka	-	40	-	-	-	-	80	-	-	40	-	-	-	-	80	40
Saccharum spontaneum	20	-	-	-	-	-	70	60	-	60	-	-	-	-	70	80
Setaria glauca	70	30	90	40	30	-	-	70	70	30	90	50	90	-	-	80
Setaria palmifolia	-	-	70	-	-	-	40	-	-	-	70	50	-	-	50	50

Table 4.10 (Contd.)

Species	1987								1988							
	W_1	W_2	W_3	W_4	W_5	W_6	W_7	W_8	W_1	W_2	W_3	W_4	W_5	W_6	W_7	W_8
LEGUMES																
Crotolaria striata	-	-	-	-	-	-	50	-	-	-	-	-	-	-	40	-
Desmodium heterophyllum	50	40	90	20	40	50	70	50	-	-	-	-	30	20	60	-
Desmodium microphyllum	70	60	30	-	-	80	80	80	60	90	70	-	50	60	80	100
Indigofera sp.	-	-	-	-	-	-	-	-	-	-	-	-	20	-	-	30
Mimosa pudica	70	70	70	60	60	60	70	80	70	60	70	50	50	50	70	80
Stylosanthes guianensis	-	-	30	-	-	-	-	-	-	-	60	-	-	-	-	30
OTHER FORBS																
Acrocephalus indicus	30	20	30	30	40	30	50	40	-	-	-	-	-	-	-	-
Ageratum conyzoides	100	100	100	100	100	100	40	60	100	100	100	100	100	100	50	80
Ageratum houstonianum	100	100	100	100	100	100	40	80	100	100	100	100	100	100	50	100
Ajuga macrosperma	30	-	40	-	-	40	-	-	-	-	-	-	20	-	-	-
Alectra indica	30	20	80	-	-	-	-	-	30	50	50	-	-	60	60	-
Alternanthera philoxeroides	-	-	-	-	-	-	-	-	20	10	40	-	-	20	20	-
Alternanthera sessilis	-	-	-	-	-	-	-	40	-	-	-	-	10	-	20	-
Anaphilis adnata	40	30	50	-	-	-	-	-	-	10	30	-	-	-	-	40
Argostemma khasianum	-	-	-	-	50	50	40	20	-	-	-	-	30	-	-	50
Aristolochia tagala	40	50	40	-	50	60	80	50	20	30	40	-	40	20	80	70
Artemisia vulgaris	-	-	-	20	-	-	-	-	20	-	-	30	-	-	-	-

Table 4.10 (Contd.)

Species	1987								1988							
	W_1	W_2	W_3	W_4	W_5	W_6	W_7	W_8	W_1	W_2	W_3	W_4	W_5	W_6	W_7	W_8
Bidens pilosa	100	100	100	100	80	90	40	80	100	100	100	100	100	100	40	100
Biophytum sensitivum	40	50	50	60	60	40	-	50	20	-	-	20	50	-	-	-
Blumea sp.	20	-	60	-	-	80	60	60	20	20	40	-	-	70	40	60
Borreria hispida	90	90	70	90	80	80	80	80	80	90	70	90	80	80	80	80
Buddleja asiatica	30	30	30	-	-	30	50	60	20	10	20	-	-	-	50	50
Callicarpa rubella	40	20	20	40	-	-	-	40	20	20	20	-	-	-	30	-
Cannabis sativa	-	-	-	-	-	-	-	-	20	-	-	-	-	-	-	-
Carex composita	50	60	70	20	40	50	60	80	-	40	30	-	40	-	-	-
Centella asiatica	60	70	70	70	40	40	-	70	70	60	30	40	-	-	-	-
Commelina paludosa	-	-	30	70	30	-	-	-	40	-	-	60	80	-	-	-
Cosmos bipinnatus	60	40	50	70	60	40	50	30	60	30	-	40	-	-	60	20
Crassocephalum crepidioides	60	40	70	60	60	80	40	70	30	80	20	20	30	20	-	60
Cyanotis vaga	-	-	-	-	-	-	-	-	-	30	20	-	-	-	30	30
Cyclea sp.	20	-	-	-	-	10	-	-	-	-	-	-	-	-	-	30
Cyperus tuberosus	60	60	60	40	50	40	20	90	60	50	60	40	50	30	50	50
Drymeria cordata	30	-	-	30	-	-	-	-	-	-	-	20	-	-	-	-
Dysophylla linearis	40	40	50	-	-	-	-	40	20	10	20	-	-	-	30	20
Elephantopus scaber	-	30	-	-	-	-	-	-	50	-	40	-	20	-	-	-
Elsholtzia blanda	60	50	90	-	50	50	80	100	20	10	-	-	-	-	-	-

Table 4.10 (Contd.)

Species	1987								1988							
	W_1	W_2	W_3	W_4	W_5	W_6	W_7	W_8	W_1	W_2	W_3	W_4	W_5	W_6	W_7	W_8
Emelia sonchifolia	50	50	70	70	50	70	20	40	20	20	30	20	20	20	-	-
Eupatorium adenophorum	90	70	80	40	70	90	100	70	80	60	30	30	70	70	90	80
Eupatorium odoratum	80	80	100	60	80	100	100	100	40	70	100	20	60	80	90	80
Eusteralis stellata	40	80	70	40	50	80	100	90	60	70	70	40	30	70	80	90
Erigeron bonariansis	60	50	60	40	60	60	60	70	20	50	40	20	30	20	80	60
Fimbristylis complanata	40	30	70	-	30	40	-	70	-	50	60	-	50	30	-	50
Galinsoga parviflora	40	-	-	90	50	30	-	-	60	-	-	80	90	-	-	-
Gentiana quadrifaria	-	-	-	-	-	-	-	-	10	-	-	-	-	-	-	-
Gleichenia dichotoma	-	80	60	-	-	30	-	-	-	80	60	-	-	30	40	30
Hypericum japonicum	30	-	-	-	-	-	-	-	20	-	-	-	-	-	-	-
Hypochaeris radicata	40	-	50	-	-	-	-	-	-	-	-	40	-	-	-	80
Inula cappa	50	70	60	30	50	80	90	90	20	70	50	10	30	40	80	80
Kyllinga melanosperma	30	50	60	60	60	70	50	30	-	-	-	20	-	-	-	-
Lantana camara	40	100	80	50	40	70	80	90	40	100	80	30	40	70	80	90
Lygodium sp.	40	100	60	40	-	60	80	90	40	100	80	30	-	60	80	90
Melastoma normale	60	60	50	40	60	70	80	80	60	60	50	30	60	60	80	80
Mikania micrantha	-	-	-	50	-	-	-	-	-	-	-	-	60	-	-	-
Nelsonia canescens	-	-	-	-	-	-	-	-	-	-	-	-	20	-	-	-
Osbeckia crinita	80	80	80	40	70	70	90	80	80	70	70	40	70	70	90	50
Oxalis corniculata	30	-	-	-	-	-	-	-	50	-	-	20	-	-	-	-

Table 4.10 (Contd.)

Species	1987								1988							
	W_1	W_2	W_3	W_4	W_5	W_6	W_7	W_8	W_1	W_2	W_3	W_4	W_5	W_6	W_7	W_8
Oxalis latifolia	40	50	60	60	40	60	30	70	30	60	30	40	-	-	-	-
Phyllanthes urinaria	-	40	40	-	-	-	-	-	-	60	30	-	-	-	-	50
Plantago major	30	-	-	-	-	-	-	-	20	-	-	-	-	-	-	-
Plectranthus ternifolius	-	-	-	-	-	-	-	40	-	-	-	-	-	-	40	60
Polygala persicariaefolia	20	30	30	-	40	30	20	30	-	30	-	-	-	-	-	-
Pteridium aquilinum	50	70	40	-	-	50	60	90	50	70	40	20	-	50	60	60
Richardsonia sp.	60	50	60	70	60	40	70	80	-	50	-	30	-	-	80	-
Rubus ellipticus	50	40	-	-	-	80	50	90	50	40	20	-	-	70	50	50
Rubus moluccanus	80	70	80	30	70	70	90	90	80	70	70	30	70	70	90	80
Rungia pectinata	-	-	-	-	60	-	-	-	-	-	-	-	30	-	-	-
Salmonia cantoniensis	10	20	10	10	10	-	30	10	-	-	-	20	-	-	-	-
Sida rhomboidea	-	30	-	-	-	-	20	30	10	-	-	-	20	30	-	20
Solanum khasianum	10	-	-	-	-	-	-	-	20	-	-	-	-	-	-	-
Sonchus oleraceus	-	-	90	50	-	-	-	-	-	-	-	10	-	-	-	-
Sonerila maculata	20	-	-	20	-	30	-	-	-	-	-	-	-	30	-	-
Spilanthes paniculata	-	-	-	30	30	-	-	-	30	-	-	60	80	-	-	-
Stachytorpheta dichotoma	50	60	80	-	-	-	50	-	50	60	80	40	-	-	50	-
Triumfetta rhomboidea	-	-	80	-	-	80	-	70	-	-	70	-	-	40	-	-
Urena lobata	50	30	50	-	-	50	50	30	30	10	50	-	20	40	50	90
Verbena vinosa	20	-	-	-	-	-	-	20	-	20	-	-	20	20	-	-

Table 4.11. Importance value indices (IVI) of different species at the peak growth period (August) in different farming systems during 1987 and 1988. W = Watersheds, - = Species absence.

Species	1987								1988							
	W_1	W_2	W_3	W_4	W_5	W_6	W_7	W_8	W_1	W_2	W_3	W_4	W_5	W_6	W_7	W_8
GRASSES																
Arundinella benghalensis	-	14.4	12.9	-	10.1	12.2	24.4	22.9	-	13.2	28.9	-	29.3	30.6	46.4	43.1
Bothriochloa intermedia	-	5.6	9.7	-	-	-	15.6	12.3	-	15.3	19.6	-	-	-	20.8	17.0
Cynodon dactylon	1.8	-	-	6.1	3.2	-	-	-	11.1	-	4.4	11.4	8.0	-	-	-
Digitaria sanguinalis	-	-	-	-	-	-	-	-	-	4.3	-	-	4.9	7.6	-	6.2
Echinochloa crusgalli	-	-	-	-	-	-	-	-	-	-	-	5.0	3.6	-	-	-
Eleusine indica	-	-	-	2.1	2.4	-	-	-	-	-	-	5.9	4.7	-	-	-
Eragrostis rubra	3.2	3.9	3.8	4.0	7.4	3.7	4.9	2.5	3.8	2.4	4.0	2.3	6.4	4.1	4.9	2.1
Eulalia fustigiata	0.8	1.5	0.3	0.6	1.1	1.3	1.2	1.8	-	-	-	-	-	3.9	-	-
Guinea panicummaximum	-	-	-	-	-	-	-	5.0	-	-	-	-	-	-	-	10.2
Imperata cylindrica	10.2	11.5	16.3	9.6	11.3	25.8	9.5	11.0	28.6	41.7	36.1	21.0	26.3	72.2	18.1	24.8
Panicum montanum	-	8.3	5.1	4.2	5.2	3.5	6.3	5.9	5.3	6.5	3.7	4.4	4.7	4.3	6.5	4.5
Paspalum dilatatum	-	-	-	-	-	-	-	-	-	2.6	2.9	3.5	1.6	1.7	-	-
Pennisetum polystachyon	-	-	-	4.8	-	-	-	-	-	-	-	7.9	4.6	2.8	-	3.7
Phragmites karka	-	5.9	-	-	-	-	15.1	-	-	7.9	-	-	-	-	18.2	3.0
Saccharum spontaneum	2.1	-	-	-	-	-	9.8	6.9	-	10.7	-	-	-	-	9.8	7.5
Setaria glauca	9.9	2.9	8.0	6.9	3.7	-	-	4.8	16.8	3.8	10.6	10.2	7.5	-	-	6.2
Setaria palmifolia	-	-	7.6	-	-	-	5.3	-	-	-	11.5	10.8	-	-	6.7	6.5

Table 4.11 (Contd.)

Species	1987								1988							
	W_1	W_2	W_3	W_4	W_5	W_6	W_7	W_8	W_1	W_2	W_3	W_4	W_5	W_6	W_7	W_8
LEGUMES																
Crotalaria striata	-	-	-	-	-	-	2.7	-	-	-	-	-	-	-	2.1	-
Desmodium heterophyllum	2.6	3.8	5.2	1.2	2.5	3.6	5.2	2.8	-	-	-	-	1.6	1.1	2.7	-
Desmodium microphyllum	8.9	8.7	1.6	-	-	7.6	10.4	10.0	9.6	9.4	9.4	-	4.1	5.0	11.3	14.3
Indigofera sp.	-	-	-	-	-	-	-	-	-	-	-	-	1.0	-	-	1.4
Mimosa pudica	4.4	4.2	4.5	5.9	6.0	4.0	5.6	5.1	4.2	2.8	4.0	3.3	4.2	3.7	4.0	3.7
Stylosanthes guianensis	-	-	2.8	-	-	-	-	-	-	-	5.9	-	-	-	-	2.3
OTHER FORBS																
Acrocephalus indicus	1.5	1.1	1.6	2.7	4.3	2.3	2.4	2.4	-	-	-	-	-	-	-	-
Ageratum conyzoides	13.9	10.0	9.4	19.1	18.9	15.4	3.1	5.8	16.1	11.9	12.4	32.5	20.3	15.8	6.1	8.5
Ageratum houstonianum	24.0	15.3	13.7	31.0	23.1	20.1	3.9	7.8	29.5	14.8	16.7	31.8	24.7	16.1	5.2	13.8
Ajuga macrosperma	1.5	-	1.7	-	-	2.6	-	-	-	-	-	-	1.0	-	-	-
Alectra indica	1.3	0.8	3.1	-	-	-	-	-	2.4	2.2	2.5	-	-	3.8	3.0	-
Alternanthera philoxeroides	-	-	-	-	-	-	-	2.6	-	-	-	-	-	-	-	-
Alternanthera sessilis	-	-	-	-	-	-	-	-	-	-	-	-	0.5	-	0.9	-
Anaphilis adnata	2.2	1.5	2.0	-	-	-	-	-	-	0.4	1.2	-	-	-	-	1.9
Aristolochia tagala	2.3	2.5	1.6	-	3.6	3.0	5.2	2.1	1.2	1.7	1.9	-	2.6	1.2	5.0	2.9
Artemisia vulgaris	-	-	-	1.5	-	-	-	-	1.8	-	-	2.1	-	-	-	-
Bidens pilosa	15.1	11.9	9.8	19.6	12.0	11.1	5.9	5.9	26.6	17.1	16.7	50.1	21.1	27.7	6.1	12.2
Biophytum sensitivum	1.9	3.3	1.8	3.9	5.4	2.6	-	1.9	1.1	-	-	1.3	2.5	-	-	-
Blumea sp.	1.1	-	2.2	-	-	5.6	4.5	3.3	1.1	0.8	1.7	-	-	4.7	2.2	2.7

Table 4.11 (Contd.)

Species	1987								1988							
	W_1	W_2	W_3	W_4	W_5	W_6	W_7	W_8	W_1	W_2	W_3	W_4	W_5	W_6	W_7	W_8
Borreria hispida	29.8	15.5	16.3	17.5	11.9	14.6	13.4	8.3	13.1	11.7	8.6	9.4	8.7	10.6	8.2	6.4
Borreria stricta	-	-	-	-	-	-	-	-	-	-	-	-	1.7	-	-	2.8
Buddleja asiatica	1.5	1.5	1.2	-	-	1.6	2.6	3.4	1.1	0.5	0.9	-	-	-	2.7	2.5
Callicarpa rubella	2.0	0.9	0.7	2.3	-	-	-	1.6	1.1	0.8	0.8	-	-	-	1.3	-
Cannabis sativa	-	-	-	-	-	-	-	-	1.0	-	-	-	-	-	-	-
Carex composita	4.4	5.7	5.2	1.4	3.7	3.2	5.9	5.5	-	4.3	2.0	-	3.4	-	-	-
Centella asiatica	7.3	8.0	7.6	8.5	6.7	6.4	-	7.2	6.1	5.0	3.0	4.5	-	-	-	-
Commelina paludosa	-	-	2.1	10.3	4.0	-	-	-	4.6	-	-	7.1	6.0	-	-	-
Cosmos bipinnatus	16.2	8.0	5.0	13.3	12.9	7.0	5.1	2.2	10.5	2.9	-	3.4	-	-	2.9	0.8
Crassocephalum crepidioides	5.7	2.4	4.5	7.2	5.9	7.4	2.6	4.7	2.3	4.9	0.9	1.2	1.6	1.2	-	3.6
Cyanotis vaga	-	-	-	-	-	-	-	-	-	1.4	0.8	-	-	-	1.4	1.0
Cyclea sp.	0.8	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1.1
Cyperus tuberosus	4.3	5.8	4.0	3.8	6.1	2.8	1.1	8.3	5.2	4.2	4.9	3.6	5.8	3.5	4.1	4.4
Drymeria cordata	2.4	-	-	3.1	-	-	-	-	-	-	-	4.0	-	-	-	-
Dysophylla linearis	2.2	2.2	1.9	-	-	-	-	1.5	1.2	0.4	0.9	-	-	-	1.3	0.7
Elephantopus scaber	-	1.6	-	-	-	-	-	-	2.7	-	0.5	-	1.7	-	-	-
Elsholtzia blanda	3.8	4.6	5.5	-	4.8	2.7	5.4	6.5	1.1	0.5	-	-	-	-	-	-
Emilia sonchifolia	2.6	2.9	2.2	5.3	4.5	4.0	1.4	1.8	1.0	0.8	1.5	1.2	1.4	1.3	-	-
Eupatorium adenophorum	12.6	6.5	8.3	4.1	8.1	8.6	10.4	7.6	8.0	3.8	3.8	1.9	5.2	6.5	6.6	5.2
Eupatorium odoratum	7.2	6.5	12.5	7.3	10.4	9.5	10.7	7.6	3.2	3.5	7.9	1.4	3.6	6.3	7.2	5.2
Eusteralis stellata	3.9	9.3	6.7	5.2	7.2	9.0	10.7	7.7	6.2	7.3	4.8	3.3	3.4	6.6	7.8	6.6
Erigeron bonariansis	4.6	3.4	2.9	3.7	6.0	3.9	3.1	3.5	1.1	2.4	1.7	1.2	1.8	1.2	3.4	2.2

Table 4.11 (Contd.)

Species	1987								1988							
	W_1	W_2	W_3	W_4	W_5	W_6	W_7	W_8	W_1	W_2	W_3	W_4	W_5	W_6	W_7	W_8
Fimbristylis complanata	3.1	2.9	3.7	-	4.3	2.7	-	4.4	-	4.2	3.3	-	5.3	2.8	-	1.9
Galinsoga parviflora	4.7	-	-	24.0	18.9	3.8	-	-	12.2	-	-	19.1	27.2	-	-	-
Gentiana sp.	-	-	-	-	-	-	-	-	0.6	-	-	-	-	-	-	-
Gleichenia dichotoma	-	9.3	4.1	-	-	2.1	-	-	-	6.5	4.1	-	-	2.5	3.2	1.4
Hypericum japonicum	2.1	-	-	-	-	-	-	-	1.0	-	-	-	-	-	-	-
Hypochaeris radicata	2.9	-	3.2	-	-	-	-	-	-	-	-	2.4	-	-	-	4.0
Inula cappa	4.3	5.1	4.2	2.0	4.9	6.8	7.3	8.1	1.2	4.3	2.9	0.7	1.7	2.8	6.0	6.0
Kyllinga melanosperma	1.9	4.1	3.8	9.3	6.9	5.8	3.5	1.6	-	-	-	1.7	-	-	-	-
Lantana camara	3.6	7.7	5.6	4.8	4.5	7.1	6.3	6.1	4.1	4.9	4.2	1.9	2.7	4.6	5.0	4.6
Lygodium sp.	2.4	13.2	3.7	3.5	-	5.1	6.1	10.1	3.3	8.6	6.1	2.2	-	4.3	5.8	7.7
Melastoma normale	5.2	3.8	2.6	3.6	5.3	5.7	7.8	6.7	5.1	3.4	3.0	2.1	4.3	4.4	7.9	5.9
Mikania micrantha	-	-	-	2.9	-	-	-	-	-	-	-	-	7.0	-	-	-
Nelsonia canescens	-	-	-	-	-	-	-	-	-	-	-	-	1.1	-	-	-
Osbeckia crinita	4.7	6.2	4.1	3.2	5.1	4.3	6.8	5.7	6.8	3.3	3.3	2.4	3.5	4.3	5.2	2.7
Oxalis corniculata	2.4	-	-	-	-	-	-	-	2.4	-	-	1.3	-	-	-	-
Oxalis latifolia	3.0	5.7	6.0	8.4	5.0	5.9	2.3	6.7	1.5	3.7	2.0	2.9	-	-	-	-
Phyllanthes urinaria	-	1.9	2.0	-	-	-	-	-	-	3.0	2.3	-	-	-	-	3.5
Plantago major	1.6	-	-	-	-	-	-	-	1.0	-	-	-	-	-	-	-
Plectranthus ternifolius	-	-	-	-	-	-	-	4.8	-	-	-	-	-	-	4.0	3.2

Table 4.11 (Contd.)

Species	1987								1988							
	W_1	W_2	W_3	W_4	W_5	W_6	W_7	W_8	W_1	W_2	W_3	W_4	W_5	W_6	W_7	W_8
Polygala persicaraiefolia	0.8	1.8	1.3	-	2.7	1.9	1.1	1.0	-	1.8	-	-	-	-	-	-
Pteridium aquilinum	3.6	6.3	3.3	-	-	5.6	4.5	3.3	4.2	4.5	3.2	1.2	-	4.8	4.3	3.7
Richardsonia sp.	9.8	6.7	5.2	8.5	8.2	3.6	12.5	10.3	-	5.6	-	4.3	-	-	6.9	-
Rubus ellipticus	4.0	3.2	-	-	-	6.9	4.5	6.2	9.5	4.7	1.2	-	-	10.1	6.2	2.6
Rubus moluccanus	6.5	6.0	5.5	2.4	6.8	7.6	8.5	7.9	4.0	3.6	3.5	1.9	4.4	5.5	5.7	4.6
Rungia pectinata	-	-	-	-	5.0	-	-	-	-	-	-	-	1.5	-	-	-
Salmonia cantoniensis	0.6	0.9	0.4	0.8	0.6	-	1.2	0.4	-	-	-	1.7	-	-	-	-
Sida rhomboidea	-	1.5	-	-	-	-	-	0.7	0.6	-	-	-	1.0	1.7	-	0.8
Solanum khasianum	0.5	-	-	-	-	-	-	-	1.0	-	-	-	-	-	-	-
Sonchus oleraceus	-	-	-	5.0	3.3	-	-	-	-	-	-	0.6	-	-	-	-
Sonerila sp.	0.9	-	-	1.2	-	1.3	-	-	-	-	-	-	-	1.6	-	-
Spilanthes paniculata	-	-	-	3.4	3.3	-	-	-	2.5	-	-	4.2	6.0	-	-	-
Stachytorpheta dichotoma	4.0	6.5	8.8	-	-	-	5.0	-	4.2	5.9	7.8	3.4	-	-	4.3	-
Triumfelta rhomboidea	-	-	7.6	-	-	7.9	-	5.9	-	-	6.9	-	-	2.3	-	-
Urena lobata	2.6	1.8	3.1	-	-	4.1	2.7	1.5	1.6	0.4	2.4	-	1.0	3.0	3.1	3.4
Verbena vinosa	0.8	-	-	-	-	-	-	0.7	-	0.8	-	-	1.0	1.1	-	-

Table 4.12. Monthly variation in diversity indices of weed communities growing in different farming systems during 1987 and 1988.

Month	Watersheds (1987)								Watersheds (1988)							
	FSW_1	FSW_2	FSW_3	FSW_4	FSW_5	FSW_6	FSW_7	FSW_8	FSW_1	FSW_2	FSW_3	FSW_4	FSW_5	FSW_6	FSW_7	FSW_8
January	3.81	4.33	4.50	3.51	3.03	4.27	4.24	4.82	4.56	5.08	5.00	4.46	4.60	4.45	4.74	4.76
February	3.50	4.05	4.47	3.02	4.63	3.85	4.36	4.66	4.17	4.68	4.82	3.93	4.10	4.16	4.61	4.62
March	4.25	4.36	4.63	3.53	4.61	4.30	4.35	4.79	4.78	4.46	4.44	3.64	3.82	3.70	4.56	4.40
April	4.00	4.00	4.47	3.49	4.37	3.96	4.27	4.72	3.84	4.51	4.55	2.74	3.91	3.60	4.84	4.25
May	4.30	4.50	4.60	3.51	4.25	4.06	4.42	4.76	4.12	4.77	4.77	3.50	4.05	3.82	4.90	4.46
June	4.58	4.71	4.92	4.42	4.63	4.47	4.54	4.81	4.24	4.75	4.79	3.57	4.17	3.92	4.92	4.67
July	4.66	4.57	4.89	4.61	4.62	4.62	4.70	4.84	4.48	4.85	4.94	3.91	4.48	4.06	5.35	4.93
August	4.77	5.14	5.22	4.64	4.88	4.85	4.98	5.13	4.33	4.84	4.73	3.59	4.32	3.95	4.94	4.86
September	4.82	5.17	5.26	5.54	4.93	4.91	5.06	5.21	4.51	4.92	4.85	3.86	4.48	4.04	4.97	4.97
October	4.94	5.19	5.31	4.68	4.97	4.86	5.05	5.00	4.58	4.96	4.91	4.38	4.50	4.09	4.91	5.02
November	4.85	5.20	5.26	5.91	4.96	4.91	5.00	5.20	4.43	4.89	4.83	4.29	4.59	4.01	4.94	4.92
December	4.97	5.47	5.28	4.75	4.94	4.96	5.06	5.25	4.46	4.93	4.86	4.11	4.42	4.07	4.97	4.96

Table 4.13. Similarity indices (%) of weed communities at peak growing period (August) between different farming systems during 1987 and 1988.

(a) 1987

	$FS\text{-}W_1$	$FS\text{-}W_2$	$FS\text{-}W_3$	$FS\text{-}W_4$	$FS\text{-}W_5$	$FS\text{-}W_6$	$FS\text{-}W_7$	$FS\text{-}W_8$
$FS\text{-}W_1$	100	80.7	81.3	70.5	71.1	80.7	74.1	80.0
$FS\text{-}W_2$		100	89.3	68.7	75.5	81.6	84.3	86.2
$FS\text{-}W_3$			100	69.9	74.5	78.5	79.2	83.2
$FS\text{-}W_4$				100	83.1	70.2	64.5	68.0
$FS\text{-}W_5$					100	79.6	73.9	76.8
$FS\text{-}W_6$						100	82.5	84.6
$FS\text{-}W_7$							100	85.4
$FS\text{-}W_8$								100

(b) 1988

	$FS\text{-}W_1$	$FS\text{-}W_2$	$FS\text{-}W_3$	$FS\text{-}W_4$	$FS\text{-}W_5$	$FS\text{-}W_6$	$FS\text{-}W_7$	$FS\text{-}W_8$
$FS\text{-}W_1$	100	71.7	73.8	69.4	61.4	63.8	66.0	60.2
$FS\text{-}W_2$		100	87.4	59.2	57.4	74.5	80.4	79.6
$FS\text{-}W_3$			100	61.1	61.2	74.7	76.6	76.0
$FS\text{-}W_4$				100	64.5	55.8	53.9	54.7
$FS\text{-}W_5$					100	69.7	51.7	65.2
$FS\text{-}W_6$						100	70.6	70.3
$FS\text{-}W_7$							100	76.6
$FS\text{-}W_8$								100

CHAPTER V

BIOMASS AND PRODUCTIVITY OF WEED COMMUNITIES AND ECONOMIC YIELD OF THREE IMPORTANT CROPS

The photosynthetic apparatus of green plants converts radiant energy captured from the sun into chemical energy in the form of organic material. A part of this organic material is utilized by the green plants in respiration to provide energy for metabolic activities and the remaining amount is accumulated in the plant body. This part of organic matter which is not respired contributes to net primary production. Primary productivity of the vegetation provides the basic energy for functioning of all the biotic components of the ecosystem. The accumulated organic matter or the standing crop of the biomass also serves as an important structural characteristic of the ecosystem (Golley, 1965; Odum, 1975) and regulates the overall energy flow and nutrient circulation within the ecosystem. Information on aboveground standing crop is fundamental to a variety of plant ecological studies (Frank & McNaughton, 1990).

Weeds cause tremendous losses in crop yield (Thakur, 1964; Shaw, 1964; Tripathi, 1967; Akobundu, 1979; Ayeni et al., 1984; Dagar & Dagar, 1986; Beckett et al., 1988, and Ezueh & Amusan, 1988). In crop fields the herbaceous weeds compete to a great extent in the early vegetative phase of crop growth (Babu, 1975; Dagar & Dagar, 1986) and the relative density of crop plants and weeds play a crucial role in the outcome of competition between them (Tripathi, 1977), and biomass and economic yield of crop declines considerably.

Studies on the biomass and productivity of grasslands and herbaceous communities have been carried out by several workers (e.g. Singh & Yadava, 1974; Falk, 1980; Ayeni et al., 1984; Kummerow & Ellis, 1984; Ramakrishnan & Ram, 1988; Karunaichamy & Paliwal, 1989 and Sah & Ram, 1989). Some of the important studies on biomass, productivity and yield of crop plants are those of Ovington, Heitkamp & Lawrence (1963), Lal & Ambasht (1979), Falk (1980), Ayeni et al. (1984), Khokhar (1985), Dagar & Dagar (1986).

MATERIALS AND METHODS

Biomass and productivity of weed communities were determined for all the eight watersheds, whereas the biomass and yield of important crops (maize, rice and peas) were determined taking samples from the watershed under agriculture-based farming system during 1987-1988. The weeds were collected from four replicate quadrats of 1 m^2. The harvested aboveground parts of plants were clipped at monthly intervals from these quadrats and were taken to the laboratory, oven-dired at 80°C to a constant weight and weighed.

The belowground biomass was estimated by digging out monoliths (25 x 25 x 25 Cms) from harvested quadrats. The soil adhering to the roots was carefully removed by thoroughly washing the belowground parts with water. The belowground parts of crops and weeds were separated wherever necessary by floatation method (McKell, Wilson & Jones, 1961). Dry weight estimation was done as in the case of aboveground biomass. The aboveground primary productivity was calculated in all watersheds by difference method (Ovington Heitkamp & Lawrence, 1963).

The contribution of three dominant weeds viz., Ageratum conyzoides, Ageratum houstonianum and Bidens pilosa to the total biomass was calculated. A portion of the crop field in the agriculture-based farming systems (FS-W_4), from which the weeds were constantly removed was declared to be a weed free area. From this weed free sub-plot the crop plants were harvested at maturity to determine the biomass and economic yield. Maize was planted at a row spacing of approximately 50 cm keeping 25 cm plant to plant distance in the row, the inter-row and inter-plant distance in a row in the case of rice and green peas being 20 x 10 cm and 30 x 10 cm respectively.

