WEED DYNAMICS IN RICE FIELDS : INFLUENCE OF SOIL REACTION AND FERTILITY

By

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THESIS

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DECLARATION

I hereby declare that this thesis entitled **"Weed dynamics in rice fields: Influence of soil reaction and fertility"** is a bonafide record of research work done by me during the course of research and the thesis has not previously formed the basis for the award to me of any degree, diploma, fellowship or other similar title, of any other university or society.

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CERTIFICATE

Certified that the thesis entitled **"Weed dynamics in rice fields: Influence of soil reaction and fertility"** is a record of research work done independently by Ms. Vidya.A.S, under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, associateship or fellowship to her.

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INTRODUCTION

INTRODUCTION

Weeds pose a recurrent and ubiquitous threat to agricultural productivity. Even after thousands of years of tillage and hand weeding and 50 years of herbicide technology weeds are still there in our fields. Very often, new species of weeds appear and spread across the landscape, while only a few major weed species have disappeared from the production fields. This situation has led many growers to conclude; "the weeds always win".

One of the most important reasons for the failure of weed control is the weed biodiversity. Weed diversity in the rice ecosystems all over the world is complex, and is the result of the interplay of many factors like geographic, edaphic, cultural and management practices. The floristic composition and distribution of weeds often serve as indicators of field conditions. Fuente *et al.* (1999) and Suarez *et al.* (2001) found relationship between environment and weed vegetation, and proposed that species composition may be used as an indicator of environment. The presence or absence of certain weeds in a field can be correlated well with the soil reaction and availability or deficiency of some soil nutrients. Thus, some weed species can act as bio indicators of depleted soils, whereas presence of some other weeds can be an indication of high soil fertility.

A thorough understanding of the biology and ecology of weeds is an important prerequisite for using them as indicator plants. These plants can be used to predict soil conditions, so that appropriate ameliorations can be made to manage important weed species and prevent the build up of difficult to control species.

In Kerala rice occupies an area of 3.9 lakh hectares with an annual production of 7.7 lakh tons (FIB, 2002). The main rice growing tracts of Kerala are the acid sulphate soils of Kuttanad, *Kole* lands of Thrissur and Malappuram, acid saline soils of *Pokkali* lands, sandy soils of *Onattukara* and the rice fields of Palakkad, including the alkaline black soils of Chittur. The agroecological situations and cropping pattern in these different rice-growing tracts are entirely different and the weed communities also vary accordingly. Characterizing and understanding the spatial and temporal distribution of weed population in the various rice ecosystems of Kerala will provide an insight into the factors and forces allowing their spread and enduring occupation. These forces and factors leading to 'hot spots' (heavy infestation) and areas of no weeds in a field could be manipulated by changes in production practices. The sustainable weed management system demand a thorough understanding of the weed diversity so that comprehensive strategies can be developed either to reduce their opportunities or to avoid economic crop losses resulting from them. Information on species response to environment and crop production strategies is needed to develop new approaches to weed management. Coupling information from experiments and field surveys can provide a broader basis for understanding weed species response to agronomic and environmental factors.

Considering the need for more information on the biology and ecology of weeds in the various rice ecosystems of Kerala, the present study was undertaken with the following objectives:

1) To understand the weed diversity in the various rice ecosystems of Kerala.
2) To evaluate the changes in weed flora as influenced by soil fertility and soil reaction.
3) To identify weeds which can serve as indicators of soil conditions.
4) To study the mechanisms that help weeds to adapt to different soils.
5) To understand the change in soil micro flora with soil fertility.

REVIEW OF LITERATURE

2. REVIEW OF LITERATURE

Information on various geographic and management factors which influence the distribution and dominance of weed flora in cropped lands as well as the ecological methods for the analysis of weed vegetation are reviewed in this chapter.

2.1. FACTORS INFLUENCING WEED FLORA OF CROP LANDS

Weed vegetation on arable land can change rapidly over time and vary tremendously between fields and regions. Biotic factors including competition from the crop and other weeds, abiotic factors such as edaphic or soil factors, and historic and random factors determine the regional distribution and dispersal of species (Andreasen *et al.*, 1991).

2.1.1. *Edaphic* factors

The word '*Edaphic*' comes from the Greek 'edaphos' meaning soil or ground. The soil properties such as soil fertility, moisture, pH, aeration, temperature, and the cropping systems and associated practices imposed on a soil determine what weeds survive to compete (Zimdahl, 1999).

2.1.1.1. *Soil fertility*

There is wide variation in the response of weeds as well as other plants to soil nutrients. Many weeds do well in soils too low in fertility for crop production, but others grow only in well-fertilized soils (Zimdahl, 1999). Only a few species associate with a particular soil type. There is a considerable change in the relative density of weed species because of the long-term continuous application of a particular fertilizer schedule. Numerous observational and experimental studies have shown strong effects of the availabilities of nutrient resources on the species diversity, species composition and species dominance of both aquatic and terrestrial plant communities (Tilman, 1986).

2.1.1.1.1. *Permanent Manurial Trials*

Long term experiments, ie., experiments running for decades are considered important in agronomic research for evaluating the long term sustainability and productivity of cropping system as well as changes in plant community composition (Silvertown *et al.,* 1994). Such experiments could give an insight into the long-term effects not easily evaluated otherwise.

The oldest long-term fertilization study in the world is the Park Grass Experiment at Rothamsted. In 1856 in Rothamsted, England, a mowed pasture was divided into 20 plots, each receiving a different combination of mineral fertilizers (Lawes and Gilbert, 1880). The species diversity of the plots receiving all mineral fertilizers, with a high rate of nitrogen application (as ammonium) fell dramatically. These plots became dominated by a single species that comprised 90 – 99 per cent of the total biomass (Tilman, 1982). Each pattern of fertilization has tended to favour a different plant species. Averaging over all samples collected in a plot during the 130 years of these experiments, those plots receiving no fertilizer contained 7.9 per cent legumes by biomass and those receiving nitrogen averaged less than 0.5 per cent legumes. The plot receiving all nutrients except 'N' contained 21.4 per cent legumes. Thus adding all the nutrients except nitrogen led to an approximately three-fold increase in the abundance of legumes. This experiment also showed that at similar pH range (from 4.2 to 6) different plant species dominated at different relative availabilities of N and P.

Banks *et al.* (1976) evaluated the influence of various conventional soil fertility treatments continuously for 47 years on weed types and population, based on the data from long term experiment started in 1929 at the Oklahoma A and M college (now Oklahoma State University). Plots with the lowest weed density were those that had received no fertilizer for 47 years. The highest weed density occurred on plots that received complete fertilizer (N, P, K) and lime ($CaCO_3$). Grass weeds were most abundant with complete fertility, whereas broad leaf species declined. Carpet weed (*Mollugo verticillata* L.) and henbit (*Lamium amplexicaule* L.) numbers were the greatest in the plots receiving P alone or N+P. In general, soil which had more complete fertility levels were able to maintain higher populations of most weed species.

Mrkvicka and Vesela (1997) compared the botanical composition of grass swards at different rates of N fertilizer and after a long term of about 20 years difference in N application. They found that plots with a history of N application were more prone to weeds. The proportion of legumes in swards decreased as N rate increased. Plant species diversity was the highest where soil fertility was the lowest and on sites given low N rates in the past.

The effect of long-term application of manures and fertilizers on the changes in weed species was studied in Tamil Nadu, in the Permanent Manurial Trial, which started in 1909 (Kandasamy *et al.*, 2000). The result revealed that there was a high proportion of grass weeds (50 – 68%) in plots that did not receive N fertilization. The grasses were maximum when a single nutrient, either P (68.8%) or K (61.6%) was applied, as against balanced nutrient application with N, P and K (30.2%). Fertilization without N substantially reduced dicot weeds. *Phyllanthus maderaspatensis* and *Amaranthus viridis* were totally eliminated in plots receiving P or K alone. The maximum sedge population was recorded for the balanced NPK fertilized plots (42.4%), followed by cattle manure application (39.5%). A significant increase in weed dry weight was recorded in all the fertilized treatments except K alone.

Varughese and Sushamakumari (1993) evaluated the response of weeds to organic manures and inorganic fertilizers in the Permanent Manurial Trial started in 1964, at Rice Research Station, Kayamkulam, Kerala. In the first crop season, N limited the growth of *Cyperus* sp and *Isachne* sp whereas K or P, either alone or in combination limited growth of *Echinochloa* sp and *Sacciolepis* sp. During the second crop season, *Fuirena glomerata* and *Utricularia racemosa* dominated in plots where P and K or P alone was skipped continuously, and the leguminous weeds, *Giesapsis cristata* and *Aeschynomene indica*, occurred in plots where no N was applied.

Permanent Manurial Trials are also used to study the response of weeds to soil nutrients. Studies conducted by Hoveland *et al.* (1976) with ten warm season and seven cool season weed species grown on sandy loam soils, taken from plots of long term fertility experiment in progress for 25 years at the Auburn University, Alabama, USA, revealed that red root pigweed (*Amaranthus retroflexus* L.), Jimson weed (*Datura stramonium* L.), and Florida beggar weed (*Desmoduim tortuosum* (Sw.) DC.) were the warm season weed species most responsive to P, whereas chick weed (*Stellaria media* (L.) Cyrillo) was the most responsive cool season weed to P. These weeds developed extreme P deficiency symptoms at low P levels. Showy crotalaria (*Crotalaria spectabilis* Roth), fall morning glory (*Ipomoea purpurea* (L.) Roth), and sicklepod (*Cassia obtusifolia* L.) were the most tolerant weeds to low soil P. Red root pig weed, Jimson weed and Florida beggar weed were the most responsive warm season weeds to K. Wild mustard (*Brassica kaber* (DC) L.C. Wheeler var *Pinnatifida* (stokes) L.C. Wheeler and annual blue grass (*Poa annua* L.) were the most responsive cool-season weeds to K. Buck horn plantain (*Plantago lanceolata* L.), *Carolina geranium*, and curly dock (*Rumex crispus* L.) were the most tolerant cool-season weeds to low soil K.

2.1.1.1.2. *Response of weeds to plant nutrients*

Crops and weeds require the same nutrients for growth and development at the same time and the weeds are often more successful in obtaining them (Zimdahl, 1999). Moody (1981) reported that many weeds have a large requirement for nutrients and may have higher mineral nutrient contents than rice.

Many weeds can adapt and grow well in soils of fertility level well below that required for optimum crop yields. *Imperata cylindrica* (thatch grass) grows well in soils of low fertility (Rao, 2000). Studies conducted by Hoveland *et al.* (1976) revealed that the weeds such as showy crotalaria (*Crotalria spectabilis* Roth), fall morning glory (*Ipomoea purpurea* (L) Roth), sickle pod (*Cassia obtusifolia* L.) carolina geranium (*Geranium carolinianum* L.) and coffee senna (*Cassia occidentalis* L.) were tolerant to low soil P, where as buckhorn plantain (*Plantago lanceolata* L.), carolina geranium and curly dock (*Rumax crispus* L.) were tolerant to low soil K.

Weeds may have different adaptive mechanisms to thrive in soils of low fertility. This can be either due to the weed's capacity to utilize the atmospheric nitrogen (in the case of leguminous weeds) or due to the capacity for efficient uptake of the limiting nutrients in the soil. The latter capacity may also help them to compete out other weeds in soils of low fertility.

a) Adaptation of weeds to thrive in soils with low level of a nutrient

Various research workers suggested that legumes and other terrestrial vascular plants capable of symbiotic nitrogen fixation, reach their greatest abundance in habitats with nitrogen poor soil (Campbell, 1927; Foote and Jackobs, 1966). Ferguson and Bond (1953) also reported that Alder (*Alnus glutinosa*), which can fix atmospheric nitrogen, could grow well in nitrogen deficient soils. The bog myrtle (*Myrica gale*) capable of fixing nitrogen, also flourishes well on bog and moorland soils, which are typically low in available nitrogen.

The Park Grass experiment at Rothamsted also revealed that those plots receiving all nutrients except nitrogen contained 21.4 per cent legumes (Tilman, 1982), which was three times more than the legume population in plots receiving no nutrients. Ueda *et al.* (1977) reported that the growth of leguminous weeds such as *Vicia sativa* L. and *Trifolium repens* L. were favoured in plots to which P and K, but no nitrogen, had been applied.

b) High absorption of nutrients by weeds

Alkamper (1976) studied weed fertility interactions and emphasized that weeds usually absorb fertilizer faster and in relatively larger amounts than crops, and therefore derive greater benefit. He observed that the nitrogen concentrations of weeds range from 1 to 3.8% and were usually higher than those of crop plants, the phosphorus content of weeds were about 0.5 per cent high, while the potassium contents in most weeds were extremely high (1.5 to 5.0%).

Rogers *et al.* (1939) reported that poorjoe (*Diodia teres* Walt.) and yellow foxtail (*Setaria lufescens* (weigel) Hubb.) were particularly efficient in the uptake of zinc (Zn.).

According to De and Mukhopadhyay (1983), among the rice weeds *Monochoria vaginalis* (L.) and *Ammania baccifera* (L.) were heavy feeders of nitrogen, while *Eclipta alba* (L.) Hussk. and *Monochoria vaginalis* (L.) were high phosphate consumers and *M.vaginalis* (L.) and *Ludwigia parviflora* Roxb. were high potassium absorbers.

2.1.1.2. *Soil reaction*

Soil reaction or pH is an important factor determining the weed flora of an area. LeFevre (1956) reviewed the pH tolerance of 60 weeds and grouped them into basophile (those that love high pH, such as sow thistles, green sorrel, quack grass and dandelion), acedophile (those that love acid soil, such as red sorrel and corn marigold) and neutrophile (such as shepherd's purse, prostrate knot weed and common chickweed) groups.

Studies conducted by Buchanan *et al.* (1975) with ten warm season and six cool season weed species revealed that the growth of species varied widely in response to soil pH. They observed that *Crotalaria spectabilis* Roth, *Cassia occidentalis* L. and *Digitaria sanguinalis* (L.) Scop were highly tolerant to low pH soils, whereas *Cassia obtusifolia* L., *Poa annua* L., *Geranium carolinianum* L. and *Plantago lanceolata* L. were medium to high in tolerance. *Datura stramonium* L., *Ipomoea purpurea* (L.) Roth, *Dactyloctenium aegyptium* (L.) Richter and *Sida spinosa* L. were medium to low in tolerance to low soil pH and the growth of *Desmodium tortuosum* (Sw.) DC., *Amaranthus retroflexus* L., *Stellaria media* (L.) Cyrillo, *Taraxacum officinale* (Weber), and *Brassica kaber* ((DC) L.C. Wheeler var *pinnatifida* (Stokes) L.C. Wheeler) were severely reduced in soils with low pH .

Andreasen *et al.* (1991) found that increasing pH had a positive effect on the frequencies of six weeds species while only three species were negatively affected. Increasing pH appeared to have a negative effect on the incidence of *Chenopodium album* where as decreasing pH did not significantly affect the occurrence of *Spergula arvensis.*

Information on the sensitivity of a weed species to soil pH can be utilized for managing that weed. Crafts and Robins (1962) have studied the use of liming for managing sheep sorrel. Numerous field and pot tests point to the conclusion that sheep sorrel thrives on acid soil because of the absence of competition from those plants that are more sensitive to acid soil. The value of lime in reducing sheep sorrel is that it brings chemical and physical soil conditions that favour the growth of other plants, thus increasing their ability to exclude the sorrel.

2.1.1.2.1. Response of weeds to changes in soil reaction by fertilizers

The nature of fertilizers applied influences the soil reaction· Soil acidity is increased by adding commercial fertilizers especially NH_4 – N sources that produce H^+ during nitrification whereas soil alkalinity is increased by adding the so-called "alkaline" fertilizers such as nitrate of soda (Tisdale *et al.*, 1993).

Hartwell and Damon (1917) reported that dandelions and plantains are checked by increasing the degree of soil acidity by adding sulphate of ammonia. The development of Kentucky blue grass and clover was also checked by excessive top dressing of acid fertilizers while red top and bent grasses responded more favorably to acid fertilizers. Silvertown (1980) and Tilman (1982) noticed that soil pH which changed in response to fertilization, had a great effect on diversity. In the Park Grass Experiment, the grass *Holcus lanatus* dominated the plot which was unlimed and had a pH of less than 4.0 where as *Alopecurus pratensis*, dominated the next higher pH plot and two grasses, *Alopecurus* sp and *Arrhenatherum elatius* coexisted in the plot with highest pH.

These experiments suggest that a substantial shift in soil pH may result in a change in important weed competitors with a crop. The wide pH tolerance of some species, such as showy crotalaria and large crab grass, enable them to compete with other weed species and certain crop species over a wide soil pH range (Buchanan *et al.*, 1975).

2.1.1.3. *Soil salinity*

In areas that are subjected to periodic flooding as a result of fluctuations (tidal or nontidal) in the level of adjacent water body, incursion of heavier salt water leads to soil salinity. The ionic composition of the rooting environment for plants in saline areas is dominated by sodium and chloride. The floristic communities of saline areas will be dominated by plants, which can tolerate the prevailing environmental condition. The flora of these area, termed as 'halophytes' are those species more or less restricted to salt marsh and other saline habitats and they differ from the 'glycophytes' which are more widespread in non-saline habitats but may be as salt tolerant as many members of halophytes (Adam, 1990).

The families, which account for the major part of halophyte flora are the Gramineae, Chenopodiaceae (Scott, 1977), Juncaceae and Cyperaceae (Beeftink, 1985). Members of Plumbaginaceae and Frankeniaceae, though less widespread, are highly characteristic of the halophyte flora. Adam (1990) reported that species such as *Aster tripolium, Puccinellia maritima, Sporobolus virginicus, Spartina alternifolia, Salicornia* sp, *Festuca rubra and Agrostis stolonifera* had wide geographical distribution in the saline habitats.

In the studies conducted under the AICRP on weed control, *Diplachne fusca* [*Leptochloa fusca*] was found to be the most troublesome grass weed in the rice fields of the *Pokkali* (Saline) areas of Kerala, where other weeds common in the acidic and neutral soils were absent (KAU, 1987). Ashaur *et al.* (1999) also reported the adaptation of *Diplachne fusca* to saline soils and recommended it among the halophytes for forage production in Egypt. Asharf and Yasmin (1997) found that the shoot biomass production in *Leptochloa fusca* was not affected by salinity and this species had greater shoot fresh and dry matter yields at all salinity levels compared to other grasses such a *Panicum turgidum* and *Pennisetum divisum*. Chapman and Peat (1992) observed that kallar grass (*Leptochloa fusca*) was able to remove salt from soils degraded by poor irrigation practice. Reclamation trials conducted on saline sodic soil (pH 9.1, EC: 9.8 dS/m) by Quadir *et al.* (1997) in Pakistan and Ashokkumar *et al.* (1996) in India also confirmed the utility of *Diplachne fusca* for reclamation of such soils.

2.1.1.4. *Soil moisture*

Soil moisture has great influence on the occurrence and distribution of weed species. Some weeds like *Commelina benghalensis* (tropical spiderwort) thrive in moist soil condition while perennial grasses such as *Imperata cylindrica* and *Elytrigia repens* can persist even in drought conditions. However, weeds such as *Typha* sp live only in water logged soils (Rao, 2000).

Zimdahl *et al.* (1987) reported that water supply determine weed populations in upland or lowland rice production systems. DeDatta (1981) suggested that moist or saturated soil favoured the emergence and growth of grasses and sedges, which once established are difficult to control by flooding. With direct seeding of rice under dry conditions, grass weeds are usually as abundant as the Cyperaceae and broad leaf species, whereas with transplanting or direct seeding of sprouted seeds on puddled soil, grasses decrease and sedges dominate.

Yabuno (1983) reviewed the biology of *Echinochloa* sp in rice and showed differences in their growth depend on soil water. *Echinochloa crusgalli* (L.) Beauv. emerged 100 per cent when seeded on puddled soil (Jones, 1933). When soil moisture was maintained at 70 to 80 per cent of field capacity *E. crusgalli* emerged from as deep as 10cm. Smith and Fox (1973) found that *E.crusgalli* emerged and grew well when seeded 1.3, 2.5, 5.1 or 10.2 cm deep in a silt loam at 24 per cent water (100% of field capacity) or at 34 per cent saturation.

Sumiyoshi (2000) reported that emergence of *Echinochloa colona* decreased rapidly with increasing sowing depth from 1 to 10cm in paddy fields with normal water levels. They did not emerge in flooded fields. Seedling growth was less in flooded fields than with normal water levels.

2.1.1.5. *Soil texture*

Andreasen *et al.* (1991) conducted experiments to evaluate the distribution of 37 common weed species in Danish fields in response to seven edaphic factors. The study revealed that crop type and soil clay content had the greatest influence on occurrence of the weed species. *Chenopodium album, Erodium cicutarium, Galeopsis bifida, Junaus bufonius, Myosotes arvensis, Polygonum aviculare, Senecio vulgaris, Spergula arvensis, Viola arvensis* and *Viola tricolor* spp *tricolor* were the weed species that showed increasing frequencies in response to decreasing clay content whereas the frequencies of *Galium aparine, Lamium purpureum, Silene noctiflora, Sinapis arvensis* and *Veronica persica* increased with increasing clay in the soil.

Studies conducted by Walter *et al.* (1997) also revealed the negative correlation between the density of *Viola arvensis* and clay content.

Chikoye and Ekeleme (2001) reported that *Imperata cylindrica, Talinum triangulare* and *Oldenlandia corymbosa* occurred mainly in sandy soils and in sites with a moderate length of fallow; while the species that were associated with sites having a high clay and silt content *were Ageratum conyzoides, Ludwigia decurrens, Digitaria gayana* and *Lindernia diffusa.* Mortensen and Dieleman (1997) compared the soil analysis data and occurrence of four weed species, using multivariate techniques to determine which species were associated with particular soil conditions. The results showed that *Setaria* sp were found in more elevated areas with high sand content and low organic matter, while *Helianthus annuus* and *Abutilon theophrasti* were found in areas with high organic matter. A high abundance of *Imperata cylindrica* and other weeds were observed in sandy soils.

2.1.2. Rice growing systems

Rice is mainly cultivated as direct or wet seeded rice, semidry rice and transplanted rice. The tillage and moisture status in these systems varies greatly and has profound influence on the weed flora. Weed species in rice vary with soil, system of rice culture, water management, fertility level and weed control practices. Rice fields are colonized by terrestrial, semi aquatic or aquatic plants depending on the type of rice culture and season (Moody and Drost, 1983). They ranged from 30 species in Eastern Europe (Podkin *et al.*, 1983) to about 1800 species in South and South East Asia (Moody, 1989). In a survey of South and South East Asia, Moody (1989) listed 65 species in deep water rice, 559 species in transplanted rice, 558 species in upland rice, 194 species in dry seeded rice and 180 species in wet seeded rice.

In a given environment, the weed vegetation is most strongly affected by the biotic factors and cultural practices like tillage, method of rice culture, fertilizer management, irrigation practices, cultivar grown and crop rotation (Kim and Moody, 1980).

2.1.2.1. *Wet (Direct) seeded rice*

Wet seeding or direct seeding of sprouted seeds in puddle is used as an alternative to transplanting where there is assured water supply. Direct seeding techniques cause change in composition of weed communities with the less competitive dicotyledonous weeds and sedges being replaced by competitive grasses which had previously occurred at lower abundance along the edge of direct seeded field (Moody, 1993; Ho, 1996).

Srinivasan and Palaniappan (1994) found that *Echinochloa* sp, *Cyperus difformis, Marsilea minuta* and *Eclipta alba* were the predominant weed flora in wet seeded rice in South India.

In Kerala, Joseph (1986) reported a high population of *Scirpus supines* (*Schoenoplectus lateriflorus*) (56.8 Nos per square meter) in wet sown rice, at 40 days after sowing. He also recorded *Cyperus difformis* and *Cyperus iria* as the major weeds in wet sown rice accounting for 43.4 per cent of the total weed population; *Cyperus difformis* and *Scripus supines* together constituted 79 per cent of the total weed population which included broad leaf weeds like *Sphaeranthus indicus, Sphenoclea zeylanica, Ludwigia octovalvis and Nymphaea nouchali.*

2.1.2.2. *Semi dry rice*

In semi dry rice culture, weed problems are more intense and wider in range than those in transplanted or wet seeded rice, where puddling reduces weed problems. The prevailing ecological conditions in semi-dry system encourage the growth of upland, semi-aquatic and aquatic weeds. Hence grasses and sedges predominated the weed flora of semidry rice in Kerala (Jayasree, 1987; Suja, 1989) and the most prominent among the grasses were *Isachne miliacea, Sacciolepis interrupta* and *Echinochloa colona.*

After a detailed survey of the rice growing areas of the central zone of Kerala, Thomas *et al.* (1997) reported dominance of 48 weed species in semidry rice culture. Among them 11 were grasses, 6 were sedges, 27 were broad leaf weeds and 4 were ferns. On ranking the weeds on the basis of Summed Dominance Ratio (SDR) the grass weeds *Isachne miliacea* and *Sacciolepis interrupta* constituted 23.2 per cent of the SDR values, implying their relative importance in semidry rice cultivation. *Eriocaulon quinquagulare, Ludwigia perennis, Ammania baccifera, Dopatrium junceum* and *Eriocaulon cuspidatum* were the top rankers among broad leaf weeds and among the sedges *Cyperus albomarginatus* and *Cyperus haspan* dominated.

Thomas and Abraham (1998) reported the predominance of grass weeds in semidry system and rated *Sacciolepis interrupta, Isachne miliacea, Echinochloa colona* and *Echinochloa crusgalli* as the major weeds in semidry rice culture in Kerala.

2.1.2.3. ***Transplanted rice.***

Rice is transplanted only in areas where water is copiously available. Weeds grow and infest an irrigated field if optimum water level is not maintained.

Thomas and Abraham (1998) reported *Echinochloa crusgalli, Monochoria vaginalis, Cyperus difformis, Cyperus iria, Fimbristylis miliacea, Sphenoclea zeylanica, Ludwigia perennis,* and *Marsilea quadrifolia* as the major weeds of transplanted rice in Kerala. While studying the ecological requirements of the major rice weeds in the wetlands of Kerala, Joseph (1986) found that *Scirpus supines* L. (*Schoenoplectus lateriflorus*) alone occupied 71 per cent of the total weed population in the transplanted rice. Transplanting favoured the emergence of *Schoenoplectus* *lateriflorus* but suppressed *Cyperus difformis* and *Cyperus iria* whereas *Fimbristylis miliacea* did not emerge under transplanting.

2.2. WEEDS OF MAJOR RICE TRACTS OF KERALA

Rice is grown in diverse agro ecological situations in Kerala. It ranges from purely rainfed upland crop in the hill regions of Wyanad and Idukki to the semidry crop in Palakkad and other areas during the first crop season and to the deep-water crop in the lowlying *Kole* lands of Thrissur and *Kayal* lands of Kuttanad and the coastal saline water intruded *Pokkali* lands. Weed surveys conducted under the AICRP on weed control (ICAR) in these regions showed distinct differences in the weed flora depending on the ecological situation, season and method of rice culture (KAU ,1987).

2.2.1. Kuttanad region

The Kuttanad region, covering about 875 km^2, is a unique agricultural area in the world, wherein a major portion of the area lies 1-2 m below the sea level. In Kuttanad, rice is cultivated in the Kharif as well as in the Rabi seasons. During the Kharif season, farmers go for semidry sowing or wet sowing in the upper regions, whereas during the Rabi season (the main crop season of this region, known as the Punja crop), the crop is sown as a wet sown crop only after dewatering the fields. Abraham *et al.* (1993) observed distinct differences in the intensity of weeds with the change in season as well as the method of sowing. In the kharif crop where semi-dry system of cultivation was adopted, dominance of *Isachne miliacea* and *Sacciolepis interrupta* was observed while they were less abundant in the Rabi season. *Echinochloa colona,* a major problem in Kharif season, was not at all seen in Rabi. *Echinochloa stagnina* was the most serious weed in the wet system, though it was dominant in the dry system also.

Sasidharan *et al.* (1993) reported that the floristic composition of *Kari* lands, characterized by high content of unhumified organic matter and low soil pH, was entirely different from the *Karappadam* and *Kayal* lands of Kuttanad. *Eleocharis plantaginea* was the major component of the weed spectrum of *Kari* lands which was attributed to soil characteristics, especially the low pH of the soil. *E. plantaginea* was the only species found surviving in certain patches where the rice seedlings succumbed to extremely low pH. They found a significant negative correlation between soil pH and population of *E. plantaginea.*

2.2.2. *Kole* lands

Kole region lies continuously along the coastal strips of Thrissur and Malappuram districts. The *Kole* lands, being submersible areas, only one crop of rice is taken in the summer season from November to May.

Abraham and Thomas (2002) reported 38 weed species in *Kole* lands, of which 22 were widely distributed. *Echinochloa stagnina* and *E.crusgalli* were the two important grass weeds of *Kole* lands. Other dominant weeds based on the frequency and average density values were *Fimbristylis miliacea, Cyperus iria* and *Cyperus difformis.* In general, the predominant weed flora identified were similar to that of Kuttanad rice fields (Abraham *et al.,* 1993), which have almost similar physio-chemical characteristics as that of *Kole* lands.

2.2.3. *Pokkali* lands.

The *Pokkali* lands comprise of the marshy areas along the coastal regions exposed to the tidal currents and are highly saline and acidic. Only one crop of rice is taken during the Kharif season when fresh water is available. *Diplachne fusca* was the most troublesome grass weed of the typical saline areas of *Pokkali* having a frequency of more than 75 per cent (KAU, 1987). The other major weeds occurring in this area were *Echinochloa crusgalli* (frequency 44.4%), *Eleocharis* sp (33.3%), *Monochoria vaginalis, Nymphaea* sp, *Salvinia molesta, Hydrilla verticillata, Pistia stratiotes, Ceratopteris thalictroides, Sphaeranthus indicus, Sphenoclea zeylanica* and *Ludwigia* *parviflora*. In the fresh water areas of *Pokkali* region, the major weeds identified were *Isachne miliacea, Sacciolepis interrupta, Eleocharis sp, Ludwigia parviflora, Eichhornia crassipes, Limnocharis flava* and *Marsilea quadrifolia.*

2.2.4. Palakkad region

This region is situated in the central zone of Kerala and is the main rice bowl of Kerala. Here during Kharif season, most of the rice is raised as semidry (dry sown) crop. During the Rabi season the crop is either transplanted or wet sown, utilizing the irrigation water.

In the dry sown uplands of Palakkad region, the predominant weeds are *Sacciolepis interrupta* (SDR-10.5), *Isachne miliacea* (6.6), *Cyperus iria* (4.8), *Echinochloa crusgalli* (4.3) and *Ludwigia parviflora*(3.6) (KAU,2000).

2.2.5. Low rainfall zone (Chittur)

This zone represents the low rainfall, drought prone, rain shadow region situated in Chittur taluk in the Kerala – Tamil Nadu border. The soil is mainly loamy and sandy clay in texture. Black cotton soils occur in some areas of Chittur taluk where the soil reaction crosses over the neutral range, and in most places, it is alkaline in reaction.

The major weed flora of the transplanted rice of this zone were *Leptochloa chinensis, Sacciolepis interrupta, Echinochloa crusgalli, Oryza rufipogon, Cyperus iria, Cyperus pangorei, Fimbistylis miliacea, Ludwigia parviflora, Sphenoclea zeylanica* and *Marsilea quadrifolia* (KAU, 1990).

The above review indicates the importance of various edaphic and cultural practices in shaping the weed flora of crop lands. The differential response between crops and weeds to these factors could result in specific competitive advantage for one or the other species.

2.3. METHODOLOGY FOR WEED VEGETATION ANALYSIS

The terms diversity, ecological diversity, species diversity, biological diversity and biodiversity all refer to the variety and abundance of species at a specified place and time. Diversity is a concept that is intuitively easy to understand but remarkably difficult to quantify (Calow, 1998). This is because diversity consists of not one but two components: Species richness, ie., number of species and equitability (evenness), which is a measure of how equally abundant those species are.

Harper (1977) conceived that microsite diversity in plant population is due to the following dimensions.

a. Diversity dependent on the use of different resources, eg: differential use of nitrogen by a community of grass and legumes.
b. Diversity dependent on lateral heterogeneity of environment (eg: spatial variability of soil gradients in a field such as pH or moisture availability).
c. Diversity dependent on vertical heterogeneity of environment (soil depth)
d. Diversity dependent on temporal division of the environment (eg: seasonal variations in growth, flowering

Whittaker (1972) classified the spatial measures as alpha, beta and gamma diversity, where

α diversity: the diversity of species within a community or habitat.

ß diversity: a measure of the rate and extent of change in species along a gradient from one habitat to others.

γ diversity: the richness in species of a range of habitats in a geographical area (eg: island), which is a consequence of the α

diversity of the habitats together with extent of ß diversity between them.

2.3.1. Diversity indices

Measures of species diversity play a central role in ecological studies. A diversity index is technically a numerical expression or descriptive statistic that summarizes certain properties of data sets and that can be used to compare the diversity of different groups of organisms within a community or between different communities themselves (Calow, 1998). Magurran (1988) has classified the diversity indices into three major groups as described below.

1. Species Richness Measures

As a measure of diversity, species richness provides an instantly comprehensible expression of diversity. Species density is the most commonly used measure and is given as the number of species per specified collection area. A number of easy to calculate indices have been derived using a combination of the species (S) and total number of individuals (N) sampled. Margalef's diversity index (Margalef, 1968) is the best known. However, these indices are all arbitrary measures strongly influenced by sample size and thus little used today (May, 1975).

2. Species – abundance models with an associated diversity index

In this group the major diversity measures are the

Log series index alpha (Fisher *et al.*, 1943)

Log normal index (Preston, 1948)

Q Statistic

These are quite complex and are not widely used.

3. Indices based on proportional abundance of species

These diversity indices are a function of species richness and evenness. Diversity can thus increase as evenness increase while species richness actually falls slightly. The various indices under this group are discussed below.

2.3.1.1. *Simpson's diversity index (D)* (Simpson, 1949)

The simplest measure of the character of a community that takes into account both the abundance pattern and the species richness is Simpson's diversity index. Thus for a given richness, D increases with equitability, and for a given equitability, D increases with richness. It is also possible for a species rich but inequitable community to have a lower index than one that is less species rich, but highly equitable. The value of this index ranges from one to the total number of species (S). An index of one indicates that all of the individuals in the area belong to a single species, when D=S every individual belongs to a different species.

2.3.1.2. *Shannon Diversity Index (H)*

This is also referred to as Shannon Wiener index. It is the most commonly used index in ecological studies owing to the fact that it is dimensionless, independent of sample size and expresses the worth of each species (Kochsiek *et al.,* 1971). This index is a unique indicator of environmental stress as the sensitive species gradually shift or get eliminated from a habitat with the increase in the magnitude of environmental stress (Wilhm and Dorris, 1968). A decrease in the value of this index indicates an increase in the magnitude of environmental stress on the species (Cairns and Dickson, 1971).

2.3.1.3. *Brillouin Index* (Brillouin, 1960)

This is closely related to the Shannon index and is only appropriate where the community is completely censussed with every individual accounted for.

2.3.1.4. *Evenness Index*

As diversity is at the maximum when all species within a community are equally abundant, a measure of evenness is the ratio of the observed diversity to the maximum possible for the observed species number (Southwood and Henderson, 2000). It is a measure of the uniformity of different species in a community and the value increases as the environment becomes favourable for a number of species (Mitra, 2000).

