ECOPHYSIOLOGY AND MANAGEMENT OF *ISACHNE* IN RICE FIELDS OF ONATTUKARA

By

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THESIS

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DECLARATION

I hereby declare that the thesis entitled **'Ecophysiology and management of *Isachne* in rice fields of Onattukara'** is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award to me of any degree, diploma, fellowship, associateship or other similar title, of any other university or society.

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Introduction

INTRODUCTION

Rice forms the staple food for more than half of the world population. Though it is grown in every continent of the world, 90 per cent of it is grown and consumed in Asia. In India, rice is grown in almost all states. The production of rice in India during 1994-95 was 81 million tonnes from 40 million hectares. It amounted to 19 per cent of world's rice production. By AD 2000, the global rice production should go upto 560 million tonnes in order to meet the demand of growing human population (Swaminathan, 1989).

In Kerala rice occupies an area of 4.50 lakh hectares with an annual production of 10.03 lakh tonnes (FIB, 1996). The main rice growing tracts of Kerala are sandy soils of Onattukara, acid sulphate soils of Kuttanad, Kole lands of Trichur and rice fields of Palghat. The agro-climatic situations in these different rice growing tracts are entirely different. The cropping pattern also vary accordingly. Three main seasons are there for rice cultivation in Kerala - the 'Virippu' crop starting from April-May to August (*Kharif*), the 'Mundakan' crop starting from August-September to December-January (*Rabi*) and the 'Punja' crop from December-January to March-April (Summer). The *Kharif* crop is mostly dry sown whereas the *Rabi* crop is mainly transplanted and the summer crop is wet sown.

The agro-climatic region of Onattukara lies in the coastal sandy belts of Kollam and Alapuzha districts. In the 28,000 ha of low lands, rice-rice-sesamum is the major cropping pattern. In Onattukara, weeds have been identified as one of the most important constraints to rice production (KAU, 1980). *Isachne miliacea* Roth. ex. Roem. & Schult. has been reported to be the predominant weed in rice fields of Onattukara both in *Kharif* (KAU, 1988) and *Rabi* seasons (KAU, 1990). The weed belongs to the family Poaceae. It is found in low land rice fields of Kerala, commonly known as 'Isachne'. The weed is called *Njammal* in Malayalam.

Weed control is the most expensive operation in rice culture. In Kerala traditional methods of weeding have become very costly due to high labour wages. Herbicides have become popular in many parts of Kerala. The weed control method should be based on many factors such as socio-economic and environmental hazards. The use of herbicide can create unemployment. It can cause pollution and often lead to weed shifts and herbicide resistance in weeds. Where ever labourers are available in plenty, traditional methods are still the best and ecofriendly. Weeding should be done considering the weed thresholds ie., only when the density is such that the weed removal will be economically rewarding.

Most of the research works on weed management in rice have been done with a single season approach. Weed control in field crops should be considered in a system basis involving all the seasons. According to the agro-climatic situation, various weed control methods such as manual, chemical, biological or cultural methods should be integrated so that the strategy has wider socio-economic acceptance, less environmental hazards and checks development of weed resistance and weed shifts. For efficient weed management various aspects of weed biology, phenology, ecology and crop weed competition and allelopathic interaction of the predominant weed species in the crop should be understood. It is the better management of the weed that is needed and not a clean crop. With the above view in mind an investigation on the ecophysiology and management of *I. miliacea* in rice based cropping system of Onattukara was undertaken during 1991 to 1994 at Rice Research Station, Kayamkulam.

The main objectives of the study were:

1. Survey the weed flora in the low land rice ecosystem of Onattukara.
2. Study the biology, phenology and ecology of *I. miliacea*.
3. Study the seed physiology of *I. miliacea*.
4. Study the competitive efficiency of *I. miliacea* in rice and to study the nutrient uptake by crop and weeds and
5. Develop a management strategy for controlling the weeds dominated by *I. miliacea* in rice based cropping system involving "rice-rice-fallow" and to work out the comparative economics of weed control.

Review of Literature

REVIEW OF LITERATURE

Literature on various aspects of crop-weed interactions in rice such as weed biology, phenology, ecology, propagation, crop-weed competition and methods of management of weeds in rice are reviewed in this chapter. Since *Isachne miliacea* is not a serious weed in rice in many other parts of the world, very little literature is available on the weed.

2.1 Weed flora in rice

Weeds in a crop have evolutionary and taxonomic similarity and are satellitic to crop i.e., it cannot survive without the crop concerned. Weed species in rice vary with soil, system of rice culture, water management, fertility level and weed control practices. Information on weed flora in rice helps in formulating weed control methods.

Holm *et al.* (1977) reported *Echinochloa crus-galli* (L) P. Beauv. to be the most troublesome weed of rice in the world; and *E. colona* (L) Link. is second in importance. Other rice weeds of world importance are *Cyperus difformis* L., *C. rotundus* L., *C. iria* L., *Eleusine indica* L. Gaertn., *Fimbristylis miliacea* L. Vahl., *Ischaemum rugosum* Salisb, *Monochoria vaginalis* (Burmf. f.) Presl. and *Sphenoclea zeylanica* Gaertn.

Species belonging to the Poaceae are the most common weeds with more than eighty reported as weeds of rice fields. Members of Cyperaceae rank next in abundance with more than fifty species observed as weeds in rice fields. Other families with ten or more species reported as weeds of rice include, Alismataceae, Asteraceae, Fabaceae, Lythraceae and Scrophulariaceae (Smith, 1983).

Rice field weeds of Kerala reported by various workers (Nair *et al.*, 1975; Sreedevi, 1979; Sukumari, 1982; Jayasree, 1987; KAU, 1988; Palaikudy, 1989; KAU, 1990) are listed below:

Grasses

Brachiaria mutica (Forssk) Stapf

Cynodon dactylon (L.) Pers.

Digitaria ciliaris Retz Kod.

Echinochloa crus-galli (L.) P. Beauv.

E. colona (L.) Link.

Eleusine indica (L.) Gaertn.

Isachne miliacea Roth. ex. Roem. & Schult.

Ischaemum rugosum Salisb.

Panicum repens L.

Paspalum distichum L.

Sacciolepis interrupta (Willd.) Stapf

Oryza sativa var. *fatua* Sharma & Shastry

Sedges

Cyperus rotundus L.

C. iria L.

C. difformis L.

Fimbristylis miliacea (L.) Vahl.

Scirpus maritimus L.

2.2 Biology and Phenology of weeds

Studying the biology, physiology, reproduction, dynamics of seed dormancy and germination in relation to environment would help in better management of weeds. Weeds in general exhibit early germination, rapid growth, deeper roots, more spreading roots, more tillers, longer leaves, numerous flowers and seeds (Donald, 1963). Another advantage of weed is its greater phenotypic plasticity than crops helping in adjusting with changing environmental factors such as temperature, light and water potentials. Most of the pernicious weeds have C_4 photosynthetic pathway capable of thriving in tropics with high light and temperature and limited moisture (Patterson, 1985).

In many weeds flowering occurred within a wide range of day length. Most of the weeds belonging to Poaceae and Cyperaceae complete their life cycle along with crops and most weed seeds exhibit 30-35 per cent germination even after two years interval (Saraswat, 1977). Weeds often showed high reproductive capacity such as large quantity of seed production, short life span, capacity for vegetative regeneration etc. *Cyperus difformis, C. iria* and *Fimbristylis* produced 50,000, 5,000 and 10,000 seeds per plant respectively (Reissig *et al.*, 1985).

Many weeds spread vegetatively from stem cuttings, underground stolons and auxiliary buds. Weeds like *Commelina benghalensis* propagate by means of stem cuttings (Budd *et al.*, 1979). *Paspalum distichum* spreads by creeping underground stolons whereas *Cynodon dactylon* can propagate by rhizomes or auxiliary buds (Reissig *et al.*, 1985).

2.3 Physiology of weed seeds

Studying the dormancy and germination behaviour of weed seeds in soil will help in better management of the weed. Dormancy is usually considered to be the failure of a seed to germinate under conditions normally favourable for the germination and growth of seedlings. The ability of the seeds to survive as a dormant tissue for long periods and germinate at the right time is a very important survival advantage of weeds.

Seeds of *Scirpus articulatus* possessed internal dormancy and required an after ripening period of four months to germinate (Datta and Roy, 1973). Twenty five species of weeds exhibited definite periodicity in germination in a particular season and at a particular point of time (Mani and Singh, 1977). Even under optimal conditions only a part of the seeds germinated at one time while the rest remained in the earth's seed bank (Elgey and Duke, 1985). It was also found that in the field weed seeds alternatively lost and acquired dormancy and displayed seasonal rhythmic germinability during their periods of persistence in the soil.

Light requirement is a principal means by which seed germination is restricted to the proximity of soil surface (Woolley and Stoller, 1978, Karssen, 1980). The requirement of oxygen for breaking dormancy and for initiation of germination varies with weed species. Fewer weeds emerged when the soil was flooded. At field capacity or soil saturation all weed species emerged readily (Smith and Fox, 1973). *Echinochloa crus-galli* germinated under anaerobic or aerobic conditions (Kennedy *et al.*, 1980). Most weed species have a single temperature optimum for germination. Temperature strongly influenced the breaking of both primary and secondary dormancy especially the onset and breaking of secondary dormancy (Elgey and Duke, 1985). They also found that allelochemicals like coumarin inhibited germination of seeds. Nitrite or gibberellic acid stimulated germination of *Lactuca sativa*. Nitrite broke dormancy of *Oryza sativa*.

Roberts and Dawkins (1967) found that in the absence of reseeding weed seeds in cultivated soil were reduced in number by about 25 per cent per year. Germination of seeds varied with depth of burial. In fact secondary dormancy is induced by burial. Emergence of seeds of *C. benghalensis* were 19.5, 9.8, 2.5, 1.0 and 0.5 per cent for seeds buried at zero, two, four, six and eight centimetre depth, respectively (Budd *et al.*, 1979). In general, weed seeds buried near soil surface lost viability more rapidly than seeds buried more deeply (Toole, 1946). High soil temperature also favoured loss of seed viability (Schafer and Chilcote, 1970). Burial of stem cuttings of *Commelina* (Budd *et al.*, 1979) and *Paspalum* below two centimetre depth failed to regenerate but longer segments sustained for longer periods (Reissig *et al.*, 1985).

Smith and Fox (1973) and Vamadevan *et al.* (1974) reported that the weight and number of weeds decreased with increase in water depth so much that maximum weed count and weight was noticed under the treatment of field capacity to saturation point. Bhan (1983) also observed that weed emergence was maximum at field capacity, but the emergence was reduced upto 15 cm submergence. Gill *et al.* (1985) reported that five to six centimetre standing water for four weeks significantly reduced seedling emergence of *E. crus-galli* than at three centimetre water depth.

Soil is a reservoir of weed seeds therefore burial of seeds should be minimised to reduce weed problem. Submergence of field can be exploited for weed control.

2.4 Weeds as alternate hosts of insect pests and disease pathogens

Many weeds serve as alternate hosts to many insect pests and disease organisms. Kannaiyan and Prasad (1979) reported twenty weed hosts of *Rhizoctonia solani* of which the major three species were *Cynodon dactylon, Ischaemum rugosum* and *Eriochloa procera* (Retz.). Singh and Singh (1988) identified many rice weeds as alternate hosts of fungi *Pyricularia oryzae* causing blast in rice. They are *Leersia, Panicum, Brachiaria, Cyperus compressus, C. rotundus* and *C. iria*.

Dubbe (1981) reported that steel blue beetle (*Haltica cyanea*) feeds voraciously on *Ludwigia* sp. in rice fields. Reissig *et al.* (1985) have reported the host range of common rice pests. They found that *Echinochloa* spp. served as alternate host to a great majority of insect pests of rice.

2.5 Allelopathic interaction of weeds in rice

Allelopathy is the influence of higher plants (donor) of one species on the germination, growth or development of plants of another species (recipient) by release of chemicals by weathering, leaching, exudation or volatilisation.

Wirjahardja and Nurfilmarasa (1975) found, wild rice (*O. sativa* var. *fatua*) and red rice (*O. perennis*), to release an allelopathic substance which hampered the root formation of rice seedlings of the cv. IR-5. Lopes *et al.* (1987) found that root and shoot aqueous extracts of *Echinochloa* and *Cyperus* did not affect the germination of rice but reduced radicle and coleoptile growth. Extracts from *Echinochloa* shoot was found more inhibitory to rice. Jayakumar *et al.* (1988) found the allelopathic effect of *Amaranthus viridis* and *Boerhaavia diffusa* on the germination and seedling growth of *E. colonum*.

Research should be directed to screen allelopathic potential of different crops and their varieties for weed suppression under field conditions. Allelopathy should be exploited through genetic manipulation of crops through classical breeding programmes or biotechnology for effective weed control through development of safer bioherbicides from allelochemicals.

2.6 Crop-weed competition in rice

Competition is not an intrinsic property of any particular weed or crop; it is only measurable in comparison with other species. Weed competition is probably the most important single factor limiting yield of field crops. Competition begins when crop and weed grow in close proximity to one another and when the resources are insufficient to sustain the growth and development of either or both.