Since the farming systems vary in terms of crop grown, farming operations, associated vegetation, soil microclimate etc., the study was carried out to see the impact of these farming systems on the biomass and productivity of weeds and yield of crops.

RESULTS

Biomass

Analysis of data presented in Table 5.1 reveals that the plant biomass varied considerably through different months. During 1987, the maximum biomass of weedy species was recorded in control system (FS-W_7) closely followed by jhum fallow (FS-W_8) and the least biomass was observed in FS-W_6 (Table 5.1). In FS-W_1 and FS-W_2 the biomass production of weeds tended to be higher than the watersheds on which crops were grown. During 1987, the aboveground biomass of weeds ranged between 311 g/m^2 during January in FS-W_5 to 1408 g/m^2 in September in FS-W_7 (Table 5.1), while during 1988 it ranged between 372 g/m^2 in March in FS-W_2 to 1234 g/m^2 in October in FS-W_8 (Table 5.2). During 1987, the belowground biomass of weeds ranged between 99 g/m^2 in January in FS-W_5 to 1039 g/m^2 in August in FS-W_7 (Table 5.1), while during 1988 it ranged between 92 g/m^2 in March in FS-W_5 to 1023 g/m^2 in October in FS-W_8. During 1987, both the aboveground and below-ground biomass production showed an increasing trend from January to October in all the farming systems. From November onwards the biomass production showed a decreasing trend. The peak aboveground biomass in all the watersheds were recorded during September except in FS-W_1 where it was recorded in October. The peak belowground biomass in all watersheds was also recorded in September except in FS-W_2 and FS-W_8 where it was recorded in October. During 1988, a decreasing trend was observed in biomass production from January onwards upto March, however, with the onset of monsoon both the aboveground and belowground biomass production showed an increasing trend upto October and from November onwards it started decreasing (Table 5.2). The biomass of weed species during 1988 was maximum in FS-W_8 closely followed by FS-W_7 (Table 5.2), while in the previous year the maximum biomass was recorded in FS-W_7 (Table 5.1). On the other watersheds, however, the weed biomass was much lower than in FS-W_8 or FS-W_7. The FS-W_3 recorded the least production throughout the year (Table 5.2). During 1988, the highest aboveground and belowground biomass was observed in the month of October except in the case of FS-W_6 where the highest belowground biomass was observed in the month of September (Table 5.2).

Productivity

The highest total annual net primary productivity (1125 g/m^2) of weed community during 1987 was recorded in FS-W_7 and the least (691 g/m^2) in FS-W_4. The forestry-based land use (FS-W_2) showed the highest (634 g/m^2) annual aboveground productivity which amounted to 66% of its total NPP

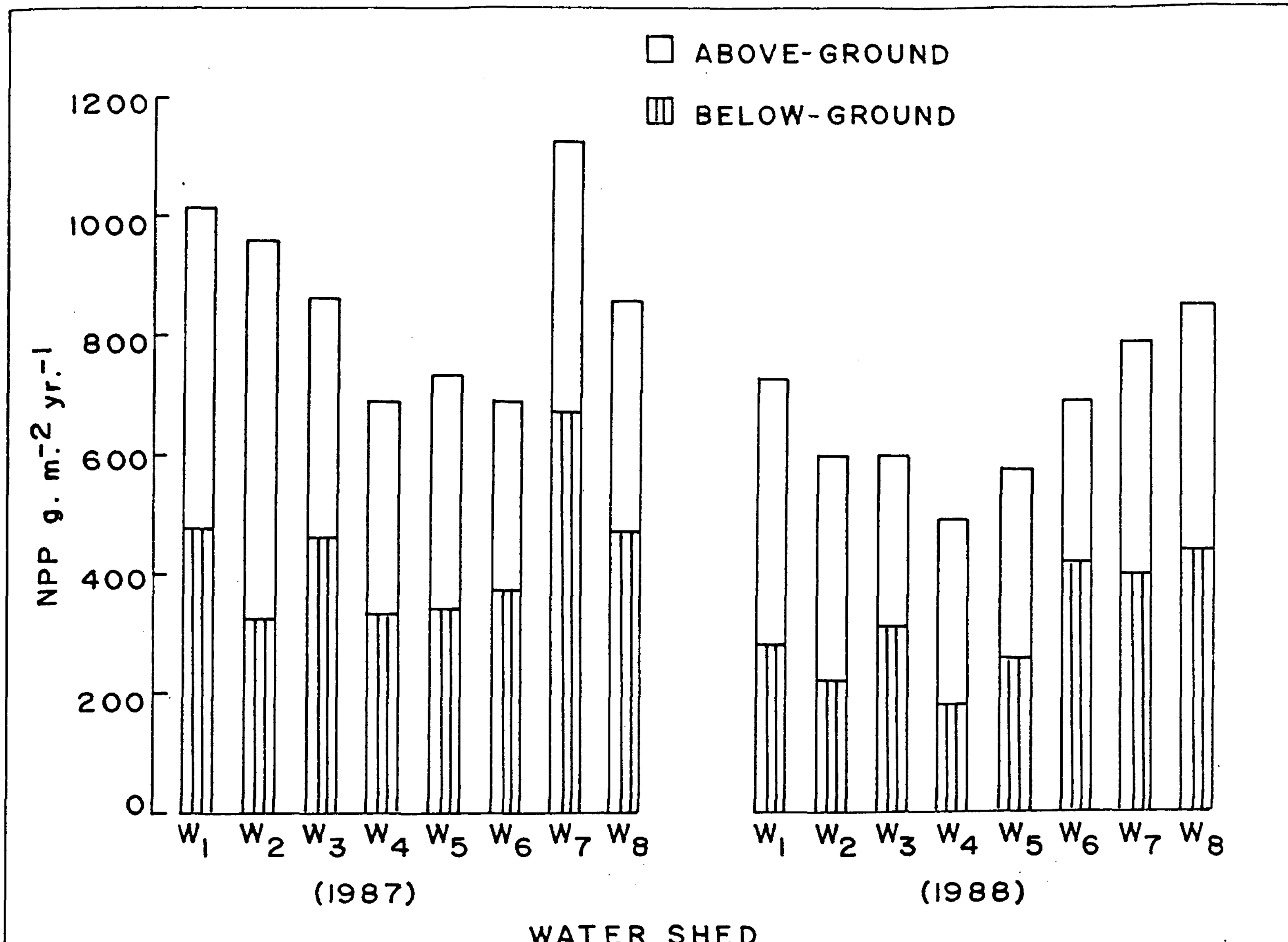
(Fig. 5.1). The 'jhum' fallow (FS-W_8) showed the highest belowground productivity amounting to 55% of the total NPP. The belowground productivity tended to be quite high in FS-W_3, FS-W_6 and FS-W_7 indicating that the weed community in these watersheds allocate more resources to the belowground parts, however, in FS-W_7 the aboveground to belowground NPP was almost equal (Fig. 5.1).

The annual net productivity during 1988 was lesser than in the previous year in all the farming systems. The highest annual net productivity (850 g/m^2) of weed community was recorded in FS-W_8 and the least (490 g/m^2) in FS-W_4 (Fig. 5.1). The watershed under livestock-based farming system (FS-W_1) showed the highest aboveground productivity 441 g/m^2) which amounted to 60.8% of its total NPP (Fig. 5.1) while in 1987 the highest annual aboveground productivity was recorded in FS-W_2. The highest belowground productivity (425 g/m^2) during 1988 was recorded in FS-W_6 which amounted to 61.5% of the total NPP followed by FS-W_3, FS-W_8 and FS-W_7. In the control system (FS-W_7) the aboveground to belowground NPP was equal in 1988 also.

Percentage contribution of the three weeds to the total weed biomass

An analysis of data (Table 5.3) reveals that during 1987, the aboveground biomass contributions by the three

Fig. 5.1 Aboveground and belowground annual net primary productivity of weeds in different watersheds under various farming systems during 1987 and 1988.



ABOVE-GROUND
BELOW-GROUND
NPP g. m.$^{-2}$ yr.$^{-1}$
1200
1000
800
600
400
200
0
W1 W2 W3 W4 W5 W6 W7 W8
(1987)
W1 W2 W3 W4 W5 W6 W7 W8
(1988)
WATER SHED

FIG. 5·1

dominant weeds to the total aboveground biomass of all weeds were quite high (23.4% by Bidens pilosa, 13.6% by Ageratum houstonianum and 7.7% by A. conyzoides). The corresponding values in the case of belowground biomass for the above three weeds were 5.1, 4.0 and 2.9% respectively. The relative contribution by these weeds to total weed biomass was in the order, B. pilosa > A. houstonianum > A. conyzoides in all the watersheds except in FS-W_1, where A. houstonianum contributed maximum and A. conyzoides minimum to the total weed biomass, B. pilosa occupying the intermediate position. The contribution by all the three weeds to total weed biomass during 1988 was greater than in 1987 in all the watersheds. The peak biomass contribution of all the three weeds were recorded in agriculture-based farming system (FS-W_4) for both aboveground and belowground parts in both years.

During 1987, the peak biomass of all the species was recorded in October, whereas in 1988 it was recorded in September. The contribution of these weed species was minimum in control system (FS-W_7) in both years.

Biomass and economic yield of crops

The mean economic yield per plant as well as per m^2 were markedly low in the weed-infested area of the crop fields during both years (Table 5.4). The economic yields of rice, maize and green pea were, however, greater in 1987 than in 1988. The decrease in the economic yield of maize during 1988 was more pronounced. Maize, among the three crops, recorded the highest economic yield in both years. In the weed-free area the yield of maize was 748 g/m^2 during 1987 compared to 591 g/m^2 in the weed-infested area, while the corresponding values during 1988 were 646 g/m^2 and 551 g/m^2. There was a decrease in the economic yield of all the three crops in the weed-infested area.

Table 5.5 shows the biomass of the three crops under weed-free and weed-infested area. Maize produced maximum biomass followed by green pea and rice. There was a pronounced difference in the biomass of all the three crops in weed-free and weed-infested areas. Like economic yield, there was a decrease in the biomass of all the three crops in the weed-infested area in both years, however, the biomass of all the crops in 1987 was greater than in 1988.

DISCUSSION

The fluctuations in the biomass are governed by the climatic factors, crop interference and nature and growth behaviour of the dominant species. The watersheds under control system ($FS-W_7$) and jhum fallow ($FS-W_8$) which recorded the maximum biomass of weedy species, differ from the rest of the farming systems in two respects. Firstly, the weedy species are allowed to grow without any disturbance to them and secondly, there are no crop plants to offer competition. These two factors coupled with greater species diversity and density probably account for greater biomass production in these watersheds compared to FS-W_3, FS-W_4, FS-W_5 and FS-W_6 where the crop plants exercised competitive suppression and weeding operation reduced the population density and competitive ability of weeds.

The biomass production by weeds also tended to be greater in FS-W_1 and FS-W_2 compared to the watersheds on which the crops were grown. This may again be ascribed to the absence of competition and weeding. The role of other factors in determining the biomass, however, remains to be analysed. Despite greater weed density biomass production was less in all the farming systems during 1988 than in 1987 which may be attributed to the suppression of slow emerging species by fast emerging ones. This conforms with the findings of Ayeni et al. (1984). The plant growth form may also be responsible for the difference in the biomass production (Frank & McNaughton, 1990).

Productivity

The form and structure of vegetation are important factors influencing productivity and it is significant that annual productivity was more where proportion of tall grasses was greater. The higher annual net productivity of weed community in FS-W_7 and least in FS-W_4 could be attributed to various kinds of agricultural operations in the latter. The agricultural operations prevalent in FS-W_4 and the competition from the crops grown might have suppressed the growth of the associated weeds. The greater annual aboveground productivity in forestry-based land use (FS-W_2) may also be attributed to the absence of agricultural operations in this farming system. Besides this, the growth of tree canopy and shrubs reduces the light availability to the weeds, which respond to the reduced light condition by growing taller and producing more leaves. Lal & Ambasht (1977) also observed that the size of the individual leaf in open sunlight is smaller than those growing in moderate and deep shade.

The larger belowground productivity in FS-W_3, FS-W_6, FS-W_7 and FS-W_8 indicates that the weed community in these watersheds allocates more resources to belowground parts. It may be mentioned that weed communities in these watersheds are characterised by high density and luxuriant growth of grass species like Imperata cylindrica and Arundinella benghalensis which are rhizomatous. Another reason for higher productivity of belowground parts could be the low fertility of soil in these watersheds and to cope with this situation an extensive root system is required for efficient uptake of nutrients from the soil (White, 1973; Christie & Moorby, 1975; Nye & Tinker, 1977 and Ramakrishnan & Ram, 1988). Sims & Singh (1971), Singh & Yadava (1974) and Tiwari (1986) attributed the higher belowground net productivity at lower temperatures to an enhanced downward translocation of the assimilates with lower respiratory loss or the changes in botanical composition. The variations noticed in the net primary productivity may be due to differences in micro climatic conditions, floristic composition and resource concentration. The individual effects of these attributes alone do not seem to influence production behaviour. In fact, the combined effects of these and many other factors like topography, micro-edaphic conditions and intrinsic behaviour of different species determine the productivity.

Contribution of individual species to the total biomass

Most of the total plant biomass is contributed by a relatively small number of species in different months. Blaisdell (1958) in north eastern Idaho, Bray et al. (1959) in Minnesota, Pearson (1965) in eastern Idaho, Singh (1968) at Varanasi and Singh & Yadava (1974) at Kurukshetra have also reported that the bulk of biomass is made up of a few dominant species. However, during the rainy season a relatively greater number of species contributed to the total herbage.

All the three weeds showed their peak biomass contribution during September-October which may be attributed to the attainment of maturity by them during this period. The total biomass is linked with their density in different farming systems. For example, in FS-W_4 where their density was greater, they contributed more and in FS-W_7 where their density was low their relative contribution to total biomass was low. The greater contribution of biomass during 1988 compared to 1987, may also be attributed to relatively higher population density of these weeds in 1988. Bidens pilosa among the three weeds seems to be more competitive as the contribution made by this weed was maximum.

Biomass and yield of crops

Many biological and physical factors influence the competitive abilities of weeds and crops. These factors include relative and absolute growth rates, rate of canopy development, branching pattern, rate of root development, extent and depth of root systems, efficiency of water and nutrient uptake and utilization and interactions with other plants, physical and chemical properties of soil, water and nutrient availability etc. (Patterson et al., 1988). The time of emergence of weeds after germination of crop seeds may have great influence on biomass and grain yield of crops. Allelopathy may also play an important role in influencing the competition between weed and crop plants. Weed plants may produce certain metabolites or exudates which may be harmful to crop plants thus inhibiting the growth of the latter (Welbank, 1963; Overland, 1966; Sharma et al., 1976; Mall & Dagar, 1979; Dagar & Dagar, 1986).

Thomas & Allison (1975) found that populations of Rottboellia cochinchinensis (weed) as low as 10-15 plants/m^2, can cause appreciable reduction in maize yield. Thakur (1964), Shaw (1964), Tripathi (1967), Okubundu (1979), Ayeni et al. (1984), Dagar & Dagar (1986), Beckett et al. (1988), Ezueh & Amusan (1988) and several other workers have reported the losses to the crop yield due to presence of weeds.

The greater yield of crops during 1987 may be attributed to the availability of longer duration (4.53 hrs) of daily sunshine during peak growing period compared to 3.48 hrs during 1988. The crops sown possess different growth and developmental strategies and diverse nutrient requirements which enable them to make an optimal use of space and resources.

The reduction in the biomass and economic yield of crops during 1988 may be attributed to resource competition from greater weed population than in 1987. The presence of weeds may also bring about an increased damage to crops by major pests (Ezueh & Amusan, 1988). Weeding gave a better result in terms of biomass and yield increment of all the crops not only because the competition offered by the weeds to the crops is lessened but also the incidence and severity of disease are minimised.

Table 5.1. **Average monthly aboveground (A) and belowground (B) biomass (g.m^{-2} ± S.E.) of weeds in different farming systems during 1987.**

Month		Watersheds							
		FS-W_1	FS-W_2	FS-W_3	FS-W_4	FS-W_5	FS-W_6	FS-W_7	FS-W_8
JAN	A	560±27	405±57	402±37	463±32	311±46	415±55	856±48	817±53
	B	211±14	214±57	225±42	200±47	99±15	213±15	571±69	607±59
FEB	A	610±69	501±16	461±38	483±37	439±28	443±38	877±37	869±31
	B	243±40	293±35	266±34	219±57	121±22	266±55	611±51	599±48
MAR	A	643±49	534±13	489±32	521±52	471±31	479±45	916±40	916±24
	B	298±51	331±36	289±31	263±51	163±28	298±54	603±41	576±63
APR	A	680±34	580±74	529±46	552±53	503±23	499±31	1032±50	993±28
	B	316±40	409±67	309±34	291±41	201±34	345±49	733±56	681±69
MAY	A	763±21	636±74	565±46	597±65	527±20	521±32	1118±60	1013±27
	B	367±29	473±81	327±35	342±42	252±36	444±45	812±58	737±70
JUN	A	819±25	719±85	632±56	637±36	589±34	580±33	1210±72	1066±28
	B	420±26	505±81	592±78	386±34	301±14	611±47	1033±67	811±66
JUL	A	893±23	841±103	703±38	709±28	642±23	639±29	1321±76	1102±71
	B	476±18	497±82	511±88	419±37	334±25	723±83	936±68	1011±67
AUG	A	911±20	981±109	739±19	762±30	682±15	691±32	1391±98	1167±37
	B	523±27	511±71	523±66	473±34	411±41	701±83	1039±209	923±74
SEP	A	1012±37	1039±118	802±40	821±29	707±42	730±28	1408±66	1203±68
	B	688±25	502±76	622±68	533±60	439±46	733±85	988±154	900±72
OCT	A	1102±38	1011±100	791±34	803±30	696±30	722±21	1396±54	1191±93
	B	630±26	521±71	522±38	524±43	427±44	610±106	899±140	937±71
NOV	A	1062±61	962±74	733±61	783±28	683±32	701±21	1268±35	1150±86
	B	609±16	489±47	503±34	479±64	389±35	578±36	832±121	811±95
DEC	A	923±30	717±59	592±32	579±33	559±29	605±37	1019±25	1031±95
	B	561±17	464±44	418±42	365±49	322±37	471±50	758±119	722±92

Table 5.2. **Average monthly aboveground (A) and belowground (B) biomass ($g.m^{-2}$ ± S.E.) of weeds in different farming systems during 1988.**

Month		Watersheds							
		$FS\text{-}W_1$	$FS\text{-}W_2$	$FS\text{-}W_3$	$FS\text{-}W_4$	$FS\text{-}W_5$	$FS\text{-}W_6$	$FS\text{-}W_7$	$FS\text{-}W_8$
JAN	A	747±28	588±59	520±30	453±20	510±29	553±39	948±20	967±93
	B	355±27	271±44	267±43	211±34	176±37	419±46	699±122	706±83
FEB	A	559±30	463±43	442±31	417±19	458±24	512±41	867±17	875±69
	B	259±9	177±6	170±31	203±34	124±29	335±20	623±111	626±84
MAR	A	432±33	372±37	381±28	385±14	397±15	471±33	782±12	821±64
	B	215±6	126±13	125±12	163±24	92±12	276±19	529±101	586±75
APR	A	563±35	459±28	402±30	416±20	421±15	496±37	804±13	838±64
	B	220±4	162±10	197±19	193±16	136±22	392±18	563±101	614±73
MAY	A	609±31	501±41	434±30	456±21	417±16	534±39	844±13	899±66
	B	240±9	187±15	232±22	217±13	176±14	419±17	608±99	652±69
JUN	A	660±33	544±43	471±27	502±22	517±20	576±41	909±14	959±68
	B	374±9	214±13	273±21	252±14	196±16	447±21	669±99	692±70
JUL	A	719±35	611±43	532±25	560±20	580±19	631±39	997±27	1042±74
	B	406±10	251±35	338±20	283±17	235±9	574±18	642±25	778±73
AUG	A	774±31	659±51	573±27	610±22	620±21	653±36	1042±23	1120±72
	B	423±11	281±35	367±18	298±13	311±13	662±21	722±64	864±73
SEPT	A	849±34	734±51	652±31	675±24	688±28	696±45	1126±20	1201±69
	B	488±14	328±34	431±18	341±19	345±23	701±5	837±40	965±71
OCT	A	873±32	747±48	670±31	694±26	717±35	737±21	1168±15	1234±64
	B	499±15	344±33	443±17	344±14	356±30	693±6	903±42	1023±64
NOV	A	804±43	694±47	637±29	644±32	673±32	715±83	1041±16	1102±69
	B	446±21	306±33	347±18	311±6	322±22	608±21	887±46	1015±55
DEC	A	711±39	609±44	572±27	512±33	533±35	602±28	829±17	917±69
	B	389±19	288±30	303±15	268±8	274±20	552±15	721±40	807±49

Table 5.3. Percentage contribution of A. conyzoides, A. houstonianum and B. pilosa to the total biomass during the period of their peak growth i.e., September/October. Values in the parentheses pertain to belowground biomass.

Watersheds	Ageratum conyzoides		Ageratum houstonianum		Bidens pilosa	
	1987	1988	1987	1988	1987	1988
$FS\text{-}W_1$	4.3 (1.7)	5.9 (1.7)	8.1 (2.5)	9.8 (2.8)	7.9 (2.1)	8.6 (2.2)
$FS\text{-}W_2$	3.1 (1.4)	4.3 (1.8)	5.8 (1.4)	6.3 (1.6)	7.4 (3.0)	7.5 (3.1)
$FS\text{-}W_3$	5.7 (1.8)	5.9 (1.9)	7.8 (2.4)	8.2 (2.7)	8.4 (2.1)	9.2 (2.8)
$FS\text{-}W_4$	7.7 (2.9)	8.9 (3.0)	13.6 (4.0)	15.3 (4.7)	23.4 (5.1)	26.1 (6.2)
$FS\text{-}W_5$	6.5 (2.0)	6.9 (2.0)	11.1 (3.4)	12.6 (3.8)	12.6 (3.0)	15.2 (3.8)
$FS\text{-}W_6$	7.4 (2.7)	8.1 (2.9)	9.0 (2.3)	9.6 (2.4)	9.0 (2.6)	10.9 (3.8)
$FS\text{-}W_7$	1.6 (0.3)	3.3 (0.6)	2.8 (0.4)	3.9 (1.0)	3.6 (0.8)	6.1 (1.2)
$FS\text{-}W_8$)	3.3 (0.9)	4.1 (1.7)	5.7 (1.4)	6.1 (2.0)	3.9 (0.9)	6.2 (1.9)

Table 5.4. **Economic yield of the crops under weed-free area and weed-infested area of the crop field in agriculture-based farming system (FS-W_4) during 1987 and 1988.**

CROPS	1987		1988	
	Weed-free area	Weed-infested area	Weed-free area	Weed-infested area
Rice				
Yield per plant (g)	5.1	4.2	4.5	3.8
Yield per m^2(g)	255.0	210.0	225.0	190.0
Maize				
Yield per plant (g)	88.0	70.0	76.0	65.0
Yield per m^2 (g)	748.0	595.0	646.0	551.0
Green pea				
Yield per plant (g)	5.5	4.2	4.9	3.9
Yield per m^2 (g)	183.1	136.2	163.2	126.4

Table 5.5. **Biomass of the crops under weed-free area and weed-infested areas of the crop field in agriculture-based farming system (FS-W_4) during 1987 and 1988.**

CROPS	1987		1988	
	Weed-free area	Weed-infested area	Weed-free area	Weed-infested area
Rice				
Biomass per plant (g)	26.0	22.0	22.0	19.0
Biomass per m^2 (g)	1300.0	1100.0	1100.0	950.0
Maize				
Biomass per plant (g)	377.0	352.0	362.0	340.0
Biomass per m^2 (g)	3204.5	2992.0	3077.0	2890.5
Green pea				
Biomass per plant (g)	45.0	40.0	39.0	34.0
Biomass per m^2 (g)	1485.0	1320.0	1287.0	1122.0

CHAPTER VI

POPULATION DYNAMICS OF *AGERATUM CONYZOIDES* AND *AGERATUM HOUSTONIANUM* UNDER DIFFERENT FARMING SYSTEMS

The study of population dynamics involves the quantification of birth, death, immigration and emigration rates of a species population and it seeks to explain the changes in time and space that occur in these parameters (Rai & Tripathi, 1984). Studies on the population dynamics of several perennial grasses and herbs have been carried out by Williams (1970), Antonovics (1972), Sarukhan & Harper (1973), Hawthorn & Cavers (1976), Bishop et al. (1978), Tripathi & Dwivedi (1978), Kushwaha, Ramakrishnan & Tripathi (1981), Law (1981), Lovett-Doust (1981), Mishra & Ramakrishnan (1981), Yadav & Tripathi (1981), Auld & Myerscough (1986), Kataoka et al. (1989). Some of the important studies in population dynamics of biennials are those by Holt (1972), Werner (1977), and Klemow & Raynal (1981). Compared to perennial plant species, the study of population dynamics of annuals has engaged less attention. A few detailed studies carried out on annual plant species are those by Sharitz & McCormick (1973) on Sedum smallii and Minuartia uniflora, Watkinson & Harper (1978) on Vulpia fasciculata, Regehr & Bazzaz (1979) on Erigeron canadensis, Weiss (1981) on Emex australis, Rai & Tripathi (1984) on Galinsoga ciliata and G. parviflora, Kelly (1989) on Euphrasia pseudokerneri, E. nemorosa and Rhinanthus minor, and Pandey & Dubey (1989) on Parthenium hysterophorus.

Ageratum conyzoides and *Ageratum houstonianum* (family Asteraceae) are both indigenous to tropical America. They grow in a wide range of arable crops and also sometimes in the grasslands in many tropical and sub-tropical countries. The adaptability of these species has made them a rapid and successful colonizer of disturbed and cultivated areas in many countries of the world (Holm *et al*., 1977; also see Chapter III). The watersheds under different farming systems at Barapani in which these two weeds grow abundantly differ markedly from each other in respect of farming operations, crops grown and several other ecological factors (Table 3.1, Chapter III). Due to their high seed production and staggered germination these two weeds are characterised by the emergence of seedling populations at different times under a wide range of conditions. These populations emerging at different times represent different seedling cohorts. Both species of *Ageratum* form thick carpet of plants which compete with crops for nutrients and moisture (Holm *et al*., 1977). The fate of different seedling cohorts needs to be analysed for a fuller understanding of the population behaviour of these two species. Thus, the present study aims at analysing the population dynamics of different seedling cohorts of the two weeds as related to the conditions prevailing in different farming systems.

MATERIALS AND METHODS

Demographic studies were carried out in 10 permanent quadrats of 1 m^2 each randomly positioned in each watershed. The location of quadrat was chosen subjectively to ensure that each quadrat has almost uniform/equal density of plants. The seedling emergence and survivorship of the two species were studied in the permanent quadrats during April 1987 to February 1989. The weed seedlings which emerged on three different dates and which could be correctly identified subsequently, were designated as cohort I, cohort II and cohort III. A. houstonianum in the watershed under control system (FS-W_7), however, showed only two seedling cohorts. The seedling cohorts of Ageratum conyzoides in all the watersheds were marked in early May, late May and late August in 1987 and early April, late April and early August in 1988. The seedlings of Ageratum houstonianum were identifiable in early May, late May and late August in 1987 and early April, early May and late August in 1988. The densities of the plant species growing along with Ageratum conyzoides and Ageratum houstonianum in the permanent quadrats demarcated on all the eight watersheds representing different farming systems were recorded (Table 6.1).

The soil seed bank of Ageratum spp. was also estimated at bimonthly intervals from March 1988 to January 1989. Since the species wise determination of seed population was not possible due to close morphological similarity of seeds of the two species, the total seed population of the two species was done together. The soil seed bank was estimated by taking five 10 x 10 x 5 cm soil samples from an area adjacent to the permanent quadrats on all the watersheds. The soil was air-dried and seeds of Ageratum spp. were sorted out manually and counted. In order to ensure accuracy, the sorting was done twice.

RESULTS

The seeds of Ageratum conyzoides and Ageratum houstonianum germinate during April and May (Spring) when the temperature rises and the first showers are received. During 1987, three flushes of seedling germination were observed in early May, late May and late August in both species thereby giving rise to three distinct seedling cohorts. However, in watershed representing control (FS-W_7) A. houstonianum gave rise to only two seedling cohorts which appeared in early May and early June. The plants from cohort I & II flowered and seeded in July/August. The third seedling cohort which emerged during August completed its life cycle in December in the case of A. conyzoides and in January in the case of A. houstonianum. All the individuals died after the completion of their life cycle and as a result, no live plants could be observed during February and March. Similar observations were recorded the following year also except that the time of seed germination was preponed by one month, which eventually affected the other phenological events.

Soil seed bank

In both species the soil seed bank decreased from March onwards due to germination of buried seeds which contributed to cohorts I and II. A fraction of the seeds from some plants of I and II cohorts grew to maturity and produced seeds in July/August. Some of the seeds produced from the I & II cohorts along with the fraction of the buried seed population not germinated earlier, gave rise to the III seedling cohort. There was a drastic reduction in soil seed bank after the emergence of the III seedling cohort (Table 6.2). An increase in soil seed bank from September onwards indicates that the survivors of the I and II seedling cohorts were responsible for the fresh input of seeds to the soil.