2.3.1.5. *McIntosh Index* (McIntosh, 1967)

This is a little known index that was derived as a measure of dissimilarity between two communities. The value of this index ranges from 0 to 1.

2.3.1.6. *Sequential Comparison Index* (Cairns *et al.*, 1968)

It is used to estimate the relative differences in biological diversity and is based on the chance of any one individual being the same species as the previous individual in a sample. The value of this index varies from near zero (where all individuals selected are identical) to one (where each individual selected is different from the previous one).

2.3.1.7. *Berger – Parker index (d)* (May, 1975)

This is a simple dominance measure that is easy to calculate

$d = N_{max}/N$

where N_{max} is the number of individuals in the most abundant species. Diversity is usually expressed as 1/d, such that the value increases as diversity increase and dominance reduces. This index is independent of species richness but is influenced by sample size.

2.3.1.8. *Co-efficient of similarity*

Two communities, geographically wide apart from each other may also show similarity with respect to their species composition (Mitra, 2000). This similarity arises due to the closeness of two habitats with respect to environmental characteristics. The co-efficient of similarity value varies from zero for communities having no species in common to 100 per cent for communities identical both in species composition and in quantitative values for the species (Raju, 1997).

The indices discussed above are useful for analyzing the changes in the flora of an area in response to variability of spatial or temporal nature. Of these indices, the Simpson's diversity index (D), Shannon index (H), Evenness index (E) and Co-efficient of similarity(C) are widely used as they are easy to calculate and are able to discriminate communities based on richness or dominance of the species present.

2.4. INFLUENCE OF SOIL FERTILITY ON SOIL MICRO FLORA.

A multitude of different microbial species is present in most soils. Microorganisms exert profound and varied effects on plant growth and reproduction (Westover *et al.*, 1997). The soil environment can have a direct influence on the type and number of microorganisms that will colonize the root, survive, grow and affect plant growth. Understanding how microorganisms are influenced by their environment is an important aspect of rhizosphere microbial ecology and will assist in identifying soil microbial technologies suitable for manipulating the rhizosphere microflora. Organic matter content of the soil is well known to affect the activity of soil microbial populations (Insam and Domsch, 1988). The fertility status of the soil also affects the microbial population in various ways.

The influence of fertilization on grassland fungi was experimentally studied by Lange (1982). He compared the effects of $Ca(NO_3)_2$, P_2O_5 and K_2O in different combinations in plots with recently sown monocultures of grasses on a moraine clay. Phosphorus and potassium application did not show significant effects, but nitrogen fertilization had a significant positive effect on species diversity: an average of 9.7 species in treated plots against 4.0 species in untreated plots. Nitrogen also influenced the species composition. Lange (1982) regarded 24 species as nitrophilous, 10 as nitrophobous and six as indifferent.

Bissett and Parkinson (1979) reported that difference in the mycoflora of alpine tundra sites were due to pH effects and difference in nitrogen content. Studies conducted to find out the relationship between forest soil micro fungi and their environment had clearly shown the importance of temperature, moisture, potassium, nitrogen and to a lesser extent, pH, as important aspects of the environment influencing the fungal community (Widden, 1986).

Guillemat and Montegut (1956), using dilution plates, found fertilization of agricultural soils with NPK and stable manure to stimulate some fungal species. The effects of NPK was less pronounced than those of manure. Tripathi and Upadhyay (2001) positively correlated the proliferation of soil microbes with the availability of fertilizer nutrients. They found a marked increase in the soil microbes by the application of nitrogen and potash.

MATERIALS AND METHODS

3. MATERIALS AND METHODS

This study on the distribution, characterization and dynamics of weeds in the various rice ecosystems of Kerala was carried out at the Department of Agronomy, College of Horticulture, K.A.U, Thrissur during 2000-2002. The investigations pertaining to the study were grouped into two separate experiments.

1) Influence of soil fertility on weeds and soil micro flora
2) Influence of agroecological conditions on weed flora

The materials used and methods employed for the study are discussed below.

3.1. INFLUENCE OF SOIL FERTILITY ON WEEDS AND SOIL MICRO FLORA:

Observations from the Permanent Manurial Trials being conducted at Rice Research Station (RRS), Kayamkulam, Rice Research Station (RRS), Moncombu and Regional Agricultural Research Station (RARS) Pattambi were the basis of this study. Details of these trials are given in the Table1 and Appendix I.

Table 1.Details of PMTs in rice (in K.A.U.)

Location	RRS Kayamkulam	RRS Moncombu	RARS Pattambi
Year of Start	1964	1987	1973
Soil Textural Class	Loamy sand	Alluvial clay loam	Alluvial clay
Plot Size	8 X 4 m^2	8 X 5 m^2	7.8 X 5.25 m^2
No. of treatments	8	10	8
No. of replications	4	3	4
Design	Randomized Block Design	Randomized Block Design	Randomized Block Design
Spacing	20 X 15 cm	20 X 10 cm	15 X 15 cm
Variety	Bhagya	Pavizham	Jyothi

3.1.1. Treatment Details

3.1.1.1. *PMT at Rice Research Station (RRS), Kayamkulam.*

T_1: N 80 kg ha $^{-1}$ as Cattle manure.

T_2: N 80 kg ha $^{-1}$ as Ammonium sulphate.

T_3: N 80 kg ha $^{-1}$ as Ammonium sulphate + P_2O_5 40 kg ha $^{-1}$ as Single Super Phosphate.

T_4: N 80 kg ha $^{-1}$ as Ammonium sulphate + K_2O 40 kg ha $^{-1}$ as Muriate of Potash

T_5: P_2O_5 40 kg ha $^{-1}$as Single Super Phosphate + K_2O 40 kg ha $^{-1}$as Muriate of Potash

T_6: N 80 kg ha $^{-1}$ as Ammonium sulphate + P_2O_5 40 kg ha $^{-1}$as Single Super Phosphate + K_2O 40 kg ha $^{-1}$as Muriate of Potash

T_7: N 80 kg ha $^{-1}$ (N 60 kg ha $^{-1}$ as Ammonium sulphate + N 20 kg ha $^{-1}$ as Farm Yard Manure)+ P_2O_5 40 kg ha $^{-1}$ as Single Super Phosphate + K_2O 40 kg ha $^{-1}$ as Muriate of Potash

T_8: Control

3.1.1.2. *PMT at Rice Research Station (RRS), Moncombu*

T_1: Absolute Control.

T_2: Control

T_3: N 90 kg ha $^{-1}$ as Urea

T_4: N 90 kg ha $^{-1}$as Urea + P_2O_5 45 kg ha $^{-1}$ as Mussooriphos

T_5: N 90 kg ha $^{-1}$as Urea + K_2O 45 kg ha $^{-1}$ as Muriate of Potash

T_6: P_2O_5 45 kg ha $^{-1}$as Mussooriphos + K_2O 45 kg ha $^{-1}$ as Muriate of Potash

T_7: N 90 kg ha $^{-1}$ as Urea + P_2O_5 45 kg ha $^{-1}$as Mussooriphos + K_2O 45 kg ha $^{-1}$ as Muriate of Potash

T_8: N 90 kg ha $^{-1}$as Urea + P_2O_5 45 kg ha $^{-1}$as Mussooriphos + K_2O 45 kg ha $^{-1}$ as Muriate of Potash + 600 g lime

T_9: Fertilizer application as per soil test + Farm Yard Manure (3 tons)

T_{10}: Fallow

3.1.1.3. *PMT at Regional Agricultural Research Station (RARS), Pattambi*

T_1: N 90 kg ha $^{-1}$ as Cattle manure

T_2: N 90 kg ha $^{-1}$ as Green leaf manure

T_3: N 90 kg ha $^{-1}$ (50% as Cattle manure + 50% Green leaf manure)

T_4: N 90 kg ha $^{-1}$ as Ammonium sulphate

T_5: N 90 kg ha $^{-1}$ (50% as Cattle manure + 50% as Ammonium sulphate or Urea)+ P_2O_5 45 kg ha $^{-1}$ as Single Super Phosphate or Mussoori rock phosphate + K_2O 45 kg ha $^{-1}$ as Muriate of Potash

T_6: 50% N as Green leaf manure + N, P, and K doses as in T_5

T_7: 25% N each as Cattle manure and Green leaf manure + N, P and K doses as in T_5

T_8: N 90 kg ha $^{-1}$as Ammonium sulphate or urea + P_2O_5 45 kg ha $^{-1}$ as Single Super phosphate or Mussoori rock phosphate + K_2O 45 kg ha $^{-1}$ as Muriate of Potash.

3.1.2. Observations

Observations on weeds were taken form the Permanent Manurial Trials during the Kharif, Rabi and summer seasons at RRS, Kayamkulam and RARS, Pattambi. At RRS, Moncombu these observations were taken during the kharif and Rabi seasons only, as the field has flooded condition and no crop is taken during summer season. The observations were taken at the 20^{th} day of sowing (before giving any weed control operations).

3.1.2.1. *Weed Count*

In each plot, the weeds were sampled from three spots using a quadrat of 0.5 m X 0.5 m size. The species wise count of weeds from each spot was taken and expressed in number per square metre (no/m^2).

3.1.2.2. *Weed Dry Weight*

The weeds from the observational area were uprooted, cleaned and separated species wise and dried in a hot air oven at 80± 5°C and the dry weight was recorded as gm^{-2}.

3.1.3. Plant Analysis

Weed samples were collected from the different treatments and were oven dried at 80±5°C and ground in a wiley mill. Before the actual weighing for analysis, it was once again oven dried. The method used for the analysis of different nutrients are given below in Table 2.

Table 2. Methods used for analysis of plant samples

Nutrient	Digestion Procedure	Method of estimation	Reference
N	H_2SO_4 digestion	Distillation and titration	Jackson(1973)
P	2:1 HNO_3-HClO diacid digestion	Vanado Molybdate yellow colour method using Spectrophotometer.	"
K	"	Direct reading using Flame photometer	"
Ca, Mg	"	Titration using EDTA	Page (1982)
S	"	Turbidimetry method using Spectrophotometer	Hart (1961)
Zn, Mn	"	Direct reading using Atomic Absorption Spectrophotometer	Page (1982)

3.1.4. Estimation of soil micro flora

The influence of soil fertility on soil micro flora was studied by estimating their counts in the soil samples collected from the plots of the Permanent Manurial Trial at Rice Research Station, Kayamkulam. Using a core sampler, soil samples (15 cm depth) were taken from three random spots in each plot on 18 th day after transplanting of rice. The samples taken from all the three replications were pooled treatment wise and air-dried. Serial dilution plate technique (Johnson and Curl, 1972) was employed for determining the population of microorganisms in the soil. One gram of the pooled sample was diluted with water at a dilution of 10^{-3} for fungi, 10^{-4} for actinomycete and 10^{-6} for bacteria and replicated three times. They were separately plated on enrichment media designed to promote these organisms. Martin's Rose Bengal Streptomycin agar, Thortan's Standardized agar and Kenknight's agar were used for estimation of fungi, bacteria and actinomycetes. respectively. The samples were incubated at room temperature and the count was taken on the 3^{rd} day for bacteria, 5^{th} day for fungi and 7^{th} day for actinomycetes. The values were subjected to square root transformation for statistical analysis.

3.1.5. Statistical analysis

Analyses of variance were performed on the data collected from the Permanent Manurial Trials, using the statistical package 'MSTAT' (Freed, 1986). Data on weed count and weed biomass that showed wide variation were subjected to square root transformation ($\sqrt{x} + 0.5$) to make the analysis of variance valid (Gomez and Gomez, 1984). Comparisons among treatment means were done by using Duncan's Multiple Range Test (DMRT).

3.2. INFLUENCE OF AGROECOLOGICAL CONDITIONS ON WEED FLORA

A survey was conducted across the major rice growing regions of Kerala to know the influence of soil conditions, seasonal variation and method of growing rice on the associated weeds. The sites selected for survey were rice fields of the following areas (Fig.1).

1. *Kole* lands (Thrissur District)
2. *Kari, Karappadam* and *Kayal* lands of Kuttanad (Alappuzha and Kottayam Districts)
3. *Pokkali* lands (Ernakulam District)
4. Palakkad region (Palakkad District)
5. Chittur Thaluk (Palakkad District)

Twenty locations were surveyed in each region (listed in Table 3).

3.2.1. Major rice ecosystems of Kerala

3.2.1.1. *Kole Lands*

The *Kole* lands which form the rice granary of Thrissur and Malappuram districts comprise of a unique ecosystem in Kerala. These are low lying tracts extending over an area of 13,000 ha and is located 0.5 to 1m below mean sea level. The major portion of the area lies submerged for about six months in a year by the periodical inundation of floodwater.

Acidity, salinity, poor drainage and presence of toxic salts make soils of this tract very unique. The soils are heavy in texture with large proportion of clay and organic matter in the range of 1.97 to 5.58 per cent. The soils of *Kole* lands are generally acidic with pH ranging from 2.6 to 6.3. The electrical conductivity varies from 0.16 to 15 dS/m. The high values observed are mainly in areas vulnerable to seawater inundation. The physico-chemical characteristics and morphology of the

Fig. 1. Map of Kerala showing the major rice ecosystems

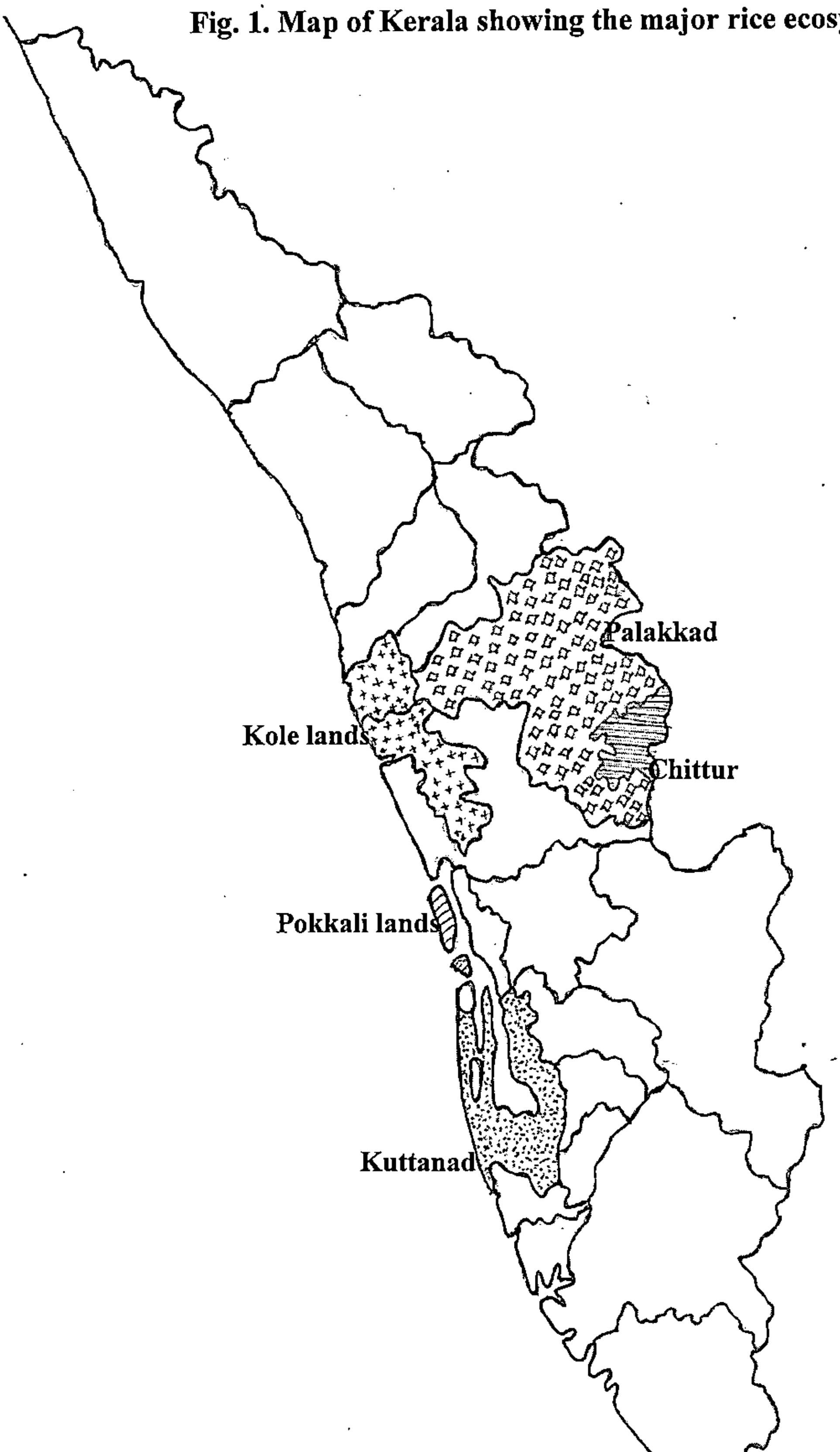


Table 3. Sites of weed survey in rice, the ecosystems of Kerala

Sl No.	Kole lands	Kari	Karappadam	Kayal	Pokkali lands	Palghat region	Chittur Taluk
1	Adat	Ambalapuzha	Ayamkudi-1	Arayiram kayal-1	Alangad	Alathoor-1	Alankodu
2	Alappad	Arpookara	Ayamkudi-2	Arayiram kayal-2	Cheraikkom	Alathoor-2	Ambalathupalayam
5	Anchumuri padavu	Kaippuzhamuttu	Changanassery-2	C block-1	Cherakk	Chithali-1	Ananthodu
3	Arimpur	Kaipuzha	Changanassry-1	C block-2	Deevasom padam	Chithali-2	Arandapallam
4	Avinissery	Kallara	Edathua-1	D block-1	Edapaily	Kanakkanoor	Arikode
6	Chazhur	Karumadi	Edathua-2	D block-2	Edavanakkad	Kannambra panchayat	Chittur
8	Cheruvathoor	Kavilppadam	Kedangara-1	Kaeneri	Elamkunnapuzha	Modappalur	Kakayoor
9	Chettupuzha	Kayamkari	Kedangara-2	Mangalam kayal-North	Kadamakuzhy	Naripotta	Koduvayoor
7	Chittilapally	Madhuraveli	Kumaranalloor-1	Mangalammkayal-south	Karappuzhapadam	Pallipuram	Kollamkodu
10	Karatte	Mampuzhakkari	Kumaranalloor-2	Manikyamangalam-1	Kumbalam	Panayoor	Mettupalayam
11	Krishnankota	Mannanam	Mancombu	Manikyamangalam-2	Munampu	Pandalampadam	Mulliringi
12	Manakody	Neendur	Mitrakkari-1	Manimangalam North	Nayarambalam	Panthaparampu	Muthalamada
13	Nedupuzha	Pulinkunnu	Mitrankari-2	Manimangalam-west	Njarakkal	Polpulli-1	Nallepalli
18	Padinjaremuri	Puthukkari	Muttar-1	Marthandam kayal-1	Pallippuram	Polpulli-2	Nathukallu
15	Palaikkal	Thakazhi-1	Muttar-2	Marthandam kayal-2	Paravoor	Ponniyamkara	Palapallam
14	Parpoor	Thakazhi-2	Pallikuttuma	Mathikayal-North	Thevarkadu	Thripalur	Ponniperunthalam
17	Pozhaikkal	Thalavadi	Ramankari-1	Mathikayal-south	Thundathum kadavu	Vadakkencheri-1	Puthunagaram
16	Pullazhi	Vechur-1	Ramankari-2	Moovayiram kayal -1	Varappuzha	Vadakkencheri-2	Tattamangalam
19	Vari	Vechur-2	Vazhapally-1	Moovayiram kayal-2	Vypeen	Vandithavalam	Vandithavalam
20	Variampadavu	Veyappra	Vazhapally-1	Nalayiram kayal	Vyttila	Vilayode	Vithanasseri

soils of *Kole* lands reveal close similarities to those of *Kari* soils of Kuttanad (Johnkutty and Venugopal, 1993)

Two crops of rice are being grown in the *Kole* lands one in the Punja season of January-May and the other during the Mundakan season of September-December.

3.2.1.2. *Kuttanad Region*

Kuttanad, the rice bowl of Kerala, forming the interface of marine, estuarine and fluvial systems represents a highly complex ecosystem. It is a deltaic formation of four river systems together with the low-lying areas in and around Vembanad lake. The whole of Kuttanad area practically lies 1-2.5 m below mean sea level, and is subjected to continued flood submergence during the monsoon. Saline water ingression is a problem during the summer months. The soils of Kuttanad area are grouped into three categories, namely the *Kari* lands, *Kayal* lands and the *Karappadam* lands.

3.2.1.3. *Kari Lands*

Kari Lands are confined to certain pockets in a non-contiguous manner along the coastal plains adjoining the backwaters in Alappuzha and Kottayam districts covering an area of about 20,000 ha. The soils are characterized by deep black colour, heavy texture, poor aeration, bad drainage and low contents of available plant nutrients. They are affected by saline water incursion with consequent accumulation of soluble salts. They are also highly acidic in reaction. The presence of large quantities of organic matter that have resisted decomposition for long time and high acidity in spite of large accumulation of calcareous lime shells, are some of the peculiar characteristics of *Kari* soils. The pH of air-dried samples ranged from 2.8 to 5.3 (Koshy, 1970). The specific conductance of *Kari* soils varied from 4.6 to 6 $dS^{-1}m$ and organic matter content varied widely from 5.35 to 17.55 per cent.

During the early years of rice cultivation in *Kari* lands, only one crop was taken (in two or three years). At present an additional crop is also being raised during May-June to August-September in places where better water management facilities exist.

3.2.1.4. *Karappadom Lands*

Karappadom lands occur along the inland waterways and rivers and form the major part of upper Kuttanad. They cover an area of about 41,000 ha in Alappuzha and Kottayam districts. These riverine alluvial soils are very deep, poorly drained, dark grey in colour with clay loam surface texture. Soils are characterized by high acidity, high salt content and a fair amount of decomposing organic matter.

Among the chemical properties, pH of the fresh soil samples varied from 3.8 to 5.7 and that of dry samples from 2.8 to 5.5 (Padmaja *et al*, 1994). These soils recorded an EC of 2.4 to 3.6 dSm^{-1} at 25°C. Available N, P_2O_5 and K_2O ranged from 114 to 218, trace to 14 and 56 to 113 kg ha^{-1}, respectively.

The entire area in the zone is under rice during Punja season. In some areas, an additional crop of paddy is also taken from April-May to August-September.

3.2.1.5. *Kayal Lands*

Kayal lands extending over an area of 8,000 ha constitute about 14.3 per cent of the total area of Kuttanad. These are found in the reclaimed lakebeds in Kottayam and Alleppy districts. The fields are submerged 1.5 to 2.0 m below mean sea level for a period of 5 to 6 months in a year. These soils are more severely affected by salinity than other soil types of Kuttanad, and crop failure is a common feature. Intrusion of seawater is prevented to a certain extent by the construction of the permanent bund between Vechoor and Thanneermukkam in Shertalai thaluk and two crops are being raised in many places.

The pH of the air dried soils varied form 4.5 to 6.9 and that of submerged soils ranged from 5.0 to 7.1 (Padmaja *et al.*,1994). The electrical conductivity ranged from 2.6 to 3.9 dSm^{-1} at 25°C. The soil was low in available nitrogen and phosphorus but was comparatively rich in potassium.

3.2.1.6. *Pokkali Lands*

Pokkali soils are low lying acid saline marshes found near the mouth of streams and rivers situated near the Arabian Sea. They are subjected to tidal waves and periodical inundation by saline water. In their natural state this area is over grown with mangrove and other salt loving vegetation. The *Pokkali* lands, known after the *Pokkali* type of cultivation, is located in the coastal areas of Ernakulam and Thrissur districts mostly distributed in Cochin, Kanayannur, Paravoor, Thrissur and Kodungalloor thaluks.

Soils of *Pokkali* lands are deep, impervious and clayey in texture, and rich in organic matter. The soil is very low in phosphorus, medium in nitrogen and high in potash. These are normally acidic soils with a pH ranging form 3.0 to 6.8 in spite of high conductivity (Nair and Money, 1972). Most of these soils had EC value higher than 14 dSm^{-1}. More than 90 per cent of single crop *Pokkali* lands are cultivated during first crop season (Virippu) from May-June to September-October. During the rest of the year, the land is under fishing and prawn culture.

3.2.1.7. *Palakkad*

The Palakkad area comprises 23 per cent of the rice area of the state. The major five rice growing areas in Palakkad are 1)Palakkad 2)Chittur 3) Alathur 4)Koyalmannam and 5) Nemmara, located in three taluks, viz; Palakkad, Alathur and Chittur. The soils are relatively old and formed as a result of weathering of gneissic rocks. These soils are deep to very deep, moderately to excessively drained with moderate permeability. The textural range noticed is from loam to gravelly silty clay loam and colour varies from black to dark reddish brown (KAU, 1989). Two crops of rice are mainly taken in this region. The first crop (May to September) is mainly grown as a semidry crop with sowing done in moist soil on receipt of pre-monsoon showers. The second crop is an irrigated crop sown as transplanted in puddled soils.

3.2.1.8. *Chittur (Low Rainfall Zone)*

Chittur taluk of Palakkad district is the low rainfall, drought prone region of Kerala. It is the only area in Kerala where black soils are found. They occur in patches and are considered as extensions of the black cotton soils of adjacent Coimbatore district . These soils are dark in colour, low in organic matter, calcareous, moderately alkaline, high in clay content and cation exchange capacity, and are very sticky and plastic. They are generally located in gently sloping to nearly level lands. These soils are deficient in nitrogen and phosphorus but have moderate levels of potassium and calcium (KAU, 1989). Two crops of rice are normally taken in this area. The first crop is a semidry crop and the second crop is an irrigated crop sown/transplanted in puddled soil.

3.2.2. Procedure for survey

In each rice ecosystem, 20 sites (in farmers field) were selected where most of the common weeds of region were present indicating that the farmer has not adopted proper weed management. Fields with very low weed intensities were avoided for the survey. In each field species wise count of weeds where taken from 3 spots using a quadrat of 1m x 1m size and the mean was recorded. In Palakkad and Chittur usually two crops are taken in most of the areas. Therefore in these regions, surveys were conducted in two crop seasons-first crop season (Kharif) and second crop season (Rabi).

3.2.3. Study of weed vegetation parameters

To understand the distribution and dynamics of the weeds, weed vegetation parameters such as frequency, density, relative frequency, relative density and relative importance value were worked out as suggested by Wentworth *et al.* (1984). These values were calculated separately for each region or agroecological condition.

$$\textbf{Density} = \frac{\text{Total count of the species from all sites}}{\text{No. of sites where the species is present}}$$

$$\textbf{Frequency} = \frac{\text{No. of sites where a particular species occurred}}{\text{Total number of sites surveyed}} \times 100$$

$$\textbf{Relative Density} = \frac{\text{Density of a species}}{\text{Total density of all species}} \times 100$$

$$\textbf{Relative Frequency} = \frac{\text{Frequency of a species}}{\text{Total frequency of all species}} \times 100$$

$$\textbf{Relative Importance Value} = \frac{\text{Relative density} + \text{Relative frequency}}{2}$$

3.2.3. Weed Vegetation Analysis

Weed vegetation analysis was done using different indices to quantify the diversity as well as evenness of weed flora in each region. The details of different indices worked out are given below.

Species Richness (S)

Total no. of species present in the community.

Simpson's diversity index (D) (Whittaker, 1972)

$$D = 1 / \sum_{i=1}^{S} pi^2$$

where S=total number of species in the community (ie., Richness)

pi=Proportion of the total number of individuals composed of species i.

Shannon's diversity index (H) (Magurran, 1988)

$$H = -\sum_{i=1}^{s} p_i \ln p_i$$

where p_i= Proportion of the total number of individuals composed of species i.

l_n= natural logarithm

Evenness index (J) (Brower and Zar, 1977)

$J=H/\ln S$

where H=Shannon's diversity index

S=total number of species in the community

l_n= natural logarithm

Coefficient of similarity (C) (Pablico and Moody, 1983)

The degree of similarity in terms of floristic composition between two communities that are geographically wide apart is expressed by Coefficient of similarity. Coefficient of similarity is a simple measure to the extent to which two habitats have species in common.

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

where A and B are the quantities of all the species found in each of the two habitats to be compared and W is the sum of the lesser values for the species, common to two habitats.

Dissimilarity coefficient (d)

Coefficient of similarity was converted into dissimilarity coefficient (d) by the equation

$d=100-C$

where C is the Coefficient of similarity. The value of 'd' ranges from zero for communities identical both in species composition and in quantitative values for the species to 100 per cent for communities having no species in common.

Dissimilarity diagram

The Dissimilarity between different localities was represented schematically so that the dissimilarity coefficient value of the two ecosystems represented the distance between them and as the distance increased the region varied widely with respect to their floristic composition. The dissimilarity diagrams were prepared only for the community of grass weeds as they alone showed distinct difference between the habitats.

Cluster analysis

The cluster analysis seeks to identify habitats that are similar in species composition. When a number of sites or species are to be compared, the dissimilarity coefficient values are entered in a matrix and cluster analysis was done to produce a hierarchical classification of the various rice ecosystems of Kerala as per the procedure suggested by Sneath and Sokal (1973). The results from the cluster analysis were used to form a dendrogram to show the similarity between the different sites. The dendrogram illustrates the order in which the groups had been formed. The ordinate indicates the distance scale at which the clusters are formed.

3.2.5. Anatomical studies

To understand the adaptive mechanisms of specific weeds, to different soil conditions anatomical studies were performed on individual weed species. Cuttings of the flag leaf of the grass species *Diplachne fusca* and *Echinochloa crusgalli* were taken and preserved in FAA. Free hand sections were taken from these cuttings, stained with saffranine and mounted in DPX after washing in alcohol series. The sections were observed under microscope and photographs were taken.

RESULTS

4. RESULTS

Observations on weed flora in the Permanent Manurial Trials in rice in Kerala Agricultural University as well as surveys of the various rice ecosystems of Kerala, were made during the years 2000-2002, to understand the dynamics of weeds with changes in soil fertility and reaction. The data generated from the experiments and surveys are presented and described in this chapter, after appropriate statistical analyses.

4.1 INFLUENCE OF SOIL FERTILITY ON WEED FLORA

4.1.1. Permanent Manural Trial at RRS, Kayamkulam.

The data on the count of weeds in the PMT, Kayamkulam during the Kharif season is given in Table 4. *Echinochloa* sp and *Isachne miliacea* were the two grass weeds present in the field. Higher populations of *Echinochloa* sp were seen in the plots where all the major elements (NPK) and or FYM were applied. Among the three major elements, absence of P or K resulted in more decline in the population than the absence of N. On the other hand, for *Isachne miliacea*, deficiency of N is more critical than P or K as indicated by the very low population of the weed in 'N_0' plots (T_8, T_5) and the highest population in NK plots (T_4) followed by N alone (T_2).

Bulbostylis sp, *Fimbristylis* sp, *Scirpus juncoides* and *Cyperus* sp were the sedges present in the plot. The population of *Bulbostylis* sp was higher in treatments receiving all the three elements (T_6 and T_7) where as *Fimbristylis* sp has higher population in treatments where either of the three major elements (N, P, K) was absent (T_3, T_4 and T_5). The population of *Cyperus* sp does not show any clear response to the treatments. *Scirpus juncoides* population was lower in plots receiving 'P' (T_3, T_5, T_6, and T_7), while applications of N alone (T_2) or N and K (T_4) recorded higher population.

The major broad leaf weeds noticed in the field were *Aeschynomene indica*, *Ammania* sp, *Ludwigia parviflora* and *Monochoria vaginalis*. The population of *Aeschynomene indica*, was distinctly higher in plots deficient in N but supplied with P and K (T_5). The population of *Ludwigia parviflora* was higher in plots amended with organic matter (T_1 and T_7). *Monochoria vaginalis* also showed a similar trend to organic matter supply in addition to an increase in population due to the supply of N and P (T_3, T_6 and T_7)

Table 5 shows data on the count of weeds during the Rabi season. During this crop season also, the grass weeds *Echinochloa* sp and *Isachne miliacea* followed the same trend of the first crop season. The population of both grasses were high in the NPK treatments or treatments involving FYM (T_1, T_6 and T_7). Here also the population of *Echinochloa* sp was found to be more sensitive to absence of P and K than N, whereas *Isachne miliacea* was found to be more sensitive to lack of N than P or K.

Among the sedges, only *Scirpus juncoides* showed a definite trend to nutrient supply, similar to the first crop season. In the second season also, *Scirpus juncoides* population was higher in plots, which did not receive phosphorus.

In the second crop season also the weeds *Aeschynomene indica*, *Ludwigia parviflora* and *Monochoria vaginalis* showed the same trend of the first crop season. *Aeschynomene indica* population was the highest in T_5, which received P and K (no N). *Ludwigia parviflora* and *Monochoria vaginalis* was higher in plots receiving FYM application (T_1 and T_7). In addition, *M. vaginalis* population was high in plots receiving N and P application (T_3 and T_6) also.

Dry matter production of weeds at PMT Kayamkulam during the Kharif season is given in Table 6. In the Kharif season, the dry matter production of *Echinochloa* sp. followed the same trend of the weed count. The maximum dry weight of *Echinochloa*

Table 4. Effect of treatments on weed flora (no/m^2) in the PMT at RRS, Kayamkulam (first crop season, 2001)

Treatments	*Echinochloa.*	*Isachne*	*Bulbostylis*	*Cyperus*	*Fimbristylis*	*Scirpus*	*Aeschynomene*	*Ammania*	*Lindernia*	*Ludwigia*	*Monochoria*
T_1 CM	3.033 ^{*a} (9)	4.266 ^{b} (18.75)	2.869 ^{ab} (9)	0.707 ^{c} (0)	0.707 ^{b} (0)	2.82 ^{b} (12)	0.707 ^{b} (0)	3.037 ^{a} (15)	0.707 ^{a} (0)	4.375 ^{ab} (20.75)	5.655 ^{ab} (38.25)
T_2 N	1.346 ^{bc} (1.5)	5.528^{ab} (30.75)	2.432 ^{ab} (5.75)	0.707 ^{c} (0)	0.707 ^{b} (0)	13.067 ^{a} (190.75)	0.707 ^{b} (0)	1.55 ^{ab} (2.75)	0.707 ^{a} (0)	1.592 ^{cde} (3)	1.215 ^{c} (1.75)
T_3 NP	1.689 ^{b} (2.75)	4.302 ^{b} (16.75)	1.837 ^{b} (4.75)	0.707 ^{c} (0)	2.417^{ab} (9)	4.032 ^{b} (17.25)	0.926 ^{b} (0.5)	2.666 ^{ba} (8.5)	0.707 ^{a} (0)	3.325 ^{bcd} (10.75)	5.97 ^{ab} 35.75
T_4 NK	1.724 ^{b} (3)	6.445 ^{a} (42.5)	1.853 ^{b} (4.25)	1.764 ^{ab} (4.5)	2.683 ^{ab} (16.5)	11.339 ^{a} (132.5)	1.055 ^{b} (0.75)	0.707 ^{b} (0)	0.707 ^{a} (0)	0.707 ^{e} (0)	0.707 ^{c} (0)
T_5 PK	2.934 ^{a} (8.25)	1.899 ^{c} (5)	1.824 ^{b} (4.25)	0.707 ^{c} (0)	3.645 ^{a} (13.75)	1.742 ^{b} (5.75)	5.294 ^{a} (27.75)	1.301 ^{ab} (2.25)	1.662^{a} (5)	3.665 ^{bc} (14.25)	3.753 ^{b} (14.75)
T_6 NPK	3.658 ^{a} (13.25)	3.918 ^{b} (16)	3.96 ^{a} (16)	2.483 ^{a} (6)	0.707 ^{b} (0)	0.707 ^{b} (0)	0.707 ^{b} (0)	1.982 ab (4.5)	1.481 ^{a} (2)	2.153 ^{cde} (625)	6.488 ^{a} (43)
T_7 NPK+FYM	3.808 ^{a} (14.5)	4.401 ^{b} (20)	3.885 a (19)	1.061 ^{bc} (1)	0.707^{b} (0)	0.707 ^{b} (0)	0.707 ^{b} (0)	0.707^{b} (0)	1.301 ^{a} (2.25)	5.726 ^{a} (34.75)	7.589 ^{a} 64.25
T_8 N0P0K0	0.707 ^{c} (0)	0.707 ^{c} (0)	1.055 b 0.75	1.217 ^{bc} (1.25)	0.707 ^{b} (0)	1.055 ^{b} (0.75)	0.707 ^{b} (0)	0.707 ^{b} (0)	1.19 ^{a} (1.25)	1.217 ^{de} (1.25)	0.707 ^{c} (0)

* - $\sqrt{x}$ + 0.5 transformed values. The original values are in parenthesis.