2.6.1 Factors of competition

Cereals are most sensitive to weed competition in their early stages of growth. Weed damage to crop varied with weed species, crop variety, duration and density of infestation of weeds, environmental factors and cultural practices (Smith, 1983).

Crop and weed compete for water, light and nutrients. The availability of water is a primary limitation to crop productivity including water stress in crops as described by Kramer (1983). In fact competition for light in field crops may operate throughout the crop cycle, except when plants are young (Zimdahl, 1980). But the competition for nutrients was maximum during early period of growth of crop and weeds (De Datta *et al.*, 1969; Shetty and Gill, 1974). Pande and Bhan (1966) found more N and K content in weeds than in rice. Chakraborty (1973) and Moody (1981) found that weeds competed with rice throughout the growing season for nitrogen.

2.6.2 Type of weeds and competition

De Datta *et al.* (1968) found that grassy weeds were most influential in reducing rice grain yield followed by broad leaved species and then by sedges. Dwarf weeds are serious competitors during early growing stage of rice whereas taller weeds can compete with rice for light during later stages of the crop as well. Unlike transplanted rice, weeds that emerge with direct seeded rice are more competitive.

Annual weeds reduced yield of drilled rice by 74 per cent, *C. rotundus* by 42 per cent, and that of annual weeds plus *C. rotundus* reduced the yield by 83 per cent (Okafor and De Datta, 1974). Naidu and Bhan (1980) also found that grasses or grasses plus broad leaved weeds influenced yield significantly, than broad leaved weeds alone. Smith (1988) reported that among grasses, in density experiments, red rice reduced grain yield of rice maximum followed by *E. crus-galli, Leptochloa fasciculatus* and *Brachiaria platiphylla.*

2.6.3 Critical periods of crop-weed competition

At IRRI, Philippines maximum yields were obtained when paddy plots were kept weed free during 20 to 40 days after transplanting (IRRI, 1964).

According to Park and Kim (1971) weed competition substantially influenced grain yield during the first 30 days after transplanting (DAT) wet land rice. The critical period was between four and six weeks after transplanting (Shetty and Gill, 1974). Similar observations were made by Sasidhar (1983).

The most critical period of weed competition with regard to grain and straw yield was 20 to 40 days after sowing rice (Sukumari, 1982), whereas Sahai *et al.* (1983) observed it to be between 15 to 45 days after sowing (DAS) rice. Ali and Sankaran (1984) opined that rice in low land should be free of weeds during the first fifty days in monsoon and sixty days in summer. But in uplands the corresponding periods were sixty and seventy days. The critical period for weed removal was between 15 to 30 days after sowing upland rice (Shelke *et al.*, 1986). In All India trials the critical period of weed competition in upland rice was the initial 15 to 45 days after sowing rice (AICRPWC, 1987).

2.6.4 Weed density and competition

Investigations showed that weed plants are harmful to crops even at low densities in most normal crop situations. The threshold density of *E. crus-galli* for season long competition was five plants per square metre at which level grain yield losses were eight to 17 per cent (Senanayake *et al.*, 1986). The crop-weed competition relationship is not sigmoidal but a concave upward curve, meaning that each weed plant becomes increasingly crop yield reducing at diminishing weed population densities (Alstrom, 1990). However, even if these low density weeds are harmful, it is not economically meaningful to remove weeds below the weed density level when the additional cost of weeding is equal to the value of marginal crop yield reducing effect of the weed.

2.7 Methods of weed control

Several methods of weed control exist in rice culture; manual, cultural or chemical methods. One of the best guides for choosing appropriate method of weed control is the relative cost of labour and herbicides and the degree of weed control and yield obtained. The highest return per unit invested should be used to determine the weed control method, coupled with other social factors such as labour.

2.7.1 Manual weed control

Hand weeding, hoeing, working rotary weeders etc. were the cultural control methods adopted in traditional rice culture. For small holders use of traditional methods of weed control would be the most economic (Scolari and Young, 1975). Ahmed and Moody (1978) found fewer weed species in well puddled fields. Manuel *et al.* (1979) reported that one ploughing together with three harrowings in thirty day period effectively controlled *Paspalum distichum*. Diop and Moody (1981) got the highest grain yield in rice when plots were harrowed three times compared to zero tillage.

One hand weeding was proved to be most economic in transplanted rice (Moody, 1977 and Ahmed, 1978). Two hand weedings on 20 and 40 DAS were very effective in dibbled rice (Sukumari, 1982). Three hand weedings on 20, 31 and 45 DAS gave maximum grain yield in drilled rice (Reissig *et al.*, 1985; Sharma *et al.*, 1986). Hand weeding is widely practiced in Asia, especially in upland rice. Normally two hand weedings were done on 21 and 35 DAS. Traditional methods are still the best when labour is less costly and plentiful.

2.7.2 Chemical weed control

Though hand weeding is effective it is tedious, time consuming and labour intensive. Due to the high cost of labour and inadequate availability at the peak period and unfavourable working conditions, the situation has changed, necessitating the use of chemicals. The efficiency of a herbicide depends upon the types of rice culture and the nature of weed species present. Identification of suitable herbicides for different systems is needed. Effectiveness of herbicides depend on so many factors such as water management, soil fertility, nature of rice variety and weed species and their growth pattern.

Trials at IRRI gave good weed control with pendimethalin 0.75, pretilachlor 0.50 and oxyfluorfen 0.25, thiobencarb 1.0, butachlor 0.75 kg ha^{-1} (IRRI, 1979). Application of 0.15 kg oxyfluorfen or 1.0 kg thiobencarb per hectare or butachlor at 1.5 kg or anilofos 0.3 kg and 0.8 kg 2,4-D ethyl ester gave more than 3 t ha^{-1} of grain yields (Kumar and Gautam, 1986). Two hand weedings on 30th and 50th day increased the yields in the above treatments to 4 t ha^{-1}. Mishra *et al.* (1988) got better control with 0.1 and 0.15 kg oxyfluorfen 1.0 kg butachlor and 1.0 and 1.4 kg ha^{-1} of thiobencarb. But broadleaf weed control was poor with anilofos (arozin) 0.3 and 0.4 kg ha^{-1}.

Works at IRRI, Philippines proved that glyphosate at 2.0 kg ha^{-1} effectively controlled *P. paspalodes* (IRRI, 1976). *Paspalum distichum* was controlled by applying glyphosate at 2.0 or 2.4 kg ha^{-1} (Corbetta *et al.*, 1979; Manuel *et al.*, 1979). In Russia, Knyr *et al.* (1985) found that the application of 2.4 kg ha^{-1} of glyphosate to fallow plots or 0.6 and 2.0 kg ha^{-1} to pre-sowing rice gave effective control of *Echinochloa* and *S. maritimus* and showed no adverse effect on crop growth and paddy yield. They also found that glyphosate was degraded in soil within ten days of application.

2.8 Integrated weed management

Each weed control method has advantages and disadvantages. No single method can solve all the weed problems in a given area primarily because of differences in weed vegetation and growth habits. It is therefore necessary to use a suitable combination of physical, chemical, cultural and biological control techniques to achieve maximum benefit through minimum crop and environmental hazards and provide reasonable weed control. Economic feasibility, ecological soundness and social relevance must be the ultimate goal.

Reddy and Hukkeri (1979) reported that the most remunerative cultural practice for direct sown rice were puddling twice with partial submergence followed by either hand weeding or the use of a herbicide. Reissig *et al.* (1985) found that preventive weed control methods like dense seeds increased the effectiveness of direct weed control methods. They also reported that in transplanted crop flooding two to three DAT at five to 10 cm depth controlled weeds only with close planting and tall cultures. Singh (1993) recommended a package to utilise non monetary inputs like land preparation, choice of appropriate genotype and cultivar, timely planting, planting geometry and density, intercropping and crop rotation and fertilizer use for efficient weed management.

Most pre-emergence herbicides had too short residual effects and hence a follow up hand weeding is recommended to control residual weeds left out by pre-emergence herbicide. Misra and Roy (1971) and Manipan *et al.* (1981) obtained best control of weeds by combining pre-emergence herbicide with one hoeing or manual weeding. De Datta and Llagas (1982) reported that integrated weed management of pre-emergence herbicides together with post-emergence herbicide or hand weeding or hoeing or rototilling will be the best for upland rice. Butachlor followed by hand weeding controlled weeds in upland paddy (Pandey and Singh, 1982; Vijayaraghavan *et al.*, 1988). Pendimethalin or thiobencarb followed by hand weeding was also effective in reducing weeds in direct sown rice (Bhan *et al.*, 1980; Balyan *et al.*, 1983). Singh and Singh (1985) and Deshmukh *et al.* (1987) obtained yields similar to two hand weedings from 2.0 kg ha^{-1} of butachlor, thiobencarb, pendimethalin, 2,4-D, pre-planting when followed by one hand weeding.

Materials and Methods

MATERIALS AND METHODS

The details of the materials used and methods adopted in conducting the experiments are described below.

3.1 Experiment site

The experiments were conducted in the low lands at Rice Research Station, Kayamkulam situated at 9° 30' North latitude and 76° 20' East longitude and at an altitude of 3.6 m above m.s.l. The site represents the plain level sandy alluvium called Onattukara situation, coming under the special zone of problem areas in Kerala. Onattukara region comprises of Karunagapally, Karthikapally and Mavelikara taluks. The main cropping system of low lands is drill sown semi dry rice (*Kharif*), transplanted rice (*Rabi*) and sesamum in summer.

3.2 Soil characters of the experiment site

The Onattukara region is located mainly on the coastal belt and the soil is sandy or sandy loam. Composite surface soil sample from zero to 30 cm depth was collected from the experimental area before sowing and used for analysis of physical and chemical characteristics. The data are presented in Table 1. Rice-rice sesamum was the cropping pattern adopted in this field during previous years.

3.3 Seasons

The field experiments were conducted in *Kharif* as a dry dibbled rice and in *Rabi* as a wet transplanted rice during 1992 and 1993.

Table 1. Physical and chemical properties of the soil of the experiment site

Sl.No.	Particulars		Method used for determination
1	Physical properties (%)		Piper (1966)
	Sand	- 60.0	
	Fine sand	- 23.1	
	Silt	- 5.0	
	Clay	- 10.0	
2	Chemical properties		Jackson (1967)
	Soil pH (1:2.5)	- 5.6	
	Organic carbon (%)	- 0.3	
	Available P (%)	- 0.12	
	Available K(%)	- 0.018	

3.4 Climatic conditions

The meteorological data as recorded at the Meteorological observatory of Central Plantation Crops Research Institute, Kayamkulam located near to Rice Research Station are presented in Appendix-I and are depicted in Fig. 1 and 2.

Rainfall data for the *Kharif* season, April-May to August showed that rainfall during 1992 was much higher than the previous sixteen year's mean rainfall. But it was below normal in 1993. Heavy rain was received during June-July in both years. During *Rabi* season, August-September to December, it was above average during 1992. In 1993 rainfall was below normal during August and September, but very high during October, November and December.

Relative humidity was almost normal (67.2-87.0%) during *Kharif* and *Rabi* crop of 1992 and 1993. Maximum temperature did not vary much from the normal (30.45-34.58 °C) in any year of the study. Minimum temperature was below average in 1992 during both seasons, but in 1993 it was below normal by four