Seedling emergence

The I seedling cohort in both species was quite large, while the II and III seedling cohorts were smaller (Table 6.3). As revealed by the data (Fig. 6.1), in both years (i.e. 1987 and 1988) the density of the two weeds was higher in agriculture-based farming system (FS-W_4) compared with the other systems. The lowest density was observed in control

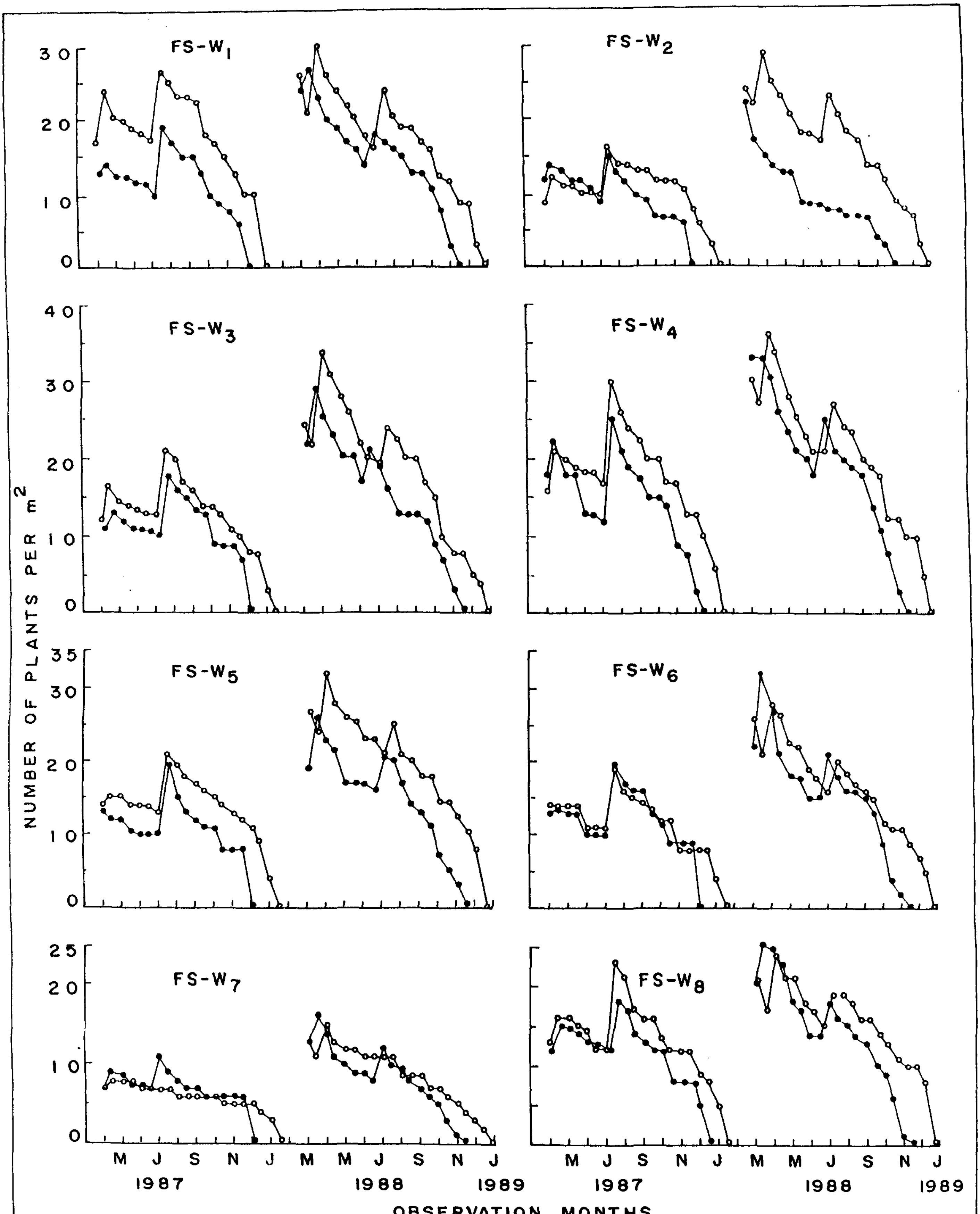
($FS\text{-}W_7$). The pattern of seedling emergence differed little in 1987 and 1988, but the number of seedlings emerged in 1988 was greater than in 1987 on all the watersheds (Table 6.3). In 1987 cohort I was greater than cohort III, which in turn, was greater than cohort II. However, in 1988 the following trend was observed: cohort I > cohort II > cohort III.

Survivorship of seedling cohorts

The I cohort of both the species showed longer half life in 1987 than in 1988 except in case of $FS\text{-}W_5$ (agri-horti-silvi pastoral system) where the I cohort of A. conyzoides showed longer half life in 1988. The II cohort of A. conyzoides showed longer half life than I cohort in $FS\text{-}W_1$, $FS\text{-}W_2$, $FS\text{-}W_5$ and $FS\text{-}W_6$ during 1987 (Table 6.3). In case of A. houstonianum, the II cohort showed shorter half life than the I cohort during 1987 in all the farming systems (Table 6.4). However, the III cohort of both species showed shorter half life than the I or II cohorts. The half life of the I cohort of A. houstonianum was almost same in all the farming systems during 1987, however, there was a great variation in case of Ageratum conyzoides.

During 1987, Ageratum conyzoides showed maximum mortality in agricultural system ($FS\text{-}W_4$) and A. houstonianum in horticultural system ($FS\text{-}W_6$). In agricultural system ($FS\text{-}W_4$) out of the 18 established plants of A. conyzoides only 9

Fig. 6.1 Population dynamics of Ageratum conyzoides (●——●) and Ageratum houstonianum (o——o) in different farming systems during 1987 and 1988.



FS-W1
FS-W2
FS-W3
FS-W4
FS-W5
FS-W6
FS-W7
FS-W8
NUMBER OF PLANTS PER m2
OBSERVATION MONTHS
M J S N J M M J S N J
1987
1988
1989

Fig. 6·1

Fig. 6.2 Survivorship curves for seedling cohorts of Ageratum conyzoides on different farming systems during 1987 and 1988. I, II and III represent the cohorts appearing at different times.

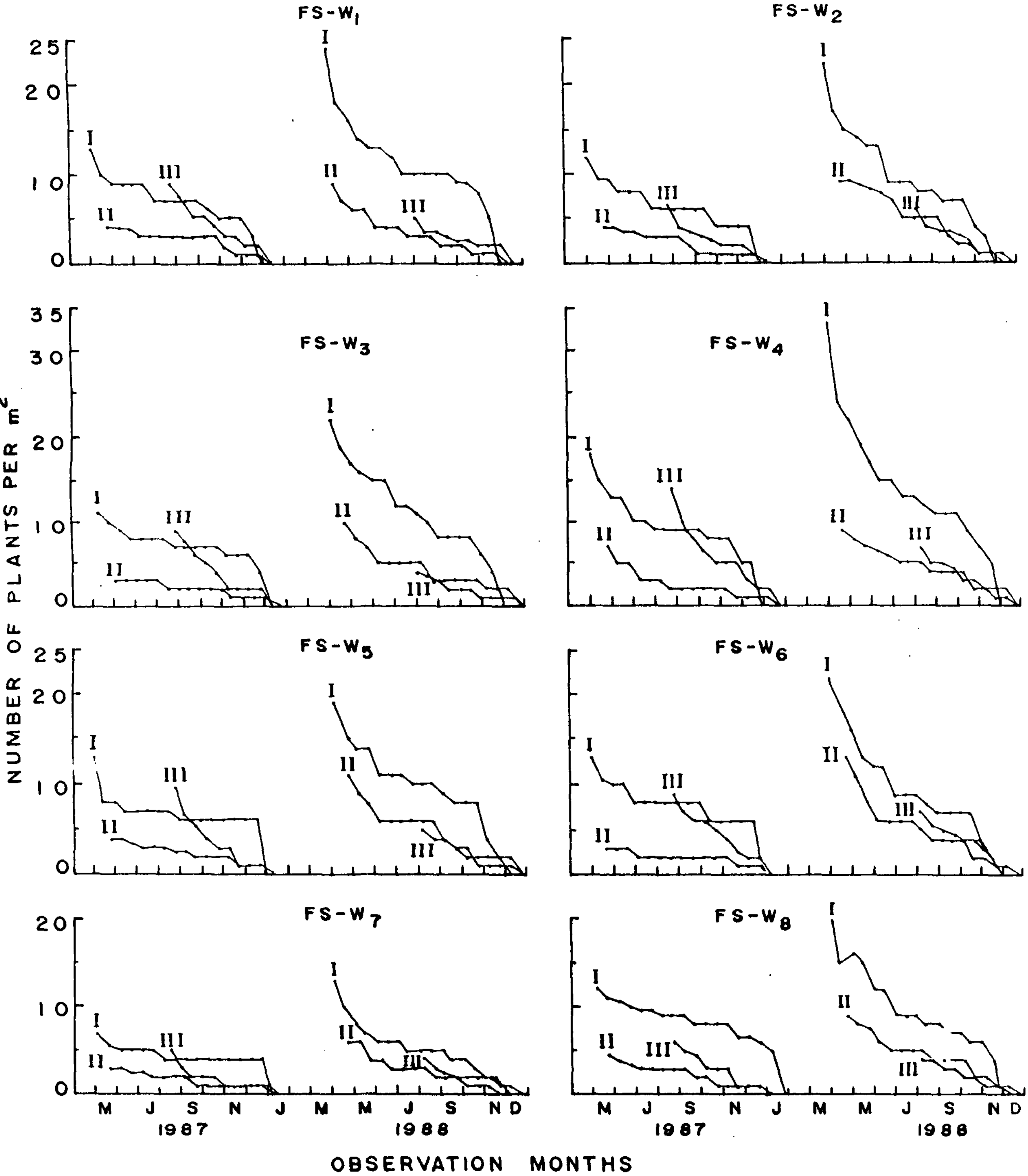

FS-W1
FS-W2
FS-W3
FS-W4
FS-W5
FS-W6
FS-W7
FS-W8
NUMBER OF PLANTS PER m2
M J S N J M M J S N D
1987
1988
OBSERVATION MONTHS

Fig. 6·2

Fig. 6.3 Survivorship curves for seedling cohorts of *Ageratum houstonianum* on different farming systems during 1987 and 1988. I, II and III represent the cohorts appearing at different times.

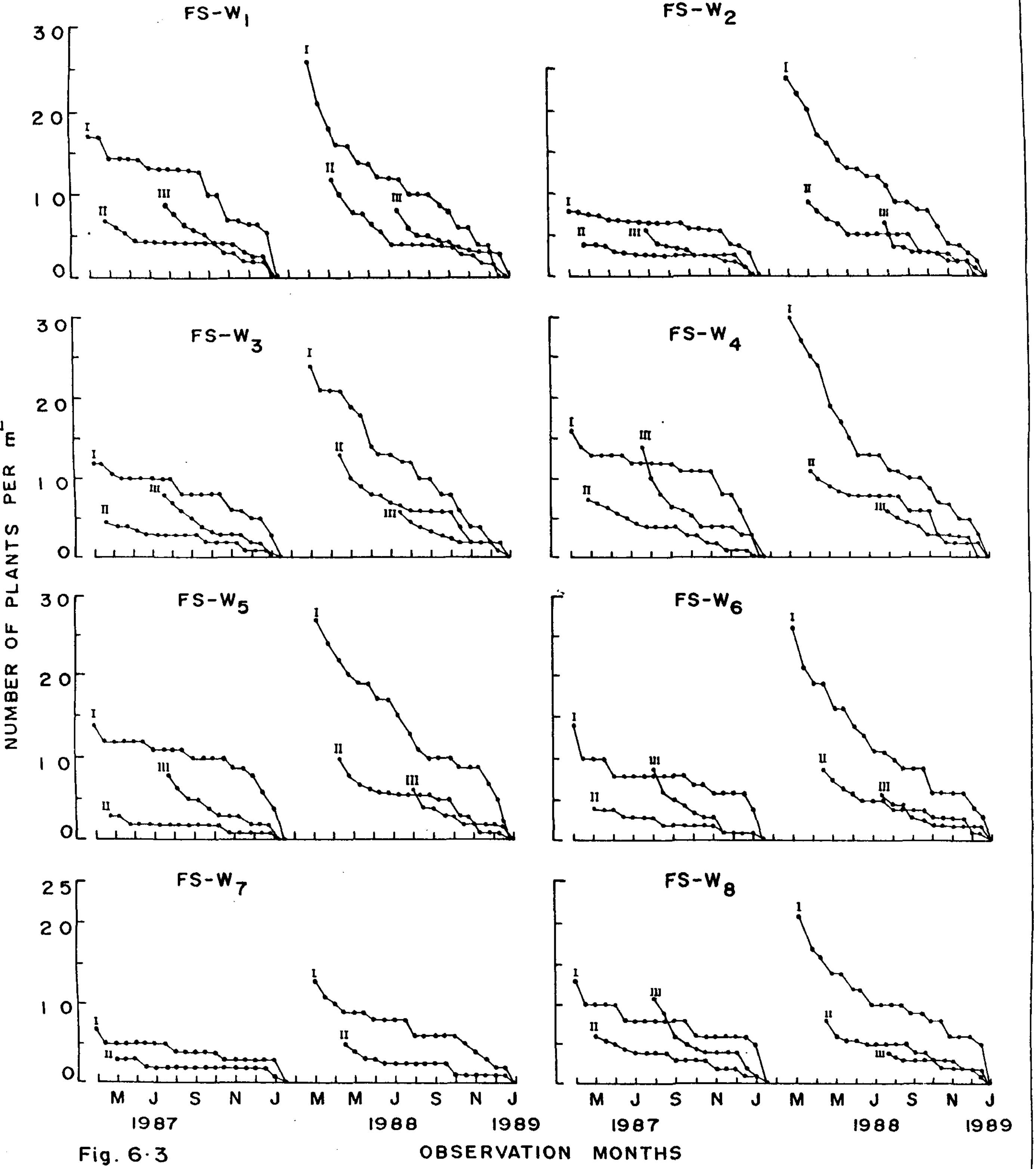

FS-W1
FS-W2
FS-W3
FS-W4
FS-W5
FS-W6
FS-W7
FS-W8
NUMBER OF PLANTS PER m2
M J S N J M M J S N J
1987
1988
1989
OBSERVATION MONTHS

Fig. 6·3

survived and produced seeds and in horticultural system out of the 14 established plants of A. houstonianum only 10 survived and produced seeds, while in the rest of the farming systems the proportion of surviving and reproducing population was higher. In 1988 also, the mortality of A. conyzoides seedlings was maximum in agricultural system ($FS-W_4$), but in case of A. houstonianum maximum mortality was observed in agri-horti-silvi pastoral system ($FS-W_5$). The seedling survival in both species was greater in 1987 than in 1988.

The II cohorts of both the weeds were smaller and showed relatively poor survival compared to the I cohorts (Fig. 6.2 and 6.3). The percentage of plants that survived upto flowering stage was more in 1987 than in 1988 (Table 6.5a & b). In 1987, the highest mortality of the II cohort was observed in agricultural system ($FS-W_4$) in case of A. conyzoides (72%) and in jhum fallow ($FS-W_8$) in case of A. houstonianum (50%).

During 1988 the survial of II cohort in case of A. conyzoides ranged between 44% in livestock-based farming system ($FS-W_1$) to 54% in forestry system ($FS-W_2$) and in case of A. houstonianum it ranged between 33% in livestock-based farming system ($FS-W_1$) to 71% in agricultural system ($FS-W_4$). In 1988, the II cohorts of both the species of Ageratum, showed the least survivorship in livestock-based farming system ($FS-W_1$) (Table 6.5a & b). However, in 1987, the survival of II cohort in case of A. conyzoides ranged between 28% in agricultural system ($FS-W_4$) to 75% in livestock-based farming system ($FS-W_1$) and in case of A. houstonianum it ranged between 50% in jhum fallow ($FS-W_8$) to 69% in forestry ($FS-W_2$) and horticultural system ($FS-W_6$) (Table 6.5a & b).

The survival pattern of the III seedling cohorts in both species was different from that observed for the I and II cohorts. The III cohort of A. houstonianum showed much greater mortality than the earlier cohorts. It showed as high as 86% mortality in agricultural system ($FS-W_4$) in 1987. A very small number of plants recruited in 1988 survived upto flowering stage. The III cohort of both the species showed better survival in 1988 than in 1987. The III cohort of A. conyzoides in horticultural system ($FS-W_6$) showed only 21% survival in 1987 and 28% in 1988. Likewise, the III cohort of A. houstonianum which showed very low survival (14%) in 1987, did better in 1988 showing 50% survival (Table 6.5a & b). However, the I cohort did better as compared to the III cohort in all the farming systems. The emergence of the III seedling cohort of A. houstonianum was not noticed in the control system ($FS-W_7$).

In general, both species exhibited almost similar survival pattern with greater mortality risk during seedling establishment and senescent phase. The A. houstonianum, however, experienced lesser mortality than A. conyzoides on all the sites.

DISCUSSION

The two species of Ageratum showed highest population density during spring due to large flush of germination and seedling emergence during this period with the onset of rains. In 1987, the weed density either remained constant or declined marginally as the loss due to mortality of the spring cohort was more or less compensated by the seedlings which emerged later. Though the II cohort was smaller than the I cohort (Table 6.3) for both the species, the II cohort during 1988 exhibited higher density compared to that in 1987. The overall density increased in July-August (Fig. 6.1) as the seeds produced by the I and II cohorts gave rise to the III seedling cohort. The density of A. conyzoides and A. houstonianum decreased drastically during winter months depicting the significant role of low temperature in regulating the populations of both weeds.

The decreasing trend in the soil seed bank from March onwards may be attributed to the emergence of I & II seedling cohorts. The soil seed bank showed an increasing trend after July (Table 6.2), which may be attributed to the seeding of the I & II cohorts in July/August. Absence of seedling emergence during October to February could be due to seed dormancy/prevailing low temperature conditions.

The decreasing size of the successive cohorts as observed in the present study conforms with the findings of Rai & Tripathi (1984) and Dubey & Pandey (1989) in Galinsoga spp. and Parthenium hysterophorus respectively. This behaviour could be attributed to depletion of germinable fraction of seeds in the soil seed bank. The high rainfall and competition from the already established associated vegetation may also be responsible for the reduced size of the seedling cohorts appearing later. This is in agreement with the findings of Tamm (1956), Antonovics & Levin (1980), Singh (1980) and Rai & Tripathi (1984) who observed poor recruitment and establishment of seedlings in established communities.

In spite of the favourable growing conditions in the rainy season, mortality was greater for both species of Ageratum during this season than during unfavourable post rainy season when plants became established (Fig. 6.1). This agrees with the low juvenile survivorship of most pioneer species and colonising species (Harper, 1965; Sharitz & Mc Cormick, 1973). Watkinson & Harper (1978) have reported the occurrence of Type II and Type III survivorship curve (Deevey, 1947) in species capable of producing large number of seeds in contrast to those which produce lesser number of seeds and exhibit Type I survivorship curve. According to some earlier works (e.g., Antonovics, 1972; Harper, 1977; Johnson and Thomas, 1978), survival of herbaceous plants is generally a linear function of time, but the present study illustrates the occurrence of both linear (Type II) and concave (Type III) survivorship, which is in agreement with the findings of Rai & Tripathi (1984) in Galinsoga spp.

The greater survival of early emerging cohort I than those emerging at a later date is in conformity with the findings of Sarukhan & Harper (1973), Hawthorn & Cavers (1976), Weaver & Cavers (1979), Weiss (1981), Rai & Tripathi (1984) and Pandey & Dubey (1989). The mortality during active growth phase of both weeds could be ascribed to increased resource competition rather than the climatic events which were not harsh during the active growth phase. The high mortality during active growth phase due to increased resource competition has been reported by Sarukhan & Harper (1973), Hawthorn & Cavers (1976), Yadav & Tripathi (1981) and Rai & Tripathi (1984).

Density-dependent early mortality is a common feature of plant populations. The role of density-induced mortality in natural populations of Ageratum seems to be less important as the desnity of seedlings was not high enough to cause mortality. Survival of the late arriving cohorts may be adversely affected by the already established individuals of the I cohorts of both weeds. Besides competition from the established cohorts, the inhibitory effects of Ageratum may also reduce its seed germination and seedling growth as reported by Sugha (1980). Despite the larger size, the I cohort in both species showed relatively greater survivorship and half life which may be due to greater availability of resources and lesser competition from the crop plants and associated vegetation as they are also not fully established. The longer half life of the I cohort during 1987 compared to 1988 may be due to the lower density of the associated species in 1987. The agricultural operations prevailing in agricultural system ($FS-W_4$) create more favourable conditions for the growth of these weeds compared to the other farming systems. The observed low seedling population of the two weeds in the control system ($FS-W_7$) also indicates that agricultural operations other than weeding are helpful to the weeds. The seedling recruitment in other farming systems was lesser than that in $FS-W_4$ and greater than that in $FS-W_7$ which was characterised by the absence of agricultural practices. This again shows that the weed infestation, at least in part, is directly related to agricultural operations.

In 1987, the I & II cohorts of *A. conyzoides* showed very high juvenile mortality which may be attributed to severe competition from the agricultural crops. However, *A. houstonianum* showed relatively better survival. The seedling mortality in 1988 was more than in 1987 which may be due to larger density of the associates in the peak season during 1988. Putwain & Harper (1970), Raynal & Bazzaz (1975b) and Tripathi & Dwivedi (1978) reported that the distribution and abundance of a species may be profoundly modified by the presence of associated species in community. The competition for light as reported by Banyikwa & Rulangaranga (1984) in the case of *A. conyzoides* and heavy rainfall (Fig. 3.1 Ch. III) received during the growing season may further contribute to mortality. The absence of seedlings from the crop fields after the maturity of the III cohort indicates that either the seeds were/became dormant or the prevailing climatic conditions did not favour seed germination. Despite a large soil seed bank, there was low seedling emergence presumably due to the fact that burial causes greater seed mortality (Weiss, 1981) and induces dormancy in seeds. Several factors viz., removal of seeds with the crop harvest, predation from the soil surface, seeds lost by wind, water and other agencies and decay of seeds may cause overall reduction in soil seed bank (Fernandez-Quintanilla *et al.*, 1986). However, since no attempt was made in the present study to determine the relative contribution of all these factors, it is rather difficult to make any generalization on this aspect.

Ageratum conyzoides and *Ageratum houstonianum* may be regarded as fugitive species as they prefer typically distrubed and open sites for their growth and reproduction. This is also evident from remarkably low population of *Ageratum* spp. in the control system (FS-W_7) which was kept under fencing and no disturbance was allowed, whereas in agricultural system (FS-W_4) which was exposed to frequent agricultural operations maximum seedling emergence occurred. They also occur in abandoned fields, jhum fallows (FS-W_8) and forestry-based farming system (FS-W_2) where some degree of disturbance took place. The emergence of different seedling cohorts in both weeds may be an important strategy in maintaining the populations and reducing the intra and inter-specific competition by avoiding crowding at the same time. As argued by Rai & Tripathi (1984), "the occurrence of more than one seedling cohorts may also ensure the successful completion of the life cycle of some cohort or the other in case the environmental conditions prevailing during the life time of a particular cohort prove to be too rigorous to render the survival really precarious."

Table 6.1. Major associates of Ageratum conyzoides and Ageratum houstonianum and their density per m^2 (± S.E.) in different watersheds during May 1987 (Based on data from permanent quadrats).

Plant species	Watersheds							
	$FS\text{-}W_1$	$FS\text{-}W_2$	$FS\text{-}W_3$	$FS\text{-}W_4$	$FS\text{-}W_5$	$FS\text{-}W_6$	$FS\text{-}W_7$	$FS\text{-}W_8$
GRASSES								
Arundinella benghalensis	-	4.3±0.7	7.1±0.8	-	2.8±0.8	3.8±0.8	19.0±4.1	16.0±2.9
Bothriochloa intermedia	-	-	1.5±0.3	-	-	-	8.1±0.7	7.2±1.1
Cynodon dactylon	-	-	-	-	1.1±0	-	-	-
Eleusine indica	-	-	-	0.5±0.0	1.2±0.4	-	-	-
Guinea panicummaximum	-	-	-	-	-	-	-	3.2±0.9
Imperata cylindrica	7.7±1.8	8.5±0.6	26.5±1.9	5.4±0.5	7.7±1.6	25.1±3.9	10.5±2.0	11.2±2.2
Pennisetum polystachyon	-	-	-	2.2±0.9	-	-	-	-
Phragmites karka	-	1.3±0.5	-	-	-	1.8±0.5	7.6±1.8	-
Setaria glauca	5.5±1.4	-	6.6±0.9	3.5±1.4	1.8±0.6	-	-	3.1±0.8
Setaria palmifolia	-	-	4.9±1.1	-	-	-	3.9±0.9	-
LEGUMES								
Crotolaria striata	-	-	-	-	-	0.2±0.0	-	-
Desmodium heterophyllum	0.5±0.1	2.2±0.8	3.0±0.3	-	-	1.4±0.3	2.7±0.6	1.5±0.3
Desmodium microphyllum	5.9±1.6	6.4±0.7	-	-	-	3.2±0.4	10.0±2.2	10.7±1.0
Mimosa pudica	1.4±0.3	1.1±0.3	2.8±0.5	1.7±0.3	1.8±0.4	0.8±0.2	3.4±0.5	2.9±0.4
Stylosanthes guianensis	-	-	2.2±0.5	-	-	-	-	-

Table 6.1. (Contd.)

Plant species	Watersheds							
	FS-W_1	FS-W_2	FS-W_3	FS-W_4	FS-W_5	FS-W_6	FS-W_7	FS-W_8
OTHER FORBS								
Alectra indica	-	-	1.5±0.2	-	-	-	-	0.5±0.1
Alternanthera sessilis	-	-	-	-	0.9±0.1	-	-	-
Anaphilis adnata	-	-	-	-	-	-	-	1.2±0.3
Bidens pilosa	25.1±3.2	24.8±3.7	25.5±4.1	62.2±8.2	30.2±4.6	27.6±5.7	17.3±4.5	19.[illegible]±5.2
Blumea sp.	-	0.9±0.1	1.6±0.4	-	-	2.0±0.3	2.1±0.4	1.5±0.1
Borreria hispida	9.5±2.2	4.2±0.5	10.7±3.1	8.9±1.0	2.4±0.4	4.3±0.8	4.6±1.3	4.1±0.6
Buddleja asiatica	0.2±0.0	-	-	-	-	-	-	0.4±0.0
Centella asiatica	5.3±1.3	6.4±1.0	10.0±1.9	4.9±0.8	5.7±4.4	5.8±0.9	-	9.1±1.7
Commelina paludosa	-	-	1.6±0.8	5.9±0.9	2.0±1.1	-	-	-
Cosmos bipinnatus	3.7±0.8	1.6±0.6	1.3±0.5	2.5±0.8	2.5±0.6	0.6±0.3	0.9±0.3	0.8±0.3
Crassocephalum crepidioides	2.4±0.3	0.3±0.2	2.7±0.6	2.4±0.3	1.7±0.3	2.7±0.3	0.8±0.0	2.3±0.8
Dysophylla linearis	0.7±0.3	0.7±0.3	0.3±0.2	-	-	-	-	-
Elsholtzia blanda	1.0±0.3	2.1±0.3	2.7±0.6	-	1.3±0.1	-	1.7±0.2	2.8±0.4
Emelia sonchifolia	1.0±0.3	1.3±0.5	1.9±0.4	1.6±0.5	1.8±0.7	1.2±0.2	0.5±2.0	1.0±0.1
Eupatorium adenophorum	5.7±1.4	2.8±0.7	5.3±0.8	1.3±0.4	2.7±0.7	3.3±0.5	5.8±0.8	5.2±0.9
Eupatorium odoratum	2.3±0.2	1.8±0.4	6.2±1.3	2.5±0.7	3.2±0.6	3.5±0.3	4.5±0.8	3.6±0.3
Eusteralis stellata	1.8±0.5	2.5±0.8	2.3±1.2	1.0±0.5	2.5±0.7	2.4±0.7	2.2±1.0	3.3±0.7
Erigeron bonariansis	2.1±0.5	1.6±0.2	1.1±0.2	0.8±0.1	2.1±0.3	1.3±0.3	0.7±0.3	1.4±0.3

Table 6.1. (Contd.)

Plant species	Watersheds							
	$FS\text{-}W_1$	$FS\text{-}W_2$	$FS\text{-}W_3$	$FS\text{-}W_4$	$FS\text{-}W_5$	$FS\text{-}W_6$	$FS\text{-}W_7$	$FS\text{-}W_8$
Fimbristylis complanata	1.2±0.7	1.2±0.3	1.6±1.0	-	1.6±1.0	0.8±0.2	-	2.2±0.3
Galinsoga parviflora	-	-	-	11.4±2.7	10.0±6.2	-	-	-
Gentiana sp.	1.4±1.0	-	-	-	-	-	-	-
Gleichenia dichotoma	-	3.2±0.7	1.8±0.3	-	-	0.4±0.1	-	-
Hypericum japonicum	1.1±0.6	-	-	-	-	-	-	-
Hypochaeris radicata	1.1±0.3	-	2.4±0.2	-	-	-	-	-
Inula cappa	1.8±0.5	1.9±0.3	2.4±0.4	0.4±0.1	1.5±0.3	2.5±0.3	3.5±0.4	5.0±0.9
Lantana camara	1.5±0.1	2.4±0.3	3.0±0.6	1.4±1.1	1.7±0.5	2.8±0.6	2.9±0.3	2.6±0.3
Lygodium sp.	-	5.9±0.3	1.2±0.2	1.1±0.1	-	1.7±0.3	0.5±0.2	6.9±2.5
Melastoma normale	2.2±0.8	0.9±0.1	1.2±0.1	1.0±0.1	1.5±0.2	1.9±0.5	4.2±0.7	3.9±1.0
Mikania micrantha	-	-	-	0.6±0.1	-	-	-	-
Nelsonia canescens	-	-	-	-	1.6±0.6	-	-	-
Osbeckia crinita	1.3±0.2	3.1±0.7	2.1±0.3	0.7±0.3	1.2±0.3	1.2±0.2	3.3±0.3	1.9±0.5
Oxalis corniculata	-	-	-	1.0±0.5	-	-	-	-
Oxalis latifolia	0.8±0.4	4.8±0.8	7.8±2.3	4.6±1.6	4.0±2.6	3.8±1.0	1.3±0.7	6.7±0.8
Plantago major	0.6±0.3	-	-	-	-	-	-	-
Plectranthus ternifolius	-	-	-	-	-	-	-	2.5±0.8
Pteridium aquilinum	1.2±0.1	1.6±0.3	1.3±0.4	-	-	1.4±0.4	2.1±0.6	5.0±0.8

Table 6.1. (Contd.)

Plant species	Watersheds							
	FS-W_1	FS-W_2	FS-W_3	FS-W_4	FS-W_5	FS-W_6	FS-W_7	FS-W_8
Richardsonia sp.	6.4±1.3	3.5±0.7	2.7±1.0	3.3±1.4	3.9±0.5	1.4±0.4	3.1±0.6	2.3±0.5
Rubus ellipticus	1.1±0.2	0.4±0.0	-	-	-	1.7±0.3	2.1±0.5	3.2±0.8
Rubus moluccanus	2.3±0.4	2.2±0.5	3.0±0.3	0.6±0.0	2.0±0.4	3.1±0.5	4.5±0.4	4.7±0.8
Rungia pectinata	-	-	-	-	1.5±0.3	-	-	-
Spilanthes paniculata	-	-	-	1.5±0.5	1.1±0.2	-	-	-
Stachytorpheta dichotoma	-	2.1±1.0	5.5±0.8	-	-	-	0.3±0.0	-
Triumfetta rhomboidea	-	-	7.6±1.2	-	-	4.6±0.5	-	5.0±0.5
Urena lobata	0.6±0.1	0.8±0.4	1.3±0.5	-	-	1.3±0.2	0.7±0.1	-
Verbena vinosa	0.2±0.0	-	-	-	-	-	-	-
Ageratum conyzoides	14.0±3.2	13.8±3.3	13.0±2.9	22.4±6.2	12.3±3.3	13.8±4.4	9.2±3.1	15.2±4.2
Ageratum houstanianum	24.1±6.1	12.5±3.1	16.5±4.2	21.2±5.5	15.0±3.1	14.3±2.8	8.0±2.7	16.2±4.8

- = indicates species absence.