Values followed by same letters do not differ significantly in DMRT

Table 5. Effect of treatments on dry weight of weeds (g/m^2) in the PMT at RRS, Kayamkulam (first crop season, 2001)

Treatments	*Echinochloa.*	*Isachne*	*Bulbostylis*	*Cyperus*	*Fimbristylis*	*Scirpus*	*Aeschynomene*	*Ammania*	*Lindernia*	*Ludwigia*	*Monochoria*
T_1 CM	1.44*^{bc} (1.64)	1.951^{ab} (3.69)	1.52^{ab} (2.00)	0.707^{b} (0)	0.707^{b} (0)	1.07^{bc} (0.8)	0.707^{b} (0)	1.057^{a} (0.76)	0.707^{b} (0)	2.304^{a} (5.38)	3.434^{a} (11.41)
T_2 N	1.054^{cde} (0.66)	1.944^{ab} (3.32)	1.34^{bc} (0.84)	0.707^{b} (0)	0.707^{b} (0)	2.711^{a} (7.1)	0.707^{b} (0)	1.099^{a} (0.95)	0.707^{b} (0)	0.97^{b} (0.53)	0.936^{c} (0.53)
T_3 NP	1.185^{bcde} (2.05)	2.38^{a} (5.30)	1.043^{bc} (0.75)	0.707^{b} (0)	1.165^{b} (0.24)	1.663^{b} (2.62)	0.833^{b} (0.24)	0.995^{a} (0.54)	0.707^{b} (0)	1.59^{ab} (2.55)	2.215^{b} (4.63)
T_4 NK	0.927^{de} (0.38)	2.169^{ab} (4.79)	1.018^{bc} (1.00)	1.1^{b} (1.00)	1.106^{b} (0.44)	2.756^{a} (7.13)	0.937^{b} (0.44)	0.707^{a} (0)	0.707^{b} (0)	0.707^{b} (0)	0.707^{b} (0)
T_5 PK	1.348^{bcd} (1.39)	1.272^{bc} (1.63)	1.232^{bc} (1.36)	0.707^{b} (0)	1.678^{a} (12.61)	1.017^{c} (0.82)	3.600^{a} (12.61)	0.997^{a} (0.75)	0.188^{b} (0.14)	1.637^{ab} (2.4)	1.679^{b} (2.48)
T_6 NPK	1.65^{b} (2.26)	1.921^{ab} (3.75)	2.025^{a} (3.63)	1.86^{a} (2.98)	0.707^{b} (0)	0.707^{c} (0)	0.707^{b} (0)	1.216^{a} (1.09)	1.160^{a} (0.99)	1.273^{b} (1.45)	2.134^{b} (4.33)
T_7 NPK+FYM	2.283^{a} (5.4)	2.78^{a} (7.53)	1.661^{ab} (2.61)	0.766^{b} (0.1)	0.707^{b} (0)	0.707^{b} (0)	0.707^{b} (0)	0.707^{a} (0)	0.803^{b} (0.17)	2.343^{a} (5.36)	3.302^{a} (10.56)
T_8 N0P0K0	0.707^{c} (0)	0.707^{c} (0)	0.806^{c} (0.16)	0.948^{b} (0.47)	0.707^{b} (0)	0.909^{c} (0.37)	0.707^{b} (0)	0.707^{b} (0)	0.845^{b} (0.24)	0.888^{b} (0.35)	0.702^{c} (0)

* - $\sqrt{x + 0.5}$ transformed values. The original values are in parenthesis.

Values followed by same letters do not differ significantly in DMRT

Table 6. Effect of treatments on weed flora (no/m^2) in the PMT at RRS, Kayamkulam (Second crop season 2001)

Treatments	*Echinochloa.*	*Isachne*	*Bulbostylis*	*Cyperus*	*Fimbristylis*	*Scirpus*	*Aeschynomene*	*Ammania*	*Lindernia*	*Ludwigia*	*Monochoria*
T_1 CM	4.579* ^{ab} (20.98)	5.714 ^{a} (33.3)	0.707 ^{b} (0)	6.363 ^{a} (41)	1.346 ^{b} (1.5)	1.47 ^{cd} (2.25)	0.707 ^{b} (0)	3.312 ^{b} (10.98)	3.367 ^{a} (32.95)	0.707 ^{b} (0)	4.615 ^{a} (21.98)
T_2 N	1.885 ^{de} (3.63)	4.225 ^{b} (18)	2.678 ^{a} (8.31)	6.231 ^{ab} (39.15)	1.787 ^{b} (3.25)	4.955 ^{a} (22.65)	0.707 ^{b} (0)	4.085 ^{a} (16.4)	0.707 ^{b} (0)	0.707 ^{b} (0)	3.304 ^{b} (11.5)
T_3 NP	3.071 ^{cd} (9.0)	4.735 ^{ab} (22.25)	0.707 ^{b} (0)	3.585 ^{d} (8)	2.878 ^{a} (8)	3.307 ^{b} (10.75)	0.837 ^{b} (0.24)	0.707 ^{d} (0)	0.707 ^{b} (0)	1.279 ^{a} (1.5)	4.387 ^{ab} (19.5)
T_4 NK	1.979 ^{de} (4.00)	4.77 ^{ab} (23)	2.638 a (6.75)	4.162 ^{cd} (1.75)	1.335 ^{b} (1.75)	4.002 ^{ab} 16.5)	0.707 ^{b} (0)	0.707 ^{a} (0)	0.707 ^{b} (0)	0.707 ^{b} (0)	0.926 ^{c} (0.5)
T_5 PK	3.799 ^{bc} (11)	2.453 ^{c} (5.75)	0.926 ^{c} (0.5)	1.812 ^{e} (0.75)	0.998 ^{b} (0.75)	1.215 ^{d} (1.75)	3.559 ^{a} (13)	1.812 ^{c} (3.25)	0.707 ^{b} (0)	0.707 ^{b} (0)	1.352 ^{c} (1.4)
T_6 NPK	4.419 ^{ab} (20)	4.945 ^{ab} (24.5)	0.707 ^{b} (0)	5.052 ^{abc} (10)	3.222 ^{a} (10)	2.828 ^{bc} (8.75)	0.707 ^{b} (0)	0.707 ^{d} (0)	0.707 ^{b} (0)	0.707 ^{b} (0)	4.876 ^{a} (22.75)
T_7 NPK+FYM	5.01 ^{a} (25)	5.517 ^{a} (31)	3.255 ^{a} (10.25)	4.72 ^{bcd} (6.75)	2.623 ^{a} (6.75)	1.127 ^{d} (1)	0.707 ^{b} (0)	0.707 ^{d} (0)	3.215 ^{a} (10.25)	0.707 ^{b} (0)	4.45 ^{ab} (19.63)
T_8 N0P0K0	0.926 ^{e} (0.5)	1.346 ^{c} (1.5)	0.707 ^{b} (0)	1.061 ^{e} (0.75)	9.998 ^{b} (0.75)	1.055 ^{d} (0.75)	0.707 ^{b} (0)	0.926 ^{d} (0.5)	0.707 ^{b} (0)	0.707 ^{b} (0)	0.707 ^{c} (0)

* - $\sqrt{x + 0.5}$ transformed values. The original values are in parenthesis.

Values followed by same letters do not differ significantly in DMRT

Table 7. Effect of treatments on dry weight of weeds (g/m^2) in the PMT at RRS, Kayamkulam (Second crop season,2001)

Treatments	*Echinochloa*	*Isachne*	*Bulbostylis*	*Cyperus*	*Fimbristylis*	*Scirpus*	*Aeschynomene*	*Ammania*	*Lindernia*	*Ludwigia*	*Monochoria*
T_1 CM	1.526 ^{*abc} (1.91)	1.77 ^{b} (3.2)	0.707 ^{c} (0)	1.889 ^{ab} (3.20)	0.834 ^{b} (0.21)	0.834 ^{c} (0.21)	0.707 ^{b} (0)	1.582 ^{a} (1.65)	0.707 ^{b} (0)	2.385 ^{a} (0)	2.385 ^{a} (5.84)
T_2 N	1.02 ^{cd} (0.6)	1.191 ^{c} (0.97)	1.080 ^{b} (0.73)	1.62 ^{abc} (2.22)	0.984 ^{b} (0.52)	2.277 ^{a} (3.64)	0.707 ^{b} (0)	1.193 ^{b} (1.77)	0.707 ^{b} (0)	0.707 ^{b} (0)	2.335 ^{a} (5.81)
T_3 NP	1.513 ^{abc} (1.84)	1.945 ^{b} (3.61)	0.707 ^{c} (0)	1.431 ^{bc} (1.66)	1.118 ^{b} (0.78)	1.39 ^{b} (1.5)	0.837 ^{b} (0.08)	0.707 ^{c} (0)	1.310 ^{a} (1.58)	1.279 ^{a} (1.5)	2.143 ^{a} (4.13)
T_4 NK	1.104 ^{bcd} (0.96)	2.229 ^{b} (4.51)	1.238 ^{b} (1.11)	1.954 ^{ab} (3.35)	0.912 ^{b} (0.38)	1.788 ^{ab} (2.8)	0.707 ^{b} (0)	0.707 ^{c} (0)	0.707 ^{b} (0)	0.707 ^{b} (0)	0.759 ^{b} (0.09)
T_5 PK	2.02 ^{a} (3.69)	1.202 ^{c} (1.07)	0.757 ^{c} (0.08)	1.081 ^{c} (0.76)	0.733 ^{b} (0.04)	0.879 ^{c} (0.36)	3.599 ^{a} (4.55)	1.012 ^{bc} (0.58)	0.707 ^{b} (0)	0.707 ^{b} (0)	1.030 ^{b} (0.71)
T_6 NPK	1.632 ^{ab} (2.33)	1.86 ^{b} (3.09)	0.707 ^{c} (0)	2.044 ^{ab} (4.02)	1.927 ^{a} (3.28)	1.802 ^{ab} (2.94)	0.707 ^{b} (0)	0.707 ^{c} (0)	0.707 ^{b} (0)	0.707 ^{b} (0)	2.310 ^{a} (4.9)
T_7 NPK+FYM	2.034 ^{a} (3.69)	3.017 ^{a} (8.71)	2.098 ^{a} (3.98)	2.384 ^{a} (5.75)	2.124 ^{a} (4.6)	0.894 ^{c} (0.34)	0.707 ^{b} (0)	0.707 ^{c} (0)	0.707 ^{b} (0)	0.707 ^{b} (0)	2.424 ^{a} (5.84)
T_8 N0P0K0	0.796 ^{d} (1.15)	1.008 ^{c} (0.53)	0.707 ^{c} (0)	0.94 ^{c} (0.55)	0.941 ^{b} (0.55)	0.876 ^{c} (0.31)	0.707 ^{b} (0)	0.754 ^{c} (0.08)	0.707 ^{b} (0)	0.707 ^{b} (0)	0.707 ^{b} (0)

* - $\sqrt{x + 0.5}$ transformed values. The original values are in parenthesis.

Values followed by same letters do not differ significantly in DMRT

sp was in treatment T_7 (NPK + FYM) which was significantly higher than all other treatments. This followed by T_6 (NPK) and T_5 (PK).

Dry matter production of *Isachne miliacea* was lower in the plots where N was not supplied (T_5, T_8) as in the case of *I. miliacea* counts. The dry matter production was significantly higher in T_7 (NPK + FYM). All the treatments receiving N recorded dry weight statistically on par.

The dry weight of individual sedge weeds followed the same trend of their population. The dry matter production of *Bulbostylis* sp. was higher in treatments receiving all the nutrients (T_6, T_7) where as the dry weight of *Fimbristylis miliacea* was higher in treatments receiving either of the major elements. The dry weight of *Scirpus* sp was higher in treatments receiving N alone (T_2) and N+K (T_4).

Among the broad leaf weeds, dry weight of *Aeschynomene indica* was the highest in T_5 (PK) as in the case of its count. For *Ludwigia parviflora* and *Monochoria vaginalis*, dry weights were higher in plots receiving organic matter (T_1 and T_7). *Ammania* sp and *Lindernia* sp recorded higher dry weight in the treatment where NPK alone was supplied (T_6).

Table 7 shows the dry weight of weeds during the Rabi season. In the Rabi season, *Echinochloa* sp dry weight was the highest in T_7 (NPK + FYM) as in the Kharif season. The weed dry weight in T_5 (PK) was higher than T_3 (NP) and T_4 (NK) as in the weed counts. *Isachne miliacea* also recorded the highest dry matter production in T_7 (NPK + FYM).

The dry weight of *Scripus juncoides* was maximum in T_2 (N), which also recorded the maximum population for this weed. The treatments T_4 (NK) and T_6 (NPK) were statistically on par with these treatments.

Table 8. Effect of treatments on weed flora (no/m^2) in the PMT at RRS, Kayamkulam (Summer fallow season,2001-2002)

Treatments	*Echinochloa*	*Isachne*	*Eragrostics*	*Cyperus*	*Fimbristylis*	*Bulbostylis*	*Cleome*	*Phyllanthus*	*Ludwigia*	*Mullugo*	*Coldenia*
T_1 CM	3.419*^{a} (12.75)	0.998^{ab} (0.75)	0.998^{a} (0.75)	2.833^{b} (0.75)	0.707^{a} (0)	0.837^{ab} (0.25)	7.386^{a} (57.25)	1.74^{ab} (3)	0.707^{a} (0)	1.606^{a} (4.5)	1.168^{a} (1.57)
T_2 N	2.106^{cd} (4.25)	0.707^{c} (0)	0.707^{a} (0)	0.926^{c} (0.5)	0.707^{a} (0)	0.707^{b} (0)	1.954^{b} (5.25)	1.055^{b} (0.75)	1.409^{a} (1.75)	0.707^{a} (0)	0.707^{a} (0)
T_3 NP	2.995^{a} (11)	1.144^{ab} (1)	0.144^{a} (1)	2.648^{bc} (8.25)	0.837^{a} (0.25)	1.43^{ab} (1.63)	1.966^{b} (5)	1.055^{b} (0.75)	1.414^{a} (2)	0.707^{a} (0)	1.117^{a} (0.16)
T_4 NK	1.335^{a} (1.75)	1.168^{ab} (1.5)	1.168^{a} (1.5)	0.92^{bc} (0.5)	0.707^{a} (0)	0.707^{b} (0)	1.297^{b} (1.75)	1.055^{b} (0.75)	1.095^{a} (0.75)	1.117^{a} (1.25)	0.707^{a} (0)
T_5 PK	3.122^{a} (11.5)	2.008^{a} (3.25)	1.117^{a} (2.25)	1.932^{bc} (4.5)	0.707^{a} (0)	0.707^{b} (0)	1.953^{b} (4)	2.272^{a} (5.75)	1.246^{a} (1.5)	1.34^{a} (2.5)	0.707^{a} (0)
T_6 NPK	3.136^{ab} (10)	1.061^{ab} (1)	1.061^{a} (1)	2.557^{bc} (7.5)	1.259^{a} (2)	0.707^{b} (0)	2.789^{b} (10)	1.297^{ab} (1.75)	1.274^{a} (1.25)	1.19^{a} (1.25)	0.707^{a} (0)
T_7 NPK+FYM	3.163^{a} (10.25)	1.340^{ab} (2.5)	0.707^{a} (0)	4.795^{a} (24)	1.246^{a} (1.5)	1.061^{ab} (1)	2.774^{b} (7.75)	1.986^{ab} (3.5)	0.707^{a} (0)	0.707^{a} (0)	0.707^{a} (0)
T_8 N0P0K0	1.515^{a} (3.75)	1.061^{ab} (1)	1.061^{a} (1)	1.694^{bc} (3.5)	0.837^{a} (0.25)	2.016^{a} (6)	2.118^{b} (5.5)	1.274^{ab} (1.25)	0.837^{a} (0.25)	0.707^{a} (0)	0.707^{a} (0)

* - $\sqrt{x + 0.5}$ transformed values. The original values are in parenthesis.

Values followed by same letters do not differ significantly in DMRT

Table 9. Effect of treatments on dry weight of weeds (g/m^2) in the PMT at RRS, Kayamkulam (Summer fallow season,2001-2002)

Treatments	*Echinochloa*	*Isachne*	*Eragrostics*	*Cyperus*	*Fimbristylis*	*Bulbostylis*	*Cleome*	*Phyllanthus*	*Ludwigia*	*Mullugo*	*Coldenia*
T_1 CM	1.905*^{a} (3.42)	0.855^{ab} (0.3)	0.771^{a} (0.11)	2.358^{ab} (6.46)	0.707^{a} (0)	0.829^{a} (0.23)	4.888^{a} (23.87)	1.277^{ab} (1.45)	0.707^{a} (0)	1.158^{a} (1.45)	1.011^{a} (0.8)
T_2 N	1.68^{a} (4.52)	0.707^{b} (0)	0.707^{a} (0)	1.022^{bc} (0.84)	0.707^{a} (0)	0.707^{a} (0)	1.452^{b} (2.08)	1.144^{ab} (1.29)	1.53^{a} (2.43)	0.707^{a} (0)	0.707^{a} (0)
T_3 NP	2.16^{a} (5.32)	1.04^{ab} (0.75)	0.885^{a} (0.32)	2.384^{ab} (6.34)	0.936^{a} (0.53)	1.226^{a} (1.63)	1.421^{b} (2.03)	1.345^{ab} (1.78)	1.39^{a} (1.9)	0.707^{a} (0)	1.769^{a} (0.10)
T_4 NK..	0.853^{a} (0.26)	0.875^{ab} (0.35)	0.944^{a} (0.56)	0.801^{c} (0.17)	0.707^{a} (0)	0.707^{a} (0)	1.217^{b} (1.45)	0.859^{b} (0.26)	1.159^{a} (1.06)	0.827^{a} (0.23)	01.026^{a} (0.86)
T_5 PK	2.183^{a} (5.12)	1.671^{a} (1.9)	1.1055^{a} (0.98)	1.604^{bc} (2.82)	0.707^{a} (0)	0.707^{a} (0)	1.524^{b} (2.28)	2.124^{a} (4.23)	0.941^{a} (0.45)	1.055^{a} (0.98)	0.707^{a} (0)
T_6 NPK	1.467^{a} (1.87)	0.92^{ab} (0.48)	0.759^{a} (0.09)	2.084^{abc} (4.53)	0.992^{a} (0.73)	0.707^{a} (0)	2.056^{b} (4.52)	1.114^{ab} (0.99)	1.593^{a} (2.43)	1.115^{a} (1.02)	0.707^{a} (0)
T_7 NPK+FYM	2.193^{a} (5.16)	1.238^{ab} (1.88)	0.707^{a} (0)	3.128^{a} (9.52)	1.179^{a} (1.17)	0.057^{a} (0.08)	1.764^{b} (3.05)	1.295^{ab} (2.37)	0.707^{a} (0)	0.707^{a} (0)	0.707^{a} (0)
T_8 N0 P0 K0	0.991^{a} (0.73)	0.805^{ab} (0.18)	0.789^{a} (0.14)	1.204^{bc} (1.33)	0.796^{a} (0.16)	1.439^{a} (2.22)	1.827^{b} (3.82)	1.144^{ab} (0.92)	0.732^{a} (0.04)	0.707^{a} (0)	0.707^{a} (0)

*- $\sqrt{x + 0.5}$ transformed values. The original values are in parenthesis.
Values followed by same letters do not differ significantly in DMRT

Broad leaf weeds like *Aeschynomene indica, Ludwigia parviflora* and *Monochoria vaginalis* showed similar trends in their dry weight as that of kharif season. *Aeschynomene indica* recorded the highest dry weight in T_5 (PK) as in the case of its count. The dry weight of *Ludwigia parviflora* and *Monochoria vaginalis* were higher in plots receiving organic matter (T_1 & T_7).

The data on weed count and dry matter production during the fallow (summer) season is given in Tables 8 & 9. It was seen that the population as well as the dry matter production of *Cleome viscosa* were significantly higher in T_1 (cattle manure). All the other treatments were statistically on par. In the case of other weeds also, there was no significant difference in their population and dry weight due to the treatments.

4.1.2. Permanent Manurial Trial at RRS, Moncombu.

The data on the count and dry matter production of weeds during the Kharif and Rabi season are presented in Tables 10 to 13. The population of the grasses, *Isachne miliacea* and *Echinochloa* sp, did not differ significantly between the treatments in both the Kharif and Rabi seasons, except for a significantly higher population of *Echinochloa* sp in the NPK+FYM treatment during the kharif season. Sedges also did not show any difference in the population due to the effect of the treatments in both the seasons.

Monochoria vaginalis in both seasons and *Ludwigia parviflora* in the second season (both broad leaf weeds) showed higher population in plots receiving NPK with lime or FYM (T_8& T_9). The dry matter production of the weeds also showed the same trend as that of the count of individual weeds in both the seasons.

4.1.3. Permanent Manurial Trial at RARS, Pattambi

Tables 14 to 19 give analysis of the data on weed count and dry matter production during the crop and fallow seasons. The major weed species observed in the PMT at RARS Pattambi were *Echinochloa* sp during the Kharif season, *Isachne miliacea,*

Table10. Effect of treatments on weed flora (no/m^2) in the PMT at RRS Moncombu (first crop season, 2001)

Treatments	*Isachne*	*Echinochloa*	*Cyperus*	*Eriocaulon*	*Fimbristylis*	*Lindernia*	*Monochoria*
T_1 Absolute control	1.171* ^{a} (1)	0.880 ^{b} (0.33)	0.88 ^{a} (0.33)	0.707 ^{c} (0)	0.707 ^{b} (0)	0.707 ^{b} (0)	0.707 ^{b} (0)
T_2 Control	2.057 ^{a} (4.67)	2.479 ^{b} (9.3)	1.179 ^{a} 1.33)	0.998 ^{b} (0.67)	4.643 ^{a} (21.33)	0.707 ^{b} (0)	1.179 ^{ab} (1.33)
T_3 N	2.121 ^{a} (8)	2.187 ^{b} (8.67)	0.707 ^{a} (0)	1.613 ^{a} (2.67)	1.741 ^{b} (4.67)	0.707 ^{b} (0)	0.707 ^{b} (0)
T_4 NP	1.613 ^{a} (2.67)	4.174 ^{b} (19.33)	1.179 ^{b} (1.33)	0.707 ^{c} (0)	1.290 ^{b} (1.33)	1.941 ^{a} (4.67)	1.443 ^{ab} (2.67)
T_5 NK	2.314 ^{a} (5.3)	1.613 ^{b} (2.67)	0.707 ^{a} (0)	0.998 ^{b} (0.67)	2.661 ^{a} (15.33)	0.707 ^{b} (0)	1.470 ^{ab} (2)
T_6 PK	1.47 ^{a} (2)	2.721 ^{b} (12)	0.707 ^{a} (0)	0.707 ^{c} (0)	1.613 ^{b} (2.67)	1.179 ^{ab} (1.33)	1.793 ^{ab} (3.33)
T_7 NPK	1.613 ^{a} (2.67)	3.116 ^{b} (10.67)	0.707 ^{a} (0)	0.998 ^{b} (0.67)	1.179 ^{b} (1.3)	0.707 ^{b} (0)	2.349 ^{ab} (5.33)
T_8 NPK+Lime	2.529 ^{d} (6)	2.966 ^{b} (8.67)	1.321 ^{a} (2)	1.179 ^{a} (1.33)	1.179 ^{b} (1.3)	0.998 ^{ab} (0.67)	2.878 ^{a} (9.3)
T_9 NPK+FYM	2.026 ^{a} (4)	7.25 ^{a} (54)	0.707 ^{c} (0)	0.707 ^{c} (0)	0.707 ^{b} (0)	0.707 ^{b} (0)	2.815 ^{a} (8)

* - $\sqrt{x + 0.5}$ transformed values. The original values are in parenthesis.

Values followed by same letters do not differ significantly in DMRT

Table 11. Effect of treatments on dry weight of weeds (g/m^2) in the PMT at RRS Moncombu (first crop season, 2001)

Treatments	*Isachne*	*Echinochloa*	*Cyperus*	*Eriocaulon.*	*Fimbristylis*	*Lindernia*	*Monochoria*
T_1 Absolute control	1.197* [a] (1.08)	0.871 [b] (0.31)	0.96 [a] (0.55)	0.707 [a] (0)	0.707 [b] (0)	0.707 [a] (0)	0.707 [a] (0)
T_2 Control	0.996 [a] (0.54)	0.972 [b] (0.51)	0.752 [a] (0.07)	0.871 [a] (0.18)	1.045 [a] (0.61)	0.707 [a] (0)	0.75 [a] (0.07)
T_3 N	1.023 [a] (0.75)	0.870 [b] (0.31)	0.707 [a] (0)	0.943 [a] (0.07)	0.744 [ab] (0.06)	0.707 [a] (0)	0.707 [a] (0)
T_4 NP	1.009 [a] (0.61)	1.358 [ab] (1.42)	0.87 [a] (0.31)	0.707 [a] (0)	1.055 [a] (0.69)	0.836 [a] (4.67)	1.47 [a] (2.44)
T_5 NK	1.016 [a] (0.59)	0.835 [b] (0.21)	0.707 [a] (0)	0.803 [a] (0.16)	0.921 [ab] (0.37)	0.707 [a] (0)	1.012 [a] (0.15)
T_6 PK	0.938 [a] (0.42)	1.213 [b] (1.11)	0.707 [a] (0)	0.707 [a] (0)	0.871 [ab] (0.17)	0.824 [a] (1.33)	1.429 [a] (1.04)
T_7 NPK	0.93 [a] (0.43)	1.495 [ab] (1.18)	0.707 [a] (0)	0.930 a (0.46)	0.806 [ab] (0.17)	0.707 [a] (0)	1.014 [a] (0.17)
T_8 NPK+Lime	0.756 [d] (0.07)	0.921 [b] (0.38)	0.742 [a] (0.05)	0.808 [a] (0.17)	0.773 [ab] (0.11)	0.770 [a] (0.67)	1.565 [a] (2.03)
T_9 NPK+FYM	1.303 [a] (1.0)	2.055 [a] (4.31)	0.707 [a] (0)	0.707 [a] (0)	0.707 [b] (0)	0.707 [a] (0)	1.42 [a] (1.69)

* - $\sqrt{x + 0.5}$ transformed values. The original values are in parenthesis.

Values followed by same letters do not differ significantly in DMRT

Table 12. Effect of treatments on weed flora (no/m^2) in the PMT at RRS Moncombu. (Second crop season, 2001)

Treatments	*Isachne*	*Echinochloa*	*Cyperus*	*Fimbristylis*	*Monochoria*	*Ludwigia*	*Lindernia*
T_1 Absolute control	2.63*^{a} (12)	0.707^a (0)	0.88^a (0.33)	3.584^a (16)	1.739^{ab} (2.67)	1.739^{ab} (2.67)	1.179^a (1.33)
T_2 Control	2.472^a (6.3)	0.707^a (0)	0.707^a (0)	3.004^a (11)	1.725^{ab} (3)	1.557^{bc} (2.67)	0.707 a (0)
T_3 N	2.284^a (14.67)	0.707^a (0)	1.179^a (1.33)	3.083^a (15.67)	1.641^b (2.67)	1.095^c (1)	1.179^a (1.33)
T_4 NP	2.061^a (4.67)	1.483^a (2)	1.443^a (2.67)	4.07^a (19.33)	2.601^{ab} (7.33)	1.88^{abc} (4)	1.384^a (2.33)
T_5 NK	3.869^a (19.67)	1.095^a (1)	0.707^a (0)	3.166^a (16.0)	1.871^{ab} (3)	0.707^c (0)	0.707^a (0)
T_6 PK	0.88^a (0.33)	1.384^a (2.33)	0.707^a (0)	1.25^a (1.67)	2.501^{ab} (6.33)	2.461^{abc} (6)	0.707^a (0)
T_7 NPK	1.253^a (1.67)	0.88^a (0.33)	0.707^a (0)	2.393 a (6.67)	3.489^a (13.67)	3.471^{ab} (12)	1.095^a (1)
T_8 NPK+Lime	1.443^a (2.67)	1.179^a (1.33)	0.707^a (0)	3.53^a (15.33)	2.426^{ab} (6)	2.832^{abc} (10.67)	0.707^a (0)
T_9 NPK+FYM	1.602^a (3.67)	1.65^a (2.67)	0.707^a (0)	4.459^a (20.33)	3.256^{ab} (10.33)	3.884^a (16)	0.707^a (0)

* - $\sqrt{x + 0.5}$ transformed values. The original values are in parenthesis.

Values followed by same letters do not differ significantly in DMRT

Table 13. Effect of treatments on dry weight of weeds (g/m^2) in the PMT at RRS Monkombu. (Second crop season 2001)

Treatments	*Isachne*	*Echinochloa*	*Cyperus*	*Fimbristylis*	*Monochoria*	*Ludwigia*	*Lindernia*
T_1 Absolute control	0.806* [a] (0.16)	0.707 [a] (0)	0.75 [a] (0.07)	1.069 [b] (0.67)	1.03 [c] (0.57)	1.059 [bc] (0.66)	0.821 [a] (0.2)
T_2 Control	1.088 [a] (0.71)	0.707 [a] (0)	0.707 [a] (0)	1.121 [ab] (0.76)	1.019 [c] (0.61)	0.931 [bc] (0.4)	0.707 [a] (0)
T_3 N	1.093 [a] (0.87)	0.707 [a] (0)	0.826 [a] (0.21)	1.0 [b] (0.55)	0.885 [c] (0.31)	0.784 [c] (0.13)	0.867 [a] (0.3)
T_4 NP	0.973 [a] (0.5)	0.944 [a] (0.42)	0.826 [a] (0.21)	1.516 [ab] (1.95)	1.133 [abc] (0.8)	0.953 [bc] (0.44)	0.873 [a] (0.32)
T_5 NK	1.063 [a] (0.68)	0.833 [a] (0.23)	0.707 [a] (0)	0.885 [b] (0.49)	1.188 [abc] (0.92)	0.707 [c] (0)	0.707 [a] (0)
T_6 PK	0.864 [a] (0.3)	0.85 [a] (0.26)	0.707 [a] (0)	0.896 [b] (0.37)	1.092 [bc] (0.71)	1.168 [bc] (0.9)	0.707 [a] (0)
T_7 NPK	0.829 [a] (0.22)	0.74 [a] (0.05)	0.707 [a] (0)	1.494 [ab] (2.04)	1.342 [abc] (1.4)	1.393 [b] (0.51)	0.877 [a] (0.33)
T_8 NPK+Lime	1.113 [a] (1.07)	0.893 [a] (0.37)	0.707 [a] (0)	1.378 [ab] (1.42)	1.6 [ab] (2.23)	1.216 [bc] (1.12)	0.707 [a] (0)
T_9 NPK+FYM	1.113 [a] (1.07)	1.095 [a] (0.82)	0.707 [a] (0)	1.845 [a] (3.04)	1.634 [a] (2.35)	2.041 [e] (3.73)	0.707 [a] (0)

* $\sqrt{x + 0.5}$ transformed values. The original values are in parenthesis.

Values followed by same letters do not differ significantly in DMRT

Table 14. Effect of treatments on weed flora (no/m^2) in the PMT at RARS Pattambi. (First crop season 2001)

Treatments	*Echinochloa*	*Isachne*	*Cyperus*	*Ludwigia*	*Marsilea*
T_1 CM	0.729* [a] (0.03)	0.793 [a] (0.14)	0716 [a] (0.01)	0.754 [a] (0.07)	1.022 [a] (0.84)
T_2 GLM	0.707 [a] (0)	0.811 [a] (0.17)	0.707 [a] (0)	0.707 [a] (0)	0.707 [a] (0)
T_3 CM+GLM	0.814 [a] (0.91)	0.728 [a] (0.03)	0.707 [a] (0)	0.739 [a] (0.05)	1.172 [a] (1.26)
T_4 N	0.711 [a] (0.01)	0.776 [a] (0.11)	0.72 [a] (0.02)	0.707 [a] (0)	0.741 [a] (0.05)
T_5 CM+NPK	0.733 [a] (0.04)	0.732 [a] (0.04)	0.707 [a] (0)	0.707 [a] (0)	1.041 [a] (0.92)
T_6 GLM+NPK	0.763 [a] (0.09)	0.897 [a] (0.37)	0.707 [a] (0)	0.732 [a] (0.13)	0.032 [a] (0.04)
T_7 CM+GLM +NPK	0.707 [a] (0)	0.816 [a] (0.18)	0.718 [a] (0.01)	0.716 [a] (0.01)	1.146 [a] (1.31)
T_8 NPK	0.707 [a] (0)	0.828 [a] (0.23)	0.707 [a] (0)	0.716 [a] (0.01)	0.937 [a] (0.45)

* - $\sqrt{x + 0.5}$ transformed values. The original values are in parenthesis.

Values followed by same letters do not differ significantly in DMRT

Table 15. Effect of treatments on dry weight of weeds (g/m^2) in the PMT at RARS Pattambi (First crop season 2001)

Treatments	*Echinochloa*	*Isachne*	*Cyperus*	*Lindernia*	*Marsilea*
T_1 CM	0.719* [a] (0.02)	0.748 [a] (0.06)	0.718 [a] (0.02)	0.772 [a] (0.29)	0.805 [a] (0.18)
T_2 GLM	0.707 [a] (0)	0.752 [a] (0.07)	0.707 [a] (0)	0.707 [a] (0)	0.707 [a] (0)
T_3 CM+GLM	0.801 [a] (0.19)	0.715 [a] (0.01)	0.707 [a] (0)	0.771 [a] (0.45)	0.854 [a] (2.7)
T_4 N	0.710 [a] (0)	0.717 [a] (0.01)	0.712 [a] (0.01)	0.707 [a] (0)	0.714 [a] (0.01)
T_5 CM+NPK	0.732 [a] (0.04)	0.711 [a] (0.01)	0.707 [a] (0)	0.707 [a] (0)	0.857 [a] (0.30)
T_6 GLM+NPK	0.738 [a] (0.05)	0.765 [a] (0.09)	0.707 [a] (0)	0.712 [a] (0.01)	0.711 [a] (0.01)
T_7 CM+GLM +NPK	0.707 [a] (0)	0.715 [a] (0.07)	0.718 [a] (0.02)	0.714 [a] (0.01)	1.823 [a] (1.21)
T_8 NPK	0.707 [a] (0)	0.773 [a] (0.11)	0.707 [a] (0)	0.719 [a] (0.02)	0.794 [a] (0.14)

* - $\sqrt{x + 0.5}$ transformed values. The original values are in parenthesis.