Fig 1. Mean weather parameters for the period from 1975 to 1991

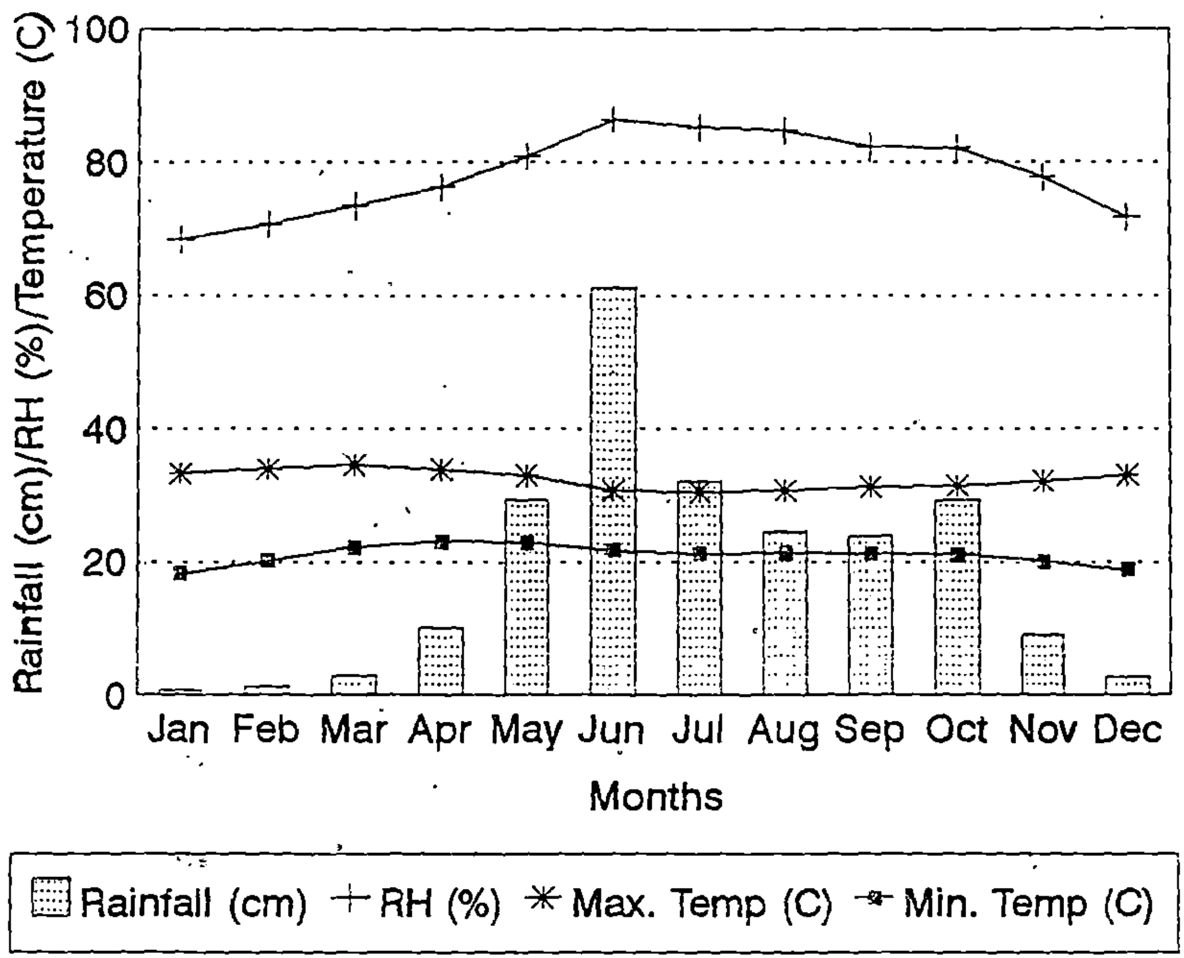
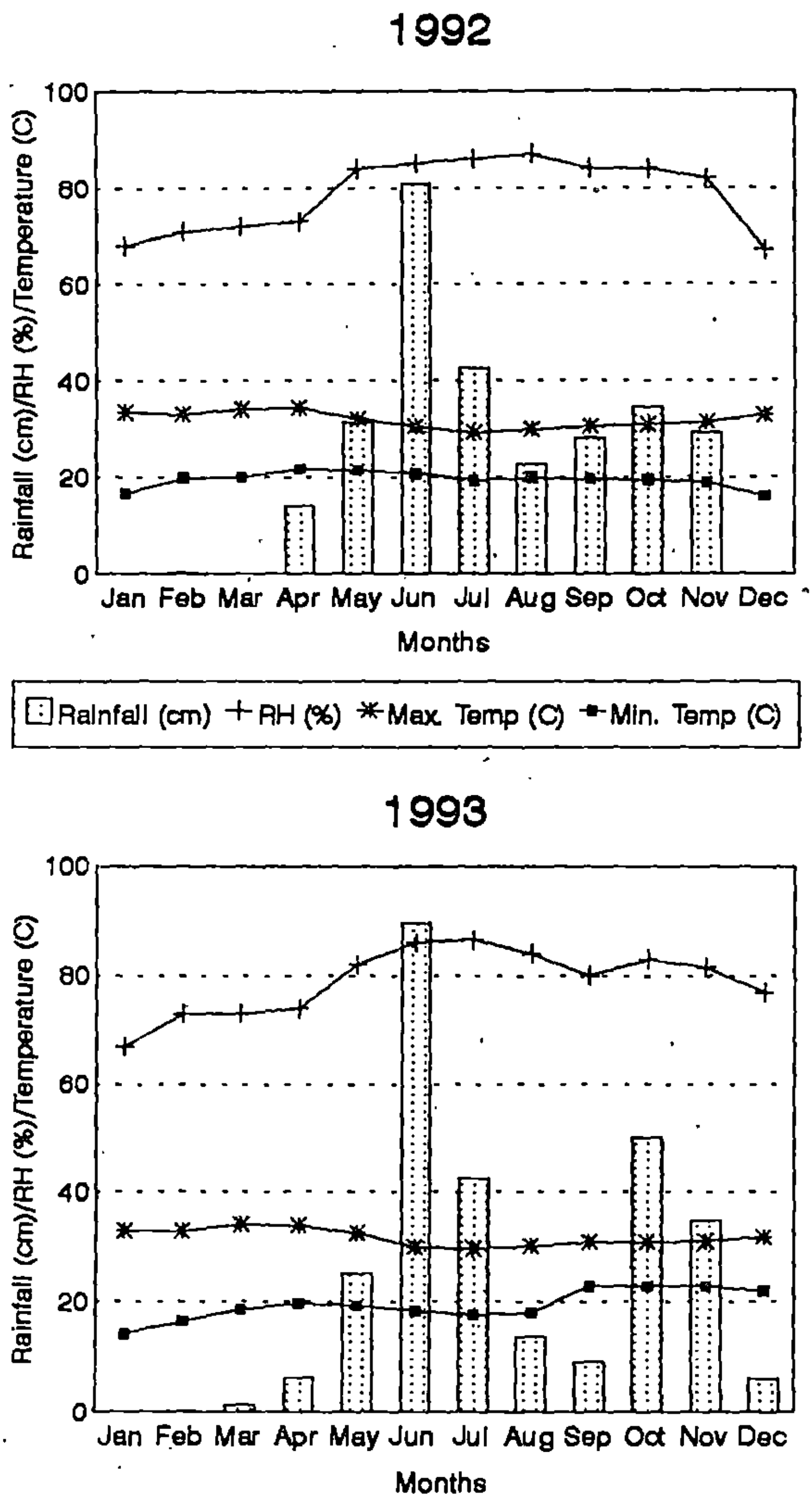


Fig 2 Meterological data for the experimental period



degree centigrade in *Kharif* and above normal by one degree centigrade in *Rabi* season.

3.5 Cultural operations

3.5.1 Preparatory tillage

The *Kharif* crop was dry dibbled and the *Rabi* crop was wet transplanted one. The field was ploughed well and levelled and plots were laid out as per the plan (Fig.3). The layout for *Rabi* crop too was done at the beginning of *Kharif* crop in the integrated weed management trial, as the attempt to control weeds was on a cropping system basis. Small bunds were formed around each plot.

3.5.2 Application of fertilizers

In the semi dry *Kharif* crop, a uniform dose of NPK @ 70:35:35 kg ha^{-1} for short duration rice (100 days), variety 'Red Triveni', was applied and for the wet transplanted *Rabi* crop NPK @ 90:45:45 kg ha^{-1} was applied uniformly for the medium duration (130 days) rice variety, 'Sabari' as per the package of practices (KAU, 1989).

3.5.3 Seeds and sowing

Seeds with more than 90 per cent germination were used for the trial. Seeds were dibbled dry during *Kharif* crop @ 80 kg ha^{-1}. Transplanting of 25 day old seedlings at 20 cm x 10 cm spacing was adopted during *Rabi* crop.

3.5.4 Weed control

The weed management was done as per the treatments. The pre-emergence herbicides anilofos, pretilachlor, butachlor, thiobencarb and oxyfluorfen were applied immediately after seeding with sufficient moisture in the soil. Glyphosate was applied on the residual weeds immediately after the harvest of *Kharif* crop.

3.5.5 Plant protection

No severe pests were noticed during *Kharif* crop 1992 and 1993 and *Rabi* crop 1992. During 1993 *Rabi* season the crop was sprayed for controlling brown plant hopper attack with sevin 50 per cent wettable powder and BHC 50 per cent wettable powder @ 2.5 kg ha^{-1} of the product.

3.5.6 Harvesting

The crop was harvested at maturity from net plots. Threshing was done manually and the produce was cleaned, dried and weighed and yield expressed as kg ha^{-1} at 14 per cent moisture.

3.6 Experimental details

The details of the experiments undertaken are outlined below.

3.6.1 Part I. Ecophysiology of *Isachne miliacea*

3.6.1.1 Survey of the weed flora in the low land rice ecosystem of Onattukara

Different rice growing tracts of Onattukara were surveyed during the *Kharif* and *Rabi* seasons. Major weed species and different eco-types of *I. miliacea* were collected and got identified at the Tropical Botanical Garden, Palode, Trivandrum. The sites selected for the survey work were

Kayamkulam, Chettikulangara, Thekkekara, Chepad, Haripad, Oachira, Thazhava, Karunagapally, Karthikapally and Pathiyoor. These pockets were surveyed during both *Kharif* and *Rabi* season and weed count per square metre of major weed species recorded from an unweeded area on 30 DAS/DAT @ five quadrats per location and the density and relative density were worked out. Dominance and relative dominance of weeds were worked out at monthly intervals during each season from an unweeded area year marked for the purpose @ five quadrats at each location as suggested by Kondap and Upadhyay (1985).

$$\text{Density} - \frac{\text{Total number of individuals of a species}}{\text{Total number of quadrats used in the sampling}}$$

$$\text{Relative density} - \frac{\text{Total number of individuals of species} \times 100}{\text{Total number of individuals of all species recorded}}$$

$$\text{Dominance} - \frac{\text{Total basal area or crown of a species}}{\text{Total area sampled}}$$

$$\text{Relative dominance} - \frac{\text{Dominance of a given species} \times 100}{\text{Total dominance of all species}}$$

3.6.1.2 Biology, phenology and ecology of *I. miliacea*

3.6.1.2.1 Life cycle of *I. miliacea*

The life cycle of *I. miliacea* starting from germination, growth, flowering, seed production and death were studied in natural field conditions. Life span of the weed was assessed using seeds and stem cuttings in pots by sowing in May and August, respectively. Growth was measured in a natural population in rice fields during *Kharif* and *Rabi* using quadrats of one square metre at monthly intervals; both inside rice crop and outside the crop.

3.6.1.2.2 Fresh weight dry weight ratio of weeds

Known fresh weights of all the major weeds were dried to constant weights and its fresh weight to dry weight ratio was worked out by dividing fresh weight by dry weight.

3.6.1.2.3 Seed production potential of *I. miliacea*

The seed production potential of *I. miliacea* was estimated by growing the weed alone and in association with rice plants. The number of seeds per square metre was estimated by counting the number of seeds per panicle and the number of panicles per square metre.

3.6.1.2.4 Effect of date of sowing on flowering of *I. miliacea*

The trial was done using seeds and four noded stem cuttings of *I. miliacea* in two separate pot cultures. The sowings were done @ four hills per pot at fortnightly intervals for one year using seeds in April and stem cuttings in August. The days to flowering were recorded. Each treatment was replicated thrice.

3.6.1.2.5 Soil conditions

Soil conditions favouring the growth of *I. miliacea* were studied by analysing soil collected from ten randomly selected rice growing pockets of Onattukara and analysed for organic carbon, available P_2O_5 and K_2O, pH and electrical conductivity.

3.6.1.2.6 Pests and diseases of *I. miliacea*

During the survey work natural enemies like insect pests or disease pathogens attacking the weed were collected and identified.

3.6.1.3 Propagation of *I. miliacea*

The study was conducted in pots using both seeds and stem cuttings in two separate trials. Seeds or four noded stem cuttings were sown at different soil depths and at different moisture levels. The treatments were the combinations of five depths of seeding (0, 2.5, 5.0, 7.5 and 10 cm) and five moisture levels (field capacity, water cover of 1, 2.5, 5 and 10 cm).

Pots of 25 cm diameter and 30 cm height were filled with soil free from any weed seeds of *I. miliacea*. Garden land soil was used since the weed does not grow in uplands. Pots in which standing water at 1, 2.5, 5 and 10 cm depth were to be maintained were filled upto the same depth from the top brim of the pots and drainage holes sealed. For pots in which the field capacity had to be maintained the drainage hole was kept open. Every day water level was maintained at desired depths.

The experiment was laid out in completely randomised design with four replications. Four hills with five seeds per hill or four stem cuttings per pot were sown at the depths specified and water level maintained periodically. The germination, growth and dry matter production were recorded after three months. Trial using seeds was conducted during May to August and that using stem cuttings during August to November.

3.6.1.4 Seed physiology of *I. miliacea*

Mature seeds of *I. miliacea* collected from the plant were air dried and stored and its germination and viability tested at fortnightly intervals. Small lots of the seeds were put in terylene cloth bags and buried in soil at 0, 5 and 15 cm depths in the paddy fields during December, 1991. Seeds were recovered at monthly intervals and tested for germination and viability. The study was conducted for two years. The viability was determined by employing tetrazolium tests (Flemion and Poole, 1948).

3.6.1.5 Allelopathic effects of *I. miliacea*

Allelopathic influences of *I. miliacea* on rice seed germination and that of common weeds on *I. miliacea* seed germination were investigated.

Water extracts of whole plant samples prepared by keeping 20 g of plant sample in 100 ml of distilled water for 24 hours and the extract was filtered (Bendall, 1975). Germination tests of the seeds on which the effects are to be tested were done using the extract of the plant to be studied using Petri dishes and filter paper. Five ml plant extract per dish with 20 seeds each were used along with an absolute control of distilled water. Observation on germination percentage of seeds were recorded.