Table 6.2. Seed population m^{-2} (±S.E.) of *Ageratum* spp. in soil in different farming systems during 1988–1989.

Watersheds	Observation dates					
	2 March	4 May	5 July	5 Sept	10 Nov	2 Jan
FS-W_1	950±76.2	424±51.2	67±12.4	501±34.0	710±53.3	1054±82.0
FS-W_2	787±59.0	440±44.0	52±10.2	404±32.2	546±66.4	775±84.3
FS-W_3	859±63.2	368±34.0	56±10.9	505±38.4	639±55.1	925±93.2
FS-W_4	1064±79.0	421±38.2	34±9.4	687±40.0	869±67.3	1212±79.0
FS-W_5	1018±63.0	347±39.8	30±8.9	557±38.0	698±54.2	876±64.1
FS-W_6	886±50.0	372±35.4	49±12.7	387±38.0	681±56.7	971±81.1
FS-W_7	481±53.0	179±32.2	60±15.2	286±38.0	414±52.3	537±53.4
FS-W_8	698±51.0	243±32.6	42±15.5	378±33.6	458±51.8	675±77.2

Table 6.3. Density and half-life (± S.E.) of seedling cohorts of <u>*Ageratum conyzoides*</u> emerging at different times in permanent quadrats.

Land use	Date cohort was first observed	No. of seedlings/m^2	Half-life (weeks)
FS-W_1	5 May 1987	13.±3.3	15.0±1.2
	28 May 1987	4.0±0.9	21.4±0.9
	23 August 1987	9.0±2.3	8.5±0.5
	2 April 1988	24.0±4.6	12.8±0.7
	27 April 1988	9.0±1.6	8.5±0.6
	4 August 1988	5.0±0.9	8.5±0.5
FS-W_2	5 May 1987	12.0±4.3	12.8±0.9
	23 May 1987	4.2±0.9	17.1±0.9
	22 August 1987	6.0±1.2	6.4±0.4
	4 April 1988	22.0±5.5	12.1±0.6
	28 April 1988	9.2±3.1	12.1±0.7
	10 August 1988	6.0±1.3	6.4±0.4
FS-W_3	8 May 1987	11.0±3.0	22.8±1.3
	2 June 1987	3.0±0.7	21.1±1.1
	29 August 1987	9.0±1.9	7.8±1.0
	5 April 1988	22.0±5.4	17.1±1.0
	28 April 1988	10.0±2.3	5.7±0.3
	4 August 1988	4.0±0.8	13.5±0.9
FS-W_4	1 May 1987	18.0±5.3	12.8±0.6
	28 May 1987	7.0±1.4	5.7±0.8
	28 August 1987	14.0±2.1	5.0±0.6
	2 April 1988	33.0±7.1	8.5±0.6
	23 April 1988	9.3±3.2	12.8±0.8
	10 August 1988	6.8±1.4	8.5±0.6

Table 6.3 (Contd.)

Land use	Date cohort was first observed	No. of seelings/m^2	Half-life (weeks)
FS-W_5	4 May 1987	13.3±4.2	15.7±0.9
	27 May 1987	4.3±0.9	17.1±1.1
	22 August 1987	9.7±1.6	6.4±0.5
	6 April 1988	19.0±5.1	19.2±1.2
	24 April 1988	11.0±2.7	17.1±0.9
	6 August 1988	5.0±1.1	7.8±0.9
FS-W_6	2 May 1987	13.0±3.8	21.1±1.2
	21 May 1987	3.0±1.0	23.7±1.3
	29 August 1987	9.2±2.1	16.4±0.9
	4 April 1988	22.0±4.8	10.7±0.7
	23 April 1988	13.1±3.1	5.1±0.3
	8 August 1988	7.0±2.0	9.2±0.8
FS-W_7	5 May 1987	7.0±2.0	22.4±1.2
	27 May 1987	3.2±0.9	14.2±0.8
	19 August 1987	5.0±1.3	3.5±0.3
	3 April 1988	13.0±3.5	7.1±0.3
	26 April 1988	6.3±2.2	7.8±0.4
	5 August 1988	4.0±0.9	7.1±0.4
FS-W_8	5 May 1987	12.0±3.1	22.2±1.2
	23 May 1987	4.2±0.8	15.7±0.9
	26 August 1987	6.3±1.2	6.1±0.3
	1 April 1988	20.0±4.4	12.1±0.8
	23 April 1988	9.8±2.4	8.5±0.8
	9 August 1988	4.2±0.9	10.0±0.6

Table 6.4. Density and half-life (± S.E.) of seedling cohorts of *Ageratum houstonianum* emerging at different times in permanent quadrats.

Land use	Date cohort was first observed	No. of seedlings/m^2	Half-life (weeks)
FS-W_1	1 May 1987	17.4±5.5	22.2±1.2
	23 May 1987	7.1±1.3	21.5±1.3
	26 August 1987	9.2±2.1	6.4±0.3
	4 April 1988	26.0±7.1	13.5±0.7
	10 May 1988	12.0±4.0	10.7±0.4
	19 August 1988	8.0±2.0	8.5±0.6
FS-W_2	3 May 1987	8.4±3.3	22.8±1.2
	25 May 1987	4.3±2.0	21.5±1.2
	30 August 1987	6.0±1.5	8.5±0.6
	2 April 1988	24.0±4.7	17.1±0.8
	7 May 1988	9.0±2.5	21.4±0.9
	24 August 1988	6.0±1.2	6.4±0.3
FS-W_3	1 May 1987	12.2±3.1	21.2±1.2
	21 May 1987	4.5±1.2	21.4±1.1
	19 August 1987	8.0±2.4	8.5±0.5
	2 April 1988	23.0±5.2	19.2±0.9
	14 May 1988	13.0±3.1	12.1±0.8
	20 August 1988	6.0±1.2	9.2±0.6
FS-W_4	5 May 1987	16.0±5.0	23.5±0.9
	29 May 1987	7.2±1.3	19.2±1.2
	20 August 1987	14.0±2.1	4.5±0.3
	2 April 1988	30.0±6.7	12.8±0.8
	4 May 1988	11.2±3.1	21.4±1.3
	29 August 1988	5.9±1.4	8.5±0.4

Table 6.4. (Contd.)

Land use	Date cohort was first observed	No. of seedlings/m^2	Half-life (weeks)
FS-W_5	3 May 1987	14.0±4.7	22.2±1.2
	25 May 1987	3.0±0.6	21.7±1.3
	23 August 1987	8.0±2.0	8.5±0.5
	6 April 1988	27.0±4.6	18.5±0.9
	11 May 1988	10.2±2.1	21.4±0.8
	30 August 1988	6.0±1.2	7.1±0.3
FS-W_6	2 May 1987	14.0±4.5	20.7±1.2
	29 May 1987	4.3±1.4	12.8±0.7
	28 August 1987	8.0±2.6	7.1±0.6
	2 April 1988	26.0±6.1	13.7±0.8
	12 May 1988	9.0±2.3	12.8±0.8
	21 August 1988	5.1±1.2	9.2±0.6
FS-W_7	3 May 1987	7.0±3.2	20.4±1.2
	1 June 1987	3.0±0.8	20.2±1.1
	1 April 1988	13.0±4.1	19.2±0.9
	14 May 1988	5.0±1.2	8.5±0.7
FS-W_8	3 May 1987	13.0±3.4	20.5±1.1
	30 May 1987	6.0±1.6	17.1±0.8
	28 August 1987	11.0±2.6	5.0±0.3
	9 April 1988	20.0±5.1	14.2±0.8
	17 May 1988	8.0±1.8	18.5±0.9
	22 August 1988	4.2±0.9	14.1±0.7

Table 6.5a. Survivorship (%) of different cohorts of *Ageratum conyzoides* during 1987 and 1988.

Watersheds	Percentage survivorship					
	1987			1988		
	C_I	C_{II}	C_{III}	C_I	C_{II}	C_{III}
FS-W_1	67	75	55	41	44	50
FS-W_2	66	71	33	40	54	16
FS-W_3	72	66	22	36	50	75
FS-W_4	50	28	35	33	53	29
FS-W_5	52	46	25	52	54	40
FS-W_6	61	60	21	40	45	28
FS-W_7	85	62	40	46	47	25
FS-W_8	75	71	47	45	51	95

Table 6.5b. Survivorship (%) of different cohorts of *Ageratum houstonianum* during 1987 and 1988.

Watershed	Percentage survivorship					
	1987			1988		
	C_I	C_{II}	C_{III}	C_I	C_{II}	C_{III}
FS-W_1	80	63	32	46	33	37
FS-W_2	83	69	50	54	55	41
FS-W_3	81	66	37	54	46	33
FS-W_4	75	55	14	43	71	50
FS-W_5	85	66	50	37	58	33
FS-W_6	71	69	37	38	44	39
FS-W_7	72	66	-	61	50	-
FS-W_8	76	50	36	47	62	71

CHAPTER VII

POPULATION DYNAMICS OF *BIDENS PILOSA* L. UNDER DIFFERENT FARMING SYSTEMS

Bidens pilosa L. (Asteraceae) is widely distributed in sub-tropical and tropical regions. It is found throughout India. *Bidens* is one of the most successful genera occurring in different natural forests of Eastern Himalayas and at margins of cultivated lands. Its effective pollination mechanism makes it a very successful colonizer. The fruits of this weed are distributed by workers, animals, wind and water.

As a pioneer weed, it possesses most of the characteristics to compete with other plant species. Since the seeds are taken far apart by different agents, new areas are successively colonized every year. It produces a large number of seeds, many of them germinating readily at maturity. It is reported to be a weed of 31 crops in more than 40 countries. Its distribution does not, however, seem to be correlated directly with soil type but rather with the system of agricultural farming and the type of crops grown.

Studies of the population dynamics of annual weed species in agricultural situations offer some advantage in that the system is relatively simple, compared to the undisturbed communities (Weiss, 1981). Any attempt to understand the population dynamics of a species involves measuring, describing and explaining changes in demographic parameters like seedling recruitment, plant mortality, plant survival etc. (Fernandez-Quintanilla *et al*., 1986).

Some of the works on the population dynamics of annuals in different agricultural settings are those of Naylor (1972), Harper (1977), Snaydon (1980), Weaver & Lechowicz (1982), Peters & Arc (1983), Smith (1983), Rai & Tripathi (1984), Zimmerman & Weiss (1984) and Fernandez-Quintanilla (1986). Studies on the population dynamics of several perennial grasses and herbs have been carried out by Williams (1970), Antonovics (1972), Sarukhan & Harper (1973), Hawthorn & Cavers (1976), Bishop *et al*. (1978), Tripathi & Dwivedi (1978), Kushwaha, Ramakrishnan & Tripathi (1981), Law (1981), Lovett-Doust (1981), Mishra & Ramakrishnan (1981), Yadav & Tripathi (1981), Auld & Myerscough (1986) and Kataoka *et al*. (1989). In the case of *Bidens pilosa* due to seedling emergence taking place at different times during the year, there are several seedling cohorts appearing in different periods. Monitoring the fate of these seedling cohorts and relating various demographic parameters of this weed to agricultural operations, farming systems and other environmental variables on different experimental watersheds could be quite interesting.

MATERIALS AND METHODS

The study was conducted over a period of two years during April 1987-January 1989 on the Farming Systems Research plot of the ICAR Farm at Barapani. Demographic studies were carried out in the 1 m^2 permanent quadrats laid out at ten places in each of the eight farming systems. The location of the quadrats was chosen subjectively so as to get an almost similar density of plants in each quadrat. The seedling cohorts of Bidens pilosa which emerged on 3 different dates, were clearly identifiable as cohorts I, II and III (Table 7.3). The seedling cohorts were marked in early April, late April and late May in all the farming systems except Livestock-based farming system (FS-W_1) in which it was marked in mid April, early May and early June during 1987. In 1988, the seedling cohorts were marked in late March, mid April and mid May to late May in all the farming systems except in FS-W_2 in which it was marked in late March, late April and early June. Each seedling was marked with a dot of paint on the tip of its first leaf. The fate of seedling cohorts was followed at forthnightly intervals from emergence until death and the time taken from emergence to 50% survivorship was calculated as half life according to Rai & Tripathi (1984). The seedling emergence, survivorship and mortality were studied in the permanent quadrats. The density of the associates of Bidens pilosa in permanent quadrats on all the eight farming systems were also recorded (Table 7.1).

The seed population, which presumably gave rise to the III cohort was determined at bimonthly intervals from February 1988 to December 1988. The III cohort appeared after 2-3 months from the appearance of the I cohort. In order to estimate soil seed population the soil cores of, 10 x 10 x 5 cm size were taken from areas adjacent to the permanent quadrats on all the farming systems. The soil samples were air-dried and seeds of B. pilosa were carefully sorted out and counted.

RESULTS

Life cycle attributes

Seeds of Bidens pilosa germinate in March and April (Spring) when the temperature rises and the first showers are received. During 1987, three flushes of germination (early April, late April and late May in all the farming systems and mid April, early May and early June in livestock-based farming system (FS-W_1) were observed in all the 8 farming systems. The three flushes gave rise to three distinct seedling cohorts designated as I, II and III. The plants from cohort I and II developed to flowering and seeded in June/July. The emergence of the III cohort from a fraction of the seeds from the I and II cohort is evident from the loss of large fraction of original seed bank in soil before the emergence of the III cohort (Table 7.2). The III cohort completed its life cycle in December and died down, as is clear from the nil survival during January and February. During the second year (1988) also, the same pattern of population changes was repeated except that the seed germination was preponed by a month.

Seedling emergence

Emergence of Bidens pilosa seedlings began soon after the first showers were received. On all the eight farming systems, the first seedling cohorts which appeared in April 1987 and March 1988 were quite large compared to the II and III cohorts which appeared later (Table 7.4). Like seedling emergence, the total density of Bidens pilosa also remained fairly high in case of agricultural system ($FS\text{-}W_4$) compared with the rest of the farming systems. The total density of this weed was the lowest in $FS\text{-}W_7$ (control system) and $FS\text{-}W_8$ (jhum fallow). Only a few seedlings was observed to emerge during June. The seedling population changed with time in all the plots following a similar pattern. In 1988, the seedling emergence was preponed by one month. The population size of the I cohort of B. pilosa during 1987 varied greatly from 12 m^{-2} in the control system ($FS\text{-}W_7$) to 53 m^{-2} in agricultural system ($FS\text{-}W_4$), and in 1988 in the same watersheds it ranged between 13 m^{-2} to 43 m^{-2}. In 1988, the overall total seedling emergence (cohort I + cohort II + cohort III) was greater in livestock-based farming system ($FS\text{-}W_1$) followed by forestry system ($FS\text{-}W_2$), agro-forestry system ($FS\text{-}W_3$), agri-horti-silvi pastoral system ($FS\text{-}W_5$), control system ($FS\text{-}W_7$) and jhum fallow ($FS\text{-}W_8$). Only agricultural system ($FS\text{-}W_4$) and horticultural system ($FS\text{-}W_6$) showed lesser overall total seedling emergence (Table 7.3) during 1988 compared to 1987.

Survivorship of seedling cohorts

In all the farming systems the cohorts emerging in 1987 showed longer half life and survived better than those emerging in 1988 except the III cohort in livestock-based farming system ($FS\text{-}W_1$) and agricultural system ($FS\text{-}W_4$) and II cohort in the control plot ($FS\text{-}W_7$) and jhum fallow ($FS\text{-}W_8$). During 1987, the I cohorts in $FS\text{-}W_2$, $FS\text{-}W_7$ and $FS\text{-}W_8$ and II cohorts in $FS\text{-}W_1$, $FS\text{-}W_2$ and $FS\text{-}W_3$ showed a longer half life compared to those in other farming systems. During a 2-year study period the shortest half life (3.1 weeks) was shown by the II cohort in $FS\text{-}W_6$ in 1988.

The seedling cohort <u>B</u>. <u>pilosa</u> marked in April 1987 experienced greater mortality in agricultural system ($FS\text{-}W_4$) than in other farming systems (Fig. 7.2). In $FS\text{-}W_4$, out of

Fig. 7.1 Population dynamics of *Bidens pilosa* in different farming systems during 1987 and 1988.

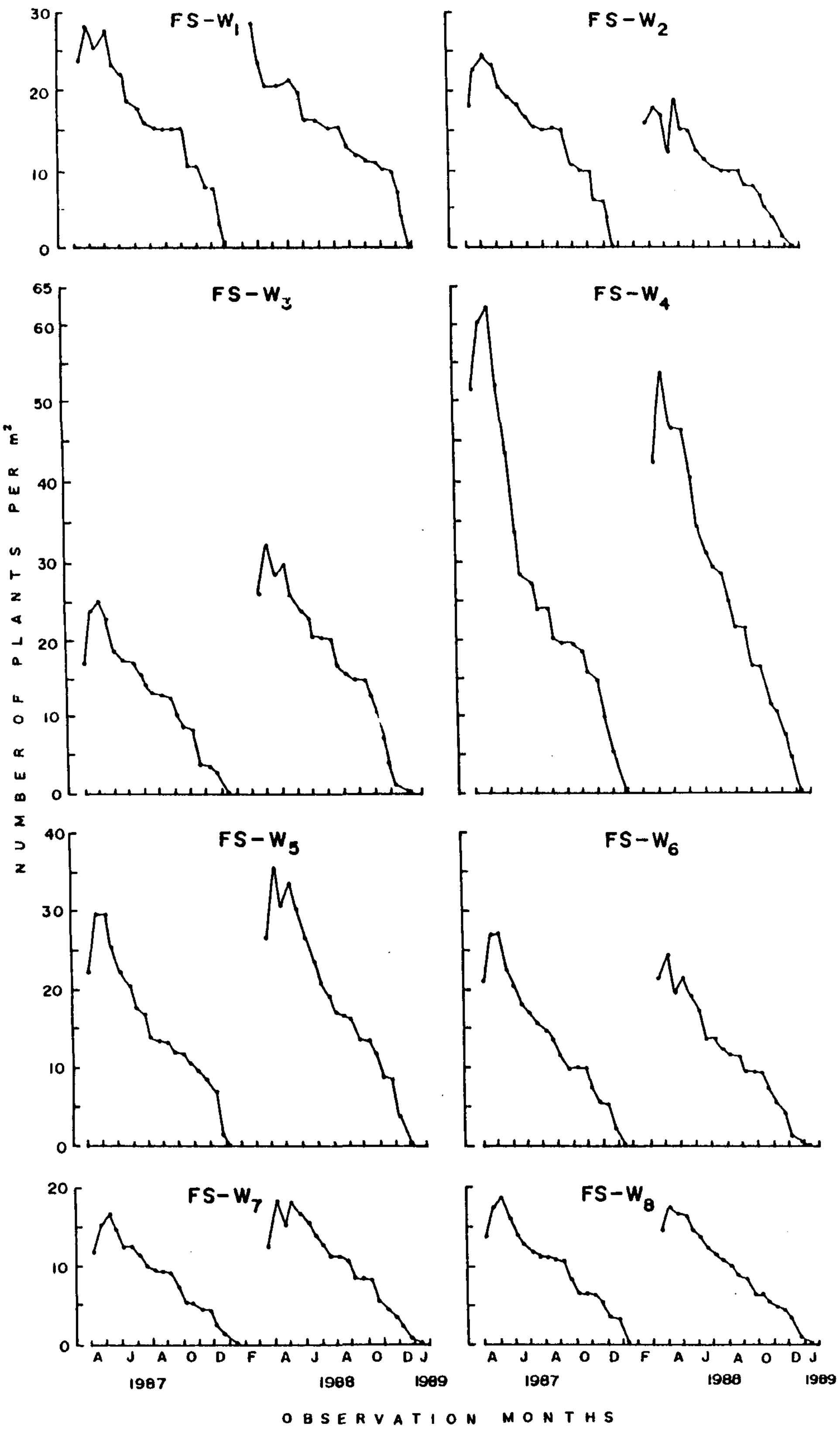

FS-W1
FS-W2
FS-W3
FS-W4
FS-W5
FS-W6
FS-W7
FS-W8
NUMBER OF PLANTS PER m²
OBSERVATION MONTHS
A J A O D F A J A O D J
1987
1988
1989

Fig. 7·1

Fig. 7.2 Survivorship curves for seedling cohorts of Bidens pilosa on different farming systems during 1987 and 1988. I, II and III represent the chorts appearing at different times.

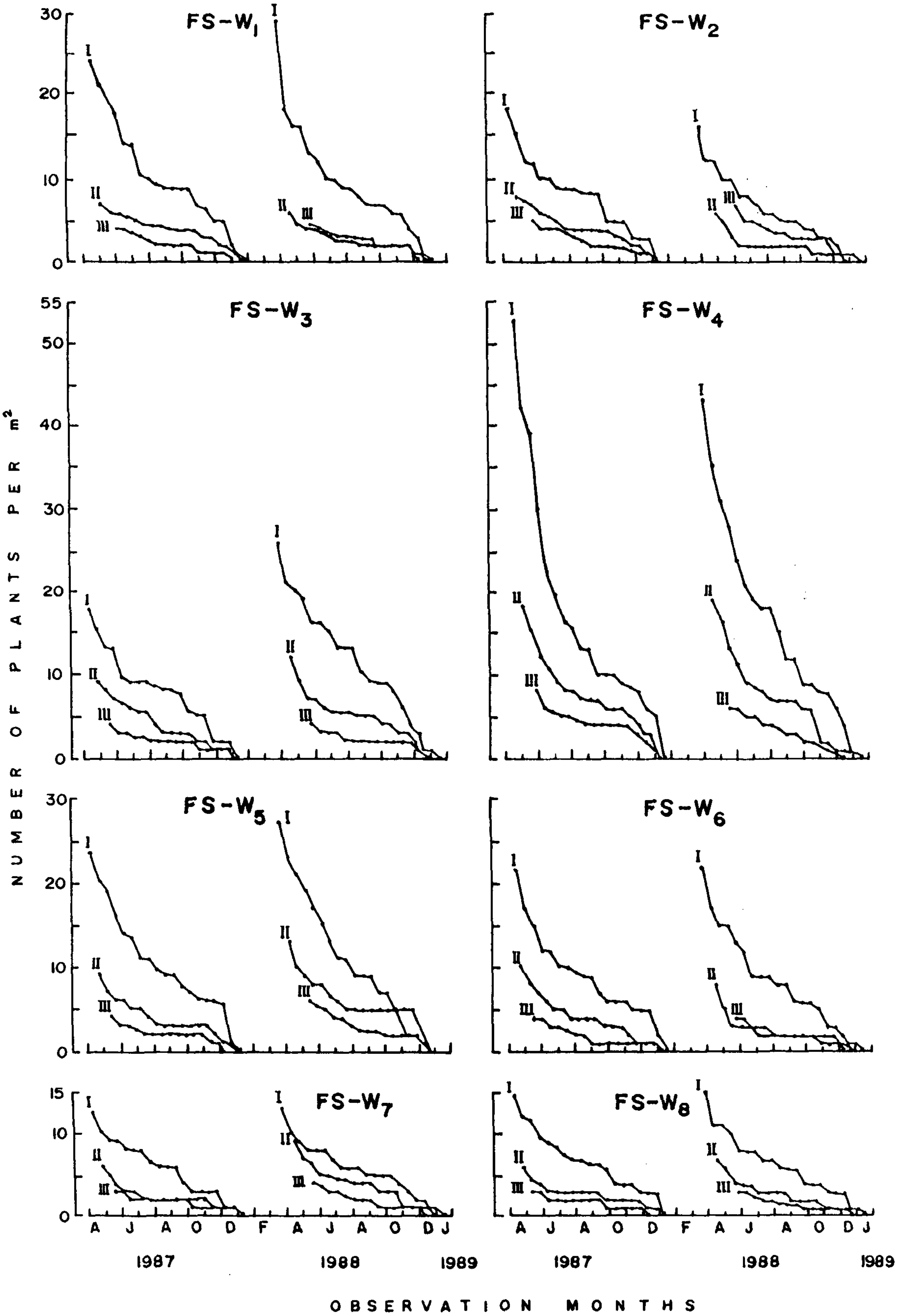

FS-W1
FS-W2
FS-W3
FS-W4
FS-W5
FS-W6
FS-W7
FS-W8
NUMBER OF PLANTS PER m2
A J A O D F A J A O D J
1987
1988
1989
OBSERVATION MONTHS

Fig. 7·2

the 53 established plants, only 19 survived and reached the flowering and seeding phase while the survival was greater in other farming systems (Table 7.5). Survival of the I cohort in FS-W_4 upto flowering and seeding stage was only 35% during 1987, while it was 48% in 1988 (Table 7.5). The highest mortality (59%) during 1988 was recorded in livestock-based farming system.

The II cohorts of B. pilosa were smaller in size than the I cohorts during 1987 and they showed relatively poor survival in all the farming systems except in agri-horti-silvi pastoral system (FS-W_5) where the survival was 74% (Table 7.5). In 1988, the survival of the II cohort was almost equal in all the farming systems. Survival of the III seedling cohort was, however, varied in different farming systems. In 1987, survival of the III cohort was quite high (66%) in FS-W_7 and FS-W_8 compared to the other farming systems. Contrary to this, in 1988, the survivorship was better in agricultural system and livestock-based farming system than in other farming systems (Table 7.5). The I and II cohorts showed almost equal survival. The I cohort, however, in both years did comparatively better than the later two cohorts in all the eight farming systems. In general, survival pattern was similar in both years.

DISCUSSION

The highest population density of *Bidens pilosa* in spring may be attributed to large flush of germination and seedling emergence due to favourable climatic conditions such as light showers and rise in temperature prevailing during this season. Baskin & Baskin (1978) reported that the timing of seedling emergence in the field is often closely related to the temperature requirement of the seeds. The optimum temperature for seed germination in *B. pilosa* is reported to be 25° C (Fenner, 1980) which is quite close to the temperature condition of the study site prevailing during spring season (Fig. 3.1). However, there was not much effect of the farming systems on the emergence time of the seedlings of *B. pilosa*. The mortality of the spring cohort (cohort I) was either equal or greater than the later emerging seedlings. The II cohort exhibited almost similar density pattern in both years. Although it was smaller in size than the I cohort (Table 7.3), in both years its population was larger than that of the III cohorts in all the eight farming systems. With the emergence of the III cohort the overall density increased once again in June-July (Fig. 7.1). With the approach of winter the weed density declined drastically touching the zero level indicating the possible negative role of low temperature and high moisture stress in influencing the population of this weed. Low temperature seems to play an important role in germination of seeds of Bidens pilosa (Valio et al., 1972). Raynal & Bazzaz (1975b), Rai & Tripathi (1984) and Kataoka et al. (1989) have also observed similar response to cold in the case of certain other annuals.

It may be assumed that seeds contributed by cohorts I, II and III in a growing season, give rise to the seedlings in the subsequent growing seasons. Thus seeds produced by the three cohorts in a given growing season are maintained as seedbank. This is also indicated by the increasing seed bank size after the completion of seeding by the I and II cohorts (i.e. after August, 1988). The larger size of the I seedling cohort may be partly attributed to the increased seed population in soil due to the seed input from the III cohort. It may be mentioned that the seeds contributed by the III cohort fail to germinate during unfavourable winter conditions prevailing after their dispersal and may remain dormant until a further disturbance brings them to the surface and favourable temperature and moisture conditions obtained in spring season stimulate seed germination. The change in population size, emergence and mortality of the seedlings are also influenced to a great extent by different farming systems. Relatively greater mortality of B. pilosa in the crop field where its density was high (Fig. 7.1) indicates that intra-specific competition plays important role in population regulation of this weed. This is in agreement with the findings of Pemadasa (1976) in Bidens chinensis where mortality was high due to high density and intra-specific interference. The I seedling cohorts emerging in 1987 were bigger than that of 1988 especially in agricultural system (FS-W_4). However, on the whole seedling recruitment was much greater in 1988 than in 1987 except in FS-W_4 and FS-W_6.

The decreasing size of the successive cohorts (Table 7.3) is in agreement with the findings of Rai & Tripathi (1984) in Galinsoga parviflora and G. ciliata, Ballare et al. (1987) in Datura ferox, and Pandey & Dubey (1989) in Parthenium hysterophorus. The decreasing size of the successive cohorts could be attributed to the depletion of germinable fraction of seeds in the soil seed bank and to the growth of associated vegetation and crops, which allows less light to reach the ground surface whereby the seed germination is slowed down. The present results conform with the findings of Fenner (1980) in Bidens pilosa. The effect of neighbours on a plant is the function of number, size, proximity etc. of all individuals in the ecological neighbourhood area (Antonovics & Lenin, 1980). Tamm (1956), Singh (1980) and Rai & Tripathi, (1984) have also observed poor recruitment and establishment of seedlings in established communities.

Early mortality was a common phenomenon in almost all the three seedling cohorts. However, in seedling cohort III, this phenomenon was not very pronounced as density of seedlings was too low to show any remarkable change. The mortality of Bidens pilosa was greater in the rainy season than in the post rainy season in spite of the prevailing favourable conditions in the former. Thus, some of these early mortalities were probably due to mechanical damage, where mortality in the later emerging groups presumably resulted from severe crop competition. This finding agrees with low juvenile survivorship observed in most pioneer and colonizing species (Harper, 1965; Sharitz & McCormick, 1973; and Peters & Arc, 1983).

The present study illustrates both concave (type III) survivorship in which high mortality was observed at juvenile stage and linear (type II) in which mortality is constant throughout the life cycle, thus conforming with the findings of Rai & Tripathi (1984) in Galinsoga spp. The greater survival of early emerging cohorts than those emerging at a later date was also influenced by the time of emergence. Similar conclusion was drawn by Sarukhan & Harper (1973), Weiss (1981), Rai & Tripathi (1984), Ballare et al. (1987) and Pandey & Dubey (1989). The enhanced mortality during active growth phase could be probably attributed to increased resource competition as has been reported in the case of other species by Sarukhan & Harper (1973), Hawthorn & Cavers (1976), Yadav & Tripathi (1981), Peters & Arc (1983) and Rai & Tripathi (1984).

Survival of late emerging cohorts may be adversely affected by the well grown-up crop plants and already established individuals of the I cohort. Despite the larger size the I cohort showed relatively greater survivorship and half life. This could be attributed to lesser competition from the associated vegetation as the number of associates was less at the time of emergence of the I cohort. One of the possible reasons for the low seedling emergence in FS-W_7 and FS-W_8 may be the inclusion of several atypical sites having very high densities of the long standing grass community in these watersheds.