Values followed by same letters do not differ significantly in DMRT

Table16. Effect of treatments on weed flora (no/m^2) in the PMT at RARS Pattambi. (Second crop season 2001)

Treatments	*Isachne*	*Ludwigia*	*Cyperus*	*Marsilea*
T_1 CM	0.74* [a] (0.05)	0.724 [a] (0.03)	0.707 [a] (0)	1.09 [a] (0.81)
T_2 GLM	0.753 [a] (0.07)	0.728 [a] (0.03)	0.707 [a] (0)	0.937 [a] (0.43)
T_3 CM+GLM	0.724 [a] (0.03)	0.711 [a] (0.01)	0.707 [a] (0.01)	0.879 [a] (0.36)
T_4 N	0.724 [a] (0.03)	0.716 [a] (0.01)	0.707 [a] (0)	1.026 [a] (0.67)
T_5 CM+NPK	0.707 [a] (0)	0.707 [a] (0)	0.711 [a] (0.01)	1.257 [a] (1.26)
T_6 GLM+NPK	0.720 [a] (0.02)	0.716 [a] (0.01)	0.707 [a] (0)	0.941 [a] (0.52)
T_7 CM+GLM+ NPK	0.707 [a] (0)	0.707 [a] (0)	0.707 [a] (0)	1.048 [a] (0.72)
T_8 NPK	0.860 [a] (0.28)	0.707 [a] (0)	0.707 [a] (0)	1.031 [a] (0.66)

* - $\sqrt{x + 0.5}$ transformed values. The original values are in parenthesis.

Values followed by same letters do not differ significantly in DMRT

Table 17. Effect of treatments on dry weight of weeds (g/m^2) in the PMT at RARS Pattambi. (Second crop season 2001)

Treatments	*Isachne*	*Ludwigia*	*Cyperus*	*Marsilea*
T_1 CM	0.729* a (0.03)	0.711 a (0.01)	0.07 a (0)	1.06 a (0.75)
T_2 GLM	0.734 a (0.04)	0.709 a (0.01)	0.07 a (0)	0.852 a (0.25)
T_3 CM+GLM	0.716 a (0.01)	0.712 a (0.01)	0.07 a (0.01)	0.9 a (0.42)
T_4 N	0.0742 a (0.01)	0.714 a (0.01)	0.07 a (0)	0.938 a (0.47)
T_5 CM+NPK	0.707 a (0)	0.707 a (0)	0.713 a (0.008)	1.081 a (0.76)
T_6 GLM+NPK	0.712 a (0.01)	0.09 a (0.01)	0.707 a (0)	0.894 a (0.22)
T_7 CM+GLM+NPK	0.707 a (0)	0.07 a (0)	0.707 a (0)	1.017 a (0.63)
T_8 NPK	0.777 a (0.11)	0.07 a (0)	0.707 a (0)	1.072 a (0.70)

* - $\sqrt{x + 0.5}$ transformed values. The original values are in parenthesis.

Values followed by same letters do not differ significantly in DMRT

Table 18. Effect of treatments on weed flora (no/m^2) in the PMT at RARS Pattambi (Summer fallow season 2001-2002)

Treatments	*Sphaeranthus*	*Mollugo*	*Grangea*	*Coldenia*	*Bulbostylis*
T_1 CM	3.323* [a] (12.23)	5.241 [a] (28.00)	3.234 [a] (15.99)	1.132 [a] (0.98)	1.662 [a] (5)
T_2 GLM	2.229 [a] (5.98)	2.451 [a] (6.66)	3.823 [a] (34.33)	0.707 [a] (0)	2.232 [a] (6.99)
T_3 CM+GLM	2.828 [a] (7.6)	4.103 [ab] (16.66)	4.931 [a] (24.66)	0.707 [a] (0)	2.748 [a] (11.25)
T_4 N	1.996 [a] (5.33)	4.106 [ab] (18.66)	4.086 [a] (18.99)	1.134 [a] (0.327)	1.814 [a] (4.33)
T_5 CM+NPK	3.405 [a] (12.0)	4.155 [ab] (21.0)	4.071 [a] (22.33)	0.971 [a] (0)	1.625 [a] (4.67)
T_6 GLM+NPK	2.832 [a] (8.33)	4.876 [ab] (24.33)	3.804 [a] (14.99)	0.707 [a] (0)	1.978 [a] (5.67)
T_7 CM+GLM +NPK	3.491 [a] (14.66)	3.983 [ab] (15.67)	3.831 [a] (21.65)	0.707 [a] (0.01)	2.501 [a] (9)
T_8 NPK	3.631 [a] (14.67)	3.834 [a] (15.99)	3.321 [a] (18.83)	1.22 [a] (0.072)	1.46 [a] (3.33)

* - $\sqrt{x + 0.5}$ transformed values. The original values are in parenthesis.

Values followed by same letters do not differ significantly in DMRT

Table 19. Effect of treatments on dry weight of weeds (g/m^2) in the PMT at RARS Pattambi. (Summer fallow season 2001-2002)

Treatments	*Sphaeranthus*	*Mollugo*	*Grangea*	*Coldenia*	*Bulbostylis*
T_1 CM	8.33* ^{a} (8.76)	3.899 ^{a} (15.39)	2.404 ^{a} (2.44)	0.896 ^{a} (0.34)	1.662 ^{a} (5)
T_2 GLM	1.696 ^{a} (13.09)	1.729 ^{b} (2.99)	4.132 ^{a} (16.81)	0.707^a (0)	2.232 ^{a} (6.99)
T_3 CM+GLM	2.153 ^{a} (4.29)	2.599 ^{ab} (6.49)	3.599 ^{a} (13.17)	0.707 ^{a} (0)	2.748 ^{a} (11.25)
T_4 N	1.479 ^{a} (2.41)	2.613 ^{ab} (6.64)	2.781 ^{a} (8.52)	0.862 ^{a} (0.32)	1.814 ^{a} (4.33)
T_5 CM+NPK	2.779 ^{a} (7.97)	2.914 ^{ab} (9.72)	2.449 ^{a} (7.78)	0.814 ^{a} (0.20)	1.625 ^{a} (4.67)
T_6 GLM+NPK	1.915 ^{a} (3.43)	3.107 ^{ab} (9.92)	2.753 ^{a} (7.74)	0.707 ^{a} (0)	1.978 ^{a} (5.67)
T_7 CM+GLM +NPK	2.664 ^{a} (8.21	3.534 ^{a} (12.39)	2.441 ^{a} (7.315)	0.707 ^{a} (0.01)	2.501 ^{a} (9)
T_8 NPK	2.573 ^{a} (6.69	2.704 ^{ab} (8.44)	2.635 ^{a} (10.92)	1.22 ^{a} (0.072)	1.46 ^{a} (3.33)

* - $\sqrt{x + 0.5}$ transformed values. The original values are in parenthesis.

Values followed by same letters do not differ significantly in DMRT

Ludwigia parviflora, Cyperus sp and *Marsilea quadrifolia* during both Kharif and Rabi sesasons. However, no significant differences in their count or dry matter production could be observed due to differences in soil fertility treatments.

During the summer season, the field was fallow and weed species such as *Sphaeranthus indicus, Mollugo pentaphylla, Grangea mederaspatana* and *Coldenia procumbens,* which are not typical of rice fields, were observed. Nevertheless, no differences in their abundance could be observed except for *Mollugo pentaphylla* whose population and dry weight were significantly lower in plots where green leaf manure alone (T_2) was supplied.

4.1.4. Nutrient composition of weeds

Nutrient composition of some of the common weeds of rice is given in Table20 and Appendix-II. It was observed that the leguminous weed *Aeschynomene indica* had the highest N content, while *Cleome viscosa* had the maximum K content. The N content of the broad leaf weeds *Ludwigia parviflora* and *Cleome viscosa* were higher than that of grasses and sedges.

Table 20. Nutrient composition of weeds on dry weight basis

Weed species	N %	P %	K %	Ca %	Mg %	S %	Mn (ppm)	Zn (ppm)
Aeschynomene indica	2.84	0.25	0.8	0.43	0.21	0.20	37	26
Cleome viscosa	1.48	0.39	2.05	0.56	0.24	0.47	26	23
Echinochloa colona	0.92	0.49	1.10	0.29	0.13	0.14	43	38
Eragrostis tenella	1.26	0.14	1.05	0.24	0.14	0.15	125	47
Cyperus iria	0.70	0.12	1.50	0.20	0.09	0.03	249	32
Cyperus rotundus	0.53	0.20	1.30	0.26	0.18	0.10	143	42
Ludwigia parviflora	1.75	0.18	1.15	0.30	0.12	0.09	119	39

4.3. Effect of soil fertility on soil micro flora

Table 21 gives the results of the studies on soil microflora in the soils from different treatments of the PMT at Kayamkulam. The maximum population of fungi was observed in T_7 (NPK + FYM) which was significantly higher than all other treatments. The treatments receiving N and P (T_3 and T_6) and cattle manure (T_1) were statistically on par with respect to fungal population (Plate 1). However, the treatments where N or P was absent (T_2, T_4 and T_5) recorded significant reduction in fungal population.

Table 21. Effect of soil fertility on population of soil micro flora

Treatments	Fungi ($\times 10^3$)c.f.u.	Bacteria ($\times 10^6$)c.f.u.	Actinomycete ($\times 10^4$)c.f.u.
T_1 $N_{80}P_0K_0$ (C M)	7.503^{*b} (56)	5.514^{bc} (31)	1.550^{d} (2)
T_2 $N_{80}P_0K_0$	5.780^{c} (33)	4.050^{c} (16)	2.160^{cd} (4)
T_3 $N_{80}P_{40}K_0$	8.036^{b} (64)	8.504^{a} (72)	3.667^{a} (13)
T_4 $N_{80}P_0K_{80}$	5.359^{c} (29)	5.386^{bc} (29)	1.858^{d} (3)
T_5 $N_0P_{40}K_{40}$	5.203^{c} (27)	3.822^{c} (15)	1.932^{d} (3)
T_6 $N_{80}P_{40}K_{40}$	7.962^{b} (53)	6.469^{ab} (42)	2.830^{bc} (8)
T_7 $N_{80}P_{40}K_{40}$ (25%N as CM)	9.330^{a} (87)	6.645^{ab} (59)	3.269^{ab} (10)

* - $\sqrt{x + 0.5}$ transformed values. The original values are in parenthesis.

Values followed by same letters do not differ significantly in DMRT.

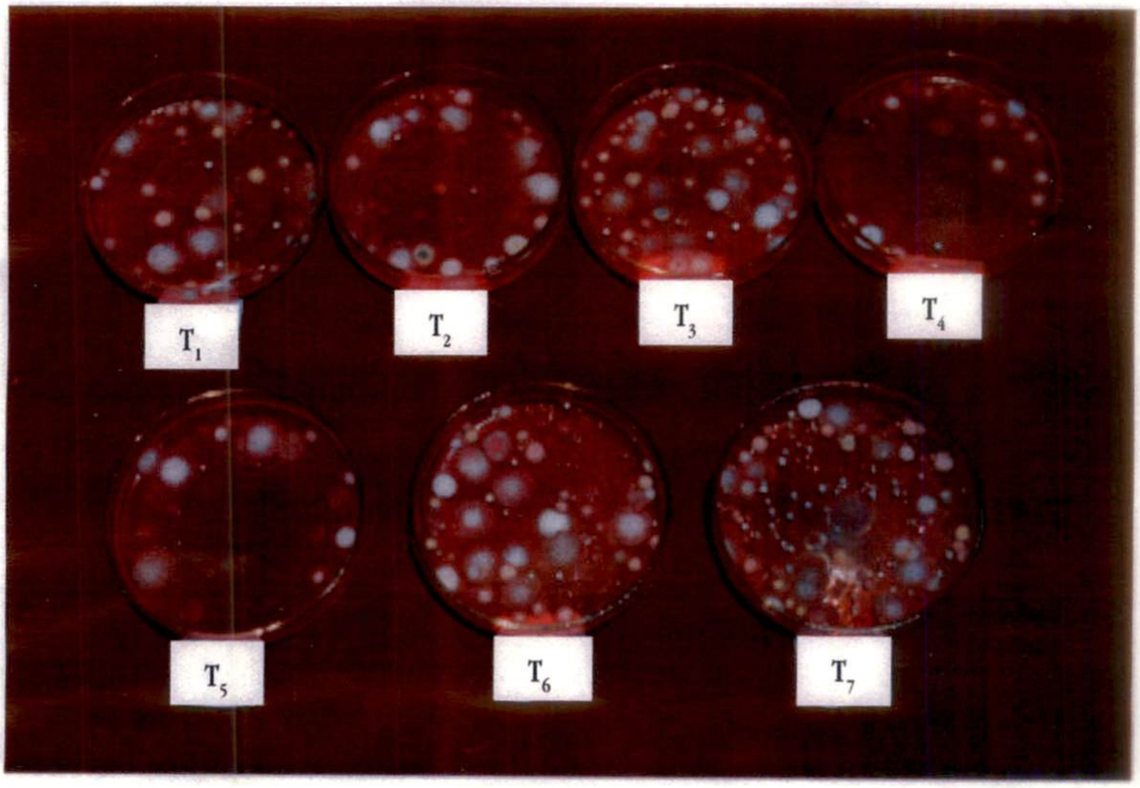
N as Ammonium sulphate

P as Single Super Phosphate

K as Muriate of Potash

c.f.u. colony forming units

Plate 1. Effect of soil fertility on the population of soil fungi



Organic manure application favourably influenced the fungal population. Even where NPK was supplied, application of FYM still resulted in significant increase in the fungal population as is seen from the data for NPK (T_6) and NPK +FYM (T_7).

The highest population of bacteria was seen in T_3 (N and P) followed by T_7 (NPK + FYM) and T_6 (NPK), which were statistically on par. The lowest population was recorded in T_5 (PK) and T_2 (N alone), which were statistically on par. Actinomycetes recorded the maximum population in treatments receiving N and P (T_3) followed by NPK + FYM (T_7), which were statistically on par. The lowest population was obtained in plots where cattle manure alone is applied (T_1) followed by T_4 (NK) and T_5 (PK).

4.3. INFLUENCE OF AGRO ECOLOGICAL CONDITION ON WEED FLORA

The information from the weed surveys conducted in the major rice ecosystems of Kerala was used for studying the influence of agroecological conditions on weed flora. Based on the data from weed survey, frequency, density, relative frequency, relative density and relative importance values were worked out to study the dominance of the weeds in each ecosystem. These results are presented here.

4.3.1. *Kole* lands

Table 22 shows information on the distribution and importance of the weeds of *Kole* lands. A total of 23 species were observed in the rice fields, of which seven were grasses, five were sedges, nine were broad leaf weeds and two were ferns.

When the weeds were ranked according to the RIV, 10 weeds ie. *Echinochloa stagnina, Echinochloa crusgalli, Eragrostis tenella, Fimbristylis miliacea, Cyperus iria, Limnocharis flava, Monochoria vaginalis, Ludwigia parviflora, Lindernia*

Table 22. Distribution and dominance of weeds of *Kole* lands

Weed species	Frequency (%)	Density (No/m^2)	Relative Frequency (%)	Relative Density (%)	Relative Importance Value (%)
Grasses					
Echinochoa stagnina(Retz. Beauv)	71.42	16.10	18.33	13.23	15.78
Echinochloa crusgalli(L.)	57.14	13.93	14.67	11.44	13.06
Eragrostis tenella (L.) beauv	3.57	12	0.91	9.86	5.38
Echinochloa colona (L.) Link	10.71	4	2.74	3.32	3.03
Sacciolepis interrupta (Wild) Stapt.	14.28	2.75	3.66	2.26	2.96
Echinochloa glabrescens Munro.ex Hook F.	10.71	2.33	2.74	1.91	2.33
Oryza rufipogon Griff	3.57	4	0.91	3.38	2.10
Sedges					
Fimbristylis miliacea (L.) Vahl.	28.57	7.13	7.33	5.8	6.56
Cyperus iria L.	32.14	3.11	8.25	2.55	5.40
Cyperus difformis L.	10.71	4	2.74	3.32	3.03
Cyperus articulatus L.	3.57	5	0.91	4.10	2.51
Schoenoplectus lateriflorus (Gmel) Lye.	3.57	1	0.91	0.82	0.87
Broad Leaf Weeds					
Ludwigia parviflora Roxb.	35.71	2.8	9.16	2.30	5.73
Lindernia crustacea(L.) F. Muell	14.28	9	3.66	7.39	5.53
Limnocharis flava (L.) Buch	3.57	12	0.91	9.86	5.38
Monochoria vaginalis (Burm.f)Presl.ex Kunth.	21.42	3.5	5.49	2.87	4.18
Cleome viscosa L.	10.71	1.6	2.74	1.31	2.03
Phyllanthus nirurii L.	7.14	2	1.83	1.64	1.74
Limnophila heterophylla (Roxb) benth	7.14	1.5	1.83	1.23	1.53
Sphenoclea zeylanica Gaertn	7.14	1.5	1.83	1.23	1.53
Alternanthera sessilis (L.) DC	3.57	2	.91	1.64	1.28
Ferns					
Marsilea quadrifolia L.	25	6.42	6.41	5.27	5.84
Ceratopteris thatictroides brong.	3.57	4	0.91	3.28	2.10

crustacea and *Marsilea quadrifolia* together had an RIV of 72.82 indicating that more than 70 per cent of the weed flora of *Kole* lands is constituted by these weeds.

Echinochloa stagnina (RIV-15.78) and *E.crusgalli* (13.06) were the most dominant weeds of this ecosystem together accounting for about 30 per cent of the RIV. These two weeds were present in majority of the sites surveyed (*E. stagnina* with frequency of 71% and *E.crusgalli* with a frequency of 57%). Although two other species of *Echinochloa* were present (*E.glabrescence* and *E.colona*), their frequency and density values were low resulting in lower RIV. *Eragrostis tenella, Sacciolepis interrupta* and *Oryza rufipogon* were the other grasses, but not very dominant in this ecosystem.

Fimbristylis miliacea was the most dominant sedge, which occurred in 29 per cent of the fields surveyed, followed by *Cyperus iria*, which was present in 1/3rd of the fields, surveyed and *C.difformis* occurring in 11 per cent of the fields surveyed.

Among the broad leaf weeds, *Ludwigia parviflora* was the most dominant one occurring in about 36 per cent of the sites surveyed followed by *Lindernia crustacea* with an RIV of 5.56. *Limnocharis flava,* a comparatively recent addition to the alien weeds in Kerala is the third important broad leaf weed in the rice fields of *Kole* lands. *Monochoria vaginalis* is another important broad leaf weed with wide distribution (Frequency – 21.42%) in this ecosystem. Among the ferns *Marsilea quadrifolia* was the most important one (RIV: 5.84) occurring in 25 per cent of the sites. *Ceratopteris thalictroides* occurred in limited areas only.

4.3.2. *Kari* Lands

The data on the distribution and importance of weeds of *Kari* lands of Kuttanad is presented in Table 23. Fifteen weeds were identified in the rice fields of *Kari* lands, which included four grasses, four sedges, six broad leaf weeds and one fern.

The weed flora of *Kari* lands was dominated by *Echinochloa stagnina, Eleocharis dulcis. Fimbristylis miliacea, Monochoria vaginalis, Oryza rufipogon* and *Ludwigia parviflora*, which accounted for more than 60 per cent of the RIV. Among these *E.stagnina* was the most dominant weed (RIV: 18.93), occurring in about 95 per cent of the fields surveyed. Although *E.crusgalli* was also present, its frequency (13.04%) and RIV (3.0) were much lower. *Oryza rufipogon* (Frequency 26%) and *Isachne miliacea* (Frequency 17%) were the other two grass species observed.

Table 23. Distribution and dominance of weeds of *Kari* lands

Weed species	Frequency (%)	Density (No/m^2)	Relative Frequency (%)	Relative Density (%)	Relative Importance Value (%)
Grasses					
Echinochloa stagnina(Retz.) Beauv	95.65	15.09	24.45	13.41	18.93
Oryza rufipogon Griff	26.08	3.16	6.66	5.93	6.29
Isachne miliacea Roth.	17.30	1.25	4.42	3.93	3.90
Echinochloa crusgalli(L.)	13.04	3.00	3.33	2.67	3.00
Sedges					
Eleocharis dulcis(N. Burman) Henschel	34.78	21.63	8.89	19.26	14.07
Fimbristylis miliacea (L.) Vahl.	47.82	7.45	12.22	6.63	9.43
Cyperus iria L.	17.39	5.25	4.44	4.67	4.55
Rhynchospora corymbosa(L.)	4.34	8.00	1.11	7.11	4.11
Broad Leaf Weeds					
Monochoria vaginalis (Burm.f) Presl.ex Kunth.	52.17	5.25	13.33	4.67	9.00
Ludwigia parviflora Roxb.	34.78	3.88	8.89	3.44	6.16
Limnocharis flava (L.) Buch	21.73	5.00	5.55	4.44	4.99
Nymphaea nouchali Burm .f	4.34	8.00	1.11	7.11	4.11
Eichhornia crassipes Solms.	4.34	7.00	1.11	6.22	3.66
Ipomoea aquatica Forsk	4.34	4.00	1.11	3.55	2.33
Ferns					
Salvinia molesta Mitchell	13.04	14.30	3.33	12.73	8.03

Eleocharis dulcis was the most predominant sedge having an RIV of 14.07. The magnitude of occurrence of *Eleocharis dulcis* in *Kari* lands is note worthy when compared to its very low population in the *Kayal* and *Karappadam* lands of Kuttand. *Fimbristylis miliacea* constituted a major portion of the sedge population with a frequency of 48 per cent. *Cyperus iria* and *Rhyncospora corymbosa* were the other two sedges occurring in lesser frequencies.

Monochoria vaginalis was the most dominant broad leaf weed (RIV: 9) occurring in more than 50 per cent of the fields surveyed. *Ludwigia parviflora* had an important position among the broad leaf weeds with a frequency of about 35 per cent. *Limnocharis flava, Nymphaea nouchali, Eichhornia crassipes* and *Ipomoea aquatica* were the other weeds occurring in lesser proportions. *Salvinia molesta* was the only fern present in the *Kari* lands, which had an RIV of 8.03.

4.3.3. *Kayal* Lands

Table 24 gives information on the distribution and importance of weeds of *Kayal* lands of kuttanad. The 14 weeds included four grasses, two sedges, five broad leaf weeds and three ferns.

The species level analysis of the floristic composition of *Kayal* lands of Kuttanad revealed the predominance of *Echinochloa stagnina, E.crusgalli, Sacciolepis* sp, *Fimbristylis miliacea, Monochoria vaginalis, Ludwigia parviflora* and *Salvinia molesta*, which accounted for more than 60 per cent of the total weed population. In the *Kayal* lands *Echinochloa stagnina* (RIV: 15.93) was the most dominant weed species occurring in about 81per cent of fields surveyed followed by *E.crusgalli* which had a frequency of 50 per cent. The other two major grass weeds were *Sacciolepis* sp and *Oryza rufipogon*, of which *Sacciolepis* sp occurred in 37 per cent of the fields. The sedge population was dominated by *Fimbristylis miliacea* having a frequency of

50 per cent. *Cyperus pangorei* was the next important sedge with an RIV value of 6.29.

Among the broad leaf weeds, *Ludwigia parviflora* (RIV: 6.78) had a wide distribution, occurring in 37per cent of the fields surveyed. Although *Monochoria vaginalis* (6.21) and *Eichhornia crassipes* (6.58) had similar RIV, their frequencies were very less compared to *Ludwigia parviflora. Lindernia crustacea* and *Nymphaea nouchali* were the other broad leaf weeds present, but were of minor importance. Among the three ferns observed, *Salvinia molesta* had a wide distribution with an RIV

Table 24. Distribution and dominance of weeds of *Kayal* lands

Weed species	Frequency (%)	Density (No/m^2)	Relative Frequency (%)	Relative Density (%)	Relative Importance Value (%)
Grasses					
Echinochloa stagnina (Retz.) Beauv.	81.25	11.92	22.8	9.06	15.93
Echinochloa crusgalli(L.)	50.00	8.38	14.03	6.37	10.20
Sacciolepis interrupta (Willd) stapf.	37.00	4.80	10.53	3.65	7.09
Oryza rufipogon Griff	6.25	5.00	1.75	3.80	5.55
Sedges					
Fimbristylis miliacea (L.) Vahl.	50.00	5.00	14.04	3.80	8.92
Cyperus pangorei Rottb.	31.25	5.00	8.77	3.80	6.29
Broad Leaf Weeds					
Ludwigia parviflora Roxb.	37.50	4.00	10.52	3.04	6.78
Eichhornia crassipes Solms	6.25	15.00	1.75	11.41	6.58
Nymphaea nouchali Burm.f	6.25	10.00	1.75	7.61	4.68
Monochoria vaginalis (Burm.f)Presl.ex Kunth.	6.25	14.00	1.75	10.65	6.20
Lindernia crustacea (L.) F. Muell	6.25	5.50	1.75	4.18	2.97
Ferns					
Salvinia molesta Mitchell	18.75	33.33	5.26	25.36	15.31
Marsilea quadrifolia L.	12.50	5.50	3.51	4.18	3.85
Ceratopteris thalictroides Brong.	6.25	4.00	1.75	3.04	2.40

of 15.31 followed by *Marsilea quadrifolia* (RIV: 3.84, frequency: 12.0%) and *Ceratopteris thalictroides* (RIV: 2.4, frequency: 6%)

4.3.4. *Karappadam* lands

The list of weeds identified in *Karappadam* lands with data on their distribution and importance are presented in Table 25.

Table 25. Distribution and dominance of weeds of *Karappadam* lands

Weed species	Frequency (%)	Density (No/m^2)	Relative Frequency (%)	Relative Density (%)	Relative Importance Value (%)
Grasses					
Echinochloa stagnina (Retz.) Beauv.	60	25.5	13.33	18.43	15.88
Isachne miliacea Roth	20	20.5	4.44	14.82	9.63
Oryza rufipogon Griff	30	1.6	6.66	1.15	3.90
Echinochloa crusgalli(L.)	10	1.0	2.22	0.72	1.47
Sedges					
Fimbristylis miliacea (L.) Vahl..	50	11.0	11.11	7.95	9.53
Cyperus pangorei Rottb.	50	8.6	11.11	6.21	8.66
Eleocharis dulcis (N.Burman) Henschel	10	1.0	2.22	0.72	1.47
Broad Leaf Weeds					
Monochoria vaginalis (Burm.f)Presl.ex Kunth.	80	11.0	17.77	7.95	12.86
Nymphaea nouchali Burm.f	20	20.5	4.44	14.82	9.63
Limnocharis flava (L.) Buch.	30	4.6	6.66	3.32	4.99
Ludwigia parviflora Roxb.	30	3.0	6.66	2.16	4.41
Eichhornia crassipes Solms	10	5.10	2.22	3.61	2.92
Ipomoea aquatica Forsk	10	1.0	2.22	0.74	1.47
Ferns					
Marsilea quadrifolia L.	20	11.0	4.44	7.95	6.92
Salvinia molesta Mitchell	20	13.0	4.44	9.39	6.92

A total of 15 weed species were observed in the rice of fields of Karappadam lands, of which four were grasses, three were sedges, six were broad leaf weeds and two were ferns. When the weeds were ranked according to the Relative Importance Values, seven weeds ie; *Echinochloa stagnina, Isachne miliacea, Fimbristylis miliacea, Cyperus difformis, Monochoria vaginalis, Nymphaea nouchali* and *Salvinia molesta* together had an RIV of 73 per cent indicating that about three-fourth of the weed problems of this ecosystem are from these weeds.

Echinochloa stagnina (RIV: 15.88) and *Isachne miliacea* (RIV: 9.63) were the most important grass weeds of *Karappadam* lands accounting for about 25 per cent of the RIV. Of these two weed species, *E.stagnina* was present in 60 per cent of the fields surveyed and with an average density of 25 plants/m^2, indicating it as the main problem weed in rice fields. *E.crusgalli* and *Oryza rufipogon* were the other two grass weeds present. However, their frequency and density were lesser resulting in lower RIV.

The predominant broad leaf weed species in the rice fields of *Karappadam* were *Monochoria vaginalis* (frequency: 80%) with an RIV of 12.86 followed by *Nymphaea nouchali* with an RIV of 9.63. *Limnocharis flava* and *Ludwigia parviflora* were the other two broad leaf weeds with a frequency of 30 per cent each. The frequency and density values of *Ipomoea aquatica* and *Eichhornia crassipes* were very less resulting in lower RIV.

Among the ferns studied, both *Salvinia molesta* and *Marsilea quadrifolia* occurred in equal proportions in the rice fields together constituting an RIV of 17.

4.3.5. *Pokkali* Region

A total of 18 weed species were observed in the *Pokkali* rice fields of which three were grasses, three sedges, nine broad leaf weeds and three ferns (Table 26). *Diplachne fusca* was the most dominant grass weed in this area having a frequency of 85 per cent and RIV of 11.23. The other important grass weed was *Echinochloa crusgalli* (RIV: 9.98) occurring in about 80 per cent of the rice fields. Among the sedges, *Fimbristylis miliacea* (frequency: 55%, RIV: 6.48) and *Eleocharis dulcis* (frequency: 45%, RIV: 6.05) were the most dominant species.

Table 26. Distribution and dominance of weeds of *Pokkali* lands

Weed species	Frequency (%)	Density (No/m^2)	Relative Frequency (%)	Relative Density (%)	Relative Importance Value (%)
Grasses					
Diplachne fusca Beauv	85	17.17	13.38	9.07	11.23
Echinochloa crusgalli (L.) Beauv.	80	13.93	12.59	7.36	9.98
Panicum repens L.	10	3.50	1.57	1.84	1.71
Sedges					
Fimbristylis miliacea (L.) Vahl.	55	8.27	8.6	4.37	6.48
Eleocharis dulcis N.Burman) Henschel	45	9.50	7.08	5.02	6.05
Cyperus difformis L.	25	6.20	3.93	3.27	3.60
Broad Leaf Weeds					
Eichhornia crassipes Solms	30	14.33	4.72	7.57	6.15
Lemna polyrrhiza L.	5	20.00	0.78	10.57	5.67
Pistia statiotes L.	3	12.60	4.7	6.65	5.67
Monochoria vaginalis (Burm.f)Presl.ex Kunth.	50	5.50	7.87	2.9	5.38
Alternanthera sessilis(L.)DC	45	6.50	7.08	3.43	5.25
Nymphaea nouchali Burm.f	35	6.28	5.51	3.31	4.41
Sphenoclea zeylanica Gaertn.	40	4.12	6.29	2.17	4.23
Ludwigia parviflora Roxb.	25	5.40	3.93	2.85	3.39
Sphaeranthus africanus L.	10	8.50	1.57	4.49	3.03
Ferns					
Salvinia molesta Mitchell	15	25.00	2.36	13.21	7.65
Azolla pennata R.Br.	5	18.00	0.78	9.51	5.15
Ceratopteris thalictroides Brang.	45	4.40	7.08	2.32	4.70

Cyperus difformis (RIV: 3.6) occurred in lesser proportions. Predominant broad leaf weeds in the weed community of *Pokkali* region were *Alternanthera* *sessilis, Pistia stratiotes, Monochoria vaginalis, Lemna polyrrhiza* and *Eichhornia crassipes* together constituting an RIV of 28.12. The other broad leaf weeds observed were *Nymphaea nouchali* (RIV: 4.41), *Sphenoclea zeylanica* (RIV: 4.23), *Ludwigia parviflora* (RIV: 3.39) and *Sphaeranthus africanus* (RIV: 3.03).Among the broad leaf weeds *Sphenoclea zeylania, Alternanthera sessilis and Monochoria vaginalis* occurred in more than 40 per cent of the fields surveyed.

Among the three ferns observed, *Salvinia molesta* (frequency: 15%) had an RIV of 7.65 followed by *Azolla* (RIV:5.15) and *Ceratopteris thalictroides* having an RIV of 4.7.

Acanthus ilicifolius, Cyperus javanicus and *Acrostichum aureum* were the weeds typically adapted to the saline areas of Pokkali region. They were found mostly inhabiting the paddy field bunds and abandoned rice fields.

4.3.6. Palakkad (Kharif)

The list of weeds identified furing the kharif season of Palakkad with data on their distribution are presented in Table 27. The analysis of the floristic composition of the Kharif season of Palakkad revealed the dominance of weeds like *Sacciolepis interrupta, Isachne miliacea, Oryza rufipogon, Cyperus iria* and *Ludwigia parviflora* together accounting for an RIV of more than 50 per cent. About seven grass species were observed during the Kharif season of which *Sacciolepis interrupta* occupied the top position with an RIV of 13.3 followed by *Isachne miliacea* (RIV: 12.54) and *Oryza rufipogon* (10.27). The other grass species present were *Echinochloa crusgalli, E. colona, Ischeamum rugosum* and *Leptochloa chinensis* whose RIV's were very less.

The sedge population was dominated by *Cyperus iria* with an RIV of 10.28. A number of other species of Cyperus namely *C.haspan, C.rotundus, C.difformis* and *C.pangorei* were also observed in the semidry crop of the Kharif season of Palakkad. *Fimbristylis miliacea* occurred in about nine per cent of the fields surveyed, while the

Table 27. Distribution and dominance of weeds of Palakkad (Kharif)

Weed species	Frequency (%)	Density (No/m^2)	Relative Frequency (%)	Relative Density (%)	Relative Importance Value (%)
Grasses					
Sacciolepis interrupta (Willd.) Stapt	54.54	23.08	12.65	13.95	13.30
Isachne miliacea Roth	31.80	29.28	7.38	17.70	12.54
Oryza rufipogon Griff	36.36	20.00	8.44	12.09	10.27
Echinochloa crusgulli (L.)Beauv.	27.27	2.30	6.32	1.39	3.86
Echinochloa colona (L.)Link	18.18	4.50	4.21	2.72	3.47
Ischaemum rugosum Salisb	9.00	5.50	2.08	3.32	2.70
Leptochloa chinensis (L.) Nees	4.50	4.00	1.04	2.42	1.73
Sedges					
Cyperus iria L.	68.18	7.86	15.8	4.75	10.28
Cyperus haspan L.	18.18	6.00	4.21	6.62	3.92
Fimbristylis miliacea (L.) Vahl	9.00	7.50	2.08	4.5	3.29
Cyperus rotundus L.	4.50	5.00	1.04	3.02	2.08
Cyperus difformis L.	9.00	3.00	2.08	1.81	1.95
Schoenoplectus lateriflorus (Gmel.)Lye	4.50	3.00	1.04	1.81	1.43
Cyperus pangorei Rottb.	4.50	2.00	1.04	1.20	1.12
Broad Leaf Weeds					
Ludwigia parviflora Roxb.	36.3	6.00	8.42	3.62	6.02
Cyanotis axillaris (L.) Sweet	9.00	7.00	2.08	4.23	3.15
Aeschynomene indica L.	13.6	4.60	3.15	2.78	2.69
Eclipta alba (L.) Hassk	13.6	3.33	3.15	2.01	2.58
*Commelina benghalensis*L.	13.6	2.60	3.15	1.57	2.3
Lindernia crustacea (L.) F Muell	4.50	5.00	1.04	3.02	2.08
Alternanthera sessilis (L.) DC	4.50	5.00	1.04	3.02	2.08
Monochoria vaginalis (Burm.f)Presl.ex Kunth.	9.00	2.00	2.08	1.20	1.64
Ferns					
Marsilea quadrifolia L.	27.27	6.80	6.32	4.11	5.22

density and frequency of *Schoenoplectus lateriflorus* was very less resulting in low RIV.