3.6.1.5.1 Effects of *I. miliacea* on rice

Five rice varieties (Red Triveni, Sabari, Onam, Bhagya and Dhanya) were tested using extracts of *I. miliacea* and distilled water control. In total there were ten treatments. The trial was laid out in completely randomised design with three replications in the laboratory.

3.6.1.5.2 Effect of weeds on *I. miliacea*

Treatments

1. *E. colona*
2. *S. interrupta*
3. *Cyperus* spp.
4. *M. vaginalis*
5. *O. sativa* var. *fatua*
6. Distilled water (control)

Trial was laid out in laboratory in completely randomised design with five replications using water extract of the weeds in Petri dishes on the germination of seeds of *I. miliacea*.

3.6.2 Part II. Rice-weed competition

This experiment was laid out in randomised block design with eight treatments and four replications during the *Kharif* and *Rabi* seasons of 1992 and 1993.

During *Kharif* crop *I. miliacea* population was maintained by sowing seeds and during *Rabi* crop by planting stem cuttings having four nodes. Population of rice was maintained by thinning or gap filling. During *Kharif* rice was dry dibbled @ 80 kg seeds per hectare and during *Rabi* seedlings transplanted @ 2 seedling per hill at 20 cm x 10 cm spacing.

The treatments

1. *I. miliacea* 5 plants per m^2
2. *I. miliacea* 20 plants per m^2
3. *I. miliacea* 80 plants per m^2
4. Weed free control
5. Unweeded rice
6. Weeds other than *I. miliacea*
7. No rice, *I. miliacea* alone
8. No rice, all weeds

Gross plot 2.0 m x 2.0 m

Net plot 1.0 m x 1.0 m

3.6.3 Part II. Integrated weed management in rice based cropping system

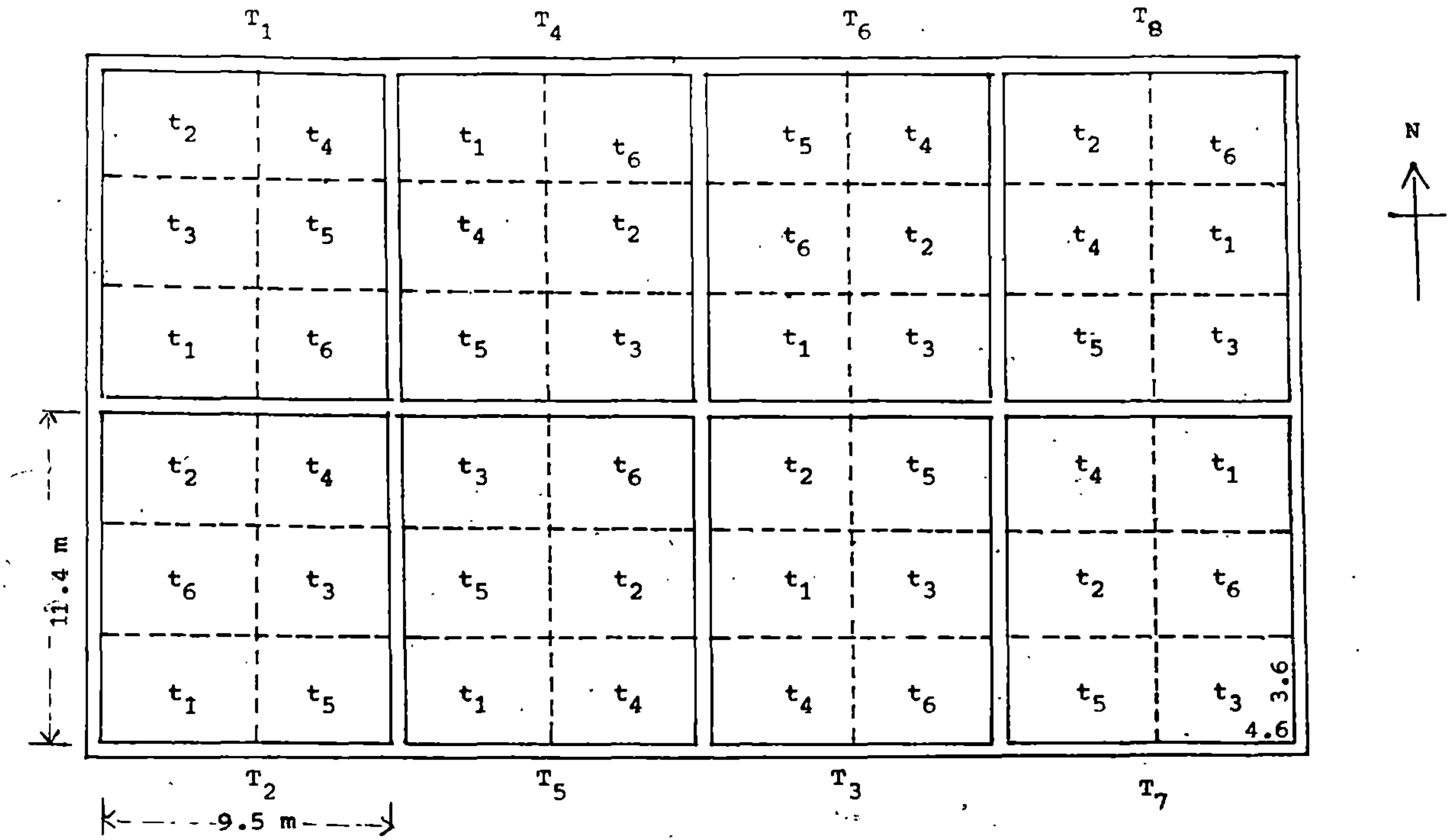
3.6.3.1 *Kharif*

This experiment was laid out in randomised block design with eight treatments and three replications during 1992 and 1993.

Treatments

1. Anilofos 0.4 kg ha^{-1} + Hand weeding (HW) on 30 DAS
2. Pretilachlor 0.5 kg ha^{-1} + "
3. Butachlor 1.25 kg ha^{-1} + "
4. Thiobencarb 1.25 kg ha^{-1} + "
5. Oxyfluorfen 0.10 kg ha^{-1} + "
6. Local practice. One hoeing 15 DAS + 2 HW on 25 and 40 DAS

Fig.3. Model plan of one replication of the layout of field experiment on integrated weed management in rice



7. Unweeded check
8. Weed free check

Gross plot - 11.4 m x 9.5 m. Variety - Red Triveni Bunds - 30 cm

Net plot - 9 m x 8 m Spacing - 15 cm x 10 cm

Model plan of one replication layout is given in Fig.3. The first crop was dry dibbled using 80 kg seeds per hectare in May and harvested in July in both years.

3.6.3.2 *Rabi*

This experiment was laid out in split plot in randomised block design with *Kharif* crop treatments as main plot having six sub plot treatments in each. The experiment was laid out in 1992 and 1993 and replicated thrice.

Gross plot - 4.6 m x 3.6 m Variety - Sabari Bunds - 30 cm

Net plot - 4 m x 3 m Spacing - 20 cm x 10 cm

Model plan of one replication layout is given in Fig.3.

Sub plot treatments

1. Glyphosate 0.75 kg ha^{-1} immediately after harvest of *Kharif* crop
2. Glyphosate 1.5 kg ha^{-1} immediately after harvest of *Kharif* crop
3. One hand weeding on 30 DAT
4. Two hand weedings on 20 and 40 DAT
5. Unweeded check
6. Weed free check

Ploughing and puddling was done uniformly in all plots. In glyphosate applied plots ploughing was done on seventh day after application. Transplanting was done during first week of September at 20 cm x 10 cm spacing and the crop was harvested in December in both 1992 and 1993.

3.7 Observations

3.7.1 Studies on rice

3.7.1.1 Sampling procedure

Plant samples were collected at required intervals. Five plants were selected at random from specified area. The plants were uprooted, washed free of soil for recording observation on growth characters and yield components. A separate area in the net plot marked for the purpose was used for sampling. The remaining area of the net plot was utilized for recording yield per plot. The techniques for the field experiments with paddy as per Gomez (1972) were adopted in this project.

3.7.1.2 Growth components

3.7.1.2.1 Tiller production

The number of vegetative tillers in one square metre area of each of the experimental plot on 60 DAS/DAT were counted and recorded.

3.7.1.2.2 Plant height

Plant height of ten plants was measured from ground level to the tip of the longest leaf in all the cases. At harvest, it was measured from ground level to the tip of the longest panicle and expressed in centimetres.

3.7.1.2.3 Leaf Area Index (LAI)

Leaf area index is the area of the leaf surfaces per unit area of land surface. Ten sample plants were selected at each time. The maximum width (W) and length (L) of all the leaves of the middle tillers were measured and leaf area per tiller was worked out using the formula.

Leaf area = K x L x W

where

K is an adjustment factor

K at 60 days after sowing - 0.705

Leaf area per plant = Total area of middle tiller x Total number of tillers

$$\text{Leaf area index} = \frac{\text{Sum of the leaf area per plant of all 10 sample plants (sq.m)}}{\text{Area of land covered by 10 plants (sq.m)}}$$

3.7.1.2.4 Dry Matter Production (DMP)

The five plants pulled out for observations at each stage were initially sun dried, then oven dried at $80^\circ \pm 5^\circ C$ and weight was recorded. Dry matter content was computed for each treatment and DMP worked out and expressed in kg ha^{-1}.

3.7.1.2.5 Rate of DMP

Rate of dry matter accumulation was calculated by dividing the differences in the total dry matter production of the plant at two stages by the interval between these two successive stages and expressed as kg per hectare per day. The following formula of Watson (1952) was used for calculation.

$$\text{Rate of dry matter accumulation} = \frac{W_2 - W_1}{t_2 - t_1}$$

where

w_1 - dry matter production at time t_1

w_2 - dry matter production at time t_2

t_2-t_1 - time interval between two stages

3.7.1.3 Yield components and yield

At harvest panicles of ten randomly selected plants were collected and used for recording other observations on the yield components such as length of panicle, number of spikelets per panicle, number of grains per panicle, number of chaff per panicle and grain chaff ratio and 1000 grain weight.

3.7.1.3.1 Number of panicles

The number of panicles in one square metre in the centre of the experimental area of each plot were counted and recorded.

3.7.1.3.2 Length of panicle

Twenty panicles were randomly selected from the observation plants, the length measured from the neck to the tip of the panicles and the average worked out and expressed in centimetres.

3.7.1.3.3 Number of spikelets per panicle

All the spikelets from the above twenty panicles were separated out and counted and the average was recorded.

3.7.1.3.4 Number of grains per panicle

The grains from the above spikelets were separated out and average for single panicle was calculated.

3.7.1.3.5 Number of chaff per panicle

The number of chaff from the above twenty panicles were counted and the average for single panicle was calculated.

3.7.1.3.6 Grain chaff ratio

The ratio of number of grains per panicle to the number of chaff per panicle was worked out by dividing number of grains by number of chaff.

3.7.1.3.7 Thousand grain weight

One thousand grains were counted from the bulk of each plot and their weight was recorded in grams.

3.7.1.3.8 Grain yield

The crop was harvested from each net plot area, threshed, winnowed and weight recorded. Moisture content of the grain was also determined by moisture meter. Grain yields were adjusted to 14 per cent moisture using the following formula (Yoshida *et al.*, 1976).

Adjusted grain weight - A x W

where

A = adjustment co-efficient

W = weight of harvested grains

$$A = \frac{100-M}{86}$$

where

M = Moisture content (per cent) of grain

Grain yield was expressed in kg ha^{-1}

3.7.1.3.9 Straw yield

The straw yield from the net plot, after threshing was dried in the sun, weighed and yield expressed in kg ha^{-1}.

3.7.1.3.10 Weed Index (WI)

Weed index is a measure of the degree of reduction in yield of crop in comparison with the maximum yield.

$$WI = \frac{\text{DMP of rice in plot with minimum weeds - DMP of treatment in which WI is to be worked out} \times 100}{\text{DMP of rice in plots with minimum weeds}}$$

(Gill and Vijayakumar, 1969)

Results

3.7.2 Studies on weeds

3.7.2.1 Weed count

The total number of weeds per square metre area were counted in each plot at various intervals. They were further separated species wise.

3.7.2.2 Weed dry weight

The weeds collected from one square metre area from each treatment at specified interval and were sun dried and later oven dried at 80 $\pm$ 5°C and weight recorded in kg ha^{-1}.

3.7.2.3 Rate of DMP by weeds

As given in the case of rice plants it was worked out as per Watson (1952).

3.7.2.4 Height of weeds

Height of the tallest weed was recorded by measuring the height upto the longest leaf from ground level for ten plants per plot and the mean height expressed in centimetres.

3.7.2.5 Weed Control Efficiency (WCE)

Weed control efficiency was worked out using the following formula

$$\text{W.C.E.} = \frac{\text{Dry weight of weeds of in unweeded check} - \text{Dry weight of weeds in treatments}}{\text{Dry weight of weeds in unweeded check}} \times 100$$

(Rao *et al.*, 1976)

3.7.2.6 Phytotoxicity of herbicides to rice

Toxicity of herbicides to rice was scored as the method suggested by Kondap and Upadhyay (1985) by using zero to nine scale of visual scoring.