B. pilosa showed longer half life and relatively greater survival in FS-W_2 during 1987 and in FS-W_8 during 1988. This may be due to a very mild agricultural operations in FS-W_2 in comparison to the other farming systems and absence of agricultural operations in FS-W_8.

B. pilosa may be said to prefer agriculturally disturbed habitats for its growth and reproduction (Table 8.3, Chap. VIII). This is confirmed by a very low population density of B. pilosa observed in $FS\text{-}W_7$ and $FS\text{-}W_8$ which were more or less undisturbed, and by a dense population of this weed in the agricultural system ($FS\text{-}W_4$) which was constantly disturbed.

B. pilosa, which is basically a crop weed also occurs in pastures and grasslands, but its population on such habits is very low. As many of the seeds germinate readily at maturity, B. pilosa shows 3-4 germination in one growing season (Holm et al., 1977), which is an important strategy in maintaining the population of this weed. This weed can perpetuate and persist under the stressed environments of agro-ecosystems by successfully completing its life cycle due to presence of more than one seedling cohort.

Table 7.1. Major associates of *Bidens pilosa* and their density per m^2 (± S.E.) in the permanent quadrats in April 1987.

Plant species	Watersheds							
	$FS\text{-}W_1$	$FS\text{-}W_2$	$FS\text{-}W_3$	$FS\text{-}W_4$	$FS\text{-}W_5$	$FS\text{-}W_6$	$FS\text{-}W_7$	$FS\text{-}W_8$
GRASSES								
Arundinella benghalensis	-	4.3±0.8	6.1±0.8	-	1.4±0.3	3.8±0.9	18.1±5.1	15.7±3.3
Bothriochloa intermedia	-	-	1.5±0.3	-	-	-	8.1±0.7	7.2±1.6
Cynodon dactylon	-	-	-	-	1.1±0.3	-	-	-
Eleusine indica	-	-	-	0.5±0.2	1.2±0.3	-	-	-
Guinea panicummaximum	-	-	-	-	-	-	-	3.2±0.4
Imperata cylindrica	7.7±1.6	8.5±0.9	26.2±3.9	5.9±0.8	6.4±1.3	23.6±4.6	10.0±1.3	11.2±2.2
Pennisetum polystachyon	-	-	-	2.4±0.9	1.3±0.2	-	-	-
Phragmites karka	-	-	-	-	-	-	7.6±1.4	-
Setaria glauca	5.3±1.3	-	6.6±1.3	4.7±1.4	1.8±0.6	-	-	3.1±0.8
Setaria palmifolia	-	-	4.9±1.2	-	-	-	3.9±0.7	-
LEGUMES								
Crotolaria striata	-	-	-	-	-	-	0.6±0.0	-
Desmodium heterophyllum	-	2.4±0.4	6.1±2.1	-	-	1.3±0.6	2.7±0.5	1.3±0.4
Desmodium microphyllum	5.9±1.6	6.4±1.9	-	-	-	2.5±0.8	10.0±3.3	9.4±4.2
Mimosa pudica	1.4±0.3	1.0±0.3	2.7±0.6	1.7±0.4	1.8±0.4	0.6±0.3	3.4±0.6	2.9±0.4
Stylosanthes guianensis	-	-	2.2±0.3	0.6±0.1	-	-	-	-

Table 7.1. (Contd.)

Plant species	Watersheds							
	FS-W_1	FS-W_2	FS-W_3	FS-W_4	FS-W_5	FS-W_6	FS-W_7	FS-W_8
OTHER FORBS								
Alectra indica	0.7±0.2	1.1±0.2	2.0±0.4	0.3±0.0	-	1.4±0.2	-	0.7±0.3
Alternanthera sessilis	-	-	-	-	0.9±0.1	-	-	-
Anaphilis adnata	-	-	-	-	-	-	-	1.2±0.2
Aristolochia tagala	0.4±0.0	0.3±0.5	0.4±0.1	0.2±0.0	0.7±0.3	0.6±0.1	2.3±0.5	0.3±0.0
Artemisia vulgaris	-	-	1.6±0.4	-	1.6±0.4	0.8±0.2	-	2.2±0.5
Blumea sp.	-	0.9±0.2	1.6±0.4	-	-	2.0±0.3	2.1±0.3	1.5±0.1
Borreria hispida	4.5±1.4	2.7±0.7	1.4±0.4	2.3±0.5	2.4±0.4	1.7±0.7	1.9±0.6	2.3±0.6
Buddleja asiatica	0.2±0.0	-	-	-	-	-	-	-
Cannabis sativa	0.2±0.0	-	-	-	-	-	-	-
Cantella asiatica	5.1±1.4	6.4±0.3	9.4±3.1	4.5±1.2	5.5±1.6	5.8±0.9	-	8.7±1.6
Commelina paludosa	-	-	1.6±0.8	8.3±2.1	2.0±1.0	-	-	-
Cosmos bipinnatus	3.7±0.9	1.6±0.6	1.3±0.5	1.9±0.6	2.5±0.6	0.7±0.3	0.9±0.3	0.8±0.3
Crassocephalum crepidioides	2.3±0.4	0.3±0.0	2.7±0.6	2.4±0.4	1.7±0.3	2.7±0.3	0.8±0.0	2.3±0.8
Dysophylla linearis	0.7±0.3	0.5±0.6	-	-	-	-	-	-
Elephantopus scaber	0.1±0.0	-	-	-	-	-	-	-
Elsholtzia blanda	1.6±0.4	2.5±0.6	3.6±1.0	-	1.3±0.3	1.4±0.4	1.7±0.4	2.8±0.4
Emelia sonchifolia	1.0±0.2	1.3±0.2	1.9±0.4	1.6±0.3	1.8±0.2	1.0±0.5	0.5±0.2	1.0±0.1

Table 7.1. (Contd.)

Plant species	Watersheds							
	FS-W_1	FS-W_2	FS-W_3	FS-W_4	FS-W_5	FS-W_6	FS-W_7	FS-W_8
Eupatorium adenophorum	6.0±1.4	2.8±0.6	5.3±1.4	1.3±1.8	2.7±0.9	2.3±0.9	5.8±1.6	5.2±1.3
Eupatorium odoratum	2.3±0.4	1.8±0.5	6.1±1.1	2.5±0.9	3.3±0.1	3.5±0.4	4.5±0.3	3.6±0.6
Eusteralis stellata	-	-	-	-	-	-	-	1.8±0.0
Erigeron bonoriansis	2.1±0.4	1.6±0.3	1.1±0.0	0.8±0.0	2.1±0.2	1.3±0.3	0.7±0.0	1.4±0.0
Galinsoga parviflora	-	-	-	11.4±2.6	10.0±2.6	-	-	-
Gentiana sp.	1.4±0.0	-	-	-	-	-	-	-
Gleichenia dichotoma	-	3.2±0.8	-	-	-	0.4±0.0	-	-
Hypericum japonicum	1.1±0.1	-	-	-	-	-	-	-
Hypochaeris radicata	1.1±0.3	-	2.4±0.3	-	-	-	-	-
Inula cappa	1.8±0.5	1.9±0.3	2.4±0.4	0.4±0.1	1.5±0.1	2.5±0.4	3.5±0.5	5.0±0.9
Lantana camara	1.5±0.1	2.1±0.3	2.7±0.5	1.5±0.2	1.6±0.5	2.8±0.6	2.9±0.3	2.5±0.3
Lygodium sp.	-	5.9±0.6	-	1.1±0.2	-	1.5±0.2	-	7.0±2.5
Melastoma normale	2.2±0.7	0.8±0.1	1.2±0.0	1.0±0.1	1.3±0.2	1.6±0.5	4.2±0.7	3.9±1.0
Mikania micrantha	-	-	-	0.7±0.2	-	-	-	-
Nelsonia canescens	-	-	-	-	1.6±0.6	-	-	-
Osbeckia crinita	1.3±0.2	2.0±0.7	1.2±0.3	0.8±0.3	0.9±0.3	0.7±0.4	2.6±0.3	1.5±0.5
Oxalis corniculata	-	-	-	1.0±0.3	0.9±0.0	-	-	-

Table 7.1. (Contd.)

Plant species	Watersheds							
	FS-W_1	FS-W_2	FS-W_3	FS-W_4	FS-W_5	FS-W_6	FS-W_7	FS-W_8
Oxalis latifolia	-	4.8±0.8	8.6±2.6	4.2±1.7	3.8±1.3	3.8±0.9	-	7.7±1.2
Phyllanthes urinaria	-	-	1.2±0.2	-	-	-	-	-
Plantago major	0.6±0.2	-	-	-	-	-	-	-
Plectranthus ternifolius	-	-	-	-	-	-	-	2.5±0.3
Pteridium aquilium	1.2±0.1	1.6±0.1	1.3±0.2	-	-	1.4±0.3	2.1±0.6	5.0±0.8
Richardsonia sp.	4.9±0.9	3.5±0.7	2.7±1.3	3.3±1.3	3.9±0.6	1.4±0.5	3.1±0.6	2.3±0.6
Rubus ellipticus	1.1±0.0	-	-	-	-	1.7±0.3	1.9±0.5	2.4±0.8
Rubus moluccanus	2.5±0.5	2.0±0.3	3.0±0.8	0.5±0.1	1.8±0.1	3.1±0.4	4.5±4.7	4.7±0.8
Rungia pectinata	-	-	-	-	1.5±0.3	-	-	-
Sida rhomboidea	-	-	0.6±0.0	-	0.1±0.0	-	-	-
Solanum khasianum	0.3±0.0	-	-	-	-	-	-	-
Spilanthes paniculata	-	-	-	1.1±0.2	0.9±0.1	-	-	-
Stachytorpheta dichotoma	-	-	5.5±1.3	-	-	-	0.3±0.0	-
Triumfetta rhomboidea	-	-	8.9±2.1	-	-	4.6±0.8	-	5.0±0.9
Urena lobata	0.6±0.1	-	1.3±0.2	-	-	1.3±0.2	0.7±0.1	-
Verbena vinosa	-	-	-	-	0.1±0.0	-	-	-
Bidens pilosa	24.3±4.1	23.3±4.1	24.5±3.8	60.6±11.2	29.8±6.8	27.4±6.7	16.4±5.1	18.2±5.6

- = indicates species absence

Table 7.2. Population m^{-2} (± S.E.) of Bidens pilosa seeds in soil under different rent farming systems during 1988.

Watersheds	Observation dates					
	1 February	3 April	1 June	5 August	6 October	1 December
$FS\text{-}W_1$	451±32.0	206±14.0	31±6.0	198±20.0	416±37.0	556±39.0
$FS\text{-}W_2$	362±21.0	141±11.0	42±7.0	271±22.2	435±30.0	462±43.0
$FS\text{-}W_3$	325±39.0	153±11.3	26±5.8	205±18.2	402±47.0	511±57.0
$FS\text{-}W_4$	688±68.0	303±20.0	16±4.7	232±15.0	566±52.0	651±59.0
$FS\text{-}W_5$	539±71.0	241±18.3	21±4.0	185±13.0	413±30.0	601±38.0
$FS\text{-}W_6$	388±44.0	174±16.2	37±6.0	197±12.0	395±21.0	419±33.0
$FS\text{-}W_7$	262±29.0	103±9.6	49±7.0	241±16.3	282±39.0	345±46.0
$FS\text{-}W_8$	305±33.0	127±10.7	63±7.2	252±23.0	390±45.0	403±53.0

Table 7.3. Dates of emergence of the I, II & III cohorts of <u>B. pilosa</u>, their initial densities and half lives (± S.E.) during 1987 and 1988.

Land use	Year	Date cohort was first observed	No. of seedlings/m^2	Half life (weeks)
FS-W_1	1987	15 April	24.3±7.2	9.5±0.8
		6 May	7.1±2.1	17.1±0.8
		1 June	4.1±0.9	10.7±0.6
	1988	28 March	29.0±8.2	9.2±0.6
		17 April	6.0±3.0	10.7±0.4
		29 May	4.0±2.7	12.2±0.8
FS-W_2	1987	8 April	10.1±5.2	15.2±0.9
		26 April	8.1±3.9	15.2±0.9
		20 May	5.0±0.3	15.2±0.9
	1988	29 March	16.0±5.8	11.7±0.7
		21 April	6.0±1.2	6.4±0.3
		2 June	7.0±2.2	10.8±0.7
FS-W_3	1987	10 April	17.5±6.3	12.8±0.9
		27 April	9.1±2.7	15.2±1.1
		18 May	[illegible]±0.7	12.2±0.8
	1988	27 March	26.0±4.1	10.7±0.7
		18 April	12.0±3.1	10.7±0.7
		26 May	4.0±0.7	10.1±0.6
FS-W_4	1987	12 April	52.6±6.8	10.7±0.8
		30 April	18.3±4.2	10.7±0.8
		22 May	7.7±2.3	12.8±1.2
	1988	30 March	43.0±8.1	10.2±0.8
		19 April	19.2±3.2	10.2±0.8
		18 May	6.1±1.6	11.1±1.1

Table 7.3. (Contd.)

Land use	Year	Date cohort was first observed	No. of seedlings/m^2	Half life (weeks)
FS-W_5	1987	11 April	23.5±4.6	12.8±0.8
		27 April	9.4±3.1	13.5±1.2
		18 May	3.8±1.3	10.7±0.8
	1988	23 March	27.0±5.2	12.5±0.9
		10 April	13.0±4.1	11.4±0.8
		12 May	6.0±2.0	10.7±0.7
FS-W_6	1987	11 April	21.5±4.7	12.7±0.9
		28 April	10.2±3.7	10.7±0.6
		20 May	4.4±3.0	10.7±0.8
	1988	28 March	22.0±6.0	12.5±1.2
		18 April	8.0±3.4	3.1±0.3
		21 May	4.0±1.2	8.5±0.5
FS-W_7	1987	8 April	12.6±4.1	15.2±1.2
		26 April	6.0±2.0	6.4±0.6
		17 May	3.0±0.9	14.2±0.9
	1988	25 March	13.0±3.6	15.2±1.1
		12 April	9.0±3.0	10.7±0.8
		19 May	4.0±1.2	10.7±0.8
FS-W_8	1987	8 April	14.5±4.1	15.5±1.2
		24 April	6.0±2.0	8.5±0.8
		10 May	3.0±0.9	14.2±1.2
	1988	25 March	15.0±3.7	15.0±1.1
		16 April	7.0±2.4	13.5±1.0
		23 May	3.2±1.1	11.4±0.9

Table 7.4. **Percentage contribution of each seedling cohort of *Bidens pilosa* to the total population of seedlings emerged in each growing season in different farming systems.**

Watersheds	1987 C_I	C_{II}	C_{III}	1988 C_I	C_{II}	C_{III}
FS-W_1	68	20	12	75	15	10
FS-W_2	44	35	21	55	21	24
FS-W_3	57	29	14	62	29	9
FS-W_4	67	23	10	63	28	9
FS-W_5	64	26	10	59	28	13
FS-W_6	60	28	12	65	23	12
FS-W_7	58	28	14	50	35	15
FS-W_8	62	25	13	59	28	13

Table 7.5. **Survivorship (%) of different cohorts of *Bidens pilosa* upto flowering stage during 1987 and 1988.**

Watersheds	Survivorship (%) 1987 C_I	C_{II}	C_{III}	1988 C_I	C_{II}	C_{III}
FS-W_1	58	56	60	41	50	75
FS-W_2	55	49	40	50	50	42
FS-W_3	51	38	45	61	45	50
FS-W_4	35	32	51	48	41	65
FS-W_5	59	74	52	55	46	41
FS-W_6	47	50	56	54	37	50
FS-W_7	63	33	66	61	50	50
FS-W_8	55	50	66	53	57	46

CHAPTER VIII

EFFECT OF DIFFERENT FARMING SYSTEMS ON THE GROWTH AND DRY MATTER ALLOCATION OF *AGERATUM CONYZOIDES*, *A. HOUSTONIANUM* AND *BIDENS PILOSA*

The success of an organism in a given environment is often determined by the allocation of limited available resources to diverse life purposes such as maintenance, growth and reproduction (Abrahamson & Gadgil, 1973). Variation in resource allocation occurs through differences in the chemical composition of structures, the relative mass of different structures as organs and the relative number of different structures a plant produces (Bazzaz *et al.*, 1987).

Growth analysis is a useful tool in understanding the complex interactions between plant growth and the environment (Lal & Ambasht, 1979). Plant growth analysis is well developed in the fields of agriculture and botany where the majority of species are annuals, biennials, or short-lived perennials (Evans, 1972; Hunt, 1982a). Harper & Ogden (1970) introduced the use of biomass allocation (proportion of the total dry matter stored in each organ type) as a way to study resource allocation pattern in plants and emphasized the significance of such studies in identification of distinct ecological strategies.

The present chapter deals with the studies on growth and dry matter allocation pattern of three dominant annual weeds viz. *Ageratum conyzoides* L., *Ageratum houstonianum*

Mill. and Bidens pilosa L. which have more or less a similar growth habit. They grow in a wide range of arable crops and grasslands in many tropical and sub-tropical countries. In the north-east India these weeds are found in gardens, on cultivated land, in open waste places and along roadsides. Both the species of Ageratum and Bidens pilosa produce seeds in large number. In nature, seed germination in all the three species commences in March-April with the onset of monsoon. After about 2-3 months of vegetative growth the plants enter into reproductive phase.

Studies on growth analysis have been carried out in relation to light and temperature (Eagles, 1973; Hughes, 1973; Rajan et al., 1973; Lal & Ambasht, 1979; Patterson et al., 1988; Bunce, 1989; Harrington et al., 1989), nutrients (Clarkson, 1967; Boston, 1986; Chapin, 1986; Shipley & Keddy, 1988; and Konings et al., 1989), and in agricultural situations (Eze, 1973; Bremester & Barnes, 1981; Saxena & Ramakrishnan, 1983; Banyikwa & Rulangaranga, 1985; Bourdot et al., 1985, and Swamy & Ramakrishnan, 1988).

Biomass allocation pattern has been extensively studied for gaining insight into the reproductive strategies of plants. Studies by Harper & Ogden (1970), Abrahamson & Gadgil (1973), Tripathi & Harper (1973), Gaines et al. (1974), Werner & Platt (1976), Hickman (1977), Bostock & Benton (1979), Abrahamson (1979), Meijden & Walls Kooi (1979), Cunningham *et al.* (1979), Trivedi & Tripathi (1982), Saxena & Ramakrishnan (1984), Bazzaz *et al.* (1987), Bittman & Simpson (1987), and Swamy & Ramakrishnan (1988), have dealt with the allocation pattern in annuals and perennials, however, there seems to have been no attempts so far to study the effects of different farming systems on the growth attributes and dry matter allocation of weeds.

An investigation into the responses of these three weeds to various farming systems might be helpful in understanding the regulation of their population in nature. The present study was therefore undertaken to investigate the growth behaviour and dry matter allocation pattern of these three species as affected by different farming systems.

MATERIALS AND METHODS

The study was carried out in field conditions at the Farming Systems Research Plot of ICAR farm at Barapani. Five replicate plants of each of the three cohorts of three weeds were harvested at monthly intervals during the entire growing season in all the 8 different farming systems for a period of one year (April 1987-January 1988). Belowground parts were carefully washed and the plants were separated into their component parts such as root, stem, leaf and reproductive structures (flowers and seeds). The different components were over-dried at 60°C to constant weight and weighed.

The number of seeds produced by a plant were estimated by multiplying the mean number of capitula per plant by the mean number of seeds per capitulum. Three lots of 100 seeds each, were weighed for the determination of average seed weight. Leaf area estimation was done by using a planimeter.

The plant growth was analysed in terms of relative growth rate (RGR), net assimilation rate (NAR) and leaf area ratio (LAR). These growth parameters were calculated following Hughes & Freeman (1967) and Radford (1967) as:

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

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

$$LAR = \frac{(A_2 - A_1)(\ln W_2 - \ln W_1)}{(\ln A_2 - \ln A_1)(W_2 - W_1)}$$

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

RESULTS

Reproductive behaviour

The number of fertile plants declined from cohort I to II in both the species of _Ageratum_. In case of _A_. _cony_-

zoides the III cohort showed greater number of fertile plants in livestock-based farming system (FS-W_1) and agricultural system (FS-W_4) compared to the rest of the farming systems where the numbers of fertile plants in the II and III cohorts were same (Table 8.1). In case of A. houstonianum the number of fertile plants was maximum in cohort I and minimum in cohort III in livestock-based farming system (FS-W_1) and agricultural system (FS-W_4), whereas in agri-horti-silvi pastoral system (FS-W_5), horticultural system (FS-W_6) and 'jhum' fallow (FS-W_8), the III cohort had greater number of fertile plants than the II cohort and in FS-W_2 and FS-W_3 there were equal number of fertile plants in cohorts II and III. A. houstonianum did not give rise to the III cohort in the control system (FS-W_7). There was a decreasing trend in the number of fertile plants from cohort I to cohort III in case of Bidens pilosa (Table 8.3). The watersheds under livestock-based farming system (FS-W_1) and agricultural system (FS-W_4) showed relatively more fertile plants for all the three species (Table 8.1, 8.2 & 8.3).

A decreasing trend was observed in the seed production from cohort I to cohort III. The per plant seed output and crude reproductive effort (CRE) of all the three weed species were relatively greater in the farming systems where agricultural operations were more frequent (FS-W_4, FS-W_1 and FS-W_5)

than the systems where agricultural operations were mild ($FS\text{-}W_6$, $FS\text{-}W_3$ and $FS\text{-}W_2$) and non-existent ($FS\text{-}W_7$ and $FS\text{-}W_8$). The I cohorts of all the three species exhibited maximum CRE in agricultural system ($FS\text{-}W_4$) (Table 8.1, 8.2 & 8.3). The contribution of the I cohorts of all the three species to the total seed output in a cropping season or year was the maximum (Table 8.4).

Dry matter allocation

The allocation pattern of biomass to different component organs, expressed as a percentage of the total, shows that in all the farming systems root biomass declined with time for both the species of Ageratum in the I and II cohorts, while in case of B. pilosa there was a decline at the initial growth phase followed by an increase at the later stage of the plant life cycle (Fig. 8.3). As the leaves started dying by July/August, conversely, the allocation of biomass to the stem increased with time. The allocation of biomass to the root was highest in the III cohort for all the three species compared to the earlier two cohorts. Allocation of biomass to the green leaves declined as the leaves started dying and this was more pronounced at the time of reproductive growth in all the cases. With the increasing age there was an increase in the allocation pattern to the standing dead leaves of all the three species. The allocation of biomass

Fig. 8.1 Dry matter allocation (%) to various parts of <u>Ageratum conyzoides</u> under different farming systems during May 1987 - December 1988. C_1, C_2 and C_3 represent seedling cohorts emerging at different times. Root , Stem , Leaf , standing dead leaves , and reproductive structures .

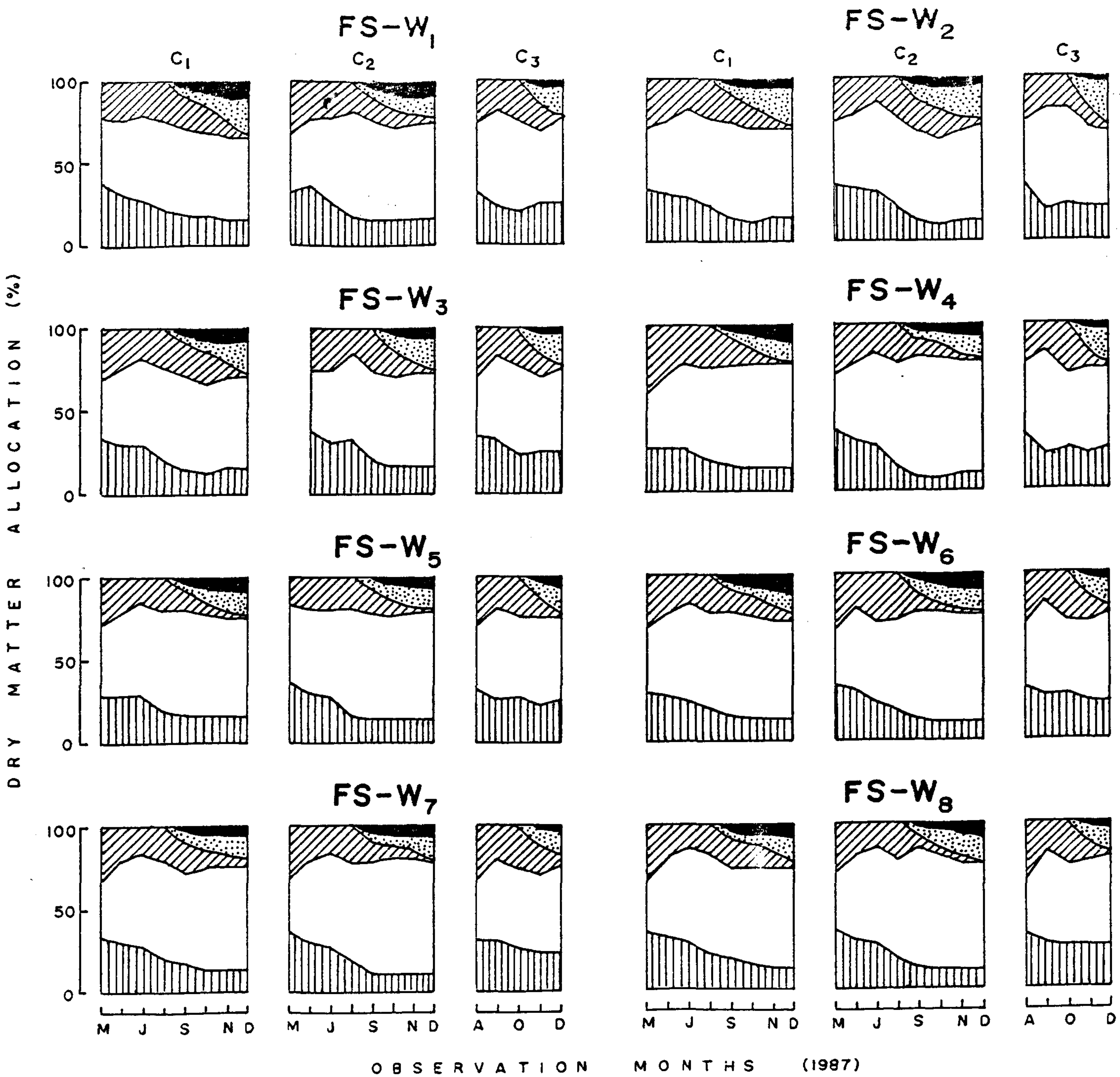

FS-W1
FS-W2
FS-W3
FS-W4
FS-W5
FS-W6
FS-W7
FS-W8
C1
C2
C3
100
50
0
DRY MATTER ALLOCATION (%)
M J S N D
A O D
OBSERVATION MONTHS (1987)

Fig. 8·1

Fig. 8.2 Dry matter allocation (%) to various parts of <u>Ageratum houstonianum</u> under different farming systems during May 1987 - January 1988. Explanation of the symbols is same as in Fig. 8.1.

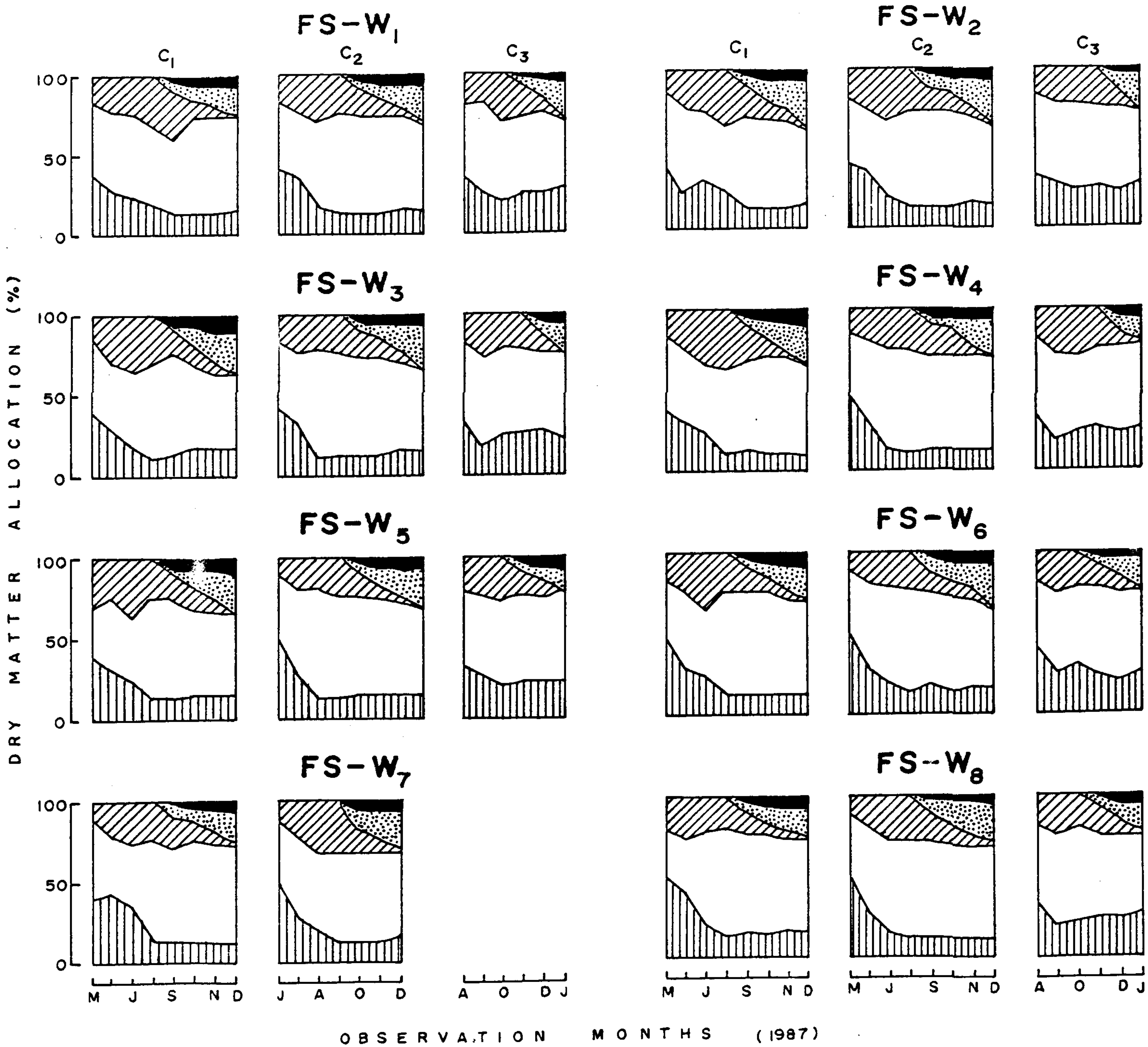

FS-W1
FS-W2
FS-W3
FS-W4
FS-W5
FS-W6
FS-W7
FS-W8
C1
C2
C3
100
50
0
DRY MATTER ALLOCATION (%)
M J S N D
J A O D
A O D J
OBSERVATION MONTHS (1987)

Fig. 8·2

Fig. 8.3 Dry matter allocation (%) to various parts of Bidens pilosa under different farming systems during April 1987 - December 1988. Explanation of symbols is same as in Fig. 8.1.