Although a number of broad leaf weeds were observed during the first crop season of Palakkad, their RIV's were less when compared to grasses. The most important broad leaf weed was *Ludwigia parviflora* (RIV: 6.02) followed by *Cyanotis axillaris* (3.15) and *Aeschynomene indica* (2.96). *Marsilea quadrifolia* was the only fern observed during the Kharif season with an RIV of 5.22.

4.3.7. Palakkad (Rabi)

Table 28 gives information on the distribution and importance of the weeds of the Rabi season of Palakkad. A total of 20 species were observed in the rice fields during the Rabi season of which four were grasses, six were sedges, nine were broad leaf weeds and one was a fern.

Among the grass weeds, *Oryza rufipogon* occurred in about 20 per cent of the fields surveyed having an RIV of 4.95 followed by *Leptochloa chinensis* (RIV: 438), *Isachne miliacea* (3.87) and *Echinochloa crusgalli* (2.86). *Cyperus iria* was the most important sedge, which occurred in 40 per cent of the fields, surveyed followed by *Cyperus pangorei*, which occurred in 20 per cent of the fields and *Fimbristylis miliacea* in 15 per cent of the fields.

The broad leaf weeds together accounted for an RIV of 46.88 during the second crop season. The most dominant weed species was *Ludwigia parviflora* (RIV: 9.92), followed by *Monochoria vaginalis* (6.84), *Sphenoclea zeylancea* (5.72) and *Sphaeranthus indicus* (4.95). *Eclipta alba, Commelina benghalensis, Alternanthera sessilis, Ipomoea aquatica* and *Cyanotis axillaris* were the other weeds occurring in lesser proportions. *Marsilea quadrifolia* was the only fern present in the Palakkad region during the Rabi season with an RIV of 9.52.

Table 28. Distribution and dominance of weeds of Palakkad (Rabi)

Weed species	Frequency (%)	Density (No/m^2)	Relative Frequency (%)	Relative Density (%)	Relative Importance Value (%)
Grasses					
Oryza rufipogon Griff	20	2.25	5.33	4.57	4.95
Leptochloa chinensis (L) Nees	10	3.00	2.66	6.10	4.38
Isachne miliacea Roth	10	2.50	2.66	5.08	3.87
Echinochloa crusgilli (L.)Beauv.	10	1.50	2.66	3.05	2.86
Sedges					
Cyperus iria L.	40	4.13	1.66	8.39	9.53
Cyperus pangorei Rottb.	20	2.75	5.33	5.59	5.46
Fimbristylis miliacea (L.) Vahl	15	3.33	4.00	6.77	5.39
Cyperus difformis L.	10	2.25	2.66	4.57	3.62
Cyperus haspan L.	5	1.00	1.33	2.03	1.68
Schoenoplectus lateriflorus (Gmel.)Lye	5	1.00	1.33	2.03	1.68
Broad Leaf Weeds					
Ludwigia parviflora Roxb.	25	6.60	6.41	13.42	9.92
Monochoria vaginalis (Burm.f)Presl.ex Kunth	35	2.14	9.33	4.35	6.84
Sphenoclea zeylanica Gaertn.	20	3.00	5.33	6.1	5.72
Sphaeranthus indicus L.	20	2.25	5.33	4.57	4.95
Eclipta alba (L.) Hassk	20	2.00	5.33	4.06	4.70
*Commelina benghalensis*L.	15	2.30	4.00	4.67	4.34
Alternanthera sessilis (L.) DC	15	2.00	4.00	4.06	4.03
Ipomoea aquatica Forsk	20	1.00	5.33	2.03	3.68
Cyanotis axillaris (L.) Sweet	5	2.00	1.33	4.06	2.70
Ferns					
Marsilea quadrifolia L.	55	2.18	14.6	4.43	9.52

4.3.8. Chittur (Kharif Season)

Table 29 shows the spectrum of weed flora of rice and relative importance of

Table 29. Distribution and dominance of weeds of Chittur (Kharif)

Weed species	Frequency (%)	Density (No/m^2)	Relative Frequency (%)	Relative Density (%)	Relative Importance Value (%)
Grasses					
Leptochloa chinensis (L) Nee	84.6	12.9	21.69	11.91	16.8
Echinochloa crusgalli (L) Beauv	7.60	8.00	1.94	7.39	4.66
Echinochloa colona (L) Link	46.15	3.16	11.79	2.92	7.35
Isachne miliacea Roth	23.07	5.66	5.89	6.15	6.02
Setaria pallide-fusca (schum) stapf et C.E. Hubb.	7.60	10.00	1.94	9.23	5.58
Ischaemum rugosum salisb	15.38	5.00	3.93	4.61	4.27
Sedges					
Cyperus iria L.	38.46	10.00	1.94	9.23	9.53
Cyperus rotundus L.	7.60	10.00	1.94	9.23	5.58
Fimbristylis miliacea (L.) Vahl	7.60	2.00	1.94	1.84	1.89
Broad Leaf Weeds					
Ludwigia parviflora Roxb.	38.45	3.60	9.82	3.32	6.57
Alternanthera sessilis (L.) DC	15.38	3.50	3.93	3.23	3.58
Commelina benghalensis L. Dc	15.38	3.00	3.93	2.77	3.35
Lindernia crustacea (L.) F. Muell	7.60	5.00	1.94	4.61	3.27
Eclipta alba (L.) Hassk	7.60	4.00	1.94	3.69	2.82
Cleome viscosa L.	7.60	4.00	1.94	3.69	2.81
Melochia corchorifolia L.	7.60	3.00	1.94	2.77	2.35
Cyanotis axillaris (L.) Sweet	7.60	3.00	1.94	2.77	2.35
Ipomoea aquatica Forsk.	7.60	2.00	1.94	1.84	1.89
Ferns					
Marsilea quadrifolia L.	38.45	9.40	9.82	8.68	9.25

each species, during the first crop season in the Chittur region. The common weeds across the Chittur taluk of Palakkad district during the first crop season were *Leptochloa chinensis, Echinochloa crusgalli, Isachne miliacea, Cyperus iria, C.rotundus, Fimbristylis miliacea, Ludwigia parviflora* and *Marsilea quadrifolia.* The survey indicated the dominance of *Leptochloa chinensis* (RIV: 16.8) occurring in more than 80 per cent of the fields surveyed. This annual grass weed shows a consistent association with the alkaline black cotton soils of Chittur, and is not present in the other rice ecosystems of Kerala. The other grass weeds were *Echinochloa crusgalli* with a frequency of 46.15 per cent followed by *Isachne miliacea* (frequency: 23.07%), *Ischaemum rugosum* (15.38%) and *Setaria palidaefusca* (7.6%).

Although a total of about nine broad leaf weeds, namely *Cyanotis axillaris, Ludwigia parviflora, Alternanthera sessilis, Commelina benghalensis, Ipomoea aquatica, Cleome viscosa, Melochia corchorifolia, Eclipta alba* and *Lindernia crustacea* were present in the rice fields, their frequencies and relative densities were much lower except that of *Ludwigia parviflora* (RIV: 6.57), which occurred in 39 per cent of the fields surveyed. *Marsilea quadrifolia* was the only fern present in the rice fields of Chittur, with a frequency of 38.45 per cent and density of nine plants/m^2.

4.3.9. Chittur (Rabi)

The distribution and importance of weed flora during the Rabi season of Chittur region is given in Table 30. *Echinochloa crusgalli, Leptochloa chinensis, Isachne miliacea, Fimbristylis miliacea* and *Marsilea quadrifolia* dominated the weed spectrum of the second crop season of Chittur together accounting for an RIV of 56.62. Weeds present with densities higher than 5 plants/m^2 were *Leptochloa chinensis, Isachne miliacea, Fimbristylis miliacea* and *Marsilea quadrifolia.* All these weeds except *I. miliacea* were present in more than 50 per cent of the fields surveyed. When the grasses were ranked according to the RIV, *Leptochloa chinensis* had the top position with an RIV of 12.8 followed by *Isachne miliacea* (RIV: 10.14) and

Echinochloa crusgalli (RIV: 8.35). *E. colona* had very low density and hence the RIV was very less. The predominant sedge species were *Cyperus iria* (RIV: 8.94) and *Fimbristylis miliacea* (RIV: 12.41) occurring in more than 40 per cent of the fields surveyed.

Lindernia crustacea, Lemna polyrrhiza and *Monochoria vaginalis* were the three broad leaf weeds present in rice fields of which *Lemna polyrrhiza* had a high density of 30 plants/m^2 which resulted in a high RIV, though it was present in a few fields only.

Table 30. Distribution and dominance of weeds of Chittur (Rabi)

Weed species	Frequency (%)	Density (No/m^2)	Relative Frequency (%)	Relative Density (%)	Relative Importance Value (%)
Grasses					
Leptochloa chinensis (L) Nees.	60	7.16	16.6	9.19	12.89
Isachne miliacea Roth	25	10.40	6.94	13.34	10.14
Echinochloa crusgilli (L) Beauv.	50	2.20	13.88	2.82	8.35
Echinochloa colona (L.) Link	10	1.00	2.77	1.28	2.03
Sedges					
Fimbristylis miliacea (L.) Vahl	55	7.45	15.27	9.56	12.41
Cyperus iria L.	45	4.20	12.50	5.39	8.94
Broad Leaf Weeds					
Lemna polyrrhiza L.	5	30.00	1.38	38.5	19.94
Ludwigia parviflora Roxb.	35	3.70	9.72	4.74	7.23
Monochoria vaginalis (Burm.f)Presl.ex Kunth.	25	2.60	6.94	3.30	5.12
Ferns					
Marsilea quadrifolia L.	50	9.20	13.88	11.80	12.84

Ludwigia parviflora and *Monochoria vaginalis* were present in more than 20 per cent of the fields surveyed. *Marsilea quadrifolia* was the only fern present in sizable proportions in the rice fields, with a frequency of 50 per cent.

4.4. WEED VEGETATION ANALYSIS

From the survey, it is evident that there are similarities in weed flora between some of the regions, which are geographically wide apart. On the other hand, differences were also noticed in the weed flora between adjacent regions or even within the region itself with changes in the method of rice growing or with changes in the season. An understanding of the similarities (or dissimilarities) between different regions, seasons, or method of cultivation will be helpful in identifying the conditions, which may be favouring or disfavouring a particular weed. These analyses were done by using the Simpson's diversity index (D), the Shannon diversity index (H), Evenness index (J) and the dissimilarity coefficient.

The values of the diversity indices worked out for weed vegetation analysis are given in Table 31 . For grasses, all the diversity indices showed distinct differences in the various rice ecosystems of Kerala. Both the diversity indices, the Simpson's diversity index (D) and the Shannon diversity index (H) as well as the Evenness index (J) had the lowest value for *Kari* lands, whereas the same were the highest during the second season of Palakkad. Such significant difference could not be observed in the indices for sedges, though in the first crop season of Palakkad and Chittur both the diversity indices (D and H) and the Evenness index had low values.

Among the broad leaf weeds, just like grasses, the *Kari* soils had the lowest value for Shannon index and Evenness index, whereas the Simpson's diversity index and Evenness index was the highest for *Pokkali* lands.

As regards to the total weed flora, the maximum species richness was observed in *Kole* lands and Palakkad (Kharif) followed by Palakkad (Rabi). Both the diversity

Table 31. Weed vegetation analysis indices of different rice ecosystems of Kerala

Agroecological zones	Grasses				Sedges				Broad leaf weeds				Total weeds			
	S	D	H	J	S	D	H	J	S	D	H	J	S	D	H	J
Kole	7	2.27	1.02	0.52	5	2.53	1.12	0.69	9	6.09	1.44	0.65	23	4.44	2.01	0.64
Karappadam	4	2.24	0.93	0.67	3	2.03	0.74	0.67	6	2.58	1.20	0.66	15	7.86	1.90	0.70
Kari	4	1.20	0.39	0.28	4	2.17	0.95	0.69	7	3.59	0.95	0.48	16	4.49	1.94	0.70
Kayal	4	2.20	1.09	0.77	2	1.90	0.66	0.96	5	4.14	1.50	0.93	13	5.81	2.08	0.81
Pokkali	3	2.00	0.75	0.67	3	2.60	1.01	0.90	9	7.2	2.07	0.94	18	8.69	2.46	0.85
Palakkad-1*	7	3.30	1.31	0.67	6	1.91	0.98	0.54	9	4.27	1.80	0.81	23	6.22	2.19	0.70
Palakkad-2**	4	3.50	1.32	0.95	6	2.78	1.28	0.71	9	5.39	1.92	0.88	20	11.04	2.65	0.88
Chittur-1*	5	1.90	0.99	0.62	3	1.47	0.58	0.53	10	6.57	2.09	1.00	19	5.17	1.50	0.51
Chittur-2**	4	2.40	1.02	0.74	2	1.76	0.62	0.90	3	2.73	1.04	0.94	10	6.77	2.04	0.88

S : Species richness

D : Simpson's diversity index

H : Shannon diversity index

J : Evenness index

* : Kharif season

** : Rabi season

Table 32. Dissimilarity matrix of total weeds based on dissimilarity coefficient

Total weeds	*Kole*	*Karappadam*	*Kari*	*Kayal*	*Pokkali*	Palakkad-1*	Palakkad-2**	Chittur-1*	Chittur-2**
Kole	0	46	9	35	23	17	47	46	20
Karappadam	46	0	44	22	45	31	45	14	14
Kari	9	44	0	21	25	43	35	21	5
Kayal	35	22	21	0	39	45	27	28	21
Pokkali	23	45	25	39	0	66	71	84	41
Palakkad-1*	17	31	43	45	66	0	58	20	7
Palakkad-2**	47	45	35	27	71	58	0	52	13
Chittur-1*	46	14	21	28	84	20	52	0	41
Chittur-2**	20	14	5	21	41	7	13	41	0

* Kharif season

** Rabi season

Table33. Dissimilarity matrix of grass weeds based on dissimilarity coefficient

Grass weeds	*Kole*	*Karappadam*	*Kari*	*Kayal*	*Pokkali*	Palakkad-1*	Palakkad-2**	Chittur-1*	Chittur-2**
Kole	0	89	21	38	1	25	90	79	81
Karappadam	89	0	67	75	99	84	68	20	28
Kari	21	67	0	33	92	84	32	33	68
Kayal	38	75	33	0	56	65	70	77	48
Pokkali	1	99	92	56	0	88	97	82	82
Palakkad-1*	25	84	84	65	88	0	89	12	20
Palakkad-2**	90	68	32	70	97	89	0	85	84
Chittur-1*	79	20	33	77	82	12	85	0	8
Chittur-2**	81	28	68	48	82	20	84	8	0

* Kharif season

** Rabi season

Table 34. Dissimilarity matrix of broad leaf weeds based on dissimilarity coefficient

Broad leaf weeds	*Kole*	*Karappadam*	*Kari*	*Kayal*	*Pokkali*	Palakkad-1*	Palakkad-2**	Chittur-1*	Chittur-2**
Kole	0	36	39	30	53	17	10	35	11
Karappadam	36	0	7	39	19	30	31	33	43
Kari	39	7	0	27	32	29	31	27	41
Kayal	30	39	27	0	54	14	12	12	1
Pokkali	53	19	32	54	0	42	45	19	19
Palakkad- 1*	17	30	29	14	42	0	11	35	14
Palakkad -2**	10	31	31	12	45	11	0	20	10
Chittur -1*	35	33	27	12	19	35	20	0	18
Chittur -2**	11	43	41	1	19	14	10	18	0

* Kharif season

** Rabi season

Table 35. Dissimilarity matrix of sedge weeds based on dissimilarity coefficient

Sedge weeds	*Kole*	*Karappadam*	*Kari*	*Kayal*	*Pokkali*	Palakkad-1*	Palakkad-2**	Chittur-1*	Chittur-2**
Kole	0	17	10	18	28	21	33	24	17
Karappadam	17	0	64	16	36	53	73	93	20
Kari	10	64	0	34	18	16	41	33	8
Kayal	18	16	34	0	39	43	51	90	34
Pokkali	28	36	18	39	0	61	96	5	5
Palakkad- 1*	21	53	16	43	61	0	47	41	8
Palakkad -2**	33	73	41	51	96	47	0	9	47
Chittur -1*	24	93	33	90	5	41	9	0	40
Chittur -2**	17	20	8	34	5	8	47	40	0

* Kharif season

** Rabi season

Table 36. Dissimilarity matrix of ferns based on dissimilarity coefficient

Ferns	*Kole*	*Karappadam*	*Kari*	*Kayal*	*Pokkali*	Palakkad-1*	Palakkad-2**	Chittur-1*	Chittur-2**
Kole	0	34	100	6	82	5	30	2	34
Karappadam	34	0	25	40	53	30	4	36	61
Kari	100	25	0	40	27	100	100	100	100
Kayal	6	40	40	0	14	58	37	62	79
Pokkali	82	53	27	14	0	100	100	100	100
Palakkad-1*	5	30	100	58	100	0	26	7	38
Palakkad-2**	30	4	100	37	100	26	0	32	59
Chittur-1*	2	36	100	62	100	7	32	0	32
Chittur-2**	34	61	100	79	100	38	59	32	0

* Kharif season

** Rabi season

indices recorded the highest value in the second season of Palakkad. The evenness index also followed the same trend.

4.4.1. Similarity in floristic composition of the rice ecosystems of Kerala

The dissimilarity coefficient values of various rice ecosystems of Kerala in terms of total weeds, grasses, broad leaf weeds, sedges and ferns is entered in a matrix (Tables 32 to 36). This matrix forms the basis of cluster analysis, which is illustrated as a dendrogram. The *Kari* lands and Chittur (Rabi season) had the least dissimilarity value in terms of total weed flora while the same was maximum in case of Chittur (Kharif season) and *Pokkali* lands with a dissimilarity coefficent value of 84.

From the dissimilarity matrix for grass weeds, it is evident that *Kole* and *Pokkali* lands had the greatest similarity followed by the Kharif and Rabi seasons of Chittur. *Karappadam* and *Pokkali* were the two regions, which differed highly in the grass weeds indicated by the dissimilarity coefficient value of 99.

The different regions did not vary much with regard to broad leaf weeds. The minimum dissimilarity was between Chittur (second crop season) and *Kayal* lands (dissimilarity coefficent value-1) and the maximum between *Kayal* lands and *Pokkali* lands (dissimilarity coefficent value-54).

With respect to the sedge weed flora, the first and second crop seasons of Chittur had the maximum similarity, while Palakkad and *Pokkali* lands showed the maximum dissimilarity.

For Kari and *Pokkali* lands the flora of ferns showed 100 per cent dissimilarity with Palakkad and Chittur regions. Similar was the case with *Kari* and *Kole* lands. However, there was close similarity between the ferns of Chittur and *Kole* lands.

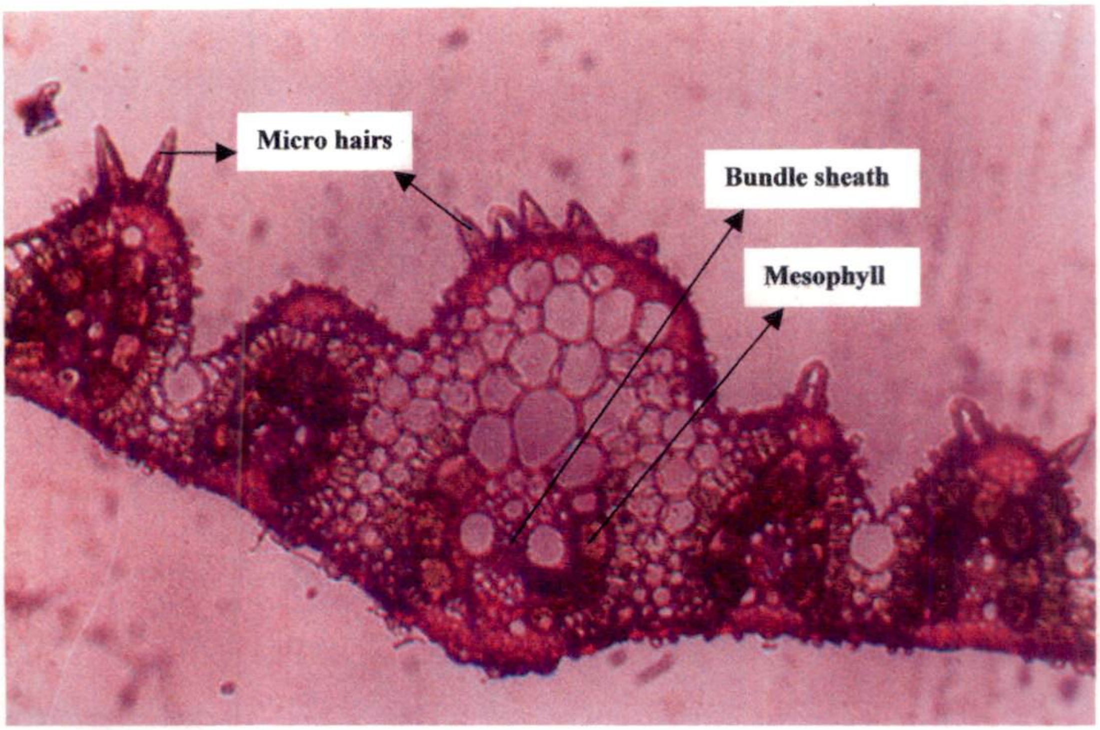


Plate 2a. Cross section of the leaf of *Diplachne fusca* showing 'Kranz' anatomy and micro hairs

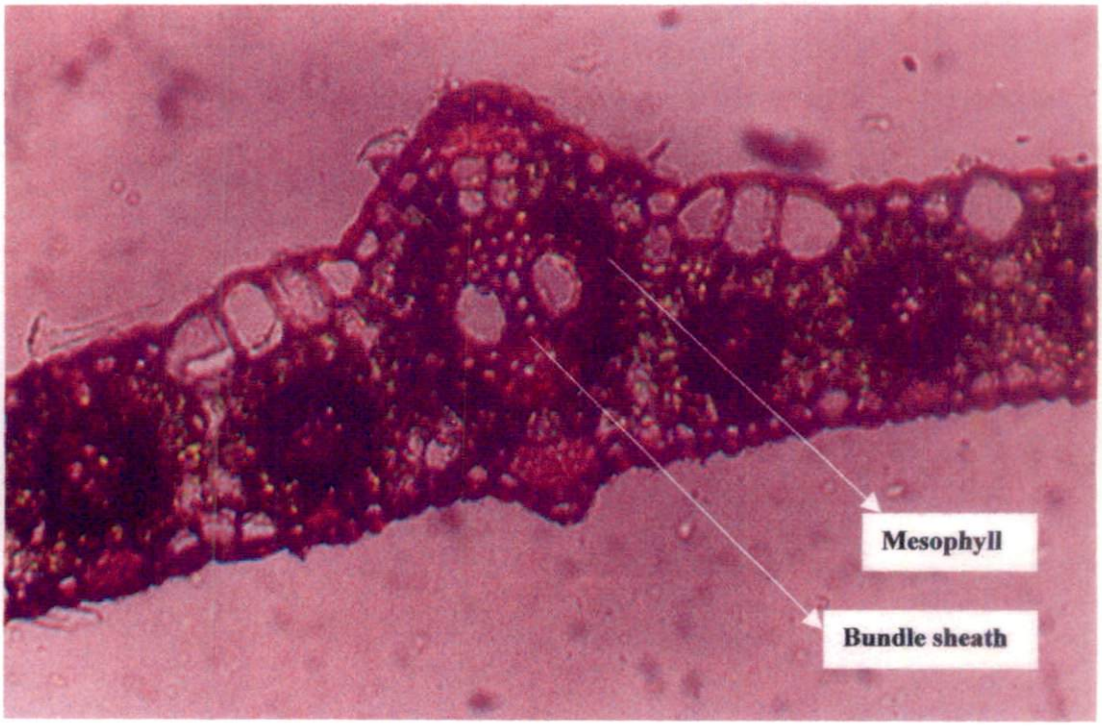


Plate 2b. Cross section of the leaf of *Echinochloa crusgalli* showing 'Kranz' anatomy

4.5. ANATOMICAL STUDIES

Anatomical studies were conducted in *Echinochloa crusgalli* and *Diplachne fusca*, which are seen adapted to the saline habitats of *Pokkali* region, to know the adaptive mechanisms that help these grasses to thrive in the stress condition.

The leaf anatomy of both these grasses showed the Kranz anatomy, which is typical of the C_4 plants (Plate 2). In Kranz anatomy there are two concentric layers of chloroplast containing cells arranged around the vascular bundles. The closest to and surrounding the vascular bundles are the bundle sheath cells, while the next layer of cells containing chloroplasts are called mesophyll cells.

The leaf anatomy of *Diplachne fusca* also revealed the presence of micro hairs, which function as salt glands.

DISCUSSION

5. DISCUSSION

Studies to understand the dynamics of weed flora with change in soil fertility and reaction were conducted in the PMTs of Kerala Agricultural University as well as the various rice ecosytems of Kerala during 2000–2002. The results obtained are discussed in this chapter.

5.1. INFLUENCE OF SOIL FERTILITY ON WEED FLORA

5.1.1. Permanent Manural Trial at RRS, Kayamkulam.

The long-term continuous imposition of a fixed manuring schedule in the PMT at RRS, Kayamkulam had a striking influence on the composition of the weed flora as well as the dry weight of individual species. In general, the dry matter production of individual species of weeds maintained the same trend of their population in different treatments. The study revealed a consistent relationship between the relative abundance of certain weed species and a particular fertilizer treatment both in the Kharif and Rabi seasons. There was a high abundance of the sedge *Scirpus juncoides* in plots receiving N alone or N+K (Fig.2), while its population and dry weight was generally low in plots receiving P. Ueda *et al.* (1977) also reported that sedges such as *Scirpus juncoides* and *Fimbristylis littoralis* dominated in plots to which no phosphorus had been applied.

Aeschynomene indica, a leguminous weed with stem nodules, emerged as the most important weed in those plots where P and K alone without N (T5) were applied (Fig.3). Absence of N in these plots stimulated the growth of this weed, which has the capacity to fix atmospheric nitrogen. This is in conformity with the results of the classical Park Grass Experiment at Rothamsted where the plots receiving all the nutrients except N contained 21.4 per cent legumes, which led to an approximately three fold increase in the abundance of legumes in contrast to those plots receiving nitrogen. Mrkvicka and Vesela (1997) observed that the proportion of legumes in

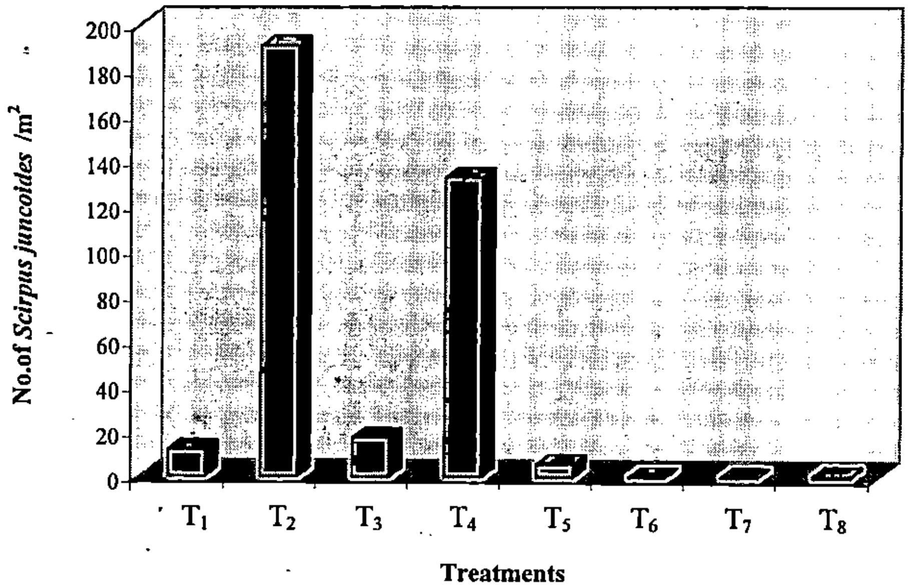


Fig. 2. Effect of treatments on count of *Scirpus juncoides* (first crop season)

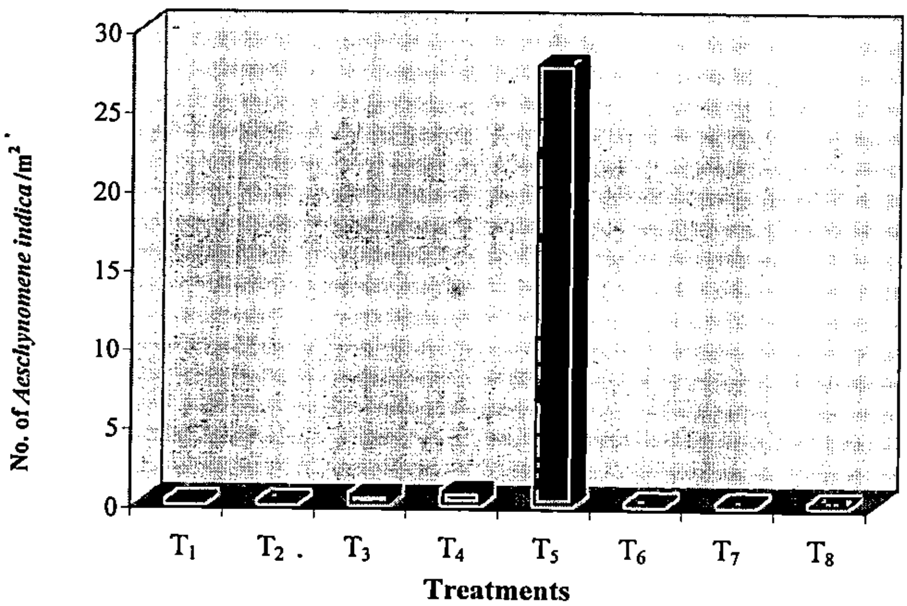


Fig. 3. Effect of treatments on count of *Aeschynomene indica* (first crop season)

swards decreased as N rate increased. Ueda *et al.* (1977) also noticed that application of P and K without N was favourable for the growth of leguminous weeds. These changes are consistent with predictions based on the assumption that nitrogen-fixing plants are superior competitors in soils of low N availability, but are inferior competitors for other resources.

Ludwigia parviflora and *Monochoria vaginalis* showed distinct preference to certain fertility treatments. *Ludwigia parviflora* dominated in plots supplied with organic matter. Chikoye and Ekeleme (2001) observed that weeds like *Ludwigia decurrens* and *Chromolaena odorata* dominated sites with high percentage of silt, clay, nitrogen and organic carbon. *Monochoria vaginalis* also predominated in those plots receiving high amount of organic matter and in plots receiving N and P. Kim (1981) also reported that *M. vaginalis* was dominant when the organic matter content of the soil ranged from 2.1 to 2.8 per cent and the P content ranged from 80-110 ppm. Studies conducted by Guh and Lee (1974) also revealed that the number of broad leaf weeds like *M.vaginalis* increased with increase in soil fertility.

The two grass weeds, *Echinochloa* sp. and *Isachne miliacea* found in the PMT at Kayamkulam behaved differently to soil fertility treatments. *Echinochloa* sp. responded more to P and K than N, where as *Isachne miliacea* was more responsive to N. Earlier workers (Nelson, 1931; Smith, 1967) have also reported that P applied directly to rice stimulated the growth of *Echinochloa* sp; and the addition of P greatly increased the dry matter yield of *E. crusgalli,* grown alone or in combination with rice.

5.1.2. PMTs at RRS, Moncombu and RARS, Pattambi

In the PMT at RRS Moncombu, the only appreciable difference in the weed species due to different soil fertility treatments was in the abundance of *Monochoria vaginalis* and *Ludwigia parviflora,* which were favoured by high organic matter similar to the results from PMT at RRS, Kayamkulam, and this can be attributed to reasons already discussed in section 5.1.1. However, at RARS Pattambi no such significant difference in weed flora due to various soil fertility treatments was observed. At RRS Moncombu and RARS Pattambi the effect of the imposed soil fertility treatments might have been masked by the high fertility of the soil. Contrary to this, at Kayamkulam with sandy soil relatively poor in nutrients, the applied fertilizers showed a distinct shift in the weed flora. In addition, the PMT at Kayamkulam was started in 1964, while the PMTs at Moncombu started in 1987 and Pattambi started in 1973, are relatively new and the soil has not been depleted of its nutrients by crop absorption. Therefore, it may still take many more years to result in a remarkable shift in the weed flora due to difference in soil fertility levels, in the PMTs at RRS Monkombu and RARS Pattambi.

5.2. EFFECT OF SOIL FERTILITY ON SOIL MICROFLORA

The results of the study on soil micro flora in different plots of the PMT at Kayamkulam showed that soil N and P are very important in maintaining the fungal population where as K does not seem to have such an influence. Several workers (Lange, 1982; Widden, 1986) have highlighted the importance of N and P as an important parameter affecting the fungal spectrum of soil.

Application of organic manure favourably influenced the fungal population. The effects of NPK were less pronounced than effects of NPK+FYM indicating the importance of organic matter in maintaining the fungal population. This is in conformity with the results of the studies conducted by Guillemat and Montegut (1956) and Insam and Domsch (1988). The organic matter content of soils has often been correlated with fungal biomass (Dowding and Widden, 1974). The addition of organic matter might reduce the soil pH, which is also favourable for the proliferation of fungi. The bacteria and actinomycetes also showed similar trends of high population in those treatments receiving N and P. This study has clearly shown the change in microbial population in response to differences in soil fertility. Bissett and Parkinson (1979) also observed changes in populations of soil micro flora due to changes in their environment, which occur as a result of temporal and spatial variation.

5.3. INFLUENCE OF AGRO ECOLOGICAL CONDITION ON WEED FLORA

Although many weeds were common in the rice ecosystems of Kerala, a few weeds dominate in one or a few agro ecological system reflecting their specific adaptations to the specific environments. The analysis of the weed flora indicates a strong association of weeds with soil conditions such as soil acidity, alkalinity, salinity and moisture. Hence, dominance of those weeds in an area can be used as indicators of the specific soil conditions.

5.3.1. Soil Acidity

Soil pH can be a significant factor in weed growth. In the rice ecosystems of Kerala, a few weed species were found tolerant to the extreme pH of the soil. Across the *Kari* lands of Kuttanad, *Eleocharis dulcis* had the highest RIV (14) among the sedges, and was the most important weed in terms of density (22 plants/m^2) and frequency (35%). Unlike the *Kayal* and *Karappadam* lands, the *Kari* lands of Kuttanad, which lie 1.5m below MSL, has very high content of unhumified organic matter and very low pH. Toxic proportions of Fe, Al and Mn are seen in these soils. The Kari soils come under the great group sulfaquent, and subgroup typic sulfaquent due to the presence of sulphidic materials with in 50 cm of the mineral soil surface (Padmaja *et al.*, 1994).

In an earlier study on weed flora of Kuttanad region, Sasidahran *et al.* (1993) noticed that in *Kari* soils *Eleocharis plantagenia* (*E.dulcis*) was the only species found surviving in certain patches where the rice seedlings succumbed to extremely low pH. They observed a significant negative correlation between soil pH and population of *E. plantaginea*. Experiments conducted in the acid sulphate soils of Mekong delta of Vietnam also showed dominance of *Eleocharis* sp. in the highly organic and hydromorphic, hydraquentic sulfaquepts soils found at sites 75 cm below MSL

(Husson *et al.*, 2000). Thus, it can be concluded that the high abundance of *Eleocharis dulcis* in an area may be an indication of the high acidity of the soil.