3.7.3 Nutrient uptake

Samples collected for chemical analysis were oven dried at $80^{\circ} \pm 5^{\circ}C$, ground in a wiley mill and used for chemical analysis. The N, P and K content of rice plant and weeds were separately analysed at harvest time of rice as explained by Jackson (1967). The total uptake of nitrogen, phosphorus and potassium were calculated as the product of the content of these nutrients and the plant dry weight; and expressed in kg ha^{-1}.

3.8 Economics of weed control

Labour charges of the locality, cost of inputs and the extra treatment costs were taken together and computed the gross expenditure and expressed in rupee per hectare. Price of paddy and that of straw at current local market rates were taken as total receipts for computing gross return and expressed in rupee per hectare. Cost benefit ratio was worked out by dividing the gross return with the total expenditure per hectare.

3.9 Statistical analysis

The data collected were subjected to statistical analyses using the analysis of variance technique as described by Panse and Sukhatme (1967). Data on weed count that showed wide variations were subjected to square root transformation to make the analysis of variance valid as suggested by Bartlett (1947). Multiple comparisons among treatment means were done by using least significant difference (LSD).

Pooled analysis of the data was done as in the case of groups of experiment after examining the heterogeneity of error mean squares by using the 'F' test (Panse and Sukhatme, 1967). In the case of heterogeneous error mean squares and nonsignificant interaction effect, pooled analysis could not be attempted.

RESULTS

4.1 Part I. Ecophysiology of *Isachne miliacea*

The results of studies on weed flora and biology, phenology, ecology, propagation, seed physiology and allelopathic effects of *I. miliacea* are given below.

4.1.1 Survey of weed flora in low land rice ecosystem

4.1.1.1 *Kharif* season

Data on mean density, and relative density of major weed species during the season are presented in Table 2 and depicted in Fig.4. Data on weed count recording during the survey are presented in Appendix-II.

Table 2. Density and relative density of major weeds of rice in Onattukara during *Kharif* season

Major weed species	Density (number/m²)	Relative density (%)
Isachne miliacea	149	45.7
Cyperus spp.	139	42.5
Echinochloa colona	15	4.9
Sacciolepis interrupta	12	3.6
Oryza sativa var. *fatua*	3	0.9
Monochoria vaginalis	5	1.6
Ludwigia parviflora	2	0.8

Table 3. Monthly dominance of weeds in rice during *Kharif* season

Weed species	30 DAS		60 DAS		90 DAS	
	Dominance	Relative dominance (%)	Dominance	Relative dominance (%)	Dominance	Relative dominance (%)
Isachne miliacea	0.020	8	0.070	18	0.200	45
Cyperus spp.	0.160	65	0.200	51	0.060	13
Echinochloa colona	0.030	12	0.050	13	0.080	18
Sacciolepis interrupta	0.020	8	0.040	10	0.060	13
Oryza sativa var. *fatua*	0.001	1	0.005	1	0.010	2
Monochoria vaginalis	0.010	4	0.015	4	0.030	7
Ludwigia parviflora	0.005	2	0.010	3	0.010	2

During *Kharif* season *I. miliacea* and *Cyperus* spp. were the most dominant weeds with a density of 149 and 139 weeds per square metre and a relative density of 45.7 and 42.5 per cent respectively. Other major weed species were *E. colona, S. interrupta.* Other weeds like *M. vaginalis, O. sativa* var. *fatua* and *L. parviflora* were of lesser importance.

The dominance and relative dominance of these major weeds at 30, 60 and 90 DAS are presented in Table 3 and depicted in Fig.5. Data showed that *Cyperus* spp. was the most dominant weed at 30 DAS and 60 DAS. Coverage of *I. miliacea* gradually increased and became the dominant weed towards 90 DAS. Relative dominance of *Cyperus* spp. decreased from 65 per cent on 30 DAS and reached 13 per cent by 90 DAS. Relative dominance of *E. colona* and *S. interrupta* were almost steady throughout the season.

4.1.1.2 *Rabi* season

Data on monthly dominance of various weed species worked out are presented in Table 4 and illustrated in Fig.5. The major weeds identified were *I. miliacea*, *Cyperus* spp. and *Marsilea quadrifolia*.

Table 4. Monthly dominance of weeds in rice during *Rabi* season

Weed species	30 DAT		60 DAT		90 DAT	
	Dominance	Relative dominance (%)	Dominance	Relative dominance (%)	Dominance	Relative dominance (%)
Isachne miliacea	0.050	67	0.100	71	0.250	91.0
Cyperus spp.	0.015	20	0.025	18	0.010	3.5
Marsilea quadrifolia	0.010	13	0.050	11	0.015	5.5

Data showed that *I. miliacea* was the major weed of rice throughout the *Rabi* season. The dominance of *I. miliacea* increased significantly towards the end of the cropping season. The relative dominance of *Cyperus* spp. was reduced from 20 per cent on 30 DAT to 3.5 per cent on 90 DAT.

4.1.2 Biology, phenology and ecology of *I. miliacea*.

4.1.2.1 Species or types

Two phenotypic variants of *I. miliacea* were obtained in the survey. The predominant variant had brown stem and the other had green stem (Plate 1). Both were identified to be *Isachne miliacea* Roth. ex. Roem. & Schult.

4.1.2.2 Life cycle, growth and seed production

Seeds of *I. miliacea* germinated in the rice fields of 'Onattukara' in April-May with the receipt of pre-monsoon showers. The emergence of the weed continued till the field became flooded by June. The population ranged from 150 to 350 plants in one square metre.

The weed *I. miliacea* was seen growing only in the wet fields. It is not seen in garden lands or even on bunds of the paddy fields. It grows along the ground and spread by rooting at nodes and forms a mat over the field. It grow upto 30 cm in height and to a maximum of 45 cm. It is a shallow rooted grass with perennial nature of growth. Growth pattern of the weed during *Kharif* season in a natural weed population recorded at rice fields of Rice Research Station is presented in Table 5. The growth rate was very slow during first 30 DAS and recorded faster growth from 31 DAS to 90 DAS.

Table 5. Weight of *I. miliacea* inside rice canopy and in open

	30 DAS		60DAS		90 DAS	
	Inside rice	Open	Inside rice	Open	Inside rice	Open
Fresh weight g m^{-2}	350	387	1060	1157	2360	2683
Dry weight g m^{-2}	30	35	132	142	300	330

The ratio of fresh weight to dry weight of major weeds noticed in the trial at the time of their flowering is given in the Table 6. The results indicated that the DMP of *I. miliacea* was low for every unit of fresh biomass, compared to other weed species. Dry matter content of mimicry weeds of rice viz. *E. colona, S. interrupta* and *O. sativa* var. *fatua* were similar to that of rice (22-24%).

The weed *I. miliacea* flowered by August in the open field and by September-October inside the crop canopy. First flower appeared on the main shoot after 21st leaf. Seeds matured in about 30 days. The weed reproduced both by seeds and by stem fragments. In the open fields it produced an average of 2700 panicles per square metre with an average of 53.6 seeds per panicle. Thus the weed produced 1,44,000 seeds per square metre. Inside rice canopy it produced 1500 panicles with 60 seeds per panicle producing 90,000 seeds per square metre.

Table 6. Ratio of fresh weight to dry weight of weeds

Species	Ratio
Isachne miliacea	10-12
Cyperus spp.	16-18
Echinochloa colona	22-24
Sacciolepis interrupta	20-22
Oryza sativa var. *fatua* (Wild rice)	22-24
Oryza sativa (rice)	22-24

In the Onattukara sandy region *I. miliacea* dried off with the onset of summer whereas in other area where water was available the weed thrive even the summer season. Life span studies using seeds and stem cuttings in pots with sandy soil also proved the drying up of the weed in January. Thus *I. miliacea* had a life span of nine months from seed to seed.

4.1.2.3 Effect of date of sowing on flowering of *I. miliacea*

4.1.2.3.1 Seeds

Number of days to flowering were recorded and are presented in Table 7.

All the plants flowered after 110 days when seeds were sown in March to June. Seeds sown after June reduced the duration of flowering and sowings after October dried off before flowering.

Table 7. Days to flowering of *I. miliacea* from seeds

Dates of seeding	Number of days to flowering
15-03-1992	111
01-04-1992	110
15-04-1992	110
01-05-1992	110
15-05-1992	109
01-06-1992	110
15-06-1992	105
01-07-1992	105
15-07-1992	105
01-08-1992	100
15-08-1992	100
01-09-1992	95
15-09-1992	95
01-10-1992	90
15-10-1992	90
01-11-1992	Plants dried off
15-11-1992	,,

4.1.2.3.2 Stem cuttings

All the plantings from December 15th dried off by January end, due to the intense heat of the summer. All the plants flowered on an average of 45 days irrespective of the date of planting.

4.1.2.4 Soil conditions

Studies on soil characters analysed at ten locations in Onattukara where *I. miliacea* grew showed that soil pH ranged from 4.8 to 6.1 and electrical conductivity from 0.10 to 0.33 millimhos cm^{-1}. Organic carbon of the soil ranged from 0.11 to 0.34 per cent. Available P_2O_5 was 31 kg ha^{-1} and K_2O ranged from 61 to 83 kg ha^{-1}. Soil nutrient values are low for N and K and medium for phosphorus (Appendix-III).

4.1.2.5 Pests and diseases

The insect pests that attack *I. miliacea* are grass hopper (*Oxya chinensis*) and green leaf hopper (*Nephotettix* sp.). No serious disease could be detected affecting the weed.

4.1.3 Propagation of *I. miliacea*

The weed *I. miliacea* is propagated by seeds germinating in April-May during kharif and is carried on to rabi crop of rice by stem cuttings during tillage.

4.1.3.1 Seeds

Viable seeds of *I. miliacea* were sown in pots @ 4 hills per pot and 5 seeds per hill at desired depth and water levels were maintained immediately after seeding. Observations on germination were recorded. None of the seeds germinate when submerged in water even at a depth of one centimetre. Only those seeds at field capacity germinated. Observations on germination of *I. miliacea* at field capacity moisture content at different depths of seeding are presented in Table 8.

Table 8. Germination of seeds of *I. miliacea* at different depths of seeding (number per pot)

Depths of seeding (cm)	Days of observation and Mean number of seeds germinated					
	6 DAS	8 DAS	10 DAS	14 DAS	30 DAS	60 DAS
0	12	18	20	..	..	..
2.5	14	20	20	..	..	..
5.0	6	12	20	..	..	..
7.5	..	..	8	10	..	..
10.0	..	..	..	..	..	..

Germination of seeds of *I. miliacea* started on 6 DAS onwards. On 6 DAS maximum germination of seeds occurred at zero and 2.5 cm depth and only 30 per cent seeds germinated from 5 cm. By 10 DAS germination was completed at zero, 2.5 and 5 cm depths. Forty per cent of seeds germinated at 7.5 cm depths on 10 DAS. It increased to 50 per cent by 14 DAS. None of the seeds germinated beyond 14 DAS from any depth. From 10 cm depth of seeding none of the seeds germinated.

4.1.3.2 Stem cuttings

Establishment of stem cuttings were evaluated at two weeks after planting and data are presented in Table 9.

Maximum establishment of stem cuttings per pot was at zero depth of planting at moisture levels of one and 2.5 cm standing water. As the depths of water increased the establishment decreased. Next highest establishment rate was at 2.5 cm depth of planting. Least establishment was at field capacity and none at 10 cm submergence. At five centimetre deep plantings the survival was 25 per cent from field capacity, and one to 2.5 cm submergence and none at five and 10 cm water depth. At deeper depths of planting of 7.5 and 10 cm none of the cuttings established irrespective of depths of submergence.

Table 9. Establishment of stem cuttings of *I. miliacea* on 14 DAT (number per plot)

Depths of planting (cm)	Moisture levels				
		Depths of submergence (cm)			
	Field capacity	1	2.5	5	10
0	1.3	4.0	4.0	2.0	1.0
2.5	1.0	2.3	1.6	1.3	--
5.0	1.0	1.0	1.0	--	--
7.5	0.5	--	--	--	--
10	--	--	--	--	--

Weed weights recorded at 90 DAT at different depths of planting are given in Table 10. Higher dry weight was at a submergence of one centimetre for zero and 2.5 cm deep plantings followed by 2.5 cm submergence. Lesser growth was noticed under field capacity from all depths of planting followed by 10 cm submergence. Planting deeper than five centimetre suppressed the weed growth at all moisture levels studied.

Table 10. Dry weight of *I. miliacea* at 90 DAT (g/pot)

Depths of planting (cm)	Moisture levels				
		Depths of submergence (cm)			
	Field capacity	1	2.5	5.0	10
0	6.2	25.0	19.0	17.7	8.3
2.5	3.0	22.0	16.9	4.5	--
5.0	2.2	2.6	2.4	--	--
7.5	--	--	--	--	--
10	--	--	--	--	--

4.1.4 Seed physiology

The innate dormancy of stored seeds and dormancy, germination and viability of buried seeds of *I. miliacea* were investigated.