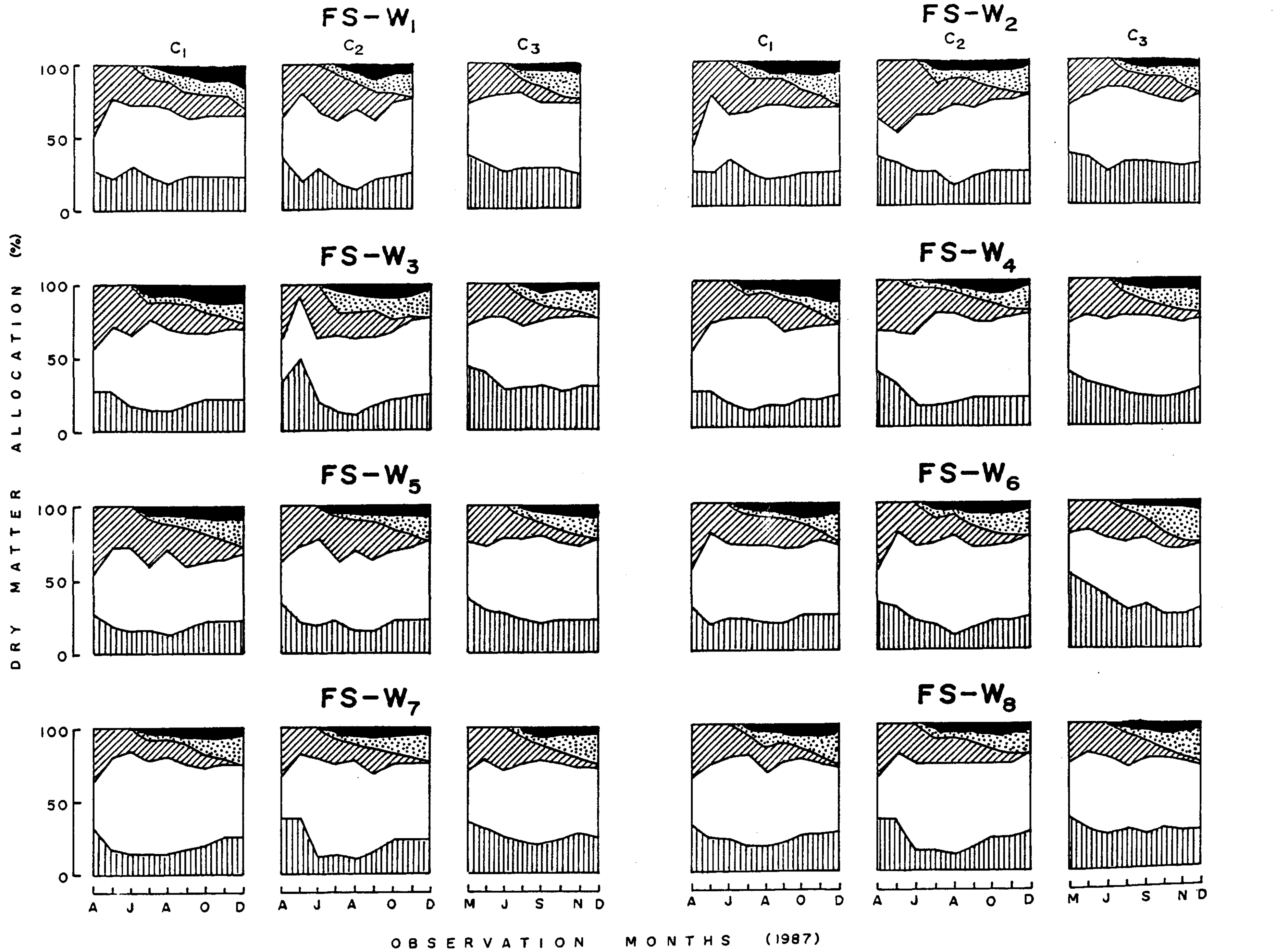

FS-W1
FS-W2
FS-W3
FS-W4
FS-W5
FS-W6
FS-W7
FS-W8
C1
C2
C3
100
50
0
DRY MATTER ALLOCATION (%)
A J A O D
M J S N D
OBSERVATION MONTHS (1987)

Fig. 8·3

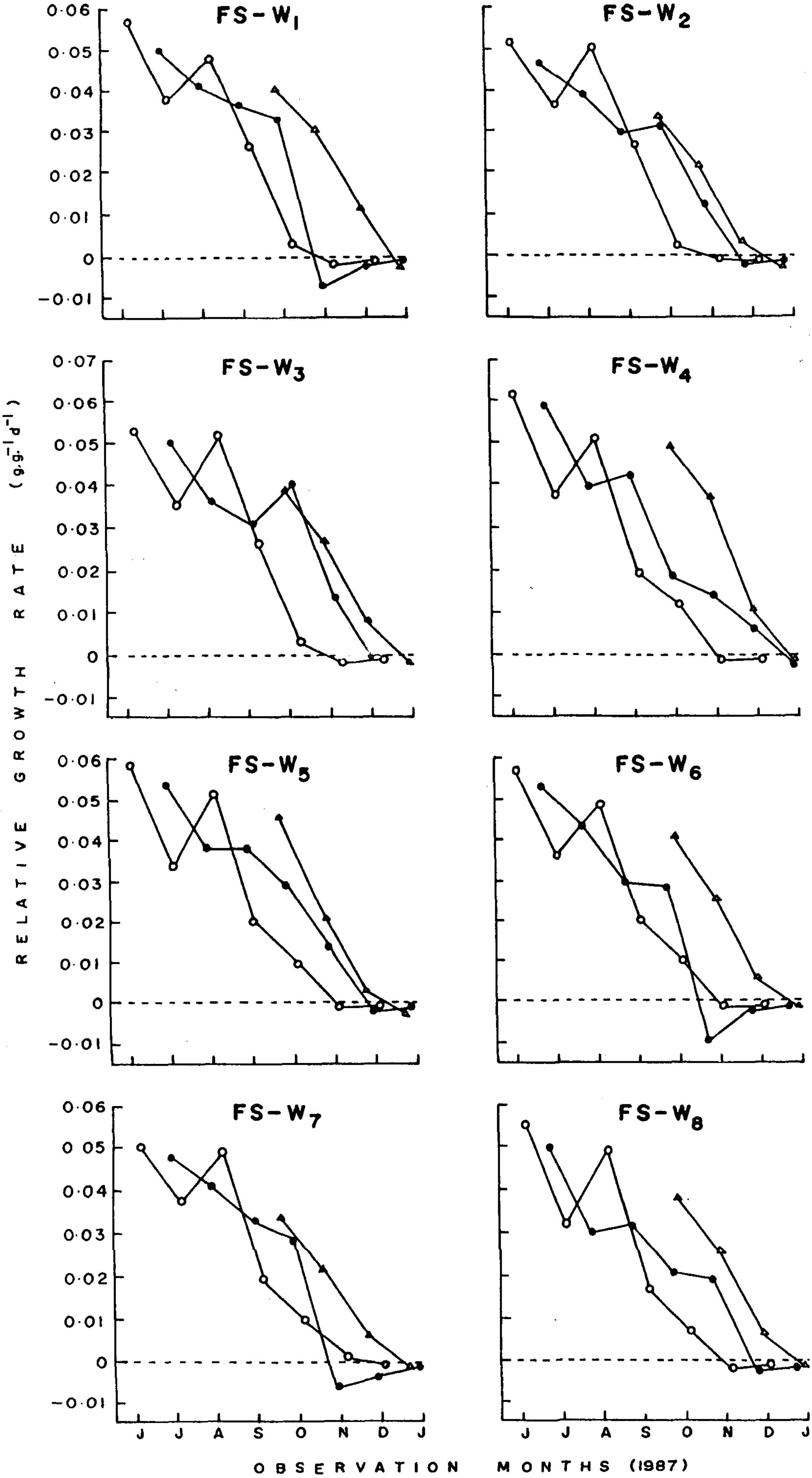
to reproductive parts increased with time and reached the maximum by October-November for all the species. There was a decreasing trend in the allocation to the reproductive parts from cohort I to III. The reproductive allocations in all the three weeds was generally higher on the watersheds under agricultural system (FS-W_4), livestock-based farming system (FS-W_1), agri-horti-silvi pastoral system (FS-W_5) and horticultural system (FS-W_6) than the rest of the farming systems (Fig. 8.1, 8.2 & 8.3). The III cohorts in all the three weeds were short-lived compared to the earlier two cohorts. The biomass allocation pattern to reproductive parts exhibited similar trend for all the three species, however, the allocation of biomass to reproductive parts started earlier in B. pilosa than in the two species of Ageratum (Fig. 8.3).

Growth analysis

Relative growth rate (RGR)

The relative growth rate was generally higher for all the three species in the watershed under agricultural system (FS-W_4) compared to the rest of the farming system (Fig. 8.4, 8.5 & 8.6). The highest RGR among the three species was shown by A. houstonianum. The RGR in case of A. conyzoides for cohort I was characterised by a rather high initial value, a descent in the month of July and a rise in August followed

Fig. 8.4 Relative growth rate (RGR) ($g.g^{-1}.d^{-1}$) of *Ageratum conyzoides* after 30 days growth from the date of seedling emergence under different farming systems, Cohort I, o——o; Cohort II, ●——●; Cohort III, Δ——Δ.



FS-W1
FS-W2
FS-W3
FS-W4
FS-W5
FS-W6
FS-W7
FS-W8
RELATIVE GROWTH RATE (g.g⁻¹d⁻¹)
0·06
0·05
0·04
0·03
0·02
0·01
0
-0·01
0·07
J J A S O N D J
OBSERVATION MONTHS (1987)

Fig. 8·4

Fig. 8.5 Relative growth rate (RGR) ($g.g^{-1}.d^{-1}$) of Ageratum houstonianum after 30 days growth from the date of seedling emergence under different farming systems. Explanation of symbols is same as in Fig. 8.4.

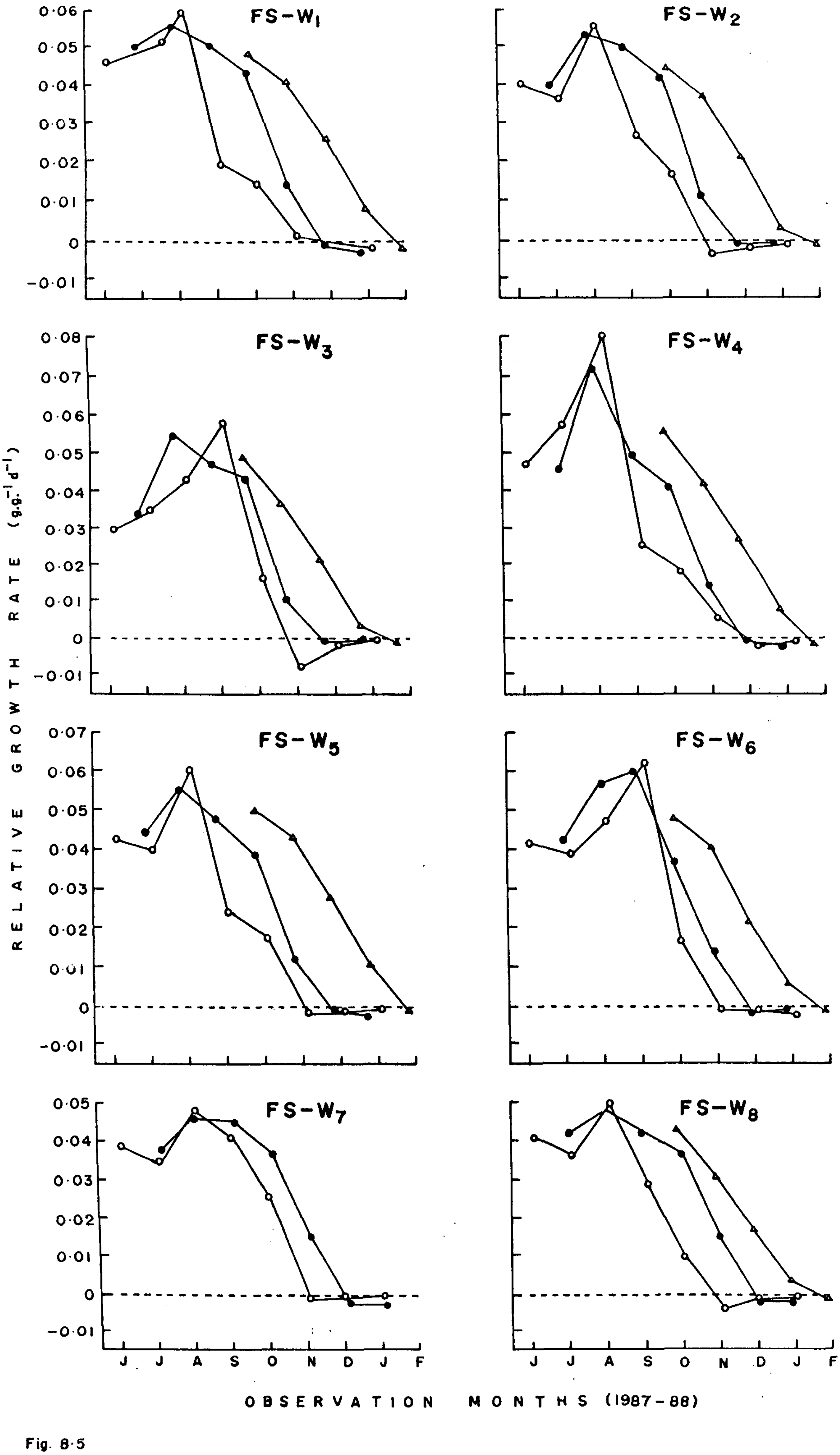

FS-W1
FS-W2
FS-W3
FS-W4
FS-W5
FS-W6
FS-W7
FS-W8
RELATIVE GROWTH RATE (g.g.⁻¹ d⁻¹)
0·08
0·07
0·06
0·05
0·04
0·03
0·02
0·01
0
−0·01
J J A S O N D J F
OBSERVATION MONTHS (1987-88)

Fig. 8·5

Fig. 8.6 Relative growth rate (RGR) ($g.g^{-1}.d^{-1}$) of *Bidens pilosa* after 30 days growth from the date of seedling emergence under different farming systems. Explanation of symbols is same as in Fig. 8.4.

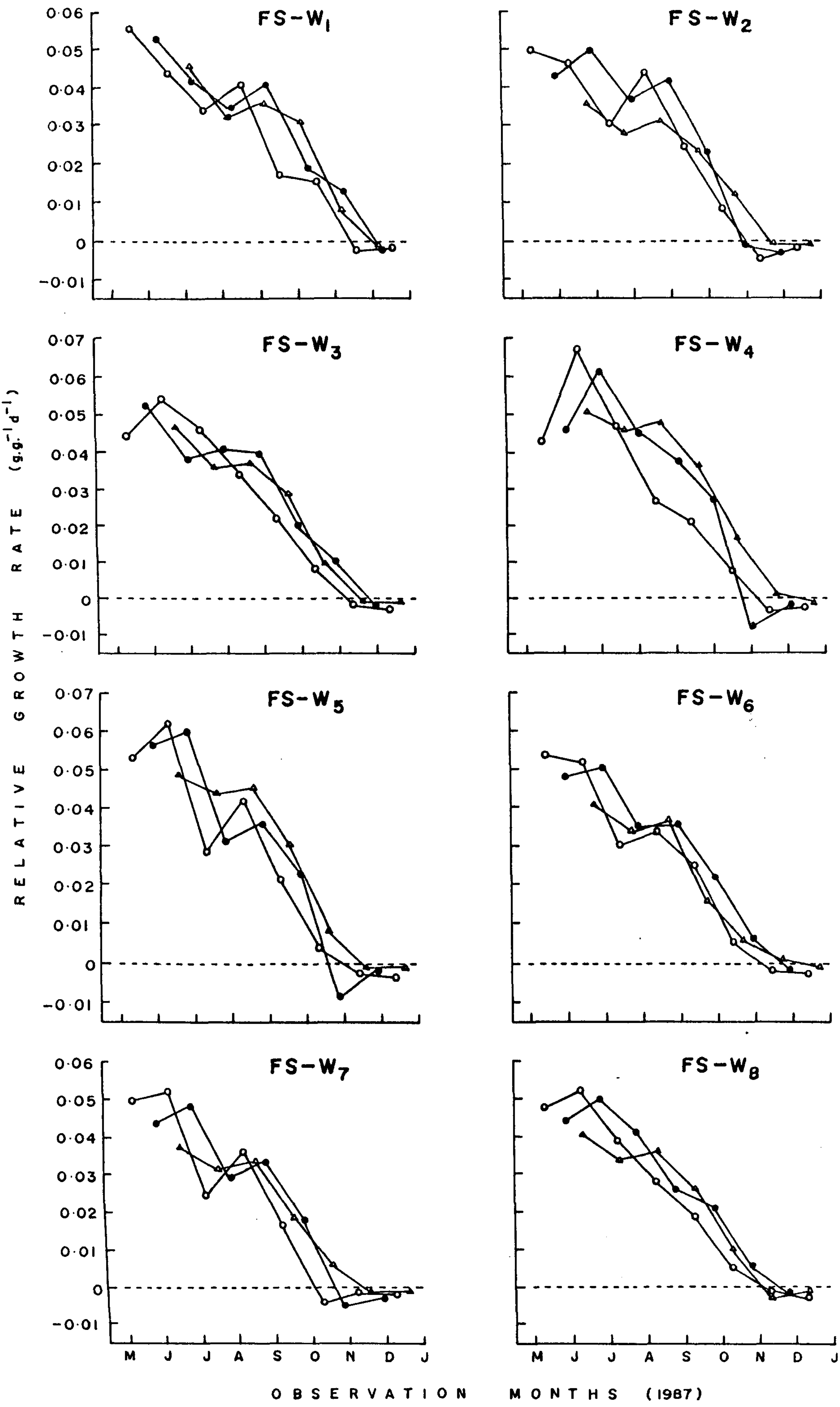

FS-W1
FS-W2
FS-W3
FS-W4
FS-W5
FS-W6
FS-W7
FS-W8
RELATIVE GROWTH RATE ($g.g^{-1}d^{-1}$)
0·07
0·06
0·05
0·04
0·03
0·02
0·01
0
-0·01
M J J A S O N D J
OBSERVATION MONTHS (1987)

Fig. 8·6

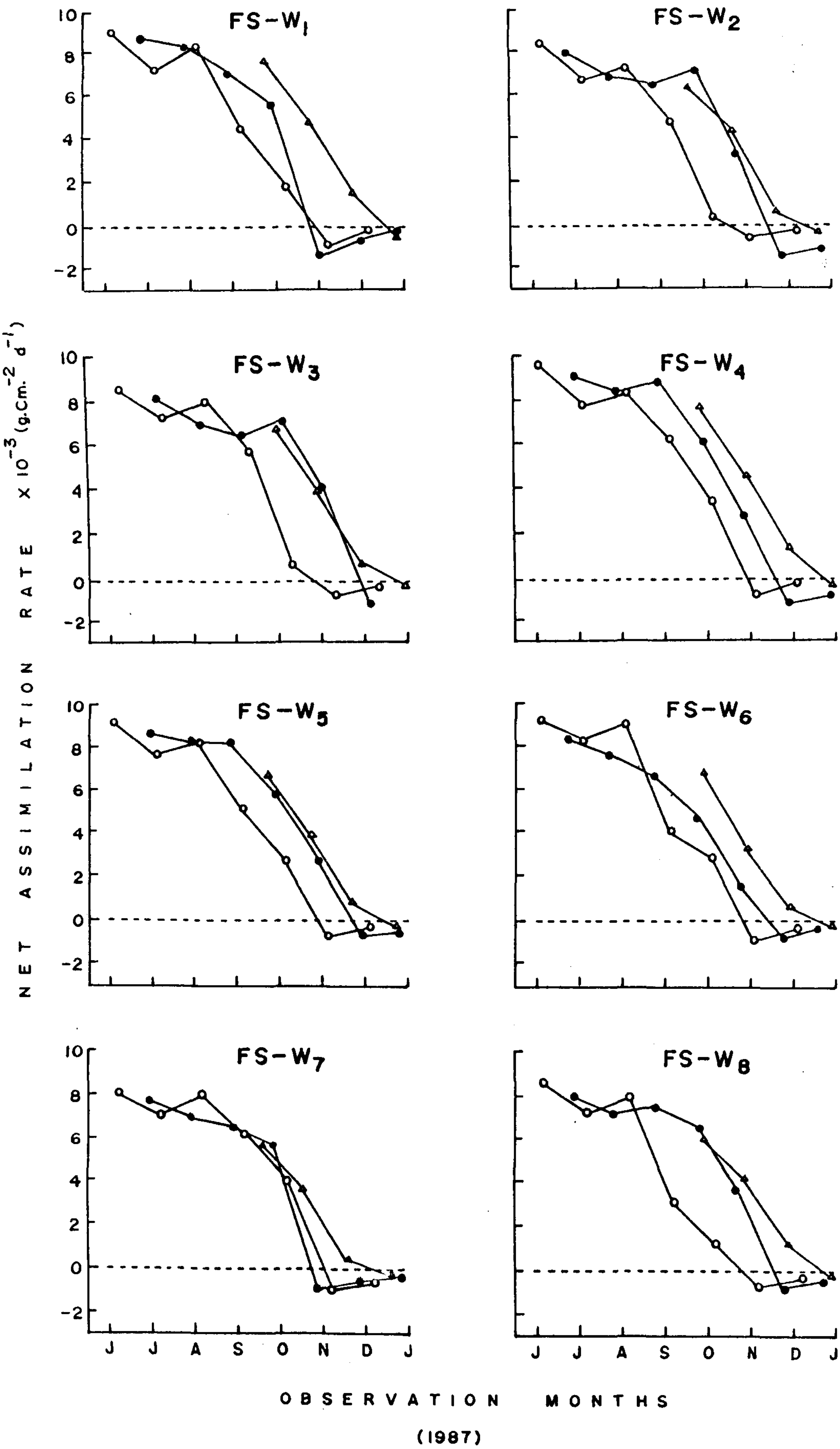
by a regular decrease to negative phase in winter in all the eight farming systems, however, cohort II of the same species exhibited a rise in RGR at 90-120 days in FS-W_2, FS-W_3, FS-W_4 and FS-W_8 followed by a descent in winter to negative phase. The III cohort in all the farming systems was characterised by a sharp decrease to negative phase from a rather high initial RGR. In all the farming systems the RGR of all the three weeds declined from cohort I to III (Fig. 8.4, 8.5 & 8.6).

The cohort I of A. houstonianum showed a high RGR in all the farming systems, however, the highest RGR amongst all the farming systems was observed in agricultural system (FS-W_4). The I cohort of A. houstonianum in FS-W_1, FS-W_3 and FS-W_4 showed a rather low initial RGR followed by a sharp increase to attain its maximum and then showing a substantial decrease from August/September attaining a negative phase during the senescent phase, while in the rest of the systems (FS-W_2, FS-W_5, FS-W_6, FS-W_7 and FS-W_8) there was a decrease in RGR at 60 days followed by an increase to reach its maximum and then showing a regular decline to negative phase. The II and III cohorts showed almost similar trend in all the farming systems except for control system (FS-W_7), where the III cohort did not appear at all. The trend of RGR progression for B. pilosa in cohort I and II varied with the farming system, while the III cohort exhibited similar trend in all the farming systems. The peak RGR for all the three cohorts was observed between 30-60 days after which the values decreased and reached negative phase during winter though there was an increase between 90-120 days in some of the systems (Fig. 8.4, 8.5 & 8.6).

Net assimilation rate (NAR)

Fig. 8.7, 8.8 & 8.9 reveal the broad trends of NAR values during the experimental period. All the three species showed the highest NAR in agricultural system (FS-W_4). The I cohort of all the three species had the highest average NAR although there was not much significant difference between cohorts I and II (Fig. 8.7, 8.8 & 8.9). The NAR for the I cohort of A. conyzoides showed similar trend in all the farming systems. The increase and decrease in NAR coincided with RGR. A high NAR was observed at the initial stages reaching a negative phase during winter in all the three cohorts (Fig. 8.7). The II cohort of A. conyzoides showed a rise in the NAR values during August-September followed by a decrease afterwards in FS-W_2, FS-W_3, FS-W_4 and FS-W_8, while in FS-W_1, FS-W_5, FS-W_6 and FS-W_7 it showed a similar trend with a high initiar NAR followed by a regular decrease with the passage of time. The III cohort did not show any variation in NAR with the farming systems.

Fig. 8.7 Net assimilation rate (NAR) x 10^{-3} ($g.cm^{-2}.d^{-1}$) of Ageratum conyzoides after 30 days growth from the date of seedling emergence under different farming systems. Explanation of symbols is same as in Fig. 8.4.



FS-W1
FS-W2
FS-W3
FS-W4
FS-W5
FS-W6
FS-W7
FS-W8
NET ASSIMILATION RATE x 10^-3 (g.Cm.^-2 d^-1)
10
8
6
4
2
0
-2
J J A S O N D J
OBSERVATION MONTHS
(1987)

Fig. 8·7

Fig. 8.8 Net assimilation rate (NAR) x 10^{-3} ($g.cm^{-2}.d^{-1}$) of *Ageratum houstonianum* after 30 days growth from the date of seedling emergence under different farming systems. Explanation of symbols is same as in Fig. 8.4.

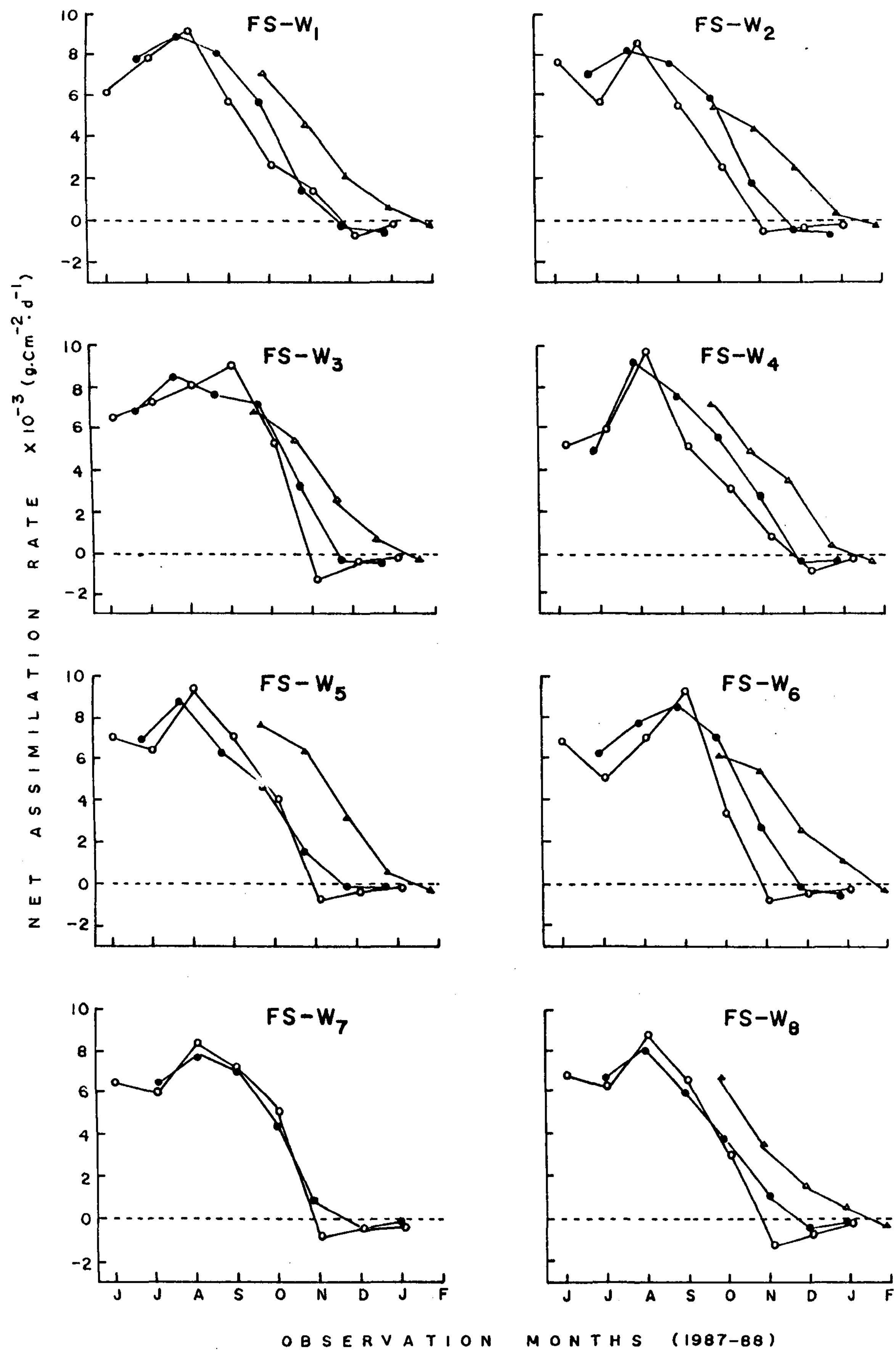

FS-W1
FS-W2
FS-W3
FS-W4
FS-W5
FS-W6
FS-W7
FS-W8
NET ASSIMILATION RATE X 10⁻³ (g.Cm⁻².d⁻¹)
10
8
6
4
2
0
-2
J J A S O N D J F
OBSERVATION MONTHS (1987-88)

Fig. 8·8

Fig. 8.9 Net assimilation rate (NAR) x 10^{-3} ($g.cm^{-2}.d^{-1}$) of Bidens pilosa after 30 days growth from the date of seedling emergence under different farming systems. Explanation of symbols is same as in Fig. 8.4.