5.3.2. Soil Alkalinity

In Kerala, black cotton soils are found only in Chittur taluk of Palakkad district. These soils are dark in colour with low organic matter, and is alkaline in reaction. The data on the weed flora of Chittur region shows the predominance of the grass *Leptochloa chinensis*, which is not present in any other agro ecological zones of Kerala indicating its tolerance to alkaline soils. Surveys conducted by AICRP on weed control also showed the dominance of *Leptochloa chinensis* in the Chittur region (KAU, 1990). Sreekumar and Nair (1991) also reported this grass from the Walayar region adjacent to Chittur in Palakkad district.

5.3.3. Soil Salinity

Analysis of the data from the survey conducted in the *Pokkali* rice fields shows the dominance of a group of weeds typically adapted to the prevailing saline soil condition of that region. The major weed species typical of the *Pokkali* rice fields are *Diplachne fusca, Acrostichum aureum, Acanthus ilicifolius, Sphaeranthus africanus Eleocharis dulcis* and *Cyperus javanicus.*

Plants in the saline habitats can be grouped into two based on their reaction to soil salinity: the halophytes and the glycophytes (Agarwal *et al.*, 1968). Halophytes include those plants that can grow in saline habitats, and glycophytes (which include cultivated plants) have a negative reaction to the presence of salts. Halophytes unlike glycophytes, have developed in them special anatomical, morphological and physiological characteristics that enable them to perform their vital functions in the presence of high concentration of salts. They can overcome high osmotic pressures of the saline medium and can store large quantities of salts in their organs. Glycophytes in the salt marshes are frequently wide spread species inland, for them, the salt marshes are but one of a large number of possible habitats. Based on this, an attempt has been made to classify plants in the *Pokkali* region into halophytes and glycophytes though it is difficult to arrive at a clear distinction between them, which may require further investigation.

5.3.3.1. ***Halophytes***

a. ***Diplachne fusca***

Diplachne fusca is the most dominant grass weed in the *Pokkali* lands. Several workers have reported the adaptability of this grass in saline soils and its utility for the reclamation of saline sodic soils, since it has the capacity to remove salt from such soils (Chapman and Peat, 1992; Ashokkumar *et al.*, 1996; Quadir *et al.*, 1997; Ashaur *et al.*, 1999). Cook (1996) also reported *D. fusca* as a weed usually found in brackish or salt marsh areas. Sreekumar and Nair (1991), in their studies on the grass flora of Kerala, identified *D. fusca* as the major grass weed in salt marshes and highly acidic paddy fields.

Mechanisms for salt tolerance in Diplachne fusca

Diplachne fusca belongs to the subfamily Chlorideae, whose members are all uniformly C_4 with Kranz anatomy (Chapman and Peat, 1992). The C_4 photosynthetic pathway would increase water use efficiency compared with morphologically similar C_3 species (Dejong *et al.*, 1982). Thus, C_4 photosynthesis may permit lower transpiration rates and therefore, limit salt uptake, which may be one of the reasons for the success of this plant in saline areas.

D.fusca has several adaptive mechanisms to tolerate salinity. A cross section of the leaf of *D.fusca* (Plate2) shows Kranz anatomy and the microhairs, which function as salt glands so that when they are grown in salted soils they can secrete salt on their leaf surface (Chapman and Peat, 1992). Gorham (1987) also suggested that excretion of salts through the glands prevent build up of salt in mature leaves of *Diplachne fusca*. Trials conducted by Ashokkumar *et al.* (1996) confirmed the use of *D.fusca* for reclamation of alkaline soils. They have reported that the growth of the grass is not affected by gypsum application or by water logging. It can improve the physical, chemical and biological properties of the soil in addition to giving palatable fodder to farm animals, as it has the capacity to excrete the salts it absorbs, through the specialized glands. The tolerance of this grass to prolonged water stagnation was due to the enhanced root aerenchyma development and root growth, enabling physiological processes and nutrient uptake to continue.

b. ***Acrostichum aureum***

Acrostichum aureum is a fern, which is typically adapted to the saline habitats of *Pokkali* lands. This weed has high invasive capacity, and it is seen that vast areas of abandoned paddy fields are invaded by this weed. Adam (1990) reported that *Acrostichum aureum* occurred widely as an understorey in the upper part of mangrove swamps. West (1977) also recorded a number of instances in South America where cut over mangroves is invaded by this fern indicating its tolerance to salinity.

c. ***Acanthus ilicifolius***

Acanthus ilicifolius is a woody perennial with spines on its leaf margins, which grows in brackish water in mangrove swamps and in the tidal zone of coastal marshes (Cook,1996). *A.ilicifoluis* owes its ability for vegetative spread to its reclining stems so that it forms large patches by vegetative means. Fahn (1988) reported the presence of salt glands from salt marsh and mangrove dicotyledons in the family Acanthaceae. Salt glands occurring in genus the *Acanthus* control the salt balance by secreting sodium chloride. The epidermal glands of *Acanthus ilicifolius* are the source of secreted salt, which gives the upper leaf surface a greasy feel on occasions.

5.3.3.2. Glycophytes

The plants which grow in low salt habitats, the glycophytes, have relatively low salt tolerance, but many are able to adapt themselves to survive somewhat higher salt concentrations, by modification of their osmotic values and other properties so as to prevent the harmful effects of the salt.

Weed species such as *Echinochloa crusgalli, Echinochloa stagnina, Eleocharis dulcis, Sphenoclea zeylanica* and *Sphaeranthus africanus* were found to tolerate, a fairly higher concentration of salt present in the saline habitats of *Pokkali* lands, though these are plants which widely occur in the non saline habitats also. The tolerance of weed species such as *Eleocharis dulcis, Sphenoclea zeylanica* and *Sphaeranthus africanus*, to brackish water is well documented by Cook (1996).

Mechanisms for salt tolerance in Echinochloa crusgalli

Echinochloa crusgalli is the most dominant species among the glycophytes of the *Pokkali* rice fields, though it is wide spread in many other rice growing areas of Kerala.

Lot of variability is noticed even in the morphology of *E.crusgalli* growing in different rice ecosystems of Kerala. The *E.crusgalli* plants in the *Pokkali* rice fields, where sea water incursion occurs are bigger in size having a height of more than 2 m and produce large inflorescence with long awns (Plate 3). It was also noticed that the height of the plants, growing in areas where the water level is higher, were taller than those in shallow water areas. The significant increase in the size of these plants may be regarded as an adaptation to thrive in the saline habitats, as the ion uptake by these plants can be diluted by growth or succulence. An example of dilution of salts by growth is provided by the mangrove *Rhizophora mucronata* (Atkinson *et al.*, 1967). In this species, chloride and sodium concentrations remain almost constant for much

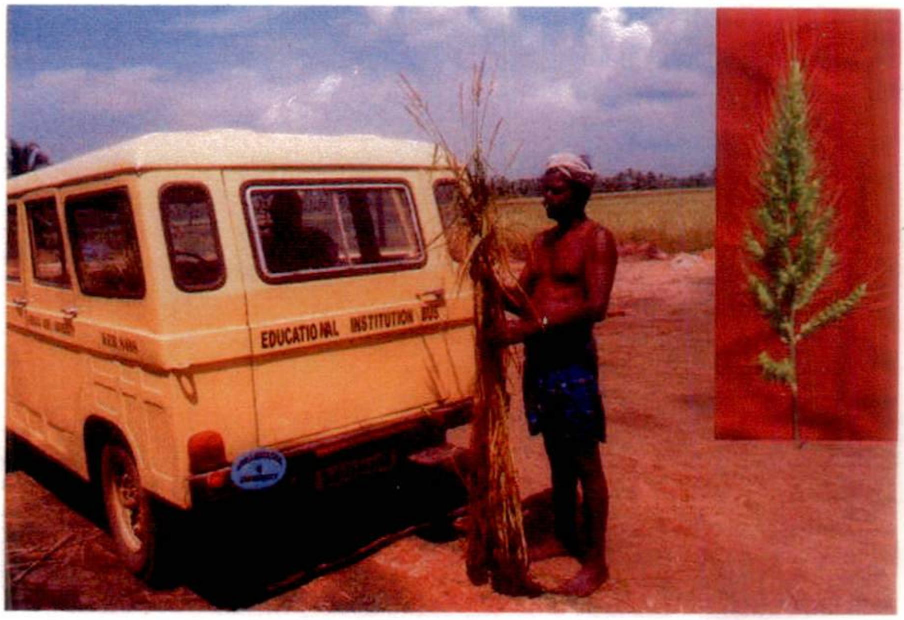


Plate 3a. ***Echinochloa crusgalli*** **of** ***Pokkali*** **lands with luxuriant vegetative growth and large inflorescence with prominent awns**

Plate 3b. Variability in the inflorescence of ***Echinochloa*** **species in Kerala**

(From L-R: ***Echinochloa crusgalli, E. glabrascens , E. crusgalli, E. stagnina, E. colona*****)**

of the life of a leaf. In order to maintain the observed leaf concentration by growth a mean dry weight increase of three per cent per day was necessary. Steiner(1939) also reported similar dilution by growth for the American salt marsh composite, *Iva oraria*. In *Spartina maritima* the rate of ion uptake and relative growth are balanced, so that the tissue salt concentration in the foliage remains fairly constant (Yeo and Flower, 1986).

Therefore the increase in growth shown by plants of saline habitats may be for the dilution of the salts taken up by the plants, and thereby enabling them to survive in high salt concentration.Increased size is also observed in the rice plants and in the weed *Diplachne fusca* of *Pokkali* lands which also exhibits a good amount of salt tolerance.

5.3.4. Soil moisture

Soil moisture is found to have a profound influence in shaping the weed flora of a particular region. This can be well understood by observing the distribution pattern of various species of *Echinochloa* in the different rice ecosystems of Kerala. In the *Kole* and Kuttanad region of Kerala where rice is cultivated as a deep-water crop, *Echinochloa stagnina* was the principal species of *Echinochloa*. This indicates its preference to water stagnation. Many workers have also reported *E.stagnina* as the dominant weed associated with deep-water rice (DeDatta, 1981;Abraham *et al.*, 1993).

In the *Pokkali* lands of Kerala, *E.crusgalli* emerged as a major grass weed indicating its high adaptability in water logged and saline conditions, though the weed is present in all the other rice ecosystems of kerala. Rumpho and Kennedy (1983) observed that seed germination of *E.crusgalli* commonly occurred under anaerobic condition. It can produce over 20000 seeds m^{-2} and upto 90 per cent may germinate 16 days after flowering, and thus possess a potentially greater range of habitats in which it can become established via seed. *E.crusgalli* is seen in transplanted and wet sown conditions in all the rice ecosystems of Kerala. *E.glabrescens* is also seen in the low lands. On the other hand, *E.colona* is a weed, which prefers dry upland conditions and this explains its occurrence in the semidry crop during the first season in palakkad region.

The influence of soil moisture conditions on the weed flora of rice is evident from the analysis of the flora associated with different methods of rice cultivation. In Kerala, the predominant systems of rice cultivation are semidry sown rice, broadcast sown rice in wet puddle condition and transplanted rice in wet puddle condition. Of these in the latter two situations puddle soil conditions exist, which favours standing water conditions. In the semidry rice at least during the initial phase of the crop, there exists a moist well-drained condition without any flooding, as it is a rainfed crop. Clear differences in the flora of the semidry rice and wetland rice (direct sown transplanted) are noticed as discussed in section 5.3.5.

5.3.5 Influence of different methods of rice culture on weed spectrum

The analysed data of the survey on the weeds of major rice growing tracts of Kerala shows distinct dominance of certain weeds adapted to specific regions as well as to cultural practices. Buhler (1995) also reported that change in cultural practices might quickly cause changes in weed population dynamics because of the sensitivity of weed seeds to environmental conditions. This can be clearly observed from the survey, by comparing the weed composition of the Virippu (Kharif) and Mundakan (Rabi) season of Palakkad region (Table 37). In Palakkad, the semidry system of sowing is adopted in the majority of rice fields during the Kharif season, whereas transplanting is the method of cultivation common during the Rabi season due to the availability of irrigation water. In the Kharif season *Sacciolepis interrupta* (RIV: 13.3) dominated the weed spectrum of Palakkad indicating it as a weed associated with the semidry sowing, whereas it was not seen during the Rabi season where transplanting was adopted. This shows that the weed is endemic to the Virippu season (early Kharif) especially in the dry seeded crop. *Sacciolepis interrupta* enjoys the ecological situations associated with semidry rice, where rice is sown broadcast/drilled immediately after the receipt of pre monsoon rains and the crop is raised as a rainfed upland rice for the initial 30-45 days, till the field is flooded due to south west monsoon. Studies conducted by Abraham *et al.* (1993) also showed that *Sacciolepis interrupta* is a weed typically associated with the dry sown Kharif rice crop in the Kuttanad region of Kerala.

Isachne miliacea was another weed, which assumed greater importance during the Kharif season of Palakkad, whereas its population during the Rabi season was very less. In the kharif season, the intermittent rains result in alternate wetting and drying of the field. Thus, there is moist as well as well-aerated condition in the field resulting in the germination of a number of flushes of weeds including *Isachne miliacea.* On the other hand, during the second or Rabi season it is mostly a transplanted crop grown under irrigation. Thus, there is standing water always in the field, which prevents the germination and establishment of weeds. This may be the reason for poor population of *Isachne miliacea* during the Rabi season. Same is the case with *Oryza rufipogon*. Among the grass weeds of Palakkad, *Oryza rufipogon* (wild rice) had an RIV of 10.27 indicating it as a serious problem during the Kharif season.

From the survey, it is evident that there is a predominance of grass weeds in the weed spectrum of the first crop season of Palakkad, together constituting an RIV of 47.2 per cent, whereas its proportion decreased in the Rabi season (RIV: 19.3 per cent) where transplanting was adopted. The dominance of grass species in the Virippu season could be attributed to the higher seedling emergence and to the better survival of weeds in the semidry cultivation, due to the morphological similarities and ecological adaptations similar to rice. The more the weeds ecologically resemble the crop plants, the worse they are.

Echinochloa colona and *E.crusgalli* are the other major grass weeds of Virippu (Kharif) season. The predominance of *Echinochloa colona* in the first crop season clearly indicates it as a weed associated with upland condition. The semidry system of sowing in the first crop season favours *Echinochloa colona*, and its population was very low in the transplanted crop of Rabi season. *Echinochloa crusgalli* is usually associated with wetland crop. This explains the shift in the dominance of the two species of *Echinochloa* between the two seasons in Palakkad.

In the Palakkad region, in transplanted Rabi crop, the grass population is lesser than that in the Kharif season. This may be because the germination of grasses is usually affected by standing water. Park *et al.* (1973) also reported that the number and weight of *Echinochloa crusgalli* decreased sharply as the depth of water increased from 0 to 5 cm. The reduced oxygen level near the upper layer of submerged soil accounts for the poor germination of annual grass weeds. In addition, the mimicry weeds of rice may not be very successful in the transplanted situation since the transplanted rice seedlings have an age advantage compared to the late germinating weeds. Therefore, weeds like *Echinochloa* do not get a congenial condition to mimic and compete with rice plants.

The proportion of broad leaf weeds was more in the second crop season together accounting for an RIV of 38.74 per cent while it was only 22.82 per cent in the first crop season. Weeds like *Sphenoclea zeylanica* and *Ipomoea aquatica,* which are typical of aquatic region, was not at all seen in the first crop season, as there was no continuous flooding. *Monochoria vaginalis, Sphenoclea zeylanica* and *Ipomoea aquatica* are weeds adapted to water logged conditions. *M.vaginalis* had a higher RIV (6.84) in the Rabi season whereas it was only (1.64) in the Kharif season, clearly indicating its preference to water logging. Moody and Drost (1983) also reported that the occurrence of *M.vaginalis* is strongly related to moisture content of the soil and it needs a saturated soil for its germination. In addition, they also get enough space and light in the inter row areas, which enables them to proliferate in the second crop season. During the first crop season, only those like *Ludwigia parviflora* and *Cyanotis axillaris*, which are adapted to moist upland conditions could establish in the semidry rice. The occurrence of *Sphaeranthus indicus* only in the second crop season of Palakkad is noteworthy. Thomas and Abraham (1998) also reported it as a weed of second crop of rice. It is also noticed in the summer season in the PMT at Pattambi.

Table 37: Comparison of the RIV of weeds in Palakkad region during the first and second crop seasons

Weed species	Palakkad(1)*	Palakkad(2)**
Grasses		
Echinochloa colona	3.47	-
Echinochloa crusgalli	3.86	2.75
Isachne miliacea	12.54	3.87
Ischaemum rugosum	2.70	-
Leptochloa chinensis	1.73	4.38
Oryza rufipogon	10.27	4.95
Sacciolepis interrupta	13.30	-
Total	47.87	16.05
Broad Leaf Weed		
Aeschynomene indica	2.96	-
Alternanthera sessilis	2.03	4.03
Commelina benghalensis	2.36	4.34
Cyanotis axillaris	3.15	2.70
Eclipta alba	2.58	4.70
Ipomoea aquatica	-	3.68
Lindernia crustacea	2.08	-
Ludwigia parviflora	6.02	9.92
Monochoria vaginalis	1.64	6.84
Sphearanthus indicus	-	4.95
Sphenoclea zeylanica	-	5.72
Total	22.82	46.88
Sedges		
Cyperus difformis	1.95	3.62
Cyperus haspan	3.29	1.68
Cyperus iria	10.28	9.53
Cyperus pangorei	1.12	5.46
Cyperus rotundus	2.03	-
Fimbristylis miliacea	3.92	5.39
Schoenoplectus lateriflorus	1.43	1.68
Total	24.02	27.36
Ferns		
Marsilea quadrifolia	5.22	9.18

*Kharif season

** Rabi season

Among the sedges, *Cyperus iria* and *Fimbristylis miliacea* occurred in equal proportions during the first and second crop seasons, whereas *Cyperus rotundus,* a weed adapted to well-aerated upland condition was seen only in the first crop of semidry rice. On the contrary, *Cyperus pangorei* is a weed of flooded soil and was seen in large numbers in the second crop season. These changes in the flora are only the reflection of the change in the moisture condition of the soil during the semidry system of cultivation in the first crop season and the transplanted rice of second crop season.

5.4. WEED DYNAMICS IN THE VARIOUS AGRO ECOLOGICAL ZONES OF KERALA

5.4.1. Grass Weeds

Annual grass weeds dominated the weed spectrum in the *Kole* lands of Thrissur and *Kari* and *Kayal* lands of Kuttanad (Table 38). Among the grass weeds, *Echinochloa stagnina* had the highest RIV indicating that it is the most dominant weed in the *Kole, Kari, Kayal* and *Karappadam* lands. All these regions lie in the backwater areas, which are subjected to tidal action occasionally, and therefore the soil is slightly saline. However, it is not tolerant to high level of salinity as experienced in *Pokkali* region, which has direct connection to the seawater. This indicates that *E.stagnina* is a weed of slightly saline condition. The occurrence of *E. stagnina* in the Kuttanad and *Kole* regions of Kerala is well documented by Abraham *et al.* (1993; 2002). *E stagnina* is the principal weed associated with deep-water rice in Thailand (DeDatta, 1981) and is well distributed in tropical Asia and Africa (Michael, 1983). Cook (1996) also reported it as a weed confined to wet places in marshes and often forms floating mats of vegetation.

Echinochloa crusgalli occupies the second position with respect to RIV in *Kole* lands, *Kayal* lands and *Pokkali* region. Unlike *E. stagnina,* it is invariably present across all the agro ecological zones of Kerala irrespective of the season, method of

Table 38. Relative Importance Value (%) of grass weeds of rice in different agroecological zones of Kerala

Grasses	Agroecological zone								
Weed species	*Kole*	*Kari*	*Kayal*	*Karappadam*	*Pokkali*	Palghat 1*	Palghat 2**	Chittur 1*	Chittur 2**
Echinochloa stagnina	15.78	18.93	15.93	15.88	-	-	-	-	-
Echinochloa crusgalli	13.06	3.0	10.20	1.47	9.98	3.86	2.86	4.66	8.35
Echinochloa colona	3.03	-	-	-	-	3.47	-	7.35	2.03
Echinochloa glabrascens	2.33	-	-	-	-	-	-	-	-
Sacciolepis interrupta	2.96	-		-	-	13.3	-	-	-
Sacciolepis sp	-		7.09						
Isachne miliacea	-	3.9	-	9.63	-	12.54	3.87	6.02	10.14
Oryza rufipogon	2.10	6.29	5.55	3.9	-	10.27	4.95	-	-
Diplachne fusca	-	-	-	-	11.23	-	-	-	-
Leptochloa chinensis	-	-	-	-	-	1.73	4.38	16.8	12.89
Eragrostics tenella	5.38	-	-	-	-	-	-		-
Ischaemum rugosum	-	-	-	-	-	2.7	-	4.27	
Setaria pallide-fusca	-	-	-	-		-	-	5.58	
Panicum repens	-	-	-	-	1.71	-	-	-	
Total	44.64	32.12	38.77	30.88	22.92	47.87	16.05	44.68	33.41

* Kharif season

** Rabi season

rice culture, soil and other environmental conditions, indicating its wide ecological amplitude. Potvin (1986) also noticed that ecotypes of the C_4 emergent weed *E. crusgalli* occurred both in the northern and southern latitude of North America unlike most terrestrial C_4 plants, which are typical of the tropics. Two other species of *Echinochloa* were noticed in different locations of Kerala. *E.colona* is a major weed in the Virippu (Kharif) season of Chittur and Palakkad region and *E.glabrascens* in *Kole* lands. *E.colona* usually comes up in dry areas and is commonly an upland weed.

From the survey, it is evident that apart from *Echinochloa* sp, there was an abundance of certain grass species in particular rice tracts of Kerala, indicating their adaptation to specific environmental factors or cultural practices (Fig.4). *Sacciolepis interrupta* was the most important weed in the first crop season of Palakkad, since it is a weed usually associated with the semi dry system of sowing. The *Sacciolepis* sp observed in the *Kole* and *Kayal* lands is a perennial spreading type usually seen in flooded fields.

Isachne miliacea and *Oryza rufipogon* are the other two major grass weeds of Palakkad (Kharif season) together accounting for an RIV of 22.81. *Diplachne fusca* and *Leptochloa chinensis* are the weeds typically adapted to the saline areas of *Pokkali* lands and alkaline areas of Chittur lands, respectively, the reasons of which has been discussed in section 5.3.5.

5.4.2. Broad Leaf Weeds

Among the broad leaf weeds, the occurrence of *Limnocharis flava* in the *Kole* lands of Thrissur and the *Kari* and *Karappadam* lands of Kuttanad is note worthy (Table 39). Cook (1996) reported that this weed has assumed the status of a pest in South India due to its large population. *Ludwigia parviflora* is the broad leaf weed that is invariably present in all the rice ecosystems surveyed, irrespective of the wide variation in geographic factors or cultural practices.

Fig. 4. Grass weed flora in different rice ecosystems of Kerala

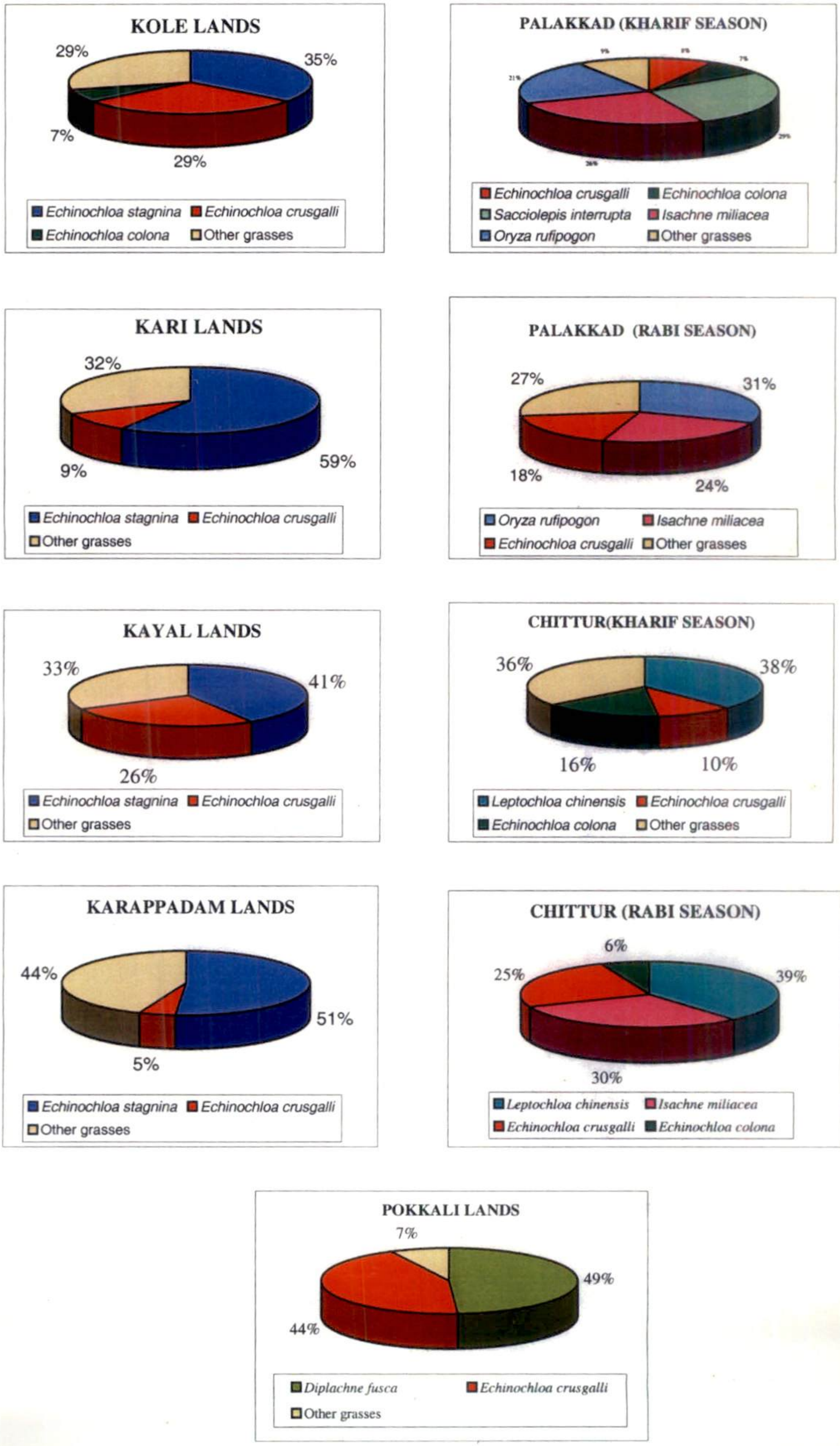


Table 39. Relative Importance Value (%) of broad leaf weeds of rice in different agroecological zones of Kerala

Broad leaf weeds	Agroecological zone								
Weed species	*Kole*	*Kari*	*Kayal*	*Karappadam*	*Pokkali*	Palakkad 1*	Palakkad 2**	Chittur 1*	Chittur 2**
Aeschynomene indica	-	-	-	-	-	2.96	-	-	-
Alternanthera sessilis	1.28	-	-	-	5.25	2.08	4.03	3.58	-
Cleome viscosa	2.03	-	-	-	-	-	-	2.81	-
Commelina benghalensis	-	-	-	-	-	2.36	4.34	3.35	-
Cyanotis axillaris	-	-	-	-	-	3.15	2.70	2.35	-
Eclipta alba	-	-	-	-	-	2.58	4.70	2.82	-
Eichhornia crassipes	-	-	6.58	2.92	6.15	-	-	-	-
Ipomoea aquatica	-	2.33	-	1.47	-	-	3.68	1.89	-
Lemma polyrrhiza	-	-	-	-	5.67	-	-	-	19.94
Limnocharis flava	5.38	4.99	-	4.99	-	-	-	-	-
Limnophila heterophylla	1.53	-	-	-	-	-	-	-	-
Lindernia crustacea	5.53	-	2.97	-	-	2.08	-	3.27	
Ludwigia parviflora	5.73	6.16	6.78	4.41	3.39	6.02	9.92	6.57	7.23
Melochia corchorifolia								2.35	
Monochoria vaginalis	4.18	9.00	6.20	12.86	5.38	1.64	6.84		5.12
Nymphaea nouchali		4.11	4.68	9.63	4.41				
Pistia stratiotes					5.67				
Sphenoclea zeylanica	1.53				4.23		5.72		
Phyllanthus nirurii	1.74								
Sphaeranthus africanus					3.03				
Sphaeranthus indicus							4.95		
Total	28.93	30.25	27.21	36.28	43.18	22.82	46.88	28.99	32.39

* Kharif season

** Rabi season

Eichhornia crassipes, Monochoria vaginalis and *Nymphaea nouchali* are the weeds present in the water logged areas of *Kari*, *Kayal* and *Karappadam* lands indicating their preference to water stagnation.

In the *Pokkali* lands, in addition to weeds adapted to fresh water areas, namely, *Eichhornia crassipes, Monochoria vaginalis, Nymphaea nouchali* and *Pistia stratiotes*, the occurrence of *Sphenoclea zeylanica* and *Sphaeranthus africanus*, which are typically adapted to the brackish water, is worth mentioning.

5.4.3. Sedges

Among the sedges, *Fimbristylis miliacea* has cosmopolitan occurrence followed by *Cyperus iria*, which has greater importance in Palakkad and Chittur regions (Table 40).

Another sedge worth mentioning is *Eleocharis dulcis*, which has high preference to the acidic soils of *Kari* lands and the acid saline regions of *Pokkali* lands. *Rhynchospora corymbosa* is noticed only in the *Kari* soil of kuttanad. Chikoye and Ekeleme (2001) reported that many of the sedges occurred in high frequencies and densities making them the world's worst weeds in many aerable crops. The lack of dormancy in sedges, the high number of seeds in the soil seed bank and the ability to germinate from seed as well as vegetative means may explain the high frequency and density of sedges across all agro-ecological zones.

5.4.4. Ferns

Salvinia molesta, Marsilea quadrifolia, Azolla pinnata and *Ceratopteris thalictroides* were the ferns present in the various rice ecosystems. *Salvinia molesta* was observed in the deep-water rice systems of Kuttanad and *Pokkali* regions, while *Marsilea quadrifolia* was present in all rice ecosystems except in *Kari* and *Pokkali* lands (Table 41). *Salvinia molesta* is a floating weed and needs water for its survival

Table 40. Relative Importance Value (%) of sedges of rice in different agroecological zones of Kerala

Broad leaf weeds	Agroecological zone								
Weed species	*Kole*	*Kari*	*Kayal*	*Karappadam*	*Pokkali*	Palakkad 1*	Palakkad 2**	Chittur 1*	Chittur 2**
Cyperus difformis	3.03	-	-	8.66	3.6	1.95	3.62	-	-
Cyperus iria	5.4	4.55	-	-	-	10.28	9.53	9.53	8.94
Cyperus haspan	-	-	-	-	-	3.92	1.68	-	-
Cyperus articulatus	2.51	-	-	-	-	-	-	-	-
Cyperus pangorii	-	-	6.29	-	-	1.12	5.46	-	-
Cyperus rotundus	-	-	-	-	-	2.08	-	5.58	-
Fimbristylis miliacea	6.56	9.43	8.92	9.53	6.48	3.29	5.39	1.89	12.41
Schoenoplectus lateriflorus	0.87	-	-	-	-	1.43	1.68	-	-
Eleocharis dulcis	-	14.07	-	1.47	6.05	-	-	-	-
Rhynchospora corymbosa	-	4.11	-	-	-	-	-	-	-
Total	18.37	32.16	15.21	23.87	16.13	24.02	27.36	17.0	21.35

* Kharif season

** Rabi season

Table 41. Relative importance value (%) of ferns of rice fields in different agroecological zones of Kerala

Broad leaf weeds	Agroecological zone								
Ferns	*Kole*	*Kari*	*Kayal*	*Karappadam*	*Pokkali*	Palakkad 1*	Palakkad 2**	Chittur 1*	Chittur 2**
Marsilea quadrifolia	5.84	-	3.85	6.92	-	5.22	9.18	9.25	12.84
Salvinia molesta	-	8.03	15.31	6.92	7.65	-	-	-	-
Azolla	-	-	-	-	5.15	-	-	-	-
Ceratopteris thalictroides	2.10	-	2.4	-	4.7	-	-	-	-
Total	7.94	8.03	21.56	13.84	17.5	5.22	9.18	9.25	12.84

* Kharif season

** Rabi season

and this explains its absence in chittur and Palakkad region where part of the season is dry, whereas *Marsilea quadrifolia* needs only moist soil, and standing water is not a must. Table 41 gives a summary of the distribution of major weeds.

5.5. WEED VEGETATION ANALYSIS

5.5.1. Grasses

Vegetation analysis is usually done by working out the Simpson's diversity index, Shannon's diversity index and Evenness index. The data on the analysis of the grass weed flora of different regions based on these indices are presented in section 4.4.

The Simpson's index (D) is an index of the diversity of the flora and as the value of D increases, the diversity increases and dominance decreases. The low value of Simpson's index in *Kari* soil is due to the very high predominance of *Echinochloa stagnina* compared to other grass weeds with very low density (Table 43). In *Kole, Karappadam, Kayal, Pokkali* and Chittur soils, the Simpson's index is slightly higher than that of *Kari* soils as more than one species have relatively higher densities. In addition to *Echinochloa stagnina, Echinochloa crusgalli* is a co-dominant in *Kole* lands, *Isachne miliacea* in *Karappadam* and *Sacciolepis interrupta* in *Kayal* lands. In the case of *Pokkali* lands *Diplachne fusca* and *Echinochloa crusgalli* were the co-dominant weeds, whereas in Chittur, *Leptochloa chinensis, Isachne miliacea* and *Echinochloa crusgalli* were the co-dominant weeds.