4.1.4.1 Seeds stored in bottle

Mature seeds of *I. miliacea* were collected in November, 1991 from rice fields air dried and stored in bottles and tested for germination in Petri dishes at fortnightly intervals. Data on germination percentage recorded are given in Table 11.

Data showed that *I. miliacea* seeds were dormant from December to February. From March onwards dormancy was broken partially. By 15th April the dormancy was completely broken.

Table 11. Effect of date of sowing on seed germination of *I. miliacea*

Date of sowing	Germination (%)
15-12-1991	--
31-12-1991	--
15-01-1992	--
30-01-1992	--
15-02-1992	--
29-02-1992	2
15-03-1992	25
30-03-1992	35
15-04-1992	95
30-04-1992	95

4.1.4.2 Seeds buried in soil

Viability of *I. miliacea* seeds were tested at zero, five and 15 cm depths of burial in paddy fields enclosing seeds in terylene bags. The study was continued for two years from December 1991 to November 1993. Data on mean germination, dormancy and viability recorded at monthly intervals are presented in Table 12 and depicted in Fig.6.

4.1.4.2.1 Dormancy and germination

Seeds of *I. miliacea* showed a seasonal response in germination and onset and breakage of dormancy. Seeds on soil surface remained dormant from December to February. Dormancy was partially broken in March and fully by April and the entire seeds on soil surface germinated.

Table 12. Seed dormancy, germination and viability of *I. miliacea* at different depths of burial

	Burial depths (cm)	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov
						First year 1991-92							
	0	100	100	98	70	5							
Dormancy (%)	5	100	100	99	85	7	8	13	50	70	80	82	88
	15	100	100	97	83	54	48	50	60	65	80	85	90
	0	-	-	2	30	95							
Germination (%)	5	-	-	1	15	93	92	87	50	30	20	18	12
	15	-	-	3	17	46	52	50	40	35	20	15	10
	0	98	98	96	95	95							
Viability (%)	5	97	94	96	94	95	93	90	80	74	73	74	72
	15	99	96	96	94	94	93	85	84	81	82	81	82
						Second year 1992-93							
Dormancy (%)	5	95	100	100	100	75	78	80	85	95	96	98	96
	15	98	100	100	100	72	68	65	70	75	80	90	95
Germination (%)	5	5	-	-	-	25	22	20	15	5	4	2	4
	15	2	-	-	-	28	32	35	30	25	20	10	5
Viability (%)	5	70	65	65	63	60	62	60	60	58	60	58	55
	15	82	84	83	82	82	81	80	81	78	77	75	75

Even in April-May periods the dormancy of buried seeds increased with increasing depths of burial and also with time. At 5 cm depth it increased from 7-8 per cent in April-May in the first year to 75-78 per cent in the second year. At 15 cm depth it increased from 48-54 per cent in April-May in the first year to 68-72 per cent in the second year (Fig.6). Dormancy increased with water stagnation from July to November at both depths of burial.

Germination was almost reverse of dormancy. At five centimetre depth germination decreased from 92-93 per cent in April-May in the first year to 22-25 per cent in the second year. At 15 cm depth it decreased from 46-52 per cent in April-May in the first year to 28-32 per cent in the second year (Fig.6). Germination decreased with water stagnation from July to November at both depths of burial.

4.1.4.2.2 Viability

Maximum viability was exhibited in the first year from December to May 1991. It decreased with time. At 5 cm depth viability decreased from 93 per cent in May 1992 to 62 per cent in May 1993 and reached 55 per cent in November 1993. At 15 cm depth it was lost slowly from 94 to 81 per cent in May 1992 to 1993 and reached 75 per cent in November 1993.

4.1.5 Allelopathic effects

4.1.5.1 Effect of *I. miliacea* on rice

Water extracts of whole plant of *I. miliacea* were tested on the germination of some recommended rice varieties (Red Triveni, Sabari, Onam, Bhagya and Dhanya) of Onattukara. The percentage of germination of rice varieties in untreated plots ranged from 94-96 and that in treated plots it ranged from 94-95. The data showed no appreciable difference in germination of rice seeds due to the treatments.

4.1.5.2 Effect of common weeds on *I. miliacea*

Seeds of *I. miliacea* with 95 per cent germination was used for the trial. Aqueous extracts of the common associated weeds were tested with distilled water as control on the germination of *I. miliacea* seeds. Data on germination on the 6th day was recorded and presented in Table 13.

Table 13. Allelopathic effects of common rice field weeds on seed germination of *I. miliacea*

Weeds tested	Germination (%)
Cyperus spp	75
Echinochloa colona	90
Sacciolepis interrupta	90
Monochoria vaginalis	85
Oryza sativa var. *fatua*	80
Control (distilled water)	95

Maximum reduction in germination was with *Cyperus* spp. weed followed by *O. sativa* var. *fatua* and *M. vaginalis*.

4.2 Part II. Rice-weed competition

The results of crop-weed competition studies are presented below and the abstracts of analysis of variance tables are given in the Appendix-VI.

4.2.1 *Kharif*

4.2.1.1 Dry matter production (DMP) of weeds

Data on DMP and rate of DMP by weeds recorded at 30 DAS, 60 DAS and at harvest of crop are presented in Tables 14 and 15 and illustrated Fig.7. Data showed that the DMP and rate of DMP by weeds were significant on all stages and periods of observation.

Maximum dry matter and rate of DMP by weeds was observed in plot where all the naturally occurring weeds alone grew at all stages of observation. Next higher dry matter and rate of DMP was noticed in unweeded plot and by weeds other than *I. miliacea*, during 30 DAS and 60 DAS. But during 61 DAS to harvest time the plots mentioned above recorded lesser dry matter accumulation than that in *I. miliacea* grew at the rate of 80 plants per square metre with rice or a natural population of *I. miliacea* without rice. Dry matter production or rate of DMP of *I. miliacea* showed that it was very low upto 30 DAS and maximum accumulation occurred during 61 DAS to harvest of crop. Dry matter production and rate of DMP of *I. miliacea* at five and 20 plants per square metre were on par during all stages of observation.

4.2.1.2 Dry matter production of rice

Data on DMP and rate of DMP of rice at 30 DAS, 60 DAS and at harvest are presented in Tables 16 and 17 and depicted in Fig.7. On 30 DAS the influence of weeds on DMP of rice crop was not that prominent. Maximum DMP and rate of DMP by crop was in weed free plot on all stages of observation. The least DMP was observed in unweeded plot.

Table 14. Influence of crop-weed densities on DMP of weeds (kg ha^{-1}) during *Kharif* season

	30 DAS			60 DAS			At harvest		
	1992	1993	Pooled	1992	1993	Pooled	1992	1993	Pooled
1. I. miliacea 5 plants/m^2	108	110	109.0	753	813	783.0	2200	2300	2250.0
2. I. miliacea 20 plants/m^2	133	130	131.5	855	880	867.5	2488	2175	2331.5
3. I. miliacea 80 plants/m^2	140	148	144.0	1190	1215	1202.5	3388	3100	3244.0
4. Weed free	15	15	15.0	40	28	34.0	175	148	161.5
5. Unweeded	345	378	361.5	2468	2750	2609.0	4190	4075	4132.5
6. Weeds other than I. miliacea	370	403	386.5	2155	2458	2306.5	3525	3250	3387.5
7. No rice, I. miliacea alone	133	118	125.5	1550	1590	1570.0	4045	3825	3935.0
8. No rice, all weeds	475	505	490.0	4080	3413	3412.5	6675	6325	6500.0
SE±	16.7	20.4	12.68	86.8	98.6	149.18	184.6	147.4	133.36
CD (0.05)	49.1	60.0	36.04	255.3	290.0	498.87	543.0	433.69	322.19

DMP - Dry matter production
DAS - Days after sowing

Table 15. Influence of crop-weed densities on rate of DMP of weeds (kg ha^{-1} day^{-1}) during the *Kharif* season

Treatments	1 to 30 DAS			31 to 60 DAS			61 DAS to Harvest (40 days)		
	1992	1993	Pooled	1992	1993	Pooled	1992	1993	Pooled
1. *I. miliacea* 5 plants/m²	3.58	3.67	3.63	21.50	23.42	22.46	36.19	37.19	36.69
2. *I. miliacea* 20 plants/m²	4.42	4.33	4.37	24.08	25.00	24.54	40.81	32.38	36.09
3. *I. miliacea* 80 plant/m²	4.67	4.92	4.79	35.00	35.58	35.29	61.19	47.13	54.16
4. Weed free	0.50	0.50	0.50	0.83	0.42	0.62	3.50	3.00	3.25
5. Unweeded	11.50	12.58	12.04	70.75	79.08	74.92	43.06	39.38	41.22
6. Weeds other than *I. miliacea*	12.34	13.42	12.88	59.50	68.42	63.96	34.25	19.81	27.03
7. No rice, *I. miliacea* alone	4.42	3.92	4.17	50.58	52.42	51.50	52.38	45.88	49.13
8. No rice, all weeds	15.83	16.84	16.33	119.49	96.92	108.20	64.88	72.81	68.84
SE±	0.56	0.68	0.42	2.75	3.34	4.80	5.28	5.71	3.88
CD(0.05)	1.64	2.00	1.20	8.08	9.81	16.32	15.54	16.80	11.03

Table 16. DMP of rice (kg ha^{-1}) as influenced by weed densities during *Kharif* season

Treatments	30 DAS			60 DAS			At harvest		
	1992	1993	Pooled	1992	1993	Pooled	1992	1993	Pooled
1. *I. miliacea* 5 plants/m²	410	386	398	1805	2585	2195	3823	4788	4305
2. *I. miliacea* 20 plants/m²	410	381	396	1680	1753	1716	3663	3738	3700
3. *I. miliacea* 80 plants/m²	390	376	383	1285	1370	1328	2760	2435	2598
4. Weed free	488	404	446	3075	3540	3263	6970	6875	6923
5. Unweeded	388	394	391	905	836	871	1788	1828	1808
6. Weeds other than *I. miliacea*	396	380	388	1085	933	1009	2420	2113	2266
SE±	21.3	9.3	+	150.6	114.1	171.9	326.3	145.0	+
CD(0.05)	64.2	NS		453.9	343.7	624.9	983.3	436.9	

\+ Pooled analysis could not be attempted due to heterogeneity of error mean squares and absence of interaction effect

NS - Non significant

Table 17. Influence of weed densities on rate of DMP of rice (kg ha^{-1} day^{-1}) during *Kharif* season

Treatments	1 to 30 DAS			31 to 60 DAS			61 DAS to Harvest (40 days)		
	1992	1993	Pooled	1992	1993	Pooled	1992	1993	Pooled
1. *I. miliacea* 5 plants/m²	13.42	12.88	13.15	46.50	73.29	59.90	50.44	55.06	52.75
2. *I. miliacea* 20 plants/m²	13.42	12.71	13.06	42.33	45.71	44.02	49.56	49.63	49.59
3. *I. miliacea* 80 plants/m²	13.00	12.54	12.77	29.83	33.13	31.48	36.88	26.63	31.75
4. Weed free	15.75	13.46	14.60	86.33	101.54	93.93	97.38	85.63	91.50
5. Unweeded	12.92	13.12	13.02	17.25	14.75	16.00	22.06	24.78	23.42
6. Weeds other than *I. miliacea*	13.21	12.67	12.94	22.96	18.42	20.69	33.38	29.50	31.44
SE±	0.55	0.31	+	5.18	3.89	5.96	6.00	1.53	1.70
CD(0.05)	1.67	NS		15.61	15.61	11.73	21.65	18.08	4.60

\+ Pooled analysis could not be attempted due to heterogeneity of error mean squares and absence of interaction effect

NS - Non significant

Influence of *I. miliacea* on DMP and rate of DMP of crop on 60 DAS and at harvest were as follows. Lower densities of *I. miliacea* viz. 5 and 20 plants per square metre recorded next higher dry matter to weed free plot and showed no difference in DMP between them. *Isachne miliacea* at 80 plants per square metre significantly suppressed DMP and rate of DMP of crop and was similar to the influence of weeds other than *I. miliacea*. The percentage reduction in DMP of rice were 38, 47 and 63 at five, 20 and 80 plants per square metre of *I. miliacea* respectively. Whereas in unweeded plot the reduction was 74 per cent.

4.2.1.3 Uptake of nutrients

Data on uptake of NPK by crop and weed recorded at harvest of crop are presented in Tables 18 and 19 and depicted in Fig.8. The nutrient contents are given Appendix-IVa. The nutrient content (NPK) of *I. miliacea* was found to be higher than that of rice crop.