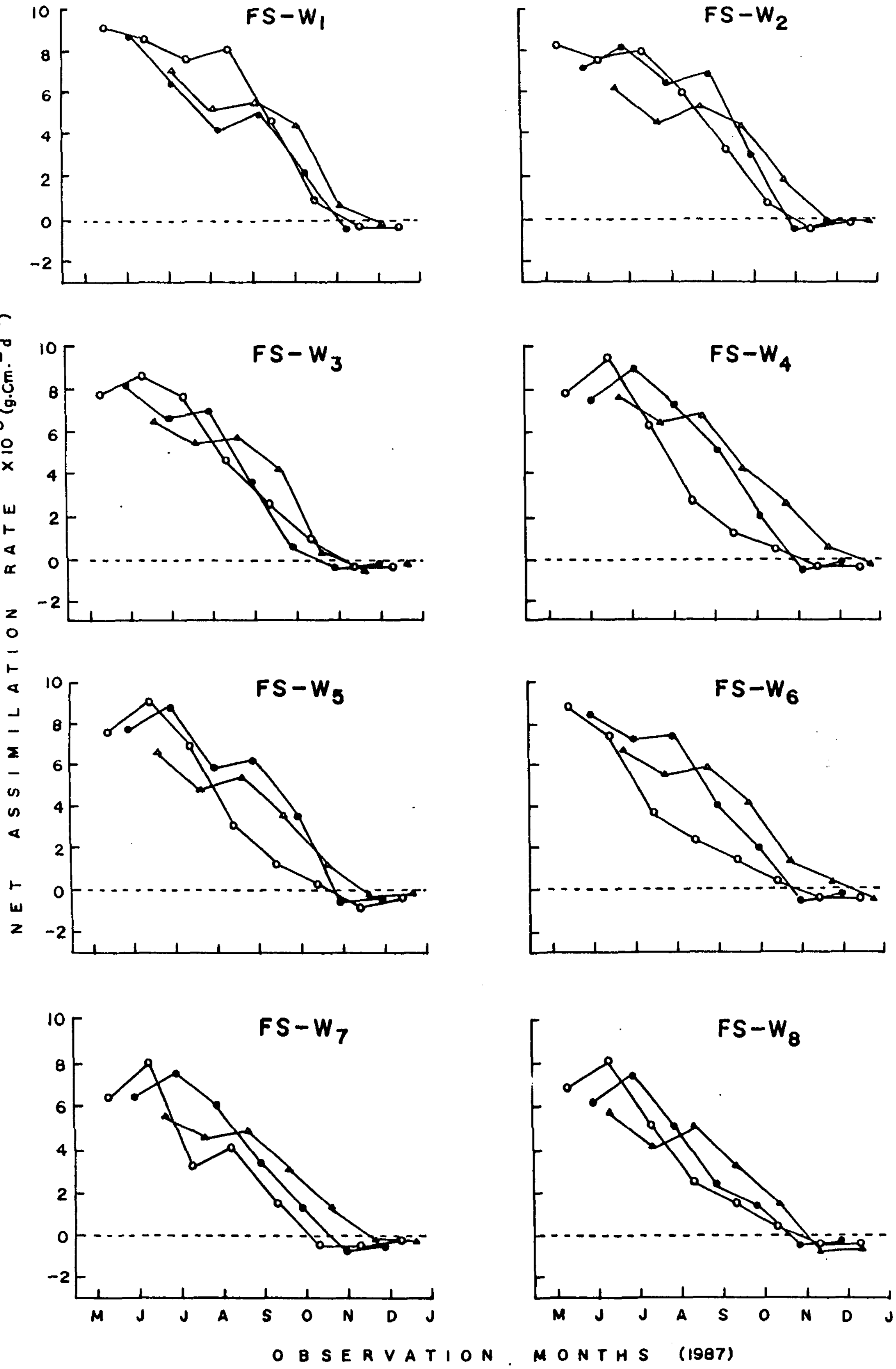

FS-W1
FS-W2
FS-W3
FS-W4
FS-W5
FS-W6
FS-W7
FS-W8
NET ASSIMILATION RATE X10^-3 (g.Cm.^-2 d^-1)
10
8
6
4
2
0
-2
M J J A S O N D J
OBSERVATION MONTHS (1987)

Fig. 8·9

Except for $FS\text{-}W_1$, $FS\text{-}W_3$ and $FS\text{-}W_4$ the I cohort of A. houstonianum in the rest of the farming systems showed a similar trend. The I cohort of A. houstonianum attained the maximum NAR values between 90-120 days in all the farming systems, while the II cohort attained the highest NAR at 30 days and reached negative phase during winter. The III cohort was short-lived and showed similar NAR pattern in all the farming systems.

The I and II cohorts of B. pilosa showed the maximum NAR at the initial stages between 30-60 days (Fig. 8.9), however, the III cohort showed maximum NAR during 0-30 days. The NAR of all the three cohorts declined to negative values during winter. Bidens pilosa showed the maximum NAR in agricultural system ($FS\text{-}W_4$) for all the three cohorts.

Leaf area ratio (LAR)

All the three cohorts of A. conyzoides showed a similar trend. The maximum LAR was attained between 90-120 days. There was a decreasing trend in the LAR from cohort I to cohort III. Like RGR and NAR the highest LAR too, was observed in agricultural system ($FS\text{-}W_4$). With the increasing age, the LAR started decreasing from 90-120 days onwards and reached the minimum in the senescent phase during winter in all the farming systems (Fig. 8.10, 8.11 & 8.12).

A. houstonianum showed two different trends of LAR. The I and II cohorts of FS-W_1, FS-W_2, FS-W_3 and FS-W_4 showed a sharp increase in the LAR upto 90-120 days (peak LAR) followed by a continuous decrease until the senescent phase in FS-W_1, FS-W_2, FS-W_3 and FS-W_4. However, in FS-W_5, FS-W_6, FS-W_7 and FS-W_8, there was an initial increase, then a decrease followed by a maximum increase (peak LAR) and then a continuous decrease. The III cohort showed similar trend in all the farming systems. The time taken by I cohort in FS-W_4, FS-W_5, FS-W_6, FS-W_7 and FS-W_8 to reach the maximum LAR was the longest compared to the rest of the systems. The III cohort took the least time for the attainment of maximum LAR though the values were far less than those attained by the I and II cohorts. The I cohort of *B. pilosa* showed a similar trend of LAR in all the farming systems except for FS-W_2, FS-W_7 and FS-W_8 (Fig. 8.12). In all the farming systems the LAR values decreased from cohort I to cohort III. The highest LAR for all the three cohorts was observed in FS-W_4. The peak LAR for *B. pilosa* was attained during 120-150 days. In case of cohort I there was a steep increase of LAR in FS-W_2, FS-W_7 and FS-W_8 followed by a decrease after the attainment of peak values. The III cohort exhibited a similar trend reaching the peak at 120 days followed by a decrease afterwards (Fig. 8.10, 8.11 & 8.12).

Fig. 8.10 Leaf area ratio (LAR) ($cm^2.g^{-1}$) of _Ageratum conyzoides_ after 30 days growth from the date of seedling emergence under different farming systems. Explanation of symbols is same as in Fig. 8.4.

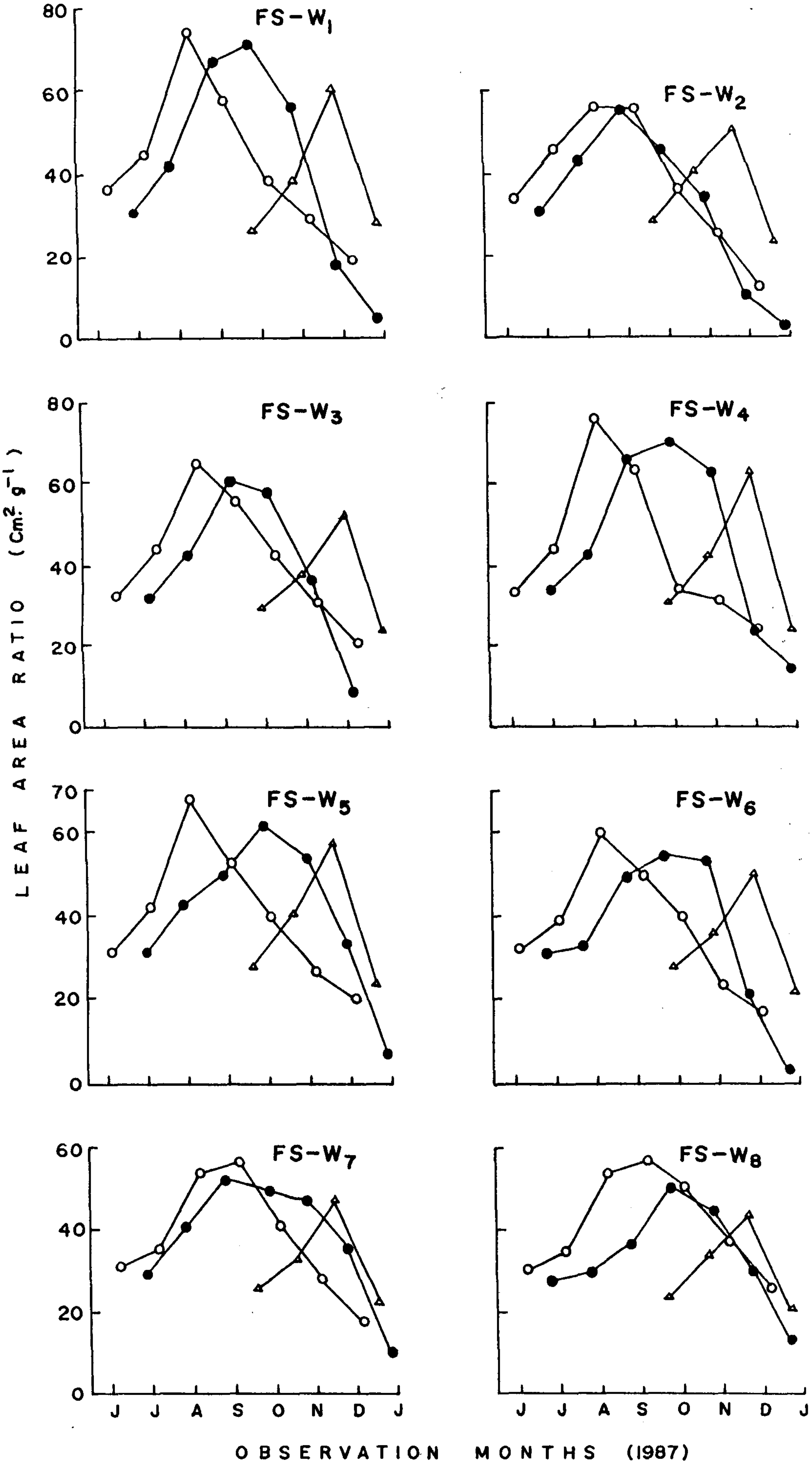

FS-W1
FS-W2
FS-W3
FS-W4
FS-W5
FS-W6
FS-W7
FS-W8
LEAF AREA RATIO (Cm². g⁻¹)
80
60
40
20
0
70
J J A S O N D J
OBSERVATION MONTHS (1987)

Fig. 8·10

Fig. 8.11 Leaf area ratio (LAR) ($cm^2.g^{-1}$) of <u>Ageratum houstonianum</u> after 30 days growth from the date of seedling emergence under different farming systems. Explanation of symbols is same as in Fig. 8.4.

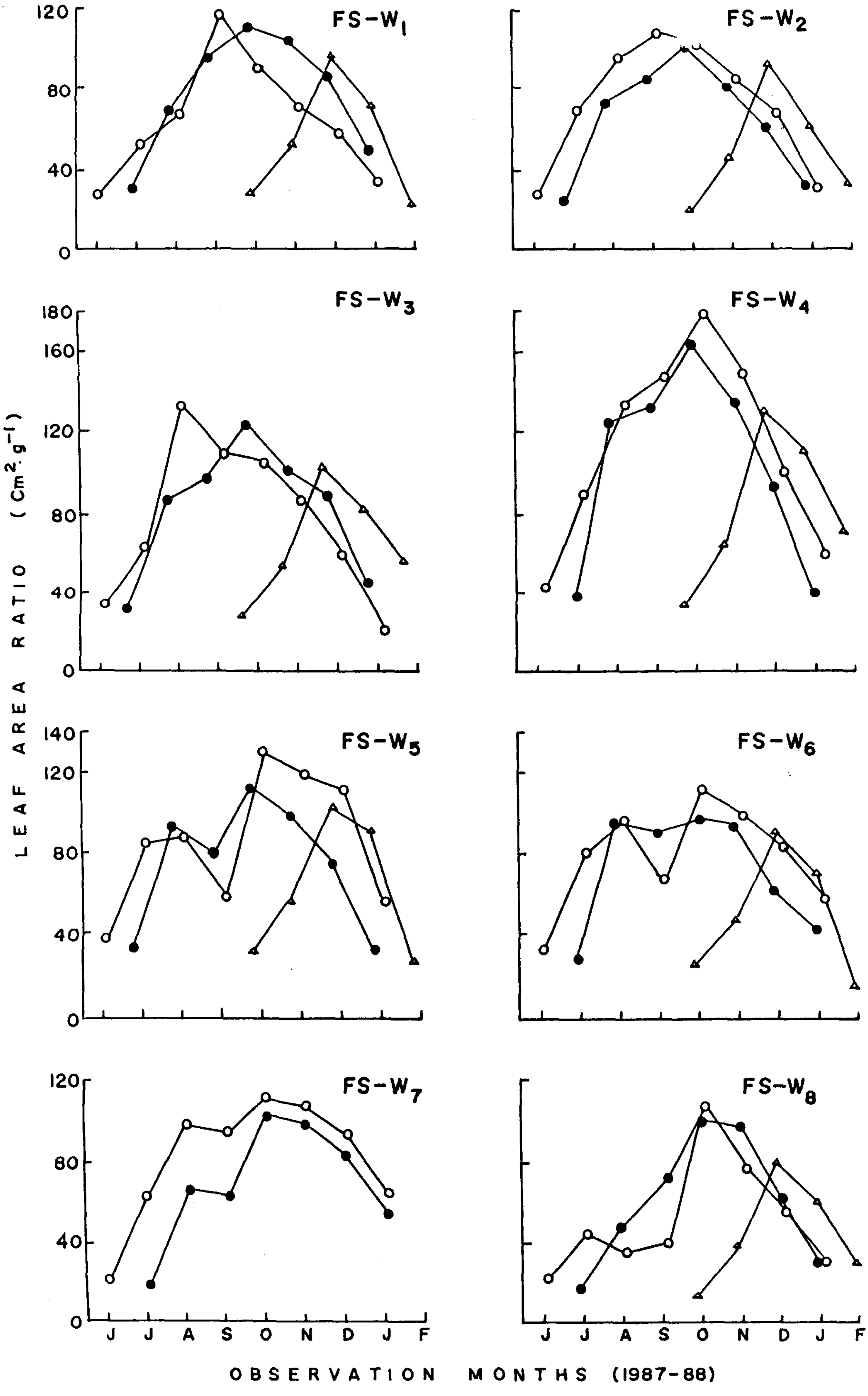

FS-W1
FS-W2
FS-W3
FS-W4
FS-W5
FS-W6
FS-W7
FS-W8
LEAF AREA RATIO (Cm2.g-1)
0
40
80
120
140
160
180
J J A S O N D J F
OBSERVATION MONTHS (1987-88)

Fig. 8·11

Fig. 8.12 Leaf area ratio (LAR) ($cm^2.g^{-1}$) of *Bidens pilosa* after 30 days growth from the date of seedling emergence under different farming systems. Explanation of symbols is same as in Fig. 8.4.

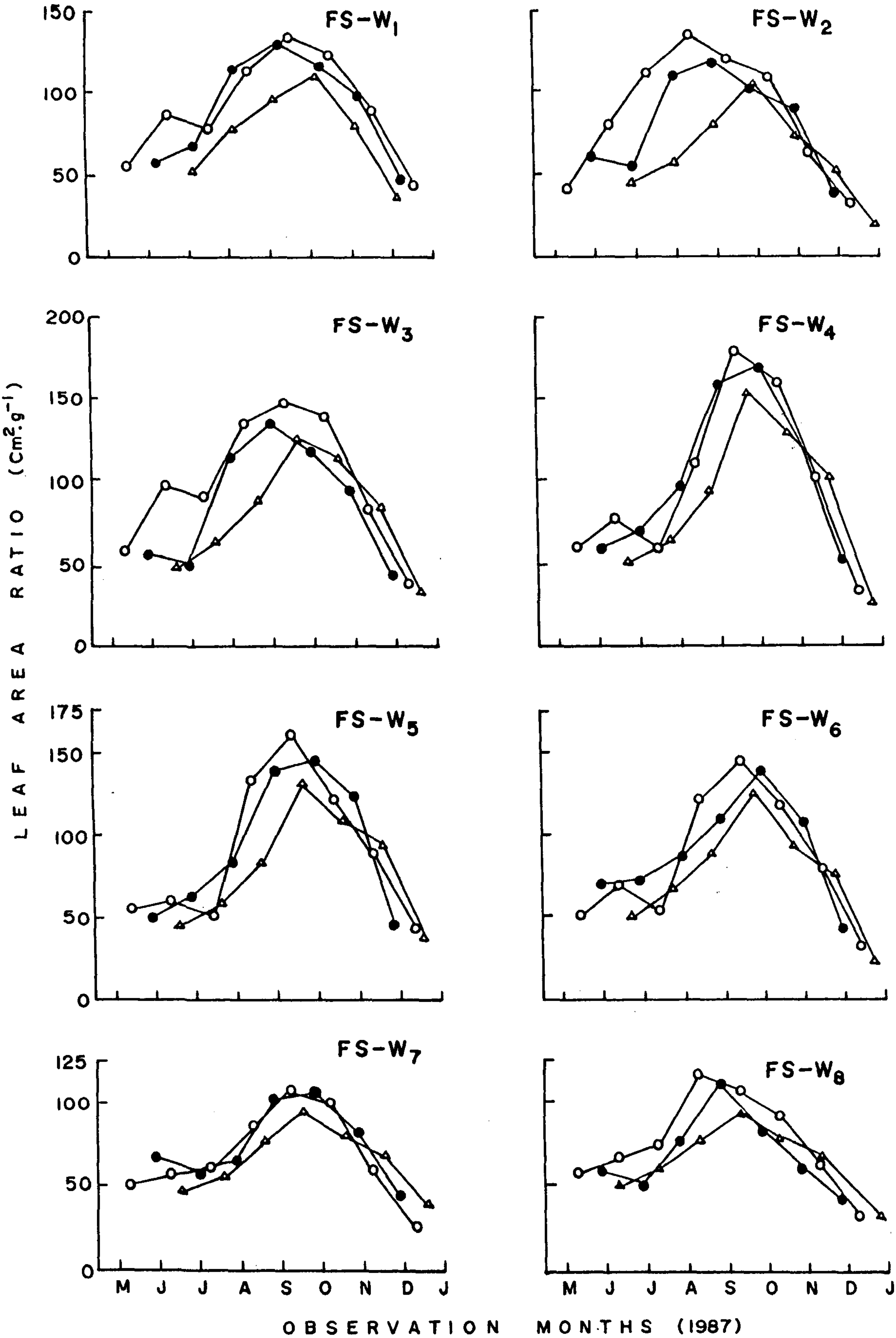

LEAF AREA RATIO (Cm^2.g^{-1})
FS-W$_1$
FS-W$_2$
FS-W$_3$
FS-W$_4$
FS-W$_5$
FS-W$_6$
FS-W$_7$
FS-W$_8$
150
100
50
0
200
175
125
M J J A S O N D J
OBSERVATION MONTHS (1987)

Fig. 8·12

The LAR (Fig. 8.11) of A. houstonianum was clearly the greatest of the three species during the experimental period, that of A. conyzoides the smallest, while B. pilosa had intermediate values. The maxima for NAR, RGR and LAR for A. houstonianum exceeded those for A. conyzoides and B. pilosa.

DISCUSSION

Among the three cohorts, the I cohort of all the three weeds had the maximum number of fertile plants which may be attributed to their early emergence compared to the two successive cohorts. The resource availability, coincidence of emergence of weeds with that of crops, lesser number of associates at the time of crop emergence (Table 4.2, Ch. IV) may be some of the factors which reduce the severity of competition to the I cohorts compared to the later emerging cohorts. The decrease in the number of fertile plants in the successive cohorts has also been reported by Rai & Tripathi (1984) in Galinsoga spp. Relatively greater number of fertile plants in FS-W_1 and FS-W_4 which were subjected to various kinds of agricultural operations, suggests that fertility in weed communities is favourably influenced by these operations.

Seed production involves variable resource costs according to the size and energy content of seeds, fruits and flowers (Silvertown, 1982). The decreasing trend in the seed production from cohort I to cohort III for all the three species can be attributed to the increasing competition from the crop plants to later emerging cohorts. As a result, the contribution made by the I cohort to the total seed output was always the maximum. The per plant seed output and crude reproductive efforts CRE of all the three weed species were relatively greater in farming systems where agricultural operations were frequent (FS-W_4, FS-W_1 and FS-W_5) than the systems where agricultural operations were mild (FS-W_6, FS-W_3 and FS-W_2) or non-existent (FS-W_7 and FS-W_8). The lesser production of seeds in FS-W_2 and FS-W_8 may be due to decreased light availability under tall grasses and large shrubs and trees. Kushwaha et al. (1981) and Swamy & Ramakrishnan (1988) have reported decrease in seed production in Eupatorium odoratum and Mikania micrantha respectively as the succession progresses. The shortage of resources, which limited fecundity is one of the major factors responsible for the low reproductive effort in the successive cohorts.

Variations in the seed production in these three species appear to be more strongly related to the different farming systems. Moisture availability and better soil aeration due to tillage in FS-W_1 and FS-W_4 could be responsible for greater seed production in these farming systems. The lower reproductive effort of cohort II and III during the experimental period have been also demonstrated by Rai & Tripathi (1985) in the species of Galinsoga and Pandey & Dubey (1989) in Parthenium hysteronhorus. The reproductive effort was highly variable cohort wise and farming system wise.

Reproduction and vegetative growth are the alternative ways in which a plant may use its limited resources (Silvertown, 1982). A striking feature of the biomass allocation pattern was the high reproductive allocation in all the species in FS-W_1 and FS-W_4. Naturally occurring annuals typically direct a high proportion of the total biomass to reproduction (11-65%) in comparison with the perennials (Harper et al., 1970; Hickman, 1975; Pitelka, 1977; Abrahamson, 1979; Bazzaz & Carlson, 1979; Trivedi & Tripathi, 1982). The strategy of all these species is to partition the limited reproductive resources into a higher number of propagules. The reproductive strategies in plants could also be evaluated in terms of the number of seeds produced in addition to the bulk allocation of biomass to reproduction (Moore, 1976; Newell & Tramer, 1978; Abrahamson, 1979; Primack, 1979; Saxena & Ramakrishnan, 1983). Thus, the reproductive development in these species seems to be under stress in the systems where agricultural operations are mild to non-existent as the weed species under study had to compete with other species for both light and soil nutrients, which are depleted during initial fallow growth. The stress on reproductive growth in older fallows has also been reported by Swamy & Ramakrishnan (1988). The present findings agree with Grime (1977) who opined that stress and disturbance interact to select for patterns of allocation. Sexual reproductive effort of both annuals and perennials tends to decrease from open habitat such as newly abandoned fields to shady habitats such as forests (Gaines et al., 1974; Abrahamson, 1975; Hickman, 1975; Ross & Quinn, 1977; Newell & Tremer, 1978; Abrahamson, 1979). The crop environment certainly influences sexual reproductive effort, however, the only probable and safe conclusion at present is that there is more than one way in which a plant species may adjust its reproductive behaviour to different habitat conditions. Differences in reproductive allocation of these annual weeds suggest that each weed species is adopted to different kinds of habitat or farming systems. Comparing among the species, it could be concluded that reproductive allocation is generally higher in species having high relative growth rate.

Allocation of high proportion of dry matter to the supporting organs but a lower proportion to the reproductive structures in the jhum fallow (FS-W_8) and control system (FS-W_7) than the other farming systems may be due to the fact that the plants tended to grow taller and avoid shadding in more mature habitats where light could be limiting. The higher allocation of biomass to the roots in the III cohorts could be attributed to the development of larger root systems as a mechanism to draw the available belowground resources to the maximum as most of the resources were probably utilized by the two cohorts that emerged earlier. Therefore, greater allocation of biomass to belowground organs could be viewed as a useful strategy for survival of plant species growing in nutrient-poor soils. Greater allocation of biomass to belowground organs in the case of the III cohort compared to the I and II cohorts is thus an adaptation for survival under stressed environment.

Greater RGR of the I cohorts may confer on them the competitive advantage over the later emerging cohorts. RGR was usually highest in the early vegetative phase and minimum at maturity when leaves become senescent as was also reported by (Blackman, 1968). Progressive fall of leaves may also be responsible for the decline of RGR. The negative growth of all the species during winter was a consequence of negative NAR indicating the loss of carbon due to respiration and minimal photosynthetic gains during this period due to abscission and shedding of leaves.

It is noteworthy that in all the three species the highest relative growth rate (RGR) was obtained for the I cohort in all the systems. The fall of RGR with time, observed in all the three species has also been observed by Thorne (1960) and Pandey & Sinha (1977) in other species. RGR in plants is dependent on NAR and LAR (Briggs, Kidd & West, 1920). Thus, the NAR and LAR values being higher during 60-90 days, the RGR of these weeds was usually highest during this period of growth.

The observed increase in NAR for the three species in case of all the cohorts and in all the farming systems with time can be related to the generally vigorous growth of these seedlings in early stages. The increase in NAR between 30-90 days is due to expansion of leaves during this period and due to less severe competition from the associated species. The decline in NAR with the age is probably due to lowering of LAR, self shedding of leaves and senescence.

The absence of any agricultural operation in FS-W_7, FS-W_8 and decrease in intensity to these operations in FS-W_2 seem to account for lower growth rate in these systems. As revealed by the data, the high RGR, NAR and LAR values in the case of all the three weeds are positively linked with increasing intensity of agricultural operations.

Leaf area ratio starts low accounting for the initial low value of RGR, rises to maximum and thereafter falls more or less steadily to reach a value below zero (negative). Under favourable conditions for growth the rate of increase in dry weight is mainly determined by the carbon assimilation rate; in most higher plants this is related directly to the activity of leaves. A large LAR is an important attribute of a species in enabling it to outgrow its competitors quickly.

The canopy growth of crop plants and other associated species caused decrease in light availability to the three weed species and hence, there was a steady decrease in the RGR, NAR and LAR of these weeds as the crop plants grew taller. After the crop harvest also, the weeds persisted in the field, but various growth parameters mentioned above showed considerable decline, sometimes, they even showed the negative values during winter months which may be attributed to the prevailing low temperature conditions.

The higher relative growth rate and net assimilation rate of the three weeds in FS-W_4 may be due to its greater leaf area ratio in this farming system. A comparison shows that the RGR, NAR and LAR values obtained in the control are lower than those observed in the agriculturally disturbed systems indicating that these weeds prefer this kind of system.

Since the climatic conditions influencing these parameters were uniform on all the watersheds, the observed differences in RGR, NAR and LAR are largely due to farming systems and edaphic and biological attributes of various watersheds.

Table 8.1. Reproductive behaviour of the three cohorts of Ageratum conyzoides emerging at different times in various farming systems during 1987.

Watersheds	Cohorts	No. of flowering plants/m^2	Average No. of capitula/plant at maturity	Average No. of seeds/ capitulum at maturity	Average No. of seeds/ plant	Crude reproductive effort (CRE)
FS-W_1	I	9.0±2.2	33.0±6.2	70.2±2.2	2316.6±263.8	12.7±1.7
	II	3.0±0.9	26.0±4.2	65.2±4.3	1695.2±186.5	11.6±1.3
	III	5.0±1.2	19.0±5.1	53.1±3.1	1008.9±132.2	10.8±1.1
FS-W_2	I	8.0±1.9	30.3±6.2	68.3±2.3	2069.4±301.2	11.6±1.2
	II	2.0±0.6	22.5±4.4	53.1±2.3	1194.7±202.9	10.6±1.2
	III	2.0±0.5	15.1±3.8	48.3±1.9	729.3±103.6	10.0±1.3
FS-W_3	I	8.0±2.1	32.3±6.3	69.0±3.2	2228.7±403.7	11.9±1.4
	II	2.0±0.3	25.2±5.4	57.2±1.8	1441.4±212.8	10.3±1.2
	III	2.0±0.2	18.1±4.1	49.1±2.1	883.8± 95.6	9.0±1.2
FS-W_4	I	9.0±2.4	36.0±5.2	72.2±4.4	2599.2±461.3	13.3±1.6
	II	2.0±0.3	29.5±3.9	66.1±3.3	1949.9±196.3	12.0±1.3
	III	5.0±0.6	22.0±2.8	50.2±2.6	1104.4±180.3	11.1±1.2
FS-W_5	I	7.0±0.9	36.0±4.7	70.3±3.9	2530.8±387.4	12.1±1.6
	II	2.0±0.2	27.0±3.8	65.2±3.2	1760.4±192.2	11.6±1.3
	III	2.0±0.2	19.2±3.7	47.8±2.1	917.7± 82.3	10.2±1.4
FS-W_6	I	8.0±1.4	32.1±6.3	69.1±4.3	2218.1±362.8	12.1±1.6
	II	2.0±0.3	26.5±6.0	64.4±3.8	1706.6±122.3	11.7±1.3
	III	2.0±0.3	18.0±4.4	60.6±2.8	1090.8±105.4	10.1±0.9
FS-W_7	I	6.0±1.3	28.2±5.8	64.2±4.5	1810.4±211.2	11.2±1.3
	II	2.0±0.2	24.2±5.2	54.1±4.1	1309.2±180.2	10.4±0.9
	III	2.0±0.2	13.0±4.6	41.2±3.1	535.6± 45.9	10.0±1.1
FS-W_8	I	9.0±2.8	30.0±6.7	65.1±3.2	1953.0±282.3	11.7±1.3
	II	3.0±0.6	24.3±4.8	57.7±3.1	1402.1±147.2	10.6±0.9
	III	3.0±0.4	13.0±4.1	41.4±2.9	538.2± 62.6	10.0±0.8

Table 8.2. Reproductive behaviour of the three cohorts of Ageratum houstonianum emerging at different times in various farming systems during 1987.