The Evenness index value was the highest in Palakkad during the second crop season and the lowest in the *Kari* lands. *Evenness* index has a range of 0 to 1 and the value is maximum when all the species have same number of individuals. This occurs when the environment is equally favourable for all the weeds resulting in higher species diversity. When the environmental stress occur, only a few adapted species are favoured, the population of which will dominate over other species. This condition resulted in low Evenness index in *Kari* lands. In *Kari* soil, because of the unfavourable

Table 42. Major weeds in the different rice ecosystems of Kerala

Agro ecosystems	Grasses	Sedges	Broad leaf weeds	Ferns
Kole lands	*Echinochloa stagnina* (15.87)	*Fimbristylis miliacea* (6.56)	*Ludwigia parviflora* (5.73) *Limnocharis flava* (5.38) *Lindernia crustacea* (5.53) *Monochoria vaginalis* (4.18)	*Marsilea quadrifolia* (5.84)
Kari lands	*Echinochloa stagnina* (18.93) *Oryza rufipogon* (6.29) *Echinochloa crusgalli* (3.0)	*Eleocharis dulcis* (14.07) *Fimbristylis miliacea* (9.43)	*Monochoria vaginalis* (9) *Ludwigia parviflora* (6) *Limnocharis flava* (4.9) *Nymphaea nouchali* (4.1)	*Salvinia molesta* (8.03)
Kayal lands	*Echinochloa stagnina* (15.93) *Echinochloa crusgalli*(10.2) *Sacciolepis* sp. (7.09)	*Fimbristylis miliacea* (8.92) *Cyperus pangorei* (6.29)	*Ludwigia parviflora* (6.78) *Eichhornia crassipes* (6.58) *Monochoria vaginalis* (6.2) *Nymphaea nouchli* (4.68)	*Salvinia molesta* (15.37) *Marsilea quadrifolia* (3.85)
Karappadam lands	*Echinochloa stagnina* (15.88) *Isachne miliacea* (9.63)	*Fimbristylis miliacea* (9.53) *Cyperus difformis* (8.66)	*Monochoria vaginalis* (12.86) *Nymphaea nouchali* (9.63) *Limnocharis flava* (4.99) *Ludwigia parviflora* (4.41)	*Salvinia molesta* (6.92) *Marsilea quadrifolia* (6.92)
Pokkali lands	*Diplachne fusca* (11.23) *Echinochloa crusgalli*(9.98)	*Fimbristylis miliacea* (6.48) *Eleocharis dulcis* (6.05)	*Eichhornia crassipes* (6.15) *Lemna polyrrhiza* (5.67) *Pistia stratiotes* (5.67) *Monochoria vaginalis* (5.38) *Alternanthera* sessilis (5.25)	*Salvinia molesta* (7.65)
Chittur (Kharif)	*Leptochloa chinensis* (16.8) *Echinocloa crusgalli* (7.35) *Isachne miliacea* (6.02)	*Cyperus iria* (9.53) *Cyperus rotundus* (5.58)	*Ludwigia parviflora* (6.57)	*Marsilea quadrifolia* (9.25)
Chittur (Rabi)	*Leptochloa chinensis*(12.89) *Isachne miliacea* (10.14) *Echinochloa crusgalli*(8.35)	*Fimbristylis miliacea* (12.41) *Cyperus iria* (8.94)	*Lemna polyrrhiza* (19.94) *Ludwigia parviflora* (7.23) *Monochoria vaginalis* (5.12)	*Marsilea quadrifolia*(12.84)
Palakkad (Kharif)	*Sacciolepis interrupta*(13.3) *Isachne miliacea* (12.54) *Oryza rufipogon* (10.27) *Echinochloa colona* (3.86)	*Cyperus iria* (10.28) *Fimbristylis miliacea* (3.92)	*Ludwigia parviflora* (6.02) *Monochoria vaginalis* (3.15)	*Marsilea quadrifolia* (5.22)
Palakkad (Rabi)	*Oryza rufipogon* (4.95)	*Cyperus iria* (9.53) *Cyperus pangorei* (5.46)	*Ludwigia parviflora* (9.92) *Monochoria vaginalis* (6.84)	*Marsilea quadrifolia* (9.52)

Values in the parenthesis are the RIV

Table 43. Count of grass weeds in various rice ecosystems of Kerala (Total number from 20 sites of 1 m^2 area)

Weed species	*Kole*	*Karappadam*	*Kari*	*Kayal*	*Pokkali*	Palakkad 1*	Palakkad 2**	Chittur 1*	Chittur 2**
Echinochloa stagnina	322	26	332	155	-	-	-	-	-
Echinochloa crusgalli	223	1	9	63	224	14	3	8	22
Echinochloa colona	12	-	-	-	-	18	-	19	2
Echinochloa glabrascence	7	-	-	-	-	-	-	-	-
Sacciolepis sp.	11	-	-	29	-	-	-	-	-
Sacciolepis interrupta	-	-	-	-	-	277	-	-	-
Isachne miliacea	4	41	5	5	-	205	5	20	52
Oryza rufipogon	12	5	19	-	-	160	9	-	-
Eragrostis tenella	-	-	-	-	-	-	-	-	-
Diplachne fusca	-	-	-	-	292	-	-	-	-
Leptochloa chinensis	-	-	-	-	-	4	6	142	86
Panicum repens	-	-	-	-	7	-	-	-	-
Ischaemum rugosum	-	-	-	-	-	11	-	10	-
Setaria pallide fusca	-	-	-	-	-	-	-	10	-
Species richness	7	4	4	4	3	7	4	6	4
Total no. of individuals	591	73	365	252	522	689	23	209	162
Simpson's diversity index (D)	2.27	2.24	1.2	2.2	2.0	3.3	3.5	2.0	2.4
Shannon index (H)	1.02	0.93	0.39	1.09	0.75	1.31	1.32	1.11	1.02
Evenness index (J)	0.52	0.67	0.28	0.77	0.67	0.67	0.95	0.62	0.74

* Kharif Season

** Rabi Season

soil conditions, only *Echinochloa stagnina* could occur in large numbers and has resulted in a low evenness index of 0.28. Similarly in *Kole* lands *Echinochloa stagnina* and *Echinochloa crusgalli* have very high densities compared to other weeds resulting in a low Evenness index of 0.52. In *Kayal* and *Pokkali* lands, the magnitude of differences in the population between the few species of weeds present are not very high as in *Kole* or *Kari,* and thus, resulted in fairly high value for evenness index.

In the second season of Palakkad, rice is grown, as transplanted rice and weed problems are comparatively low. Although four species of grasses are recorded, there is not much difference in their densities and so evenness index is very high (0.95). However in the first crop season of Palakkad, as the semidry system of cultivation is followed, weeds like *Sacciolepis interrupta*, *Isachne miliacea* and *Oryza rufipogon* could dominate the flora with very high intensities. Hence, the Evenness index is much lower than that of the second season. A similar reason can be attributed for the lower index during the first crop season of Chittur compared to the second crop season.

For the Shannon index (H), the lowest value is obtained in *Kari* lands (0.39) followed by *Pokkali* (0.75), *Karappadam* (0.93) and the first season of Chittur (1.11). A decrease in value of H indicates an increase in the magnitude of environmental stress favouring the dominance of a few adapted species of plants (that are more resistant to the existing set of physico chemical and biological variables), which are often referred to as the opportunistic species (Osborne *et al.*, 1976). The extreme acidity of *Kari* and *Karappadam* lands, salinity of *Pokkali* lands and alkalinity of Chittur region may be the reason for the low species diversity in these regions. This has resulted in the dominance of one or a few species in each of the specific rice growing regions of Kerala as already mentioned above.

5.5.2. Broad leaf weeds

For broad leaf weeds the species richness was maximum (9 species) in *Kole,* followed by *Pokkali*, Palakkad (Rabi) and Chittur even though some of the species varied depending on the region. All the three diversity indices (Simpson's diversity index, Shannon's diversity index and Evenness index) had the highest values in *Pokkali* region (Table 44).

The highest value of Simpson's index (D) in *Pokkali* compared to the other regions of same richness indicates the equitability of the weed flora of *Pokkali* region. Begon *et al.* (1990) suggested that for a given richness, 'D' increases with equitability and for a given equitabilty, 'D' increased with richness. This is again confirmed by the high value of evenness index, which will be maximum when all the species have the same number of individuals (more equitable distibution).

A high value of Shannon's diversity index in *Pokkali* lands also indicates that the environment is favourable for a number of adapted species. However, it has to be noted that in addition to the weeds like *Eichhornia crassipes, Pistia stratiotes, Monochoria vaginalis, Lemna polyrrhiza, Nymphaea nouchali* and *Ludwigia parvifora*, which are usually seen in fresh water rice fields, there is a predominance of *Sphenoclea zeylanica* and *Sphaeranthus africanus*, which seems to have tolerance to saline conditions. The last two species are not seen as dominant species in the fresh water ecosystem.

The *Kari* soils have the lowest value for Shannon diversity index and evenness index, indicating the lack of equitability between the seven species recorded. A predominance of *Lindernia crustacea, Limnocharis flava* and *Monochoria vaginalis* were noticed in *Kari* soils. A comparison of broad leaf weeds in different regions shows that *Ludwigiua parviflora* and *Monochoria vaginalis* are the two most common broad leaf weeds present in all the regions.

5.5.3. Sedge weeds

Species richness and diversity indices for the community of sedges is given in Table 45. Among the sedges, the Simpson's diversity index had the highest value in the

Table 44. Count of broad leaf weeds in the rice ecosystems of Kerala (Total number from 20 sites of 1 m^2 area)

Weed species	*Kole*	*Karappadam*	*Kari*	*Kayal*	*Pokkali*	Palakkad 1*	Palakkad 2**	Chittur 1*	Chittu 2**
Jussea repens	-	-	5	-		-	-	-	-
Ludwigia parviflora	28	9	31	24	27	48	33	18	26
Lindernia crustacea	36	-	-	5	-	5	-	5	-
Limnocharis flava	3	14	25	-	-	-	-	-	-
Limnophila heterophylla	3	-	-	-	-	-	-	-	-
Monochoria vaginalis	21	88	63	14	55	4	15	-	13
Cleome viscosa	5	-	-	-	-	-	-	4	-
Phyllanthus nirurii	4	-	-	-	-	-	-	-	-
Sphenoclea zeylanica	3	-	-	-	33	-	12	-	-
Alternanthra sessilis	2	-	-	-	59	5	6	7	-
Nymphaea nouchali	-	41	8	10	44	-	-	-	-
Eichhornia crassipes	-	5	7	15	86	-	-	-	-
Ipomoea aquatica	-	1	4	-	-	-	4	2	-
Lemna polyrrihza	-	-	-	-	20	-	-	-	30
Pistia stratiotes	-	-	-	-	76	-	-	-	-
Sphaeranthus africanus	-	-	-	-	17	-	-	-	-
Sphaeranthus indicus	-	-	-	-	-	-	9	-	-
Cyanotisaxillaris	-	-	-	-	-	14	2	3	-
Aeschynomene indica	-	-	-	-	-	14	-	-	-
Commelina benghalensis	-	-	-	-	-	8	7	6	-
Eclipta alba	-	-	-	-	-	10	8	4	-
Melochia corchorifolia	-	-	-	-	-	-	-	3	-
Total no. of individuals	105	158	143	68	417	108	96	52	69
Species richness (S)	9	6	7	5	9	8	9	9	3
Simpson's diversity index (D)	6.09	2.58	3.59	4.14	7.2	4.27	5.39	5.58	2.73
Shannon index (H)	1.44	1.20	0.95	1.50	2.07	1.80	1.92	1.95	1.04
Evenness index (J)	0.65	0.66	0.48	0.93	0.94	0.81	0.88	0.89	0.94

* Kharif season

** Rabi season

Table 45.Count of sedges in various rice ecosystems of Kerala (Total number from 20 sites of 1 m^2 area)

Weed species	*Kole*	*Karappadam*	*Kari*	*Kayal*	*Pokkali*	Palakkad 1*	Palakkad 2**	Chittur 1*	Chittur 2**
Cyperus iria	28	-	21	-	-	118	33	50	38
Cyperus difformis	12	43	-	-	31	6	5	-	-
Cyperus haspan	-	-	-	-	-	15	1	-	-
Cyperus pangorei	-	-	-	25	-	2	11	-	-
Cyperus rotundus	-	-	-	-	-	5	-	10	-
Cyperus articulatus	5	-	-	-	-	-	-	-	-
Rhynchospora corymbosa	-	-	8	-	-	-	-	-	-
Fimbristylis miliacea	57	55	82	40	91	24	-	2	82
Eleocharis dulcis	-	1	173	-	86	-	-	-	-
Schoenoplectus lateriflorus	1	-	-	-	-	3	-	-	-
Total no. of individuals	103	99	284	65	208	171	61	62	120
Species richness (S)	5	3	4	2	3	7	6	3	2
Simpson's diversity index (D)	2.53	2.08	2.17	1.9	2.6	1.0	2.78	1.47	1.76
Shannon index (H)	1.12	0.74	0.95	0.66	1.01	1.08	1.28	0.58	0.62
Evenness index (J)	0.69	0.67	0.69	0.96	0.90	0.55	0.71	0.53	0.90

* Kharif Season

** Rabi Season

second season of Palakkad indicating that the community is more diverse. Although species richness was the highest (seven number of species) in the first season of Palakkad, out of the 171 individuals in the community, 118 belonged to one species, *Cyperus iria*. Therefore, the Simpson's diversity index showed the lowest value (1.0), indicating the dominance of a species.

The evenness index values were also low for Palakkad (first crop season) and Chittur (first crop season) due to the very high number of *Cyperus iria*. The very high population of *Cyperus iria* in Palakkad (first crop season) is due to the moist conditions prevailing during the early stages of the semidry crop *Cyperus iria* is often a common weed in moist aerated conditions like in semidry rice as well as in irrigated vegetable crops.

5.5.4. Total weeds

Information on the species richness and diversity indices for total weed species is given in Table 31. The data shows that the least species richness (10) is seen in the second crop season of Chittur where transplanted rice is mostly cultivated. The standing water throughout the crop season is responsible for limiting the variability in the species. In the different types of Kuttanad soils (*Kari, Karappadam* and *Kayal*) also, species richness is low which varied form 13-16, due to the water logged condition prevailing in most part of the crop period. The *Pokkali* soils have got intermediate values for species richness (18 species). Although the saline condition restricted the presence of the common grass weeds, a few dicot weeds and the grass weed *Diplachne fusca* adapted to the saline conditions were seen in this area resulting in comparatively higher species richness. The *Kole* lands as well as the first crop season of Palakkad recorded the maximum species richness (23) because of the presence of a wide variety of weeds adapted to low land conditions and semidry conditions respectively.

The Simpson's Diversity index was the maximum in Palakkad (Rabi) followed by *Pokkali* and Chittur (Rabi) because of the even distrubution of the weeds present where as it was low in *Kole* lands, *Kari* lands and Chittur (First crop season) due to the predominance of certain grass weeds. The evenness index value also confirms to this inference. The Shannon index did not show much variability.

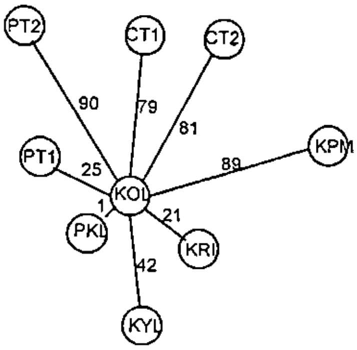
5.6. SIMILARITY IN WEED FLORA BETWEEN THE ECOSYSTEMS

The degree of similarity between two communities that are geographically wide apart, in terms of floristic composition, is expressed by the coefficient of similarity. The coefficient of similarity can be converted to a dissimilarity coefficient whose value varies from zero for communities identical both in species, to 100 per cent for communities having no species in common. This index can be used to compare the weed flora of two sites or ecosystems. It can be represented schematically so that dissimilarity coefficient value of the two ecosystems represents the distance between them and as the distance increases the regions vary widely with respect to their floristic composition. The dissimilarity coefficients between different ecosystems are presented in Tables from 32-36.This is schematically represented in Fig. 5.

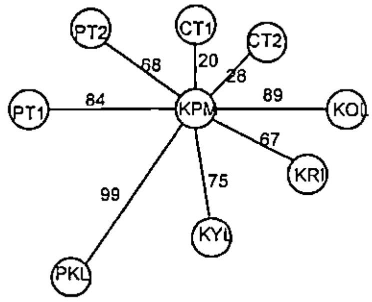
From Fig.5.1, it is evident that *Kole* and *Pokkali* lands did not vary much with regard to the composition of grass weeds. This is substantiated by the more or less similar densities of *Echinochloa crusgalli*, which is common in these two regions. (Table 38).*Kole* lands had the maximum dissimilarity coefficient with Palakkad (Rabi). Although *E.crusgalli* and *Oryza rufipogon* were common species in these two regions, their abundance varied greatly, especially for *E.crusgalli*, which had a Relative Importance Value of (RIV) of 13.06 in *Kole* lands compared to only 2.86 in Palakkad (Rabi).

Fig.5.2 shows the dissimilarity coefficient values of *Karappadam* lands with other rice ecosystems of Kerala. *Karappadam* has the minimum dissimilarity coefficient with Chittur (Kharif) indicating the closeness of these two regions with respect to floristic composition. *E.crusgalli* and *Isachne miliacea* are the common species of grasses in these two regions. *E.crusgalli* had an RIV of 1.47 and 4.66 and *Isachne miliacea* had an RIV of 9.63 and 6.02 in *Karappadam* and Chittur (Kharif)

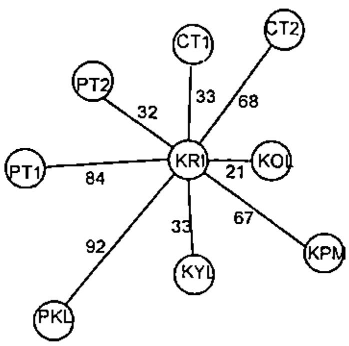
Fig.5. Dissimilarity diagrams of grass weed flora of rice ecosystems of Kerala



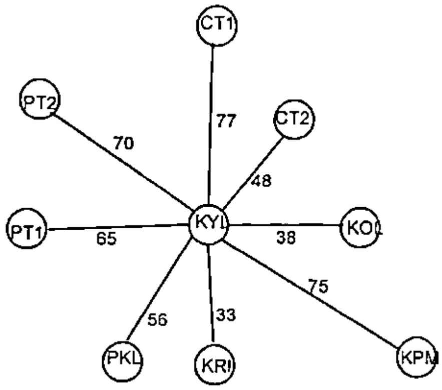
5.1. KOLE LANDS



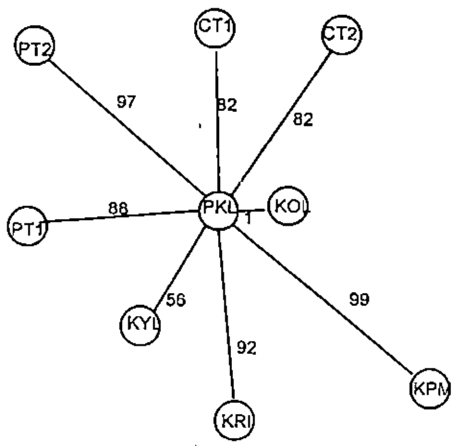
5.2. KARAPPADAM LANDS



5.3. KARI LANDS



5.4. KAYAL LANDS



5.5. POKKALI LANDS

respectively. Together these grasses had an RIV of 11.1 in *Karappadam* and 10.68 in Chittur (Kharif), which accounts for the closeness of these two regions with respect to grass weed flora.

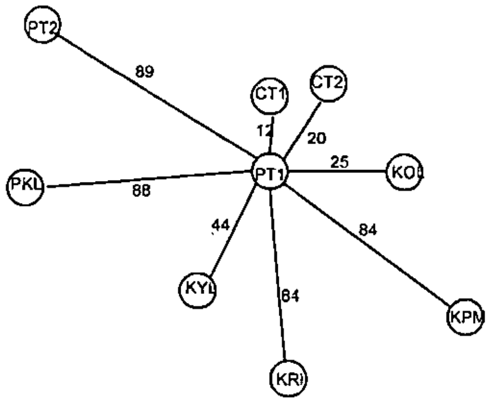
Karappadam and *Pokkali* lands showed the maximum dissimilarity, as *Echinochloa crusgalli* was the only species common between these two ecosystems and its abundance varied widely. RIV of *E.crusgalli* in *Karappadam* was 1.47 while in *Pokkali* it was 9.98.

Fig.5.3 depicts the extent of dissimilarity between *Kari* lands and other ecosystems. *Kari* lands had the maximum similarity with *Kole* lands with respect to grass weeds. This is due to the occurrence of species such as *E.stagnina, E. crusgalli* and *Oryza rufipogon* in both regions. In *Kari*, these grasses together had an RIV of 28.22, which was very close to the total RIV of 30.94 in *Kole* lands. More over the physico-chemical characteristic and morphology of the soil of *Kole* lands reveal close similarities to those of *Kari* soils of Kuttanad (Johnkutty and Venugopal, 1993). Thus, eventhough these two regions are geographically wide apart, they show close similarity in their floristic composition.

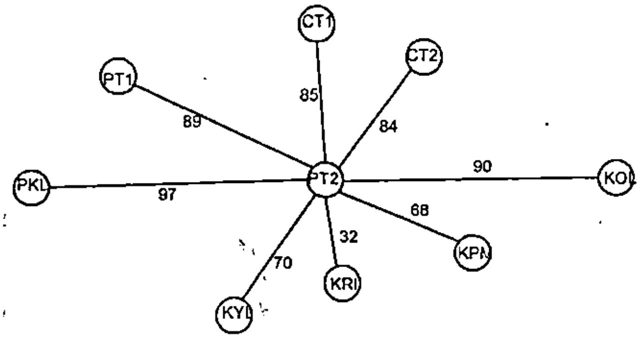
The dissimilarity co-efficient values of *Kayal* lands with other rice ecosystems are illustrated in Fig.5.4. The *Kayal* lands have the maximum similarity with *Kari* lands whereas they have maximum dissimilarity with Chittur region (Kharif). The similarity of *Kayal* and *Kari* lands with respect to grasses is mainly due to the occurrence of *Echinochloa stagnina* in both *Kayal* and *Kari* lands with an RIV of 15.93 and 18.93 respectively. The other grass weeds commonly occurring in both the regions are *E.crusgalli* and *Oryza rufipogon*.

Kayal lands have the maximum dissimilarity coefficient with the Kharif season of Chittur region. *E. crusgalli* is the only grass weed common between these two regions and its abundance vary widely in these regions.

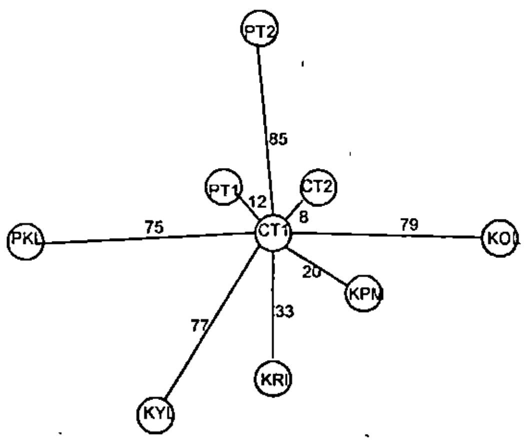
Fig.5. (contd.)



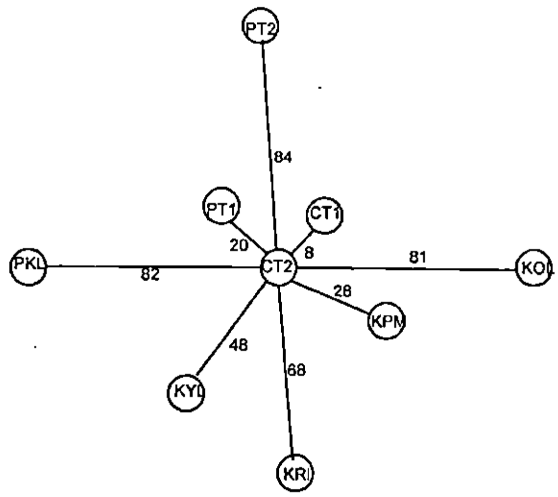
5.6. PALAKKAD (first crop season)



5.7. PALAKKAD (second crop season)



5.8. CHITTUR (first crop season)



5.9. CHITTUR (second crop season)

Legend
KOL - KOLE LANDS
KPM - KARAPPADAM LANDS
KRI - KARI LANDS
KYL - KAYAL LANDS
PKL- POKKALI LANDS
PT1 - PALAKKAD (first crop season)
PT2 - PALAKKAD (second crop season)
CT1 - CHITTUR (first crop season)
CT2 - CHITTUR (second crop season)

Fig.5.5 illustrates the dissimilarity values of *Pokkali* lands with other ecosystems. *Pokkali* lands have close similarity to *Kole* lands with respects to its grass weed community, while it has maximum dissimilarity with *Karappadam* lands, the reasons for which has been already presented in Fig.5.1 and discussed.

The dissimilarity coefficient value of Palakkad (Kharif) with other rice ecosystems is given in Fig.5.6. The grass flora of the Kharif season of Palakkad has the maximum similarity with the Kharif season of Chittur and maximum dissimilarity with the Rabi season of Palakkad, the reasons of which can be attributed to the method of sowing. During the Kharif season of both Chittur and Palakkad, semidry sowing in adopted where as in the Rabi season transplanting is the method of cultivation.

From Fig.5.7, it is evident that Palakkad (Rabi) had maximum similarity with *Kari* lands. This is due to the occurrence of weeds like *E.crusgalli, Oryza rufipogon* and *Isachne miliacea* which are common in both the regions accounting for an RIV of 11.68 and 13.19 in Palakkad (Rabi) and *Kari* lands respectively.

Fig.5.8 and Fig.5.9 depicts the dissimilarity coefficient values of Chittur(Kharif) and Chittur(Rabi)respectively, with all other regions. It is seen that the grass weed flora of both seasons of Chittur had maximum similarity, while they differed greatly with the grass flora of Palakkad (Rabi). This might be due to the high dominance of *Leptochloa chinensis* in the Chittur region.

5.7. CLUSTER ANALYSIS

The hierarchical classification showing the clustering of the different rice ecosystems based on the similarity in total weed flora, grasses, broad leaf weeds, sedges and ferns are illustrated as dendrograms from Fig.6 to10.

5.7.1. Grasses

The various rice ecosystems can be separated into two broad groups based on the floristic composition of the grass weeds (Fig.6). The first group comprises of regions like *Kole, Pokkali, Kayal, Kari* and Palakkad (Rabi) and the second region consists of Chittur (Rabi and Kharif), Palakkad (Kharif) and *Karappadam*. These two floristic groups differ by a dissimilarity of 75 per cent. The greater similarity between *Kole* and *Pokkali* can be attributed to the presence of *Echinochloa crusgalli*, which is a major weed in these two regions whereas *Kayal, Kari* and Palakkad (Rabi) has *Oryza rufipogon* also as a major weed in additon to *E.crusgulli*. In the second group, Chittur (Rabi and Kharif) and Palakkad (Kharif) has maximum similarity in the weed flora. It can be attributed to the presence of *E.crusgalli, E.colona, Isachne miliacea* and *Leptochloa chinensis*, which are common in both the seasons of this region. Although all these weeds are present and geographically near to Chittur region, Palakkad (Kharif) has some dissimilarity (16%) to Chittur region, because of the predominance of *Sacciolepis interrupta.*

5.7.2. Broad leaf weeds

Based on the similarity in occurrence of broad leaf weeds, the various rice ecosystems of Kerala can be divided into two groups (Fig.7). The first group includes sites like *Kayal* lands, Chittur (Rabi), *Kole,* Palakkad (Rabi and Kharif) and the second group comprises of *Karappadam* lands, *Kari* lands, *Pokkali* lands and Chittur (Kharif).

Among the various sites of the first group, *Kayal* lands and Chittur (Rabi) are the most similar, since these two sites have the lowest dissimilarity value (Table 34) *Ludwigia parviflora* and *Monochoria vaginalis* are the common weeds of these regions together accounting for an RIV of 12.98 and 1.35 in *Kayal* lands and Chittur (Rabi) respectively. In the first group, the other two regions *Kole* and Palakkad (Rabi

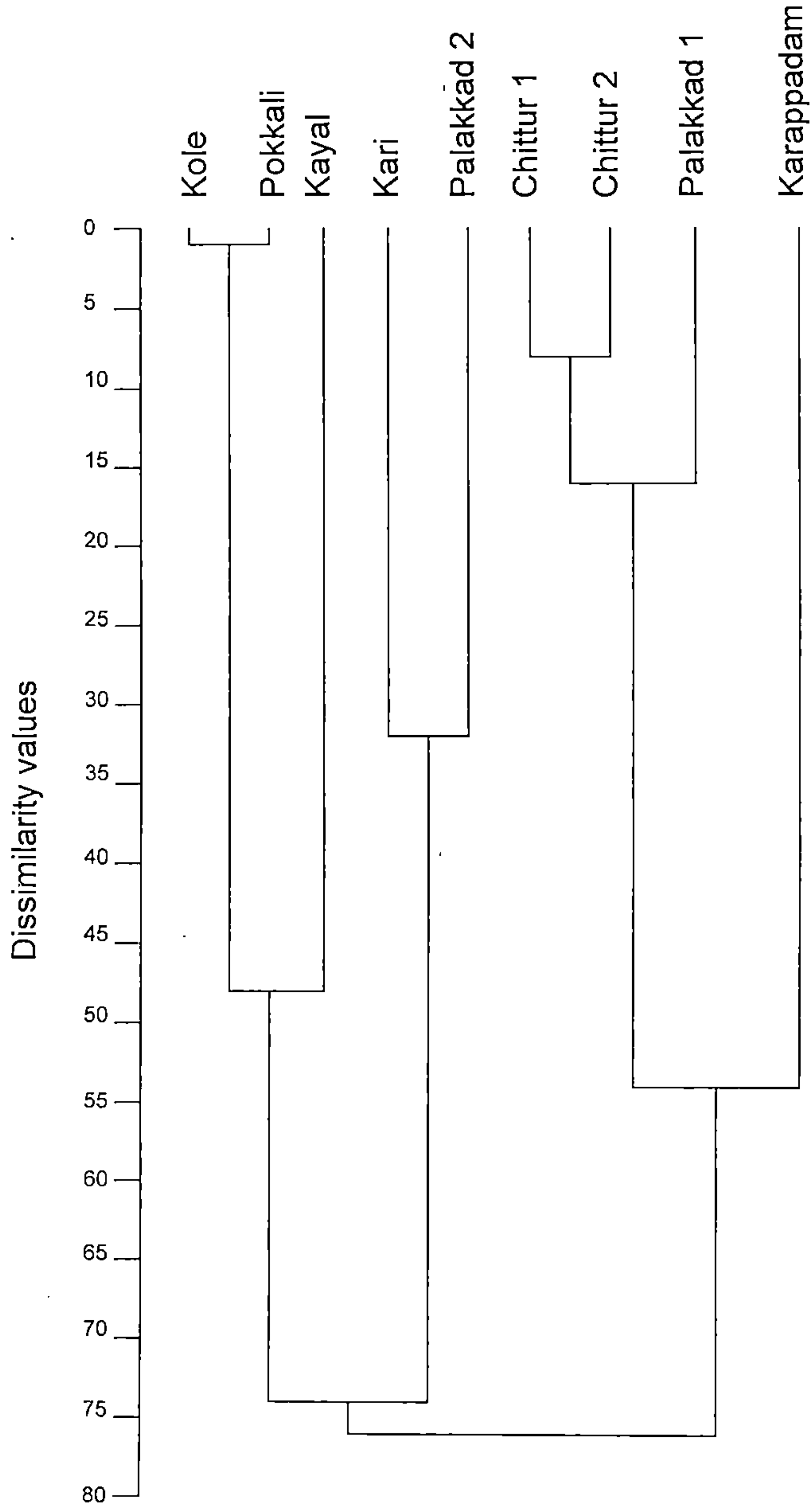


Fig.6.Dendrogram showing the clustering of rice ecosystems of Kerala based on grass weed flora

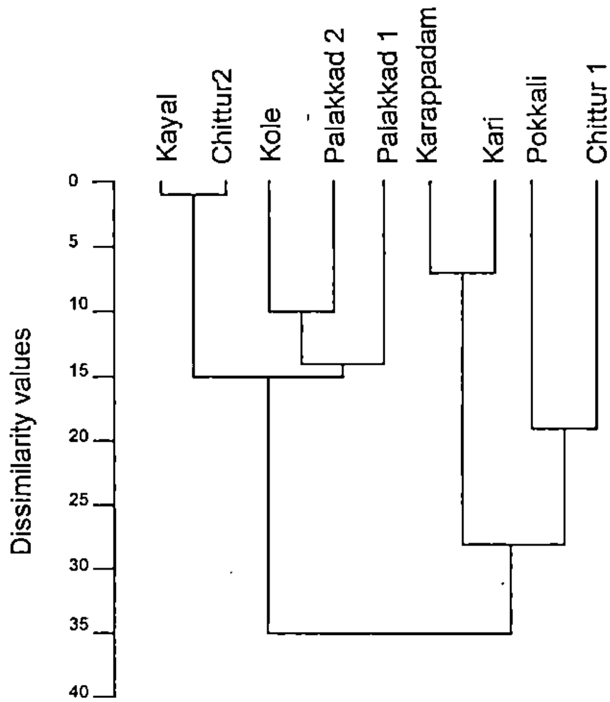


Fig.7.Dendrogram showing the clustering of rice ecosystems of Kerala based on broad leaf weeds.

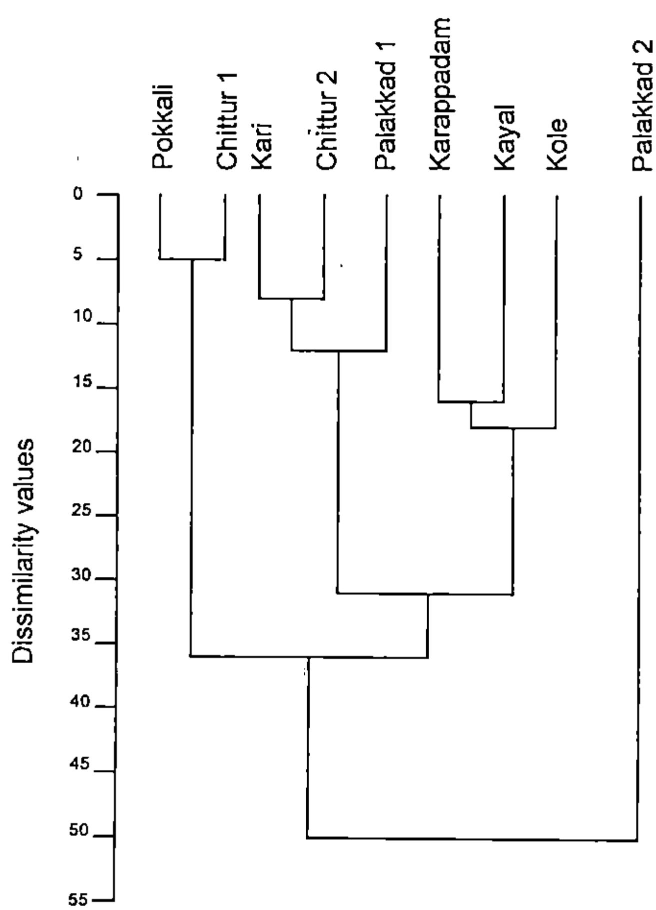


Fig.8.Dendrogram showing the clustering of rice ecosystems of Kerala based on sedge weeds

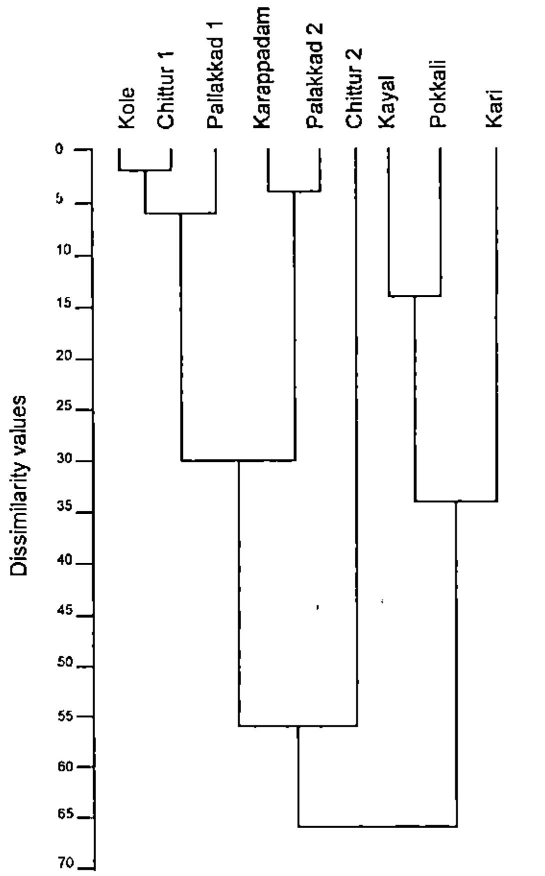


Fig.9.Dendrogram showing the clustering of rice ecosystems of Kerala based on ferns

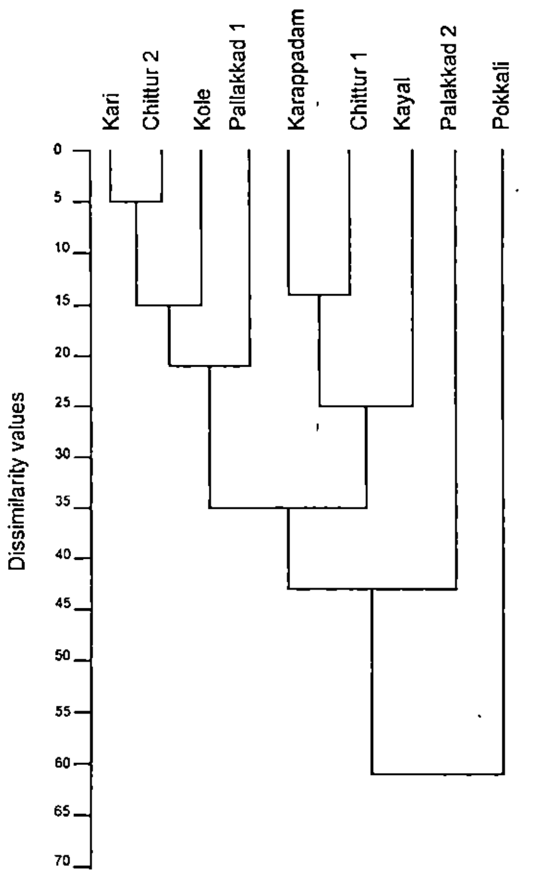


Fig.10.Dendrogram showing the clustering of rice ecosystems of Kerala based on total weed flora

and Kharif) had common weed species such as *Alternanthera sessilis, Ludwigia parviflora* and *M.vaginalis*, which are common to all sites in this group.