4.2.1.3.1 Weeds

The uptake of nutrients (NPK) by weeds at harvest of crop was significantly influenced by crop weed densities in both years (Table 18). Maximum uptake of NPK was shown in studies where weeds grew without rice, which was superior to all other treatments. Next higher uptake was observed in the plot where weeds other than *I. miliacea* grew without rice; closely followed by weeds in unweeded plot. Increasing densities of *I. miliacea* showed increasing uptake of nutrients. Uptake of nutrients by *I. miliacea* at densities of five and 20 plants per square metre were on par and that at 80 plants per square metre was on par with the uptake of unweeded plot. The NPK uptake by *I. miliacea* increased on an average

Table 18. Uptake of nutrients (kg ha^{-1}) by weeds at harvest of crop as influenced by crop-weed densities during *Kharif* season

Treatments	N			P_2O_5			K_2O		
	1992	1993	Pooled	1992	1993	Pooled	1992	1993	Pooled
1. *I. miliacea* 5 plants/m²	27.38	29.05	28.21	11.56	12.31	11.93	37.25	38.81	38.03
2. *I. miliacea* 20 plants/m²	31.37	28.04	29.70	14.29	13.30	13.79	41.87	36.52	39.19
3. *I. miliacea* 80 plants/m²	41.71	38.81	40.26	17.32	16.23	16.77	56.75	52.11	54.43
4. Weed free	2.28	1.93	2.11	0.91	0.76	0.83	2.70	2.25	2.47
5. Unweeded	42.21	39.91	41.06	21.10	21.28	21.19	62.94	62.06	62.50
6. Weeds other than *I. miliacea*	37.88	35.11	36.49	18.15	17.49	17.82	54.25	50.16	52.20
7. No rice, *I. miliacea* alone	51.36	49.30	50.33	21.74	22.45	22.10	70.67	65.57	68.12
8. No rice, all weeds	69.69	67.24	68.46	35.65	33.71	34.68	106.97	100.06	103.52
SE±	2.20	2.00	1.41	1.19	1.19	0.80	3.04	2.42	1.88
CD(0.05)	6.48	5.87	4.01	3.51	3.50	2.27	8.94	7.13	5.35

Table 19. Uptake of nutrients (kg ha^{-1}) by rice at harvest as influenced by weed densities during *Kharif* season

Treatments	N			P_2O_5			K_2O		
	1992	1993	Pooled	1992	1993	Pooled	1992	1993	Pooled
1. *I. miliacea* 5 plants/m²	35.16	43.65	39.40	19.02	21.68	20.35	39.58	50.94	45.26
2. *I. miliacea* 20 plants/m²	33.68	33.82	33.75	18.73	17.59	18.16	36.91	38.63	37.77
3. *I. miliacea* 80 plants/m²	24.53	23.85	24.19	13.34	11.96	12.65	27.70	28.53	28.11
4. Weed free	66.31	65.88	66.10	33.83	32.56	33.19	78.83	77.01	77.92
5. Unweeded	16.76	16.07	16.41	8.47	8.23	8.35	20.53	19.59	20.06
6. Weeds other than *I. miliacea*	21.18	18.33	19.76	11.23	9.18	10.21	25.99	22.34	24.17
SE±	2.84	1.34	+	1.54	0.74	+	3.26	1.23	+
CD(0.05)	8.56	3.42		4.63	2.23		9.83	3.71	

+ Pooled analysis could not be done due to heterogeneity of error mean squares and absence of interaction effect

from 34 to 56 per cent with increasing densities from five to 80 plants per square metre. A pure stand of *I. miliacea* producing 3.9 tonnes of dry matter removed 50 kg N, 22 kg P_2O_5 and 68 kg K_2O per hectare.

4.2.1.3.2 Rice

Uptake of NPK by crop was significantly influenced by weed densities (Table 19). Maximum uptake of NPK was observed in weed free plot and lowest in unweeded plot. Influence of different densities of *I. miliacea* on uptake of NPK by crop showed that the uptake decreased with increasing densities. The least uptake of NPK was found where *I. miliacea* grew at 80 plants per square metre and was almost on par with that of unweeded plot. The NPK uptake by rice decreased from 66 to 44 per cent with increasing densities of *I. miliacea* from five to 80 plants per square metre. A pure stand of rice producing 6.9 tonnes of dry matter removed 66 kg N, 34 kg P_2O_5 and 78 kg K_2O per hectare.

4.2.1.4 Effect of weed densities on growth and yield attributes of rice

Data on growth and yield attributes of rice are presented in Tables 20 to 23.

4.2.1.4.1 Height of plants

Height of rice plants and weeds recorded at harvest of rice as influenced by crop weed densities are presented in Table 20. Height of rice plants at harvest was significantly influenced by crop-weed densities. Maximum plant height was recorded in plot where all weeds except *I. miliacea* grew and was on par with the unweeded plot. Different densities of *I. miliacea*, viz., five, 20 and 80 plants per

Table 20. Height of rice and weeds (cm) at harvest of rice as influenced by crop-weed densities during *Kharif* season

Treatments	Rice			Weeds		
	1992	1993	Pooled	1992	1993	Mean
1. *I. miliacea* 5 plants/m²	80.50	75.50	78.00	26.25	24.25	25.25
2. *I. miliacea* 20 plants/m²	76.75	75.75	76.25	24.50	27.50	26.00
3. *I. miliacea* 80 plants/m²	77.50	78.25	77.88	27.50	28.50	28.00
4. Weed free	74.75	72.25	73.50	6.50	5.50	6.00
5. Unweeded	80.75	76.75	78.75	109.00	105.25	107.13
6. Weeds other than *I. miliacea*	80.75	79.25	80.00	102.50	108.75	105.63
7. No rice, *I. miliacea* alone				28.50	27.50	28.00
8. No rice, all weeds				108.75	111.50	110.13
SE±	1.32	1.28	0.94	2.21	2.08	1.53
CD(0.05)	3.95	3.86	2.69	6.49	6.11	4.35

square metre did not show any difference in plant height. And the lowest plant height was observed in weed free check. Height of weeds other than *I. miliacea* ranged between 105 to 110 cm whereas height of *I. miliacea* was only 26-28 cm.

4.2.1.4.2 Tiller production

Number of total tillers per square metre of rice on 60 DAS was significant only in 1993 (Table 21). Weed free plot recorded maximum tillers and was superior to all other treatments. Increasing densities of *I. miliacea* progressively reduced the number of tillers, but the influence was not significant. Least number of tillers was observed in unweeded plot which was as in the plot where weeds other than *I. miliacea* grew.

4.2.1.4.3 Leaf Area Index

Different weed densities significantly influenced Leaf Area Index of rice on 60 DAS (Table 21). Maximum LAI was in weed free plot and was superior to all other treatments. Unweeded plot recorded the least LAI which was on par with the maximum density of 80 *I. miliacea* plants per square metre. Influence of lower densities of *I. miliacea* were on par and recorded the next higher LAI of rice to weed free plot.

4.2.1.4.4 Number of panicles

Number of panicles per square metre was significantly affected by the weed densities (Table 21). Maximum number of panicles per square metre was in weed free plot and least number in unweeded plot; which was on par with the plot, where weeds except *I. miliacea* grew. *Isachne miliacea* at 80 plants per square metre

Table 21. Effect of weed densities on number of tillers and LAI of rice on 60 DAS and number of panicles during *Kharif* season

Treatments	No.of tillers/m²			Leaf Area Index			No.of panicles/m²		
	1992	1993	Pooled	1992	1993	Pooled	1992	1993	Pooled
1. *I. miliacea* 5 plants/m²	339	321	330.0	3.15	3.23	3.19	294.3	279.5	286.9
2. *I. miliacea* 20 plants/m²	328	319	323.5	3.04	3.09	3.06	284.5	269.0	276.8
3. *I. miliacea* 80 plants/m²	323	302	312.5	2.96	2.98	2.97	272.5	232.8	252.6
4. Weed free	356	342	349.0	3.45	3.39	3.42	317.0	309.0	313.0
5. Unweeded	313	284	298.5	2.90	2.78	2.84	240.0	207.5	223.8
6. Weeds other than *I. miliacea*	314	293	303.5	2.97	2.80	2.88	235.5	207.5	221.5
SE±	14.43	6.66	+	0.04	0.04	0.05	18.55	9.22	+
CD(0.05)	NS	20.07		0.13	0.12	0.18	55.90	27.77	

+ Pooled analysis could not be done due to heterogeneity of error mean squares and absence of interaction effect

NS - Non significant

produced the least number of panicle per square metre among the three densities studied and the influence of lower densities were not significantly different.

4.2.1.4.5 Length of panicle

Maximum panicle length was observed in weed free plot and was similar with that of lower densities of *I. miliacea* (Table 22). Lower panicle length was recorded in unweeded plot which was on par with treatments where weeds other than *I. miliacea* grew and with the lowest panicle length recorded at the maximum density of *I. miliacea*.

4.2.1.4.6 Number of spikelets and grains per panicle

Both number of spikelets and grains per panicle were significantly influenced by weed densities (Table 22). Weed free plot recorded maximum number of grains and spikelets per panicle and showed no difference with *I. miliacea* grown at five plants per square metre. Higher densities of *I. miliacea* reduced number of spikelets and grains per panicle and were on par with the plot where weeds other than *I. miliacea* grew. Lowest spikelets and grains per panicle were recorded in unweeded plot.

4.2.1.4.7 Grain weight

The weed densities affected the 1000 grain weight significantly as shown in the Table 23. The 1000 grain weight was highest in weed free plot and was similar to that at lower densities of *I. miliacea*. Lower weights were observed in unweeded plot and in plot where weeds except *I. miliacea* grew and were similar to that of the highest density of *I. miliacea* tested.

Table 22. Effect of weed densities on length of panicle, number of spikelets and grains/panicle during *Kharif* season

Treatments	Length of panicle (cm)			Number of spikelets/ panicle			No. of grains/ panicle		
	1992	1993	Pooled	1992	1993	Pooled	1992	1993	Pooled
1. *I. miliacea* 5 plants/m²	17.28	17.50	17.39	73.0	79.0	76.0	55.3	59.3	57.3
2. *I. miliacea* 20 plants/m²	16.83	16.55	16.69	66.5	71.0	68.8	47.5	53.5	50.5
3. *I. miliacea* 80 plants/m²	16.78	15.90	16.34	66.3	69.3	67.8	46.8	51.3	49.0
4. Weed free	18.83	18.48	18.63	83.3	80.3	81.8	62.8	60.0	61.4
5. Unweeded	16.65	16.28	16.46	59.3	61.3	60.3	43.3	45.0	44.1
6. Weeds other than *I. miliacea*	16.83	16.43	16.63	66.8	66.8	66.8	49.0	50.0	49.5
SE±	0.45	0.27	0.25	3.86	3.62	2.52	3.04	2.91	2.04
CD(0.05)	1.34	0.80	0.72	11.62	10.89	7.28	9.16	8.77	5.88

Table 23. Effect of weed densities on 1000 grain weight, grain and straw yield during *Kharif* season

Treatments	1000 grain weight (g)			Grain yield (kg ha^{-1})			Straw yield (kg ha^{-1})		
	1992	1993	Pooled	1992	1993	Pooled	1992	1993	Pooled
1. *I. miliacea* 5 plants/m²	22.60	22.17	22.39	1810	2238	2024	2013	2550	2281
2. *I. miliacea* 20 plants/m²	22.43	21.87	22.15	1750	1763	1756	1913	1975	1944
3. *I. miliacea* 80 plants/m²	22.05	21.60	21.83	1298	1160	1229	1463	1525	1494
4. Weed free	22.40	22.33	22.36	3170	3150	3160	3800	3725	3763
5. Unweeded	21.83	21.53	21.68	800	820	810	1113	1008	1060
6: Weeds other than *I. miliacea*	21.73	21.50	21.61	1020	900	960	1400	1213	1306
SE±	0.13	0.18	0.11	151.3	81.5	+	168.2	91.2	+
CD(0.05)	0.40	0.55	0.32	455.9	245.6		506.9	274.7	

+ Pooled analysis could not be done due to heterogeneity of error mean squares and absence of interaction effect

4.2.1.5 Grain and straw yield

Both grain and straw yields were significantly influenced by weed densities (Table 23). Maximum grain yield was found in weed free plot. Lowest yield was in unweeded plot and was on par with the plot where weeds other than *I. miliacea* grew. The lower densities of *I. miliacea* were on par during 1992. Significant difference on grain yield was noticed due to varying densities of *I. miliacea* during 1993, the yield decreased with increasing densities.

Straw yield of rice also followed a similar trend as that of grain yield. Maximum straw yield was in weed free plot and lowest in unweeded plot. *I. miliacea* decreased straw yields with increasing densities.

4.2.2 *Rabi*

4.2.2.1 Dry matter production of weeds

Data on dry matter and rate of DMP of weeds on 30 DAT, 60 DAT and at harvest of crop are furnished in Tables 24 and 25 and illustrated in Fig.7. Dry matter and rate of DMP of weeds were significantly influenced by weed densities on all stages during both the years. Maximum dry matter and rate of DMP was recorded by all naturally occurring weeds grown without rice followed by *I. miliacea* grown alone without rice. Lowest dry matter was recorded in plot where weeds except *I. miliacea* grew on all stages during both the years.