Watersheds	Cohorts	No.of flowering plants/ m^2	Average No. of capitula/plant at maturity	Average No. of seeds/ capitulum at maturity	Average No. of seeds/ plant	Crude reproductive effort (CRE)
$FS-W_1$	I	14.0±2.2	57.5±7.2	85.3±4.2	4904.7±460.7	14.8±1.8
	II	4.5±1.2	44.0±5.6	79.2±3.7	3484.8±386.8	13.0±1.3
	III	3.0±0.5	30.0±4.3	69.1±3.2	2073.0±288.8	11.3±1.2
$FS-W_2$	I	7.0±1.6	46.0±5.2	75.3±3.1	3463.8±482.9	13.1±1.7
	II	3.0±0.4	35.0±4.8	72.2±3.3	2527.0±311.2	12.7±1.6
	III	3.0±0.4	19.0±4.1	66.3±3.1	1259.7±163.6	11.0±1.2
$FS-W_3$	I	10.0±2.1	50.2±7.2	78.2±3.1	3925.6±395.5	14.0±1.9
	II	3.0±0.6	41.0±4.8	70.3±3.2	2882.3±310.2	12.8±1.5
	III	3.0±0.4	29.2±4.3	67.1±1.9	1959.3±135.5	11.2±1.5
$FS-W_4$	I	12.0±2.5	68.5±7.8	88.0±4.6	6028.0±624.2	15.8±1.4
	II	4.0±1.3	60.2±7.2	80.3±4.0	4834.1±411.2	13.2±1.5
	III	2.0±1.1	41.2±4.9	73.4±3.1	3024.1±381.4	12.5±1.3
$FS-W_5$	I	12.0±2.7	55.9±6.3	82.7±3.7	4622.9±5102.4	14.3±1.6
	II	2.0±0.5	41.3±5.5	77.3±4.2	3192.4±405.3	13.1±1.8
	III	4.0±0.8	33.0±4.3	70.2±3.7	2316.6±218.9	11.9±1.3
$FS-W_6$	I	10.0±1.8	53.1±6.1	78.3±3.7	4157.7±413.3	14.3±1.8
	II	2.0±0.2	40.2±5.3	73.8±3.1	2966.7±310.3	12.8±1.6
	III	3.0±0.3	31.3±3.9	69.9±3.1	2173.8±233.8	11.9±1.6
$FS-W_7$	I	5.0±0.8	37.0±5.4	75.5±4.2	2793.5±311.3	13.0±1.7
	II	2.0±0.3	31.0±4.2	70.2±3.9	2176.2±219.3	12.0±1.2
$FS-W_8$	I	10.0±0.9	40.1±5.9	76.3±4.2	3096.6±403.8	13.2±1.2
	II	3.0±0.3	29.2±4.7	73.1±3.0	2134.5±217.8	12.7±1.6
	III	4.0±0.3	19.2±4.0	68.2±3.7	1309.4±139.6	10.9±0.8

Table 8.3. Reproductive behaviour of the three cohorts of Bidens pilosa emerging at different times in various farming systems during 1987.

Water sheds	Cohorts	No.of flower ing plants/ m^2	Average No. of capi tula/plant at matu rity	Average No. of seeds/ capitulum at maturity	Average No. of seeds/ plant	Crude repro- ductive effort (CRE)
FS-W_1	I	14.0±2.2	36.2±4.6	53.2±3.6	1925.8±216.6	17.1±2.0
	II	4.0±1.0	32.8±4.1	48.4±3.1	1587.5±115.3	15.9±1.8
	III	3.0±0.5	27.2±3.2	29.9±2.1	813.2± 84.2	13.2±1.6
FS-W_2	I	10.0±1.8	32.4±4.3	50.3±3.9	1629.7±163.8	16.3±1.9
	II	4.0±0.6	29.6±2.8	42.2±2.8	1249.1±105.3	14.8±1.8
	III	2.0±0.2	3.2±2.8	29.9±1.6	693.6± 67.3	12.3±1.3
FS-W_3	I	9.0±1.2	34.8±3.8	51.1±4.2	1778.2±205.3	17.0±2.1
	II	3.5±0.8	30.6±3.6	44.3±3.1	1355.5±139.2	15.0±1.7
	III	2.0±0.3	24.8±2.9	29.2±2.6	724.1± 67.8	12.8±1.7
FS-W_4	I	19.0±3.1	45.1±5.6	62.2±6.1	2805.2±303.4	18.4±2.0
	II	6.0±1.2	39.5±4.2	51.1±3.9	2018.4±188.5	16.6±1.8
	III	4.0±0.8	32.2±3.1	32.3±2.2	1040.1±136.6	14.8±1.2
FS-W_5	I	14.0±2.2	40.2±5.3	56.2±5.1	2259.2±292.2	18.0±1.8
	II	7.0±1.9	33.2±4.4	50.1±4.2	1663.3±125.2	16.2±1.6
	III	2.0±0.3	29.1±2.3	30.2±2.0	878.8± 72.3	13.3±0.9
FS-W_6	I	10.0±1.8	34.4±5.1	51.1±4.6	1757.8±213.6	17.0±1.7
	II	5.0±0.9	30.3±3.6	49.2±3.8	1490.7±167.3	16.1±2.1
	III	2.5±0.3	25.8±3.0	31.1±3.1	802.3± 81.2	13.1±0.8
FS-W_7	I	8.0±1.6	25.4±3.8	42.0±3.6	1066.8±105.2	16.0±1.8
	II	2.0±0.8	21.3±3.1	[illegible]9.1±2.8	832.8± 67.3	14.1±1.5
	III	2.0±0.3	18.6±2.8	27.2±1.8	505.9±41.9	12.0±0.7
FS-W_8	I	8.0±2.1	27.9±3.2	44.4±3.7	1238.7±167.3	16.4±1.8
	II	3.0±0.7	24.3±2.9	38.2±3.1	928.2± 89.2	14.6±1.7
	III	2.0±0.2	21.7±2.2	28.3±1.3	614.1± 59.2	12.1±0.6

Table 8.4. Percentage contribution of the three cohorts of *A. conyzoides*, *A. houstonianum* and *B. pilosa* to their total seed output in different farming systems during 1987.

Watersheds	*A. conyzoides*			*A. houstonianum*			*B. pilosa*		
	I	II	III	I	II	III	I	II	III
$FS\text{-}W_1$	67.3	16.4	16.3	75.8	17.3	6.9	75.4	17.7	6.9
$FS\text{-}W_2$	76.6	16.5	6.9	68.0	21.2	10.8	71.8	22.0	6.2
$FS\text{-}W_3$	79.3	12.8	7.9	72.9	16.0	11.1	72.1	21.3	6.6
$FS\text{-}W_4$	71.2	11.8	17.0	74.0	19.7	6.3	76.6	17.4	6.0
$FS\text{-}W_5$	76.7	15.2	8.1	77.9	8.9	13.2	70.2	25.8	4.0
$FS\text{-}W_6$	76.0	14.6	9.4	76.9	10.9	12.2	65.0	27.5	7.5
$FS\text{-}W_7$	74.6	17.9	7.5	76.2	23.8	-	76.1	14.8	9.1
$FS\text{-}W_8$	75.1	17.9	7.0	72.4	15.2	12.4	71.1	20.0	8.9

GENERAL DISCUSSION

The data presented in the preceding chapters reveal the possible role of different farming systems in determining the weed community structure, productivity of weed communities and population dynamics and growth of a few important weeds such as *Ageratum conyzoides*, *Ageratum houstonianum* and *Bidens pilosa*. The weed communities developing in different farming systems had a fairly high species diversity and population densities of various component weed species were also quite high. The data reveal that *A. conyzoides*, *A. houstonianum* and *B. pilosa* also have quite a high soil seed population, but only a very few could give rise to mature plants (Chapter VI and Chapter VII).

Weed community composition studies in relation to different farming systems (Chapter IV) indicate that a progressive increase in the number of species takes place with the passage of time. Dagar (1987) & Saavedra *et al*. (1989) opined that difference in composition of weed flora is determined by difference in farming operations, types of crop grown, crop canopy, soil characteristics, differential competitive ability of crops, variation in micro-climatic conditions and crop density in different farming systems. The dominance of perennials in FS-W_7 may be attributed to the absence of agricultural operations. This is also confirmed by the lesser number of perennials in watersheds where agricultural operations took place, disturbing the plants by tillage and thus allowing minimum regeneration of the perennial plants. The resource competition offered by the crops in FS-W_4, FS-W_5 and FS-W_6 may be responsible for the lower total weed density almost throughout the study period. The disappearance of species in some of the watersheds was associated with replacement by new species thus, conforming with the findings of Mellinger & McNaughton (1975). The phytosociological data indicated the adaptation of a particular species or a small group of species to different farming systems. The farming systems seem to have a strong impact on the distribution and abundance of the weed species.

The minimal agricultural operations in FS-W_6, FS-W_7 and FS-W_8 appear to be responsible for the greater IVI values of dominant grasses like Imperata cylindrica and Arundinella benghalensis. Such a behaviour of grasses in response to disturbance has been also reported by Hakansson (1982). The occurrence of maximum number of dominant weeds in FS-W_4, makes this system ecologically different from the other systems, as it lacks certain form of vegetation control due to disturbance and agricultural manipulation. Greater species diversity values observed in FS-W_4 (disturbed due to agricultural operations), FS-W_7 and FS-W_8 (competitive and stressed environment) reflects the ability of weeds to withstand both disturbance and stress. An investigation into the similarity indices of weed communities revealed a notable difference between the farming systems, however, FS-W_2 and FS-W_3 showed the greatest similarity value and FS-W_4 and FS-W_7 the least.

The total biomass showed seasonal fluctuations, being maximum in rainy season and lower in summer and winter seasons. The increased community biomass values (Chapter V) during rainy season in all the eight watersheds was largely due to luxuriant growth of all plants in general and rainy season annuals in particular (Chapter III). FS-W_7 and FS-W_8 which recorded the maximum biomass of weedy species differed from the rest of the farming systems in two respects. Firstly, the weedy species are allowed to grow without any disturbance to them and secondly, there are no crop plants to offer competition. These two factors coupled with greater species diversity (Chapter IV) probably account for greater biomass production in these watersheds (FS-W_7 and FS-W_8) compared to others. The death of rainy season annuals and shattering of old tillers and branches of perennials during post-rainy months led to decline in plant biomass from November onwards. Heady (1960) and Ratliff & Heady (1962) attributed considerable decline in the total dry weight or herbage in California annual grassland to the approach of the dry season and normal decline following maturity.

The net primary productivity (aboveground and belowground) as computed through 'difference method' showed greater productivity in undisturbed plot (FS-W_7). The crops grown in FS-W_4 offered severe competition to weeds whereby their growth was suppressed. FS-W_5, FS-W_6, FS-W_7 and FS-W_8 which had higher density and luxuriant growth of rhizomatous species like Imperata cylindrica and Arundinella benghalensis (Chapter IV) showed greater belowground net productivity (Chapter V). Increase in the productivity of belowground parts could be due to the development of an extensive root system in nutrient-poor soils to cope with nutrient requirement of plants.

The biomass contribution of the dominant weeds showed variation with different farming systems (Chapter V) depending upon the change in their densities (Chapter VI and VII) and/or cover values (Chapter IV). The percentage biomass contribution by the three weed species was greater in FS-W_4 (disturbed plot) than in FS-W_7 (undisturbed plot) showing the favourable effect of agricultural operations on biomass production by them. The data revealed that A. conyzoides, A. houstonianum and B. pilosa are the major biomass contributors in FS-W_1, FS-W_4, FS-W_5 and FS-W_6 where the agricultural operations were frequent. Thus, the bulk of the community plant biomass in FS-W_4, FS-W_5 and FS-W_6 was composed of a few weed species.

Bray *et al.* (1959), Pearson (1965), and Singh & Yadava (1974) also reported that a few dominant species contribute maximum to the community biomass.

The time of emergence of weeds in the crop fields influences the biomass, productivity and crop yield to a great extent. The biomass and yield of rice, maize and green pea were greatly reduced in the non-weeded plots. Thomas & Allison (1975) found that population of *Rottboellia cochinchinensis* (weed), as low as 10-15 plants/m^2, can cause appreciable reduction in maize yield. The losses to the crop yield in presence of weeds have been reported by various other workers also (e.g. Shaw, 1964; Tripathi, 1967; Akobundu, 1979; Ayeni *et al.*, 1984, Dagar & Dagar 1986; Beckett *et al.*, 1988; Ezueh & Amusan, 1988). Due to larger weed population in 1988 than in 1987 (Chapter IV) in the weed-infested area the reduction in economic yield and biomass was more in 1988. However, weeding gave better result in terms of biomass and economic yield of crops.

The study pertaining to the impact of farming systems on dynamics and growth of *Ageratum conyzoides* and *Ageratum houstonianum* (Chapter VI) and *Biden pilosa* (Chapter VII) showed that germination and establishment of these weeds are determined by the interaction of soil seed bank, farming operations and available safe microsites. In spite of the high soil seed population (Chapters VI and VII) both the species of *Ageratum* (Chapter VI) and *B. pilosa* (Chapter VII) showed poor seed germination, which may be due to induced seed mortality during burial or removal of weed seeds with crop harvest and loss through other agencies (Fernandez-Quintanilla *et al.*, 1986). The inhibitory effects of *Ageratum* may also cause reduction in its seed germination and seedling growth (Chapter VI), as reported by Sugha (1980). Besides the farming operations, low temperature during winter also influences the seed germination and growth of *Ageratum* spp. as revealed by the absence of seedlings from the crop fields during cold months of December and January.

After emergence, seedlings have to face various environmental hazards together with competition for resources from the crop plants. The high juvenile mortality caused by the environmental constraints has been reported in other species by earlier workers (e.g. Williams, 1970; Sarukhan & Harper, 1973; Bazzaz & Harper, 1976; Yadav & Tripathi, 1981). Pelton (1962) has identified various factors causing seedling mortality. However, in the present study, farming operations, vegetation cover, differential competitive ability of crops, crop density and variations in the physiographic features of different watersheds appear to be the major factors contributing to seedling mortality.

The mortality of individuals continues even after the establishment of the weed seedlings as indicated by Deevey's type II and III survivorship curves. The mortality after seeding stage may take place largely due to severe competition offered by the growing vegetation, crop canopy and prevailing low temperature during winter season. The suppressive effect of the associated vegetation in control ($FS-W_7$) was so much that only a very few seedlings of *Ageratum* constituted the I and II cohorts and the III seedling cohort of *A. houstonianum* was totally absent (Chapter VI). The greater density of associated species during 1988 compared to 1987 caused greater reduction in light intensity which in turn might have resulted into higher seedling mortality in 1988. This argument finds support from Banyikwa & Rulangaranga (1984) in *A. conyzoides* (Chapter VI) and of Fenner (1980a, b) in *B. pilosa* (Chapter VII).

The seedling cohorts of *Ageratum* species (Chapter VI) and *B. pilosa* (Chapter VII) emerging earlier showed greater survivorship and longer half life than later emerging cohorts (Chapter VI and VII). This is in conformity with the findings of Sarukhan & Harper (1973), Hawthorn & Cavers (1976), Weaver & Cavers (1979), Weiss (1981), Rai & Tripathi (1984) and Pandey & Dubey (1989) in other plant species. The longer half life of the I cohort (Chapter VI and VII) during 1987 compared to 1988 may be due to the lower density of associated species in 1987. The agricultural operations prevailing in FS-W_4 presumably created greater number of safe microsites for seedling emergence compared to the other systems, as indicated by the highest seedling recruitment in FS-W_4.

Like the populations of A. conyzoides and A. houstonianum (Chapter VI), Bidens pilosa also showed variations in soil seed bank, emergence and survival of seedlings under the influence of different farming systems (Chapter VII). The increased seed input to the soil seed bank did not ensure the proportional increase in seedling population. This indicates that at each stage of life cycle, the individuals both seeds and plants, are eliminated from the population through mortality. The reduction in seed germination provides a regulatory mechanism to population as has been argued by Palmblad (1968a). Harper (1961) and Yadav & Tripathi (1981) opined that seed germination and establishment of a plant species is determined by the interaction of soil seed bank and available 'safe microsites'.

The highest population density of B. pilosa in spring may be attributed to large flush of germination and seedling emergence due to favourable climatic conditions such as light showers and increase in soil temperature. The high juvenile mortality of seedlings observed in the case of B. pilosa may be attributed to various environmental hazards and resource competition from crops. *B. pilosa* showed greater mortality in FS-W_4 (Chapter VII) where its density was relatively greater, which depicts the role of intra-specific competition in population regulation of this weed. This agress with Pemadasa (1976) who attributed a high mortality in *B. chinensis* to high density and intra-specific interference. Early mortality was a common phenomenon in almost all the three seedling cohorts and mortality of the individuals continued even after the establishment of seedlings as indicated by Deevey's type II and III survivorship curves. Poor recruitment of seedlings was noticed in established and undisturbed communities. A relatively greater survival of *B. pilosa* in FS-W_2, FS-W_8 and FS-W_7 was due to mild or non-existence of agricultural operations in these watersheds.

The co-existence of these three species in nature may be explained on the basis of their different mode of adaptability in utilizing the environmental resources over different periods of the year. The seedlings of *A. conyzoides*, *A. houstonianum* and *B. pilosa* are recruited to the population soon after the first monsoon showers are received (Chapters VI, VII and VIII). The seedlings of *B. pilosa* (Chapter VII) emerge earlier as compared to *A. conyzoides* and *A. houstonianum* (Chapter VI).

The studies on growth performance of these weeds in relation to different farming systems showed that the species populations are best suited to increased intensity of disturbances prevalent in FS-W_4, FS-W_5 etc. The decrease in the number of fertile plants and seed production in the successive cohorts (Chapter VIII) was probably due to reduced resource availability resulting from an increase in number of associates (Chapter IV) as has been reported by Rai & Tripathi (1984) in Galinsoga spp. and Pandey & Dubey (1989) in Parthenium hysterophorus. Further, the seed output and crude reproductive effort (CRE) of all the three weed species showed variation related to the type and intensity of agricultural operations.

Reproduction and growth are alternative ways in which a plant may use its limited resources (Silvertown, 1982). A striking feature of biomass allocation was the high reproductive allocation in all the three weeds in FS-W_1 and FS-W_4 (Chapter VIII). The reproductive allocation was found to be comparatively lower under stress for example, in FS-W_7 and FS-W_8, where the well developed successional fallow vegetation offered severe competition to these weeds. This is in agreement with the observations of Swamy & Ramakrishnan (1988) in some other species. The study relating to biomass allocation to different plant parts of the three weeds in various farming systems suggests that these weeds allocated higher proportion of dry matter to supporting organs than to reproductive structures in FS-W_7 and FS-W_8 depicting that under stressed condition which existed on the watersheds due to luxuriant growth of successional communities encouraged greater allocation to structures which facilitate capture of resources. The cohorts III of the three weeds which had lesser resources at their disposal compared to the cohorts I and II, allocated greater biomass to roots than what is allocated by the other two cohorts. This also supports the view that the stress condition leads to greater biomass allocation to the structures which are responsible for the absorption of water and nutrients.

Growth analysis of the three weeds (Chapter VIII) revealed that the RGR of the I cohorts was maximum. The decrease in RGR with time observed in the present study, agrees with Thorne (1960) and Pandey & Sinha (1977). RGR is dependent upon NAR and LAR (Briggs, Kidd & West, 1920) and the present study also showed higher RGR between 60-90 days when NAR and LAR were maximum. The results obtained in the present work conform to the general pattern that RGR, NAR and LAR are higher in farming systems where agricultural practices are more common. Differences in initial and final LAR values have been reported by Njoku (1959), Hodson (1967), Eze (1973) and many others. The higher RGR and NAR in the three weeds in FS-W_4 seems to be due to their greater LAR. Since the climatic conditions were similar for all the watersheds, any difference in various growth characters of weeds could be largely due to the difference in the farming systems and soil.

In conclusion, it may be said that the three weeds are adapted to conditions under which they occur in nature. The increased reproductive allocation in the three weeds in agriculturally disturbed situations indicates that these weeds are reproductively well adapted to agriculture-based farming systems. Besides agronomic operations, competition from the crops and application of fertilizers were other important conditions which affect the weed populations and growth of weed plants in agro-ecosystems. The three weeds viz. A. conyzoides, A. houstonianum and B. pilosa appear to be well adapted to grow under the existing conditions. They share the total biomass between vegetative and reproductive structures in such a manner that more emphasis is laid on the allocation of biomass to those plant parts which are concerned with resource exploitation. The consistency with which they produce seeds in various farming systems can be viewed a positive strategy adopted by these weeds to ensure their presence over a large range of habitats.

Although these weeds produce enormous seeds every year, their natural populations do not seem to show proportional increase in size, indicating that various abiotic and biotic factors of environment in different farming systems interact in such a manner that their populations are properly regulated. The interacting influence of several other factors (including competitive influence of associated species) also contributes to population regulation of these weeds in a complex manner. Although A. conyzoides, A. houstonianum and B. pilosa are the members of plant communities growing on both disturbed and undisturbed habitats, these weeds are particularly successful in agriculturally disturbed situations indicating that they have presumably developed strategies to cope with the frequent disturbances such as ploughing, weeding, herbicide application etc., prevailing in the agroecosystems. One useful strategy is the occurrence of as many as three cohorts in a single year all of which are capable of completing the life cycles successfully during the crop growing season. The existence of the three cohorts appearing at different times of the year ensures successful perpetuation of these weeds even if the unfavourable conditions prevail over a part of the year. In absence of biotic disturbances, as was the case in FS-W_7 and FS-W_8, they exhibited poor growth indicating that the populations of these weeds are also characterised by the properties of self regulating systems imposing restrictions on the population beyond a certain limit.

The present study, of course, provides a good deal of information on the weed community structure, biomass and productivity of weed communities and population dynamics and growth of *A. conyzoides*, *A. houstonianum* and *B. pilosa* as related to different farming systems. However, it is felt that a detailed study on the role played by various ecological factors and agricultural practices in determining the buried weed seed population would provide a still better insight into the dynamics and regulation of weed populations in various farming systems. In any agro-ecosystem, the type of crop grown and the growth vigour and density of the crops are the major determinants of population responses of the weed species, and therefore a study relating to the effect of these factors on weed community structure and function may also prove to be rewarding to both ecologists and agricultural scientists.

SUMMARY

The present investigation deals with the effect of different farming systems on weed community structure, community biomass and productivity and population dynamics and growth of three dominant weeds viz. Ageratum conyzoides L., Ageratum houstonianum Mill. and Bidens pilosa L. The three weeds grow luxuriantly and abundantly in the local agricultural ecosystems. They also grow in wastelands and disturbed places and along roadsides and forest margins. A. conyzoides and A. houstonianum are sympatric species and have synchronous growth. The growing period of B. pilosa also partly overlaps with that of Ageratum species. In view of the importance of these weeds in the local agro-ecosystems, a study on their population dynamics was carried out over a 2-year period to analyse the impact of different farming systems on their population behaviour. The study also included the determination of biomass and productivity and growth analysis of these weeds in various farming systems. The following farming systems which were maintained at the ICAR Research Farm at Barapani were considered. 1) Livestock-based farming system ($FS-W_1$), 2) Forestry ($FS-W_2$), 3) Agro-forestry ($FS-W_3$), 4) Agriculture-based farming system ($FS-W_4$), 5) Agri-horti-silvi pastoral system ($FS-W_5$) and Horticulture-based farming system ($FS-W_6$). Besides these systems, a control system ($FS-W_7$)

and a jhum fallow (FS-W_8) were also considered for the present study. A brief summary of the results on the various aspects is given below:

Weed community structure

The weeds growing in different watersheds were identified and their density, frequency and basal cover were determined at monthly intervals in the permanent quadrats. Importance value indices (IVI) of different species were computed as described by Misra. Shannon's diversity index and Sørensen's similarity index were computed to measure diversity and similarity between different farming systems. During 1987, the total number of weed species recorded from the various farming systems was 89 which increased to 93 during 1988. Livestock-based farming system (FS-W_1) recorded the highest number of species in both years. Asteraceae was the most dominant family. The non-leguminous dicot weeds outnumbered the grasses and legumes. The ratio between annual to perennial weeds during 1987 was greater than in 1988.

A high weed density and greater weed diversity were observed during rainy season. The herbaceous weeds showed highest density in FS-W_4 during 1987, while Arundinella benghalensis showed its dominance in FS-W_7. Most of the forbs showed lesser density during 1988 than in 1987.

The frequency of the grasses during 1988 either remained constant or increased in most of the cases. The frequency percentages of almost all forbs were higher during 1987 compared to 1988.

Imperata cylindrica, *Desmodium microphyllum* and *Ageratum houstonianum* showed the highest IVI values. The agriculture-based farming systems (FS-W_4) and control system (FS-W_7) recorded the highest diversity values during 1987 and 1988 respectively. Diversity values during 1987 were greater than in 1988 in all the farming systems. During both years the highest similarity was observed between FS-W_2 and FS-W_3 and lowest between FS-W_4 and FS-W_7. However, the similarity indices during 1987 were greater than in 1988.

Biomass and productivity of weed communities and economic yield of three important crops

The biomass and productivity of weed communities were determined at monthly intervals on all the eight watersheds to understand the impact of various farming systems on these parameters. However, the biomass and yield of important crops (maize, rice and peas) were determined taking samples only from agriculture-based farming system. There was a variation in plant biomass through different months and in different farming systems. The absence of agricultural operations in FS-W_7 and FS-W_8 led to the accumulation of the maximum biomass during both years. Comparatively less frequent weeding and other agricultural operations in FS-W_6 and FS-W_3 resulted in decreased biomass production in these systems. The peak values of aboveground and belowground biomass were recorded in September-October in both years. With the advent of winter there was a decrease in biomass.

The annual net primary production was highest in FS-W_7 and lowest in FS-W_4 during 1987. However, the annual aboveground productivity was highest in FS-W_2 whereas the highest belowground productivity was observed in FS-W_8. The annual NPP during 1988 was lesser than in 1987. During 1988, FS-W_8 showed highest annual NPP and FS-W_4 the lowest.

A. conyzoides, *A. houstonianum* and *B. pilosa* recorded peak biomass in October during 1987 and in September during 1988. The contribution of these weeds to total weed biomass was greater in 1988 than in 1987. Also their contribution was maximum in the agriculture-based farming system i.e. FS-W_4 indicating that some of agricultural operations to which this system was subjected, favour the growth of these weeds. A substantial decrease in biomass of these weeds noticed in FS-W_7, could be attributed to the competition offered by the already established vegetation in this system.

As expected, the economic yield and biomass of all the three crops were higher in the weed-free area of the crop field compared to the weed-infested plot. The economic yield and biomass of rice, maize and green pea was greater in 1987 than in 1988. In both years maize showed the highest economic yield and biomass followed by rice and green pea.

Population dynamics of *Ageratum conyzoides* and *Ageratum houstonianum* in different farming systems

Seedling emergence, seedling survival and dynamics of soil seed bank of the two species of *Ageratum* were studied in permanent quadrats on different watersheds under various farming systems by following the fate of individuals at short and regular intervals. Both species are characterised by the presence of three seedling cohorts in all farming systems which emerged in early May, late May and late August in 1987 and early April, late April to early May and early August to late August in 1988. *A. houstonianum*, however, showed only two seedling cohorts in FS-W_7. The population density of both weeds increased in July-August and decreased drastically in winter months. The seedling cohorts exhibited Deevey's Type II and III survivorship curves which were further influenced by different agricultural operations and date of their emergence. In both years, the seedling emergence and seed output of the two weeds were greater in agriculture-based farming system (FS-W_4) and least in the control system (FS-W_7). The number of seedlings emerged in 1988 was greater than in 1987 in all the watersheds. Generally, the early emerging cohorts showed greater density and were more successful than the late emerging ones. *A. conyzoides* showed maximum mortality in FS-W_4 in both years, and *A. houstonianum* in FS-W_6 during 1987 and in FS-W_5 during 1988. In general, both species exhibited almost similar survival pattern with greater mortality risk during seedling establishment and senescent phase. The *A. houstonianum*, however, experienced lesser mortality than *A. conyzoides* on all the sites.

Effect of farming systems on the population dynamics of *Bidens pilosa*

The studies on population dynamics of *B. pilosa* also revealed the presence of three seedling cohorts due to staggered seed germination which occurred in early April to mid April, late April to early May and late May to early June. The flowering and seeding took place during July to September. During January and February the survival of *B. pilosa* was nil. The first cohorts were always the largest compared to the II and III. Seedling emergence, total density and seed output of *B. pilosa* were greater in FS-W_4 compared with the other farming systems. FS-W_7 recorded the lowest total density. The overall total seedling emergence (cohort I + cohort II + cohort III) were greater in 1988 than in 1987 in all the farming systems except in FS-W_4 and FS-W_6 which showed lesser seedling emergence. The cohorts emerging in 1987 showed longer half life and survived better than those emerging in 1988 except the III cohorts in FS-W_1 and FS-W_4 and II cohorts in FS-W_7 and FS-W_8. The seedling cohorts exhibited Deevey's Type II and III survivorship curves. The seedling cohort of B. pilosa experienced maximum mortality either in FS-W_4 (during 1987) or in FS-W_1 (during 1988). The early emerging cohorts were larger in population and were more successful than the later emerging ones. B. pilosa exhibited similar pattern in both years with greater mortality risk during seedling establishment and senescent phase.

Effect of farming systems on the reproductive behaviour, dry matter allocation and growth of three weeds

The population responses of the three weeds (A. conyzoides, A. houstonianum and B. pilosa) were studied in terms of reproductive behaviour, dry matter allocation and growth (RGR, NAR and LAR). The results suggest that late emerging cohorts particularly the III one, produced smaller percentage of fertile plants compared to the I cohort. In case of all the three weeds, seed production and relative contribution of the three cohorts to the total seed output by these weeds decreased from cohort I to cohort III. The seed output and CRE of these weeds were generally greater in the disturbed systems, which is a characteristic feature of early successional species. The biomass allocation to the roots was greater in the III cohorts of all the three species compared to the I and II cohorts. The reproductive allocation showed a decreasing trend in the successive cohorts. All the three species allocated more biomass to the reproductive parts in the disturbed watersheds (FS-W_4, FS-W_1, FS-W_5) than other farming systems. The reproductive allocation was particularly low in FS-W_7 and FS-W_8, where the developed successional communities offered competitive stress.

An anlysis of the growth patterns of all the three weeds showed that relative growth rate (RGR) was generally higher in agriculture-based farming system (FS-W_4). A. houstonianum, among the three weeds, showed the highest RGR. The greater RGR of the I cohorts conferred competitive advantage over the successive cohorts. The RGR which was initially high, showed a sharp decline in August and a negative value in winter months. The RGR values were maximum during 60-90 days from the date of emergence. The pattern of change in RGR with time was similar for different cohorts of the three weeds. The late arriving cohorts exhibited low NAR which showed variation with time. The increase/decrease in NAR values coincided with change in RGR. The high RGR, NAR and LAR values were observed in FS-W_4 (agriculture-based farming system) depicting the role of agricultural practices in determining their magnitude. Among the three weeds A. houstonianum showed the highest LAR value followed by B. pilosa and A. conyzoides. All the three weeds appear to prefer agriculturally disturbed habitat.

The study reveals that the variations in weed community structure, community biomass and productivity and population dynamics and growth of the three weed species (A. conyzoides, A. houstonianum and B. pilosa) are largely controlled by the differences in human manipulations operating in various farming systems. The agricultural operations, type of crop grown, growth vigour of the crop plants, competition offered by the crop plants and other associated species and micro-environment of the agro-ecosystems regulate the growth and maintenance of the populations of the component weed species in different farming systems. The weeds respond to all these factors through mortality as well as plasticity.

One of the characteristics common to all the three weed species is the production of enormous number of seeds which show staggered germination giving rise to as many as three seedling cohorts in a year. This is an important strategy to avoid the risk of being eliminated, especially in view of the fact that the habitats which they generally occupy, are highly disturbed.

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