The second group comprises of region like *Karappadam, Kari, Pokkali* and Chittur (Kharif). Of them, the first two sites are having much similarity, which can be attributed to the presence of common weeds like *Eichhornia, Ipomoea, Limnocharis, Ludwigia, Monochoria* and *Nymphaea.* All the broad leaf weeds observed in *Kari* and *Karappadam* lands are common between these two regions accounting for the greatest similarity in the floristic composition; the reasons of which can be attributed to the geographical closeness of the two regions as well as similarity in the soil physio-chemical properties. *Pokkali* and Chittur (Kharif) are the other two regions in the second group with lesser dissimilarity with respect to broad leaf weeds, which is due to the presence of *Alternanthera* and *Ludwigia.*

5.7.3. Sedges

Among the sedges, *Pokkali* and Chittur (Rabi) showed the maximum similarity (Fig.8), which is due to the presence of *Fimbristylis miliacea. Kari* and Chittur (Rabi) and Palakkad (Kharif) also had *Fimbristylis miliacea* as the common species. In addition to *Fimbristylis* the *Karappadam, Kole* and Palakkad (Rabi) had *Cyperus difformis* also as the common species. The similarity in sedges is mainly due to the cosmopolitan occurrence of *Fimbristylis miliacea*

5.7.4. Ferns

Based on the occurrence of ferns, *Kole*, Chittur (Kharif), Palakkad (Rabi), *Karappadam*, Palakkad (Rabi) and Chittur (Rabi) can be clubbed into one group (Fig.9) mainly due to the presence of *Marsilea quadrifolia*, whereas in the second group, consisting of *Kayal* lands, *Pokkali* lands and *Kari* lands, the similarity is accounted by the occurrence of *Salvinia molesta.*

5.7.5. Total weed flora

From the dendrogram (Fig.10), it is evident that *Kari* and Chittur (Rabi) are the most similar regions in total weed flora, which is mainly attributed to the dominance of Monochoria vaginalis and *Ludwigia parviflora*, which are dominant in both the ecosystems. The region most similar to Kari and Chittur (Rabi) is the *Kole* lands, which is due to the occurrence of weeds like *Echinochloa crusgalli, Fimbristylis miliacea, Cyperus iria, Monochoria vaginalis* and *Ludwigia parviflora* in all these regions. It is also seen that *Pokkali* land is the most distinctly dissimilar region to all other agro ecosystems. It has more than 50 per cent dissimilarity to *Kari* and Chittur (Rabi) regions. This difference is due to the dominance of the grass weed *Diplachne fusca*, the broad leaf weeds *Sphaeranthus africanus, Sphenoclea zeylanica, Pistia stratiotes, Nymphaea nouchali* and *Eichhornia crassipes* which all seems to be adapted to the occasional salinity of these region brought in by the incursion of saline water as the region lies close to the sea.

A comparison of the dendrograms for the total weed flora and that of grasses, broad leaf weeds, sedges and ferns separately shows that the maximum dissimilarities between the different clusters is expressed in the case of grasses, whereas it is the least for broad leaf weeds. This is because there are certain grasses, which are typically adapted to each or some of these regions, and these grasses may be either absent or very few in the other regions, to which some other grass is more adapted. Among the grass weeds *Echinochloa crusgalli* shows wider adaptation. However, in this species itself, idiotypes adapted to different regions are noticed with difference in morphological characters.

Among the broad leaf weeds, *Monochoria vaginalis* and *Ludwigia parviflora* are seen abundantly in all the rice ecosystems accounting for the low dissimilarity between the different regions. Among the sedges *Fimbristylis miliacea* had cosmopolitan occurrence while *Salvinia molesta* and *Marsilea quadrifolia* were the ferns, which were present in most of the regions.

Hence, clustering of the various rice ecosystems based on the grass weed flora seems to be more meaningful. This is further justified by the dissimilarity coefficient values for grasses between the different regions.

5.8. WEEDS AS INDICATORS OF SOIL CONDITIONS

This study comprising of observations from Permanent Manurial Trials as well as the weed surveys conducted across the rice ecosystems of Kerala gives a clear indication about the strong association of certain weeds to specific soil conditions or cultural practices. These species can be used as indicators of inherent soil and site characteristics. A list of weed species identified as useful indicator plants (Plate 4) is given in Table 46. Analyzing the adaptations of the weed flora to the soil and environmental conditions, it is observed that two processes were operating simultaneously on the weed community. One was occurring at a regional scale in which the dynamics of the composition of the weed community is insensitive to changes in cultural practices overtime. This is clearly revealed by the occurrence of species such as *Diplachne fusca* in *Pokkali* lands, *Echinochloa stagnina* and *Eleocharis dulcis* in *Kari* lands, irrespective of changes in cultural or management practices of rice.

Another process was occurring at the field scale, where the floristic composition is responsive to changes in cultural practices overtime. This is evident from the shift in weed species during the Kharif and Rabi seasons of Palakkad where different methods of rice cultivation is adopted. The change due to application of fertilizers as that was occurred in PMT (eg. *Aeschynomene indica* in low nitrogen soil, *Scirpus juncoides* in low phosphorus soil), application of herbicides (shift to grass weeds following continuous application of 2,4-D) are examples of field scale change in the floristic composition. From the management point of view, the field scale changes are important in the sense that by adopting proper agronomic measures, we can provide conditions favourable for the crop there by reducing the competitive ability of weeds.

By observing the weed flora, we can have an understanding of the soil conditions and go for judicious ameliorative management to make the conditions suitable for the crop so that the crop productivity can be enhanced. This information can also help in the management of problem weeds. For example, this study revealed that *Sacciolepis interrupta* is adapted to semi dry conditions and that it is not at all a problem in wet seeded or transplanted rice fields. Therefore, for managing this weed in its endemic areas, a change in the method of planting from dry sowing to wet sowing or transplanting is suggested. If there is any practical difficulty for this change, adopting stale seed method will be successful as most of the weed seeds will germinate immediately on receipt of rainfall resulting in moist aerated conditions of soil as has been reported by Renu (2000).

A brief description on the indicator weeds identified in the study is given below.

1. *Aeschynomene indica* L.
   Family : Fabaceae (Leguminosae)
   Common name: Indian joint vetch

Perennial or annual. Seen usually in wet places, along ditches, around rivers, in irrigated fields and waste places. The stems are erect, soft, and somewhat woody at the base, branched, main stem cylindrical and warty at the base. They are stem nodulating plants which can fix nitrogen under water logged conditions when root nodulation is poor. Flowers yellow with orange flush, seeds oblong kidney shaped. It makes good green manure and is used as fodder. However, it can become a troublesome weed in irrigated fields, especially in low fertility, sandy soils.

Table 46.Weeds identified as indicators of soil conditions

Soil Condition	Weed species
Soil fertility	
Low N	*Aeschynomene indica*
Low P	*Scirpus juncoides*
High organic matter and high P	*Monochoria vaginalis*
High organic matter	*Ludwigia parviflora*
Soil reaction	
Acidity (Low pH)	*Eleocharis dulcis*
Alkalinity (High pH)	*Leptochloa chinensis*
High salinity	*Diplachne fusca* *Acrostichum aureum* *Acanthus ilicifolius* *Sphaeranthus africanus* *Sphenoclea zeylanica*
Low salinity	*Echinochloa stagnina*
Soil moisture (Cultural practices)	
Upland rice	*Cyperus rotundus* *Echinochloa colona*
Low land rice	*Cyperus pangorei* *Ipomoea aquatica*
Semidry rice	*Sacciolepis interrupta*

2. *Scirpus juncoides* (Gmel.) Lye

Family: Cyperaceae

Common name: Bull rush

An annual often found in wet places, swamps, riverbanks, often in shallow water, particularly common in inundated rice fields. Leaves have very short blades.

The stem is flattened at the base, strongly angled at the top. Seed normally germinate at 25-35°C with percentage germination of 10-25 per cent. This weed readily germinates at 1 cm water depth of 1 to 1.5 cm soil depth but there is no appreciable germination at 3-5 cm soil depth. This weed has dormancy, which is broken by low temperature under moist conditions. This weed reported to flourish in soils low in phosphorus content (Ueda *et al.*, 1977)

3. *Monochoria vaginalis* (Burm.f.) Presl. ex Kunth.

Family :Pontederiaceae

Common name: Pickerel weed

Semi aquatic, broadleaf, monocotyledonous, annual weed. Often highly gregarious in inundated places, in swamps or at the edges of pools, ditches and in canals. Frequently found in rice fields. Stem is usually inconspicuous and obliquely erect. Leaves are oblong-ovate to broadly ovate, sharply acuminate, heart-shaped or rounded, shiny deep green in colour, with longitudinal veins, petioles soft, hollow, growing from buds at the base. The leaf sheath is twisted together at the base. Flowers are basely opposite the sheath of the floral leaf, violet or lilac-blue. The leaves and flowers are used as pot herbs and medicine; the roots are used for tooth ache.

4. *Ludwigia parviflora* Roxb.

Family: Onagraceae

Common name: Water primrose

An erect, glabrous, many branched annual. It is very common weed in rice fields and irrigated crops also seen in moist places and shallow aquatic areas. Stem is smooth, pinkish and angular up to 1m tall often becomingwoody at the base. Leaves simple alternate, acute and tapering at base into a short petiole. Leaf blades narrowly elliptical to lanceolate. Flowers are yellow. Axillary solitary and fruits resembling cloves. Usually found in soils rich in organic matter.

5. *Eleocharis dulcis* **(N.Burman) Henschel**

Family: Cyperaceae

Common name: Chinese water chestnut

A perennial sedge. Gregarious in shallow water in ponds, rice fields and along irrigation canals. It is a wide spread and very variable species but immediately recognizable by the culms with transverse septa and spikelets narrower than the culms. They are leafless tufted perennials. The stems are fistular and round in cross section. Reproduction is by the tubers and seeds. A cultivar 'tuberosa' is sometimes cultivated for its edible tubers and is sold under the name 'Chinese water chestnut'. The aboveground parts are high in protein and low in fiber; it has been recommended to be cultivated for its leaf proteins. The culms are sometimes used for weaving and mat making. It can come up well in soils of high acidity.

6. *Leptochloa chinensis* (L.)Nees

Family: Gramineae

Common name: Chinese sprangle top

Annual or perhaps also perennial in permanent water. Not confined to wet lands but often found in shallow water around pools, in marshes and in rice fields. In aquatic habitats it is often luxuriant and makes excellent fodder. *Leptochloa chinensis* is a strongly tufted annual grass, which grows 30-120 cm high. The stem is slender or somewhat stout, erect or ascending from a branching base. Leaves are linear flat, acute, thin membranous, rough on the upper surface, sometimes reddish or purplish. Inflorescence is a panicle. It is seen in large numbers in alkaline areas of Chittur region of Palakkad district.

7. *Diplachne fusca* Beauv.

Family : Gramineae

Common name: Brown beetle grass/ Brown flowered swamp grass

Aquatic or semi aquatic perennial. Frequently found in fresh and brackish water, salt marshes, irrigation ditches and rice fields in coastal areas with problems of saline sea water incursion as in the *Pokkali* lands. Culms tufted, erect, rooting and branching on the lower nodes. Leaves linear lanceolate or linear-acuminate panicles 10-40 cm long, loose, and greyish. Spike lets stalked or sub sessile. Growing as a water grass *Diplachne fusca* remains green and flowers during the rainless months, provided the ground is flooded.The grass belongs to the subfamily chlorideae whose members are all uniformly C_4 with Kranz anatomy. The micro hairs of *D. fusca* can function as salt glands so that when they are grown in salted soil they can secrete salt on their leaf surfaces. By growing these species on soils damaged by poor irrigation practices, the soil can be rehabilitated. Removing the salt laden foliage removes salt from the soil. It is a soft herbaceous grass very palatable to stock.

8. *Acrostichum aureum* L.

Family: Pteridaceae

Common name: Acrostichum

This perennial fern is a characteristic element of back mangroves and associated tidally influenced estuarine communities. The rhizomes are short, woody, creeping to erect, clothed in large, entire-edged seals. The rhizome has an extensive proliferative capacity. Leaves erect, developing in terminal rosettes, petioles well developed but shorter than the blades. Sporangia not arranged in sori but borne on vines as well as on leaf tissues, with club-shaped hairs scattered regularly on the adaxial surface of the leaves. New individuals are readily established form spores viz. gametophytes, especially disturbed sites. This success is due in part to an appreciable salt tolerance by gametophytes. Usually seen in brackish and saline marshes, but

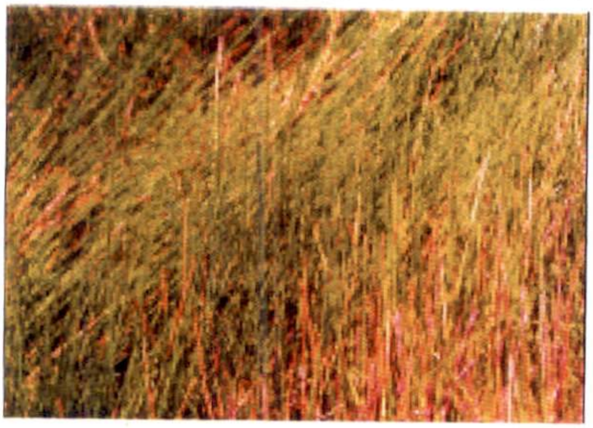
Plate 4. Weeds identified as indicators of soil conditions

Aeschynomene indica (low nitrogen)

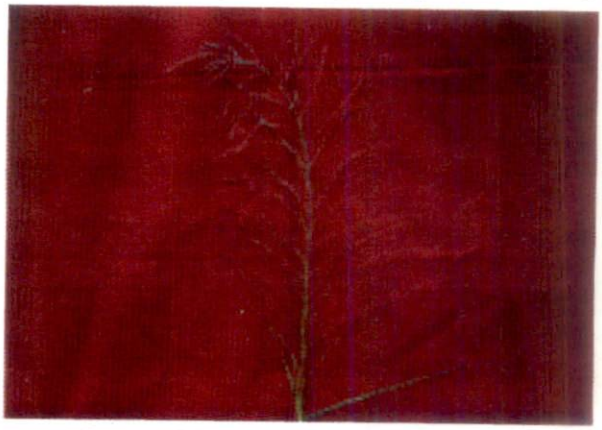
Scirpus juncoides (low phosphorus)

Monochoria vaginalis (high organic matter & high P)

Ludwigia parviflora (high organic matter)



Eleocharis dulcis (acidity)



Leptochloa chinensis (alkalinity)

Diplachne fusca (high salinity)

Acrostichum aureum (high salinity)

occasionally also found inland in freshwater swamps, marshes and around lakes. This fern has strong weedy tendencies and can be very aggressive in disturbed sites.

9. *Acanthus ilicifolius* L.

Family: Acantheceae

Common name: Holly leaved *Acanthus*

A low sprawling or somewhat viny herb, scarcely woody, to a height of 2m. Aerial roots from lower surface of reclining stems. Leaves decussate, usually with a pair of spines at the insertion of each leaf. Leaves glabrous, petiole shot, spiny margin, inflorescence terminal. Fruit is a capsule. *Acanthus ilicifolius* owes its ability for vegetative spread to its reclining stems so that it forms large patches by vegetative means. The epidermal glands of *A.ilicifolius* are the source of secreted salt, which gives the upper leaf surface a greasy feel on occasions. Large populations can be observed in the saline habitat of *Pokkali* lands of Kerala.

10. *Sphaeranthus africanus* L.

Family: Asteraceae

An annual commonly occurring in wet places, swamps, rice fields, often in brackish water, some times temporarily submerged. Stems, usually one arising from the base, erect and bearing numerous branches. Wings on stems and branches entire, glabrous or pubescent. Leaves of main stem obovate to oblanceolate, tip rounded to sub acute, leaves of branches generally smaller and narrower, sometimes elliptical. Compound head, globose or somewhat ellipsoid. This species occurs widely in the rice fields of *Pokkali* region, which is subjected to seawater incursion. While another species, *Sphaeranthus indicus* is not usually seen in a standing crop of paddy, but common after the harvest of paddy.

11. ***Sphenoclea zeylanica* Gaertn.**

Family: Sphenocleaceae

Common name: Goose weed

An annual broad leaf wet land weed. Cord like roots, hollow stem and white spike like flowers are the distinguishing features. Prolonged flooded wet land rice fields and swamps are ideal for its multiplication. It is autogamous but perhaps also sometimes pollinated by insects. The dissimules are small seeds, dispersed in mud and by other means. It is often gregarious becoming a troublesome weed in rice fields but it is also cultivated and eaten as a vegetable. Widely occurs in the saline water intruded *Pokkali* lands of Kerala indicating its tolerance to salinity.

12. ***Echinochloa stagnina* (Retz.)Beauv.**

Family: Gramineae

A perennial grass weed seen wide spread in wet rice fields of low lands such as Kuttanad and *Kole* region often outnumbering other forms of *Echinochloa.* It thrives in moist places often partly submerged in water. The culms grow upto 1.8 m height and are usually branching. Spikelets are generally awned. *Echinochloa stagnina* is the most dominant in the *Kole, Kari, Kayal* and *Karappadam* lands. All these regions lie in the backwater areas which are subjected to tidal action occasionally and therefore the soil is slightly saline. However, it is not tolerant to the high level of salinity as experienced in *Pokkali* region, which has got direct connection to the sea water indicating that it is a weed of slightly saline condition.

13. ***Cyperus rotundus* L.**

Family: Cyperaceae

Common name: Purple nut sedge

A perennial sedge found on riverbanks, in dried up pools and ditches and in rice fields. Is an erect herb with triangular stem having perennial under ground stem and chains of nut like tubers. The seeds rarely mature, the effective spread is by tubers. Leaves are grass like and remain green through out the years. The flowers are produced in terminal branched umbel and purple in colour. Tubers are collected, roasted and eaten. Powder from tubers used in fragrant incense sticks. It is also a medicinal plant; the tubers contain cyperene, cyperone and cyperol, which are used for spasms. It is also used in cooling indigenous medicines. It is not confined to wetlands and is a common and sometimes serious weed in cultivated land. It is difficult to eradicate.

14. ***Echinochloa colona*** **(L.) Link**

Family: Gramineae

Common name: Jungle rice

An annual with a slightly spreading growth habit. Leaf blades are relatively narrow. Inflorescence usually linear in out line. Spikelets relatively broad and awnless. Each plant produce thousands of seeds, which are transported form field to field by irrigation water and farm machinery. It is a serious weed in dry seeded upland rice. It is a good fodder both before and after flowering

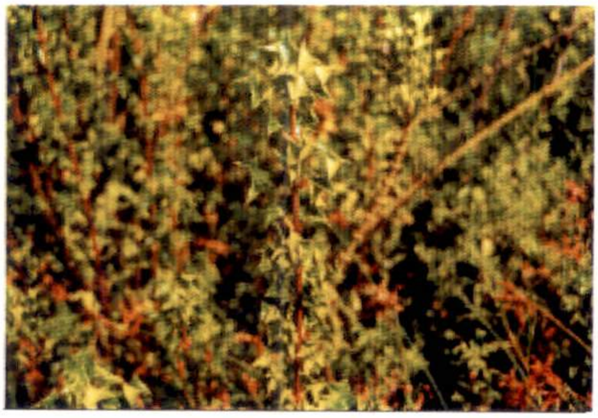
15. ***Cyperus pangorei*** **Rottboll**

Family: Cyperaceae

Common name: Nutsedge

Perennial rhizomatous creeping herbs. Often found standing in water, frequent in rice fields, wet places, marshes, riverbanks, streambeds. The clums are very flexible and can withstand strong floods. Leaves are few and often reduced to sheaths. Spikelets are linear, loose flowered and straw coloured with a reddish tinge. Culms tufted or arranged in a row along the rhizome. It is widely used for making fine mats and some times cultivated. It is often seen as a weed in low land paddy cultivation such as Kuttanad during monsoon.

Plate 4. (contd.)

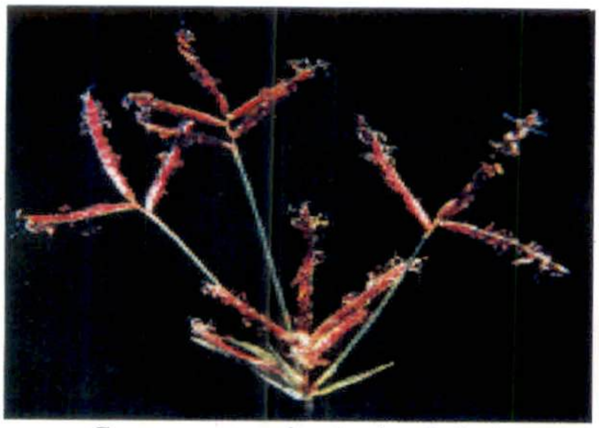


Acanthus ilicifolius (high salinity)

Sphaeranthus africanus (high salinity)

Sphenoclea zeylanica (high salinity)

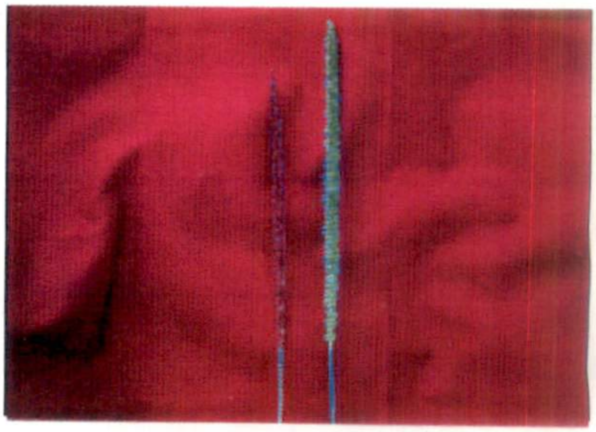
Echinochloa stagnina (low salinity)



Cyperus rotundus (upland rice)

Echinochloa colona (upland rice)

Cyperus pangorei (low land rice)



Sacciolepis interrupta (semidry rice)

16. *Ipomoea aquatica* Forsk

Family: Convolvulaceae

Common name: Water spinach/ Swamp morning glory

An aquatic annual or biennial prostrate herb. Usually floating on stagnant water but sometimes found on the banks of pools, canals and rivers. Stems are floating and somewhat swollen. Leaves simple. Flowers solitary, petals usually pink, funnel shaped. The plant multiplies by means of rooted portions of stem and seeds. It is often cultivated for its edible shoots and as a medicine. It can be a serious weed if left to grow unchecked.

17. *Sacciolepis interrupta* (Willd.) Stapt.

Family: Gramineae

A serious grass weed of dry seeded rice during the first season. It is also seen in the edges of ponds and tanks. It is a tall grass with delecate stems. The clums are stout and spongy. The inflorescence is a spike like panicle. The spikelets are densely packed, green or purplish. Occasionally, the whole plant is purple. The grass multiplies by seeds and rooted portions of stem. The inflated stems are eaten by buffaloes, and the emergent culms are often gathered for fodder.

SUMMARY

6. SUMMARY

Weed control is the most expensive operation in rice culture in Kerala. One of the reasons for the failure of weed control is the weed biodiversity. An investigation entitled 'Weed dynamics in rice fields: influence of soil reaction and fertility' was carried out in the Department of Agronomy, College of Horticulture, K.A.U. during 2000-2002, focussing on the distribution, biology and ecology of weeds in the Permanent Manurial Trials at K.A.U. as well as various rice ecosystems of Kerala. The objectives of the study were:

1. To understand the weed diversity in the various rice ecosystems of Kerala.
2. To evaluate the changes in weed flora as influenced by soil fertility and soil reaction.
3. To identify weeds which can serve as indicators of soil conditions.
4. To study the mechanisms that help weeds to adapt to different soils.
5. To understand the change in soil micro flora with soil fertility

The investigation was conducted in two parts to achieve the objectives.

Part-1 Influence of soil fertility on weeds and soil micro flora

The study was undertaken in the Permanent Manurial Trials being conducted at RRS, Kayamkulam, RRS, Moncombu and RARS, Pattambi. A clear shift in weed flora with change in soil fertility was obtained only in the PMT at Kayamkulam. *Aeschynomene indica* and *Scirpus juncoides* dominated in plots receiving no nitrogen and phosphorus, respectively. The population of *Monochoria vaginalis* was higher in soils with high content of organic matter and phosphorus and *Ludwigia parviflora* in soils with high organic matter. Soil micro flora also showed distinct difference with change in soil fertility. The fungal population was higher in plots supplied with nitrogen and phosphorus and or organic matter. The bacteria and actinomycete population also followed similar trend.

Part -2 Influence of agroecological conditions as weed flora

Surveys across the various rice ecosystems of Kerala, namely the *Kole* lands, *Kari*, *Kayal* and *Karappadam lands* of Kuttanad, *Pokkali* lands, and Palakkad region including the alkaline black soils of Chittur revealed strong association of specific weeds with soil conditions as well as method of rice culture. Weeds identified as indicators of soil conditions are *Eleocharis dulcis* (acidity), *Leptochloa chinensis* (alkalinity), *Diplachne fusca, Acrostichum aureum, Acanthus ilicifolius, Sphaeranthus africanus* and *Sphenoclea zeylanica* (high salinity), and *Echinochloa stagnina* (low salinity). *Cyperus rotundus* and *Echinochloa colona* are seen associated with upland rice whereas *Cyperus pangorei* and *Ipomoea aquatica* are seen with low land rice. *Sacciolepis interrupta* was a major problem only in semydry rice.

Mechanisms of survival of some of the indicator weeds were also investigated. The capacity of *Aeschynomene indica* to fix atmospheric 'N' in the aerial nodules is attributed for its dominance in the low 'N' soils. *Diplachne fusca* is adapted to the saline areas due to its capacity for excretion of salts through the microhairs. The high vegetative growth noticed in the weed biotypes in the saline *Pokkali* soils may help them to dilute the salts absorbed.

To understand the similarities (or dissimilarities) in weed flora between different regions, seasons or method of cultivation, weed vegetation analysis was done using the Simpson's diversity index, Shannon's diversity index, Evenness index and the dissimilarity coefficient. For the grass weed flora of *Kari* lands, both the diversity indices as well as the Evenness index showed the lowest values indicating environmental stress due to the high acidity, and therefore only a few adapted species could survive. Cluster analysis was also done and dendrograms were prepared grouping the different regions based on the similarity of the weed flora.

From the study it can be concluded that the changes in weed community of rice fields occur both at regional scale (weed community is insensitive to changes in cultural practices but sensitive to variations in soil characteristics) and at field scale(weed community is responsive to changes in cultural practices). From the management point of view the field scale changes are important in the sense that by seeing the weed flora we can have an understanding of the soil conditions and adopt judicious ameliorative management, to make the conditions unfavourable to the weed.

Future line of work

From this study certain weeds adapted to specific soil conditions or cultural practices could be identified. This information should be used for agronomic management of the problems from these weeds. Field validation of this assumption needs to be undertaken to assess the practical utility of the findings. Thus trials on soil amelioration should be conducted for the possibility of managing *Eleocharis dulcis* by liming, *Aeschynomene indica* by nitrogen application, *Scirpus juncoides* by phosphorus application etc. Similarly problems of weeds, which are adapted to specific cultural practices, can be reduced by a change in the cultural practice. A change from dry sowing to wet sowing may be tested for managing *Sacciolepis interrupta* and *Echinochloa colona* as they are typically adapted to drysown conditions.

Many wild relatives of crop plants including weeds serve as sources of useful traits in crop improvement research. Weeds identified to be tolerant to adverse conditions can be used as donors of stress tolerant genes for plant breeding/genetic engineering works.

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* Originals not seen.

APPENDICES

APPENDIX-I

SOIL ANALYSIS DATA OF PMT AT RRS, KAYAMKULAM

Treatments	pH	Available N (kg ha^{-1})	Available P (kg ha^{-1})	Available K (kg ha^{-1})
T_1	5.05	154.25	39.70	42.0
T_2	4.90	150.00	23.73	61.6
T_3	4.97	160.75	34.68	53.2
T_4	4.82	172.25	18.07	84.0
T_5	4.92	140.25	34.69	89.6
T_6	5.00	156.75	32.49	106.4
T_7	5.19	155.50	59.03	98.0
T_8	4.97	85.75	12.84	61.1

SOIL ANALYSIS DATA OF PMT AT RRS, MONKOMBU

Treatments	pH	Organic carbon(%)	Available P (kg ha^{-1})	Available K (kg ha^{-1})
T_1	5.13	1.89	7.2	65.0
T_2	5.13	1.87	8.4	65.0
T_3	5.20	1.97	8.0	55.0
T_4	5.27	2.02	10.4	61.33
T_5	5.27	2.12	8.4	78.67
T_6	5.17	1.87	10.8	78.67
T_7	5.17	2.07	12.4	92.33
T_8	5.17	2.12	11.2	73.67
T_9	5.10	2.13	10.0	81.0

(contd.)

SOIL ANALYSIS DATA OF PMT AT RARS, PATTAMBI

Treatments	pH	Organic carbon(%)	Available N (kg ha^{-1})	Available P (kg ha^{-1})	Available K (kg ha^{-1})
T_1	5.15	1.34	276	158.75	121.5
T_2	4.95	1.28	319	28.13	173.0
T_3	5.45	1.32	247	123.85	144.0
T_4	5.22	1.39	198	40.42	115.0
T_5	4.80	1.49	259	155.45	151.0
T_6	4.97	1.43	300	113.42	158.0
T_7	4.92	1.25	275	132.45	132.0
T_8	5.05	1.39	235	108.89	122.0

APPENDIX-II

NUTRIENT COMPOSITION OF COMMON WEEDS OF RICE OF KERALA

Weed species	N %	P %	K %
Grasses			
Diplachne fusca	0.37	0.23	1.73
Echinochloa colona	0.92	0.49	1.10
Echinochloa crusgalli	0.56	0.30	0.99
Eragrostis tenella	1.26	0.14	1.05
Oryza sativa (rice)	0.74	0.14	0.78
Sedges			
Cyperus iria	0.70	0.12	1.50
Cyperus rotundus	0.53	0.20	1.30
Scirpus juncoides	0.74	0.19	0.75
Broad leaf weeds			
Aeschynomene indica	2.84	0.25	0.80
Cleome viscosa	1.48	0.39	2.05
Ludwigia parviflora	1.75	0.18	1.15
Monochoria vaginalis	0.74	0.51	0.49
Fern			
Acrostichum aureum	0.93	0.47	0.85

WEED DYNAMICS IN RICE FIELDS : INFLUENCE OF SOIL REACTION AND FERTILITY

By

VIDYA. A. S.

ABSTRACT OF THE THESIS

Submitted in partial fulfilment of the requirement for the degree of

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ABSTRACT

Weed control is the most expensive operation in rice culture in Kerala. An understanding of the association of different weeds and their adaptive mechanisms to different rice ecosystems in Kerala is essential for planning effective weed management practices. Therefore an investigation focusing on the influence of soil conditions and methods of rice growing, on the distribution, biology and ecology of weeds of rice in Kerala was carried out in the Department of Agronomy, College of Horticulture, K.A.U. during 2000-2002.

Results of the Permanent Manurial Trial at RRS, Kayamkulam, revealed the dominance of *Aeschynomene indica* to low N , *Scirpus juncoides* to low P soils. The number of weed species was more in plots receiving all the fertilizers compared to those receiving no nutrients. The fungal, bacterial and actinomycete population was higher in plots supplied with nitrogen and phosphorus and or organic matter.

The influence of soil conditions on weed flora was studied by conducting surveys across the various rice ecosystems. The data from the surveys were analyzed statistically and diversity indices such as Simpson's diversity index, Shannon's diversity index, Evenness index and the dissimilarity coefficient were worked out. Cluster analysis was also done and dendrograms were prepared grouping the different regions based on the similarity of weed flora. Striking dissimilarities were noticed in the distribution of grass weeds while it was lesser in the case of sedges, total weed flora and ferns and least in the case of broad leaf weeds. Kole, Pokkali, Kayal, Kari and Palakkad (Rabi season) regions showed much similarity in the flora of grass weeds, while there was 75 % dissimilarity for these regions to Chittur and Karappadam lands.

Investigations on the mechanisms of survival of some of the indicator weeds showed that *Aeschynomene indica* thrive in low N soils by fixing atmospheric N in its aerial nodules. *Diplachne fusca* adapt to the saline habitats by excreting the excess salt

through the micro hairs. The luxuriant vegetative growth of *Echinochloa crusgalli* and other weeds in Pokkali region seems to be an adaptation for diluting the salts absorbed.

Based on the surveys as well as the data from PMT, a few weeds were identified as indicators of soil conditions which are listed below.

Aeschynomene indica	-	Low N
Scirpus juncoides	-	Low P
Monochoria vaginalis	-	High organic matter and high P
Ludwigia parviflora	-	High organic matter
Eleocharis dulcis	-	High Acidity
Leptochola chinensis	-	High Alkalinity
Diplachne fusca	-	High Salinity
Acrostichum aureum	-	High Salinity
Acanthus ilicifolius	-	High Salinity
Sphaeranthus africanus	-	High Salinity
Spehnoclea zeylanica	-	High Salinity
Echinochloa stagnina	-	Low Salinity
Cyperus rotundus	-	Upland rice
Echinochloa colona	-	Upland rice
Cyperus pangorei	-	Low land rice
Ipomoea aquatica	-	Low land rice
Sacciolepis interrupta	-	Semidry rice

The study revealed that weed flora can be used as an indicator of the soil conditions and offers scope for ameliorative management for better weed control and crop growth.