Table 24. Influence of crop-weed densities on DMP of weeds (kg ha^{-1}) during *Rabi* season

Treatments	30 DAT			60 DAT			At harvest		
	1992	1993	Pooled	1992	1993	Pooled	1992	1993	Pooled
1. *I. miliacea* 5 plants/m²	99	111	105.0	430	448	439.0	1010	983	996.5
2. *I. miliacea* 20 plants/m²	188	209	198.5	566	596	582.0	1163	1275	1219.0
3. *I. miliacea* 80 plants/m²	275	303	289.0	714	745	729.5	1543	1600	1571.5
4. Weed free	12	14	13.0	35	41	38.0	90	90	90.0
5. Unweeded	465	495	480.0	1033	1100	1066.5	1613	1950	1781.5
6. Weeds other than *I. miliacea*	104	118	111.0	170	188	179.0	425	428	426.5
7. No rice, *I. miliacea* alone	505	540	522.5	2054	2110	2082.0	3330	3638	3484.0
8. No rice, all weeds	613	663	638.5	2100	2163	2131.5	4113	4190	4151.5
SE±	16.79	9.21	+	39.70	41.44	26.92	46.30	101.76	+
CD(0.05)	49.37	27.10		116.77	121.88	76.51	136.18	299.28	

\+ Pooled analysis could not be done due to heterogeneity of error mean squares and absence of interaction effect

Table 25. Influence of crop-weed densities on rate of DMP of weeds (kg ha^{-1} day^{-1}) during *Rabi* season

Treatments	1 to 30 DAT			31 to 60 DAT			61 DAT to Harvest (40 days)		
	1992	1993	Pooled	1992	1993	Pooled	1992	1993	Pooled
1. *I. miliacea* 5 plants/m²	3.29	3.71	3.50	11.05	11.21	11.13	12.89	11.87	12.39
2. *I. miliacea* 20 plants/m²	6.25	6.96	6.60	12.63	12.92	12.77	13.25	15.08	14.16
3. *I. miliacea* 80 plants/m²	9.17	10.08	9.62	14.63	14.75	14.69	18.42	19.00	18.71
4. Weed free	0.41	0.48	0.44	0.76	0.90	0.83	1.28	1.08	1.18
5. Unweeded	15.50	16.50	16.00	18.92	20.16	19.54	18.44	18.89	18.67
6. Weeds other than *I. miliacea*	3.46	3.02	3.24	2.21	2.33	2.27	5.67	5.33	5.50
7. No rice, *I. miliacea* alone	16.83	18.00	17.42	51.63	52.33	51.98	28.36	33.95	31.15
8. No rice all weeds	20.42	22.08	21.25	49.58	50.00	49.79	44.72	45.05	44.89
SE±	0.56	0.39	0.34	1.26	1.28	0.84	1.59	1.63	1.12
CD(0.05)	1.65	1.13	0.96	3.71	3.78	2.38	4.68	4.79	3.19

The DMP and rate of DMP by *I. miliacea* grown at densities of five, 20 and 80 plants per square metre with rice crop increased significantly with increasing densities upto 30 DAT. But during 31 to 60 DAT and 61 to 100 DAT the rate DMP at lower densities were on par. Rate of DMP during 61 DAT to harvest was reduced in plots where weeds other than *I. miliacea* grew.

4.2.2.2 Dry matter production of rice

Data on DMP and rate of DMP of rice at 30 DAT, 60 DAT and at harvest of crop are presented in Tables 26 and 27 and depicted Fig.7. Crop DMP and rate of DMP during both the years on all stages were significantly influenced by weed densities. Maximum DMP and rate of DMP by crop was observed in weed free plot. The lowest DMP and rate of DMP was in unweeded plot. Dry matter production and rate of DMP of rice at different densities of *I. miliacea* were found to be reduced with increasing densities. The DMP of crop at higher densities of *I. miliacea* were similar. The percentage reduction in DMP of rice were 30, 51 and 53 at five, 20 and 80 plants per square metre of *I. miliacea* respectively. Whereas in unweeded plot the reduction was 55 per cent.

4.2.2.3 Nutrient uptake

Data on uptake of nutrients (NPK) of both rice and weeds were determined at the time of harvest of crop and are presented in Tables 28, 29 and illustrated in Fig.8. The nutrient contents are given in Appendix-IVb. Nutrient content of weed *I. miliacea* was found to be higher than that of rice crop.

4.2.2.3.1 Weeds

Data on uptake of nutrients (NPK) by weeds during 1992 and 1993 were

Table 26. DMP of rice (kg ha^{-1}) as influenced by weed densities during *Rabi* season

Treatments	30 DAT			60 DAT			At harvest		
	1992	1993	Pooled	1992	1993	Pooled	1992	1993	Pooled
1. *I. miliacea* 5 plants/m²	699	748	723	2038	2180	2109	4238	4113	4175
2. *I. miliacea* 20 plants/m²	685	710	698	1363	1533	1448	2913	2963	2938
3. *I. miliacea* 80 plants/m²	650	670	660	1260	1418	1339	2850	2825	2838
4. Weed free	786	825	806	2790	3043	2916	5963	5975	5969
5. Unweeded	588	603	595	925	1033	979	2688	2675	2681
6. Weeds other than *I. miliacea*	670	723	699	2105	2288	2196	4588	4238	4413
SE±	12.27	17.08	10.24	63.84	68.80	44.41	154.42	123.79	95.73
CD(0.05)	36.90	51.50	29.40	192.40	207.30	127.50	465.30	373.00	274.77

Table 27. Influence of weed densities on rate of DMP of rice (kg ha^{-1} day^{-1}) during *Rabi* season

Treatments	1 to 30 DAT			31 to 60 DAT			61 DAT to Harvest (40 days)		
	1992	1993	Pooled	1992	1993	Pooled	1992	1993	Pooled
1. *I. miliacea* 5 plants/m²	12.46	13.59	13.03	44.63	47.75	46.19	48.89	42.94	45.91
2. *I. miliacea* 20 plants/m²	12.46	12.91	12.68	22.58	27.42	25.00	34.50	31.78	33.14
3. *I. miliacea* 80 plants/m²	11.88	12.18	12.00	20.33	24.92	22.63	35.33	31.28	33.31
4. Weed free	14.30	15.00	14.65	66.79	74.25	70.52	70.39	65.17	67.78
5. Unweeded	10.69	10.75	10.82	11.25	14.33	12.79	39.17	36.50	37.83
6. Weeds other than *I. miliacea*	12.19	13.23	12.71	47.84	52.00	49.92	55.17	34.33	49.25
SE±	0.23	0.31	0.19	1.98	2.02	1.35	3.31	1.58	+
CD(0.05)	0.86	0.93	0.55	5.98	6.08	3.86	9.99	4.75	

\+ Pooled analysis could not done due to heterogeneity of error mean squares and absence of interaction effect significant. Maximum uptake was found in plots where weeds alone grew with all natural weeds. Uptake by *I. miliacea* grown alone ranked next followed by weeds in unweeded plot. Uptake of nutrients by weeds inside the crop canopy were comparatively lower than that grew without rice. NPK uptake by varying densities of *I. miliacea* increased with increasing densities. Uptakes at lower densities of *I. miliacea* were similar while the uptake at 80 plants per square metre was on par with the uptake in unweeded plot where all weed species grew. The nutrient uptake by *I. miliacea* on an average increased from 20 to 36 per cent with increasing densities. A pure stand of *I. miliacea* producing 3.5 tonnes of dry matter removed 39 kg N, 19 kg P_2O_5 and 57 kg K_20 per hectare (Table 28 and Fig.8).

4.2.2.3.2 Rice

Uptake of nutrients (NPK) by rice was significantly influenced by weed densities. Maximum NPK uptake was observed in weed free plot. Least uptake was recorded in unweeded plot. Significantly higher NPK uptake by crop was noticed at five *I. miliacea* per square metre. The influence of *I. miliacea* densities of 20 and 80 plants per square metre were similar with regard to NPK uptake by crop and was on par with that in unweeded plot. The uptake of NPK by rice was reduced from 80 to 64 per cent with increasing densities of *I. miliacea* from five to 80 plants per square metre. A pure stand of rice producing six tonnes of dry matter removed 49 kg N, 23 kg P_2O_5 and 57 kg K_2O per hectare (Table 29 and Fig.8).

4.2.2.4 Effect of weed densities on growth and yield attributes of rice

Data on growth and yield attributes of rice are presented in Tables 30 to 33.

Table 28. Uptake of nutrients (kg ha^{-1}) by weeds at harvest of crop as influenced by crop-weed densities during *Rabi* season

Treatments	N			P_2O_5			K_2O		
	1992	1993	Pooled	1992	1993	Pooled	1992	1993	Pooled
1. *I. miliacea* 5 plants/m^2	10.98	10.69	10.83	5.66	5.12	5.39	16.47	15.88	16.17
2. *I. miliacea* 20 plants/m^2	12.49	13.75	13.12	6.54	6.43	6.49	19.07	20.77	19.92
3. *I. miliacea* 80 plants/m^2	16.23	17.34	16.78	8.73	7.98	8.36	25.31	25.45	25.38
4. Weed free	1.03	1.04	1.03	0.52	0.47	0.49	1.27	1.41	1.34
5. Unweeded	13.77	16.53	15.15	9.00	10.49	9.75	24.52	28.93	26.73
6. Weed other than *I. miliacea*	3.58	3.62	3.60	2.35	2.38	2.36	6.18	6.16	6.17
7. No rice *I. miliacea* alone	38.44	40.07	39.25	18.81	19.82	19.31	54.80	59.24	57.02
8. No rice all weeds	35.99	35.22	35.61	22.54	22.78	22.66	61.28	57.95	59.61
SE±	0.73	1.62	+	0.43	0.67	+	0.85	1.88	+
CD(0.05)	2.14	4.76		1.26	1.98		2.51	5.52	

+ Pooled analysis could not be done due to heterogeneity of error mean squares and absence of interaction effect

Table 29. Uptake of nutrients (kg ha^{-1}) by rice at harvest as influenced by weed densities during *Rabi* season

Treatments	N			P_2O_5			K_2O		
	1992	1993	Pooled	1992	1993	Pooled	1992	1993	Pooled
1. *I. miliacea* 5 plants/m²	32.60	30.87	31.73	16.22	14.13	15.18	48.56	45.06	46.81
2. *I. miliacea* 20 plants/m²	22.27	23.53	22.90	11.55	11.54	11.54	32.53	30.52	31.52
3. *I. miliacea* 80 plants/m²	21.37	21.69	21.53	10.92	9.96	10.44	31.62	30.72	31.17
4. Weed free	49.03	49.24	49.13	22.99.	22.94	22.96	52.71	61.70	57.20
5. Unweeded	20.74	19.37	20.06	9.61	8.88	9.25	31.17	30.84	31.00
6. Weeds other than *I. miliacea*	35.51	33.19	34.35	16.60	15.02	15.81	55.05	45.51	50.28
SE±	1.34	0.95	0.80	0.65	0.60	0.44	5.46	1.59	+
CD(0.05)	4.02	2.85	2.30	1.94	1.82	1.26	16.44	4.79	

+ Pooled analysis could not be done due to heterogeneity of error mean squares and absence of interaction effect

4.2.2.4.1 Height of plants

Plant height of rice and weeds at harvest time of crop are furnished in Table 30. Data show that plant height of crop and weeds were influenced by weed densities. Maximum height of rice was found in unweeded plot and in plot where weeds other than *I. miliacea* grew. Weed free plot recorded lowest plant height of rice and was not significantly different from the rice plants that grew with different densities of *I. miliacea*. Height of weeds were maximum in plots where weeds other than *I. miliacea* grew either with or without rice and ranged from 71-74 cm. Height of *I. miliacea* in all densities were on par and ranged from 25-27 cm.

4.2.2.4.2 Tiller production

Maximum tiller production of rice on 60 DAT was observed in weed free plot and that was similar to the influence of lower densities of *I. miliacea* (Table 31). The unweeded plot and the plot with the highest density of *I. miliacea* showed lesser tiller production.

4.2.2.4.3 Leaf Area Index (LAI)

Leaf Area Index of rice on 60 DAT was highest in weed free plot and was similar to that with the lowest density of *I. miliacea* (Table 31). Unweeded plot as well as the highest density of *I. miliacea* showed significantly lower LAI.

4.2.2.4.4 Number of panicles

Number of panicles, was significantly influenced by weed densities (Table 31). Maximum number of panicles was observed in weed free plot and the

Table 30. Height of rice and weeds (cm) at harvest of rice as influenced by crop-weed densities during *Rabi* season

Treatments	Rice			Weeds		
	1992	1993	Pooled	1992	1993	Pooled
1. *I. miliacea* 5 plants/m²	65.00	68.25	66.63	26.25	25.00	25.13
2. *I. miliacea* 20 plants/m²	65.50	67.50	66.50	26.00	25.75	25.88
3. *I. miliacea* 80 plants/m²	68.25	67.00	67.63	29.00	26.00	27.50
4. Weed free	66.25	67.25	66.75	5.75	5.00	5.38
5. Unweeded	68.75	71.50	70.13	73.00	68.75	70.88
6. Weeds other than *I. miliacea*	71.50	70.25	70.88	75.50	71.50	73.50
7. No rice, *I. miliacea* alone				26.75	24.75	25.75
8. No rice, all weeds				26.25	73.50	74.88
SE±	1.28	0.58	+	1.66	1.47	1.07
CD(0.05)	3.88	1.76		4.89	4.33	3.05

+ Pooled analysis could not be done due to heterogeneity of error mean squares and absence of interaction effect

Table 31. Effect of weed densities on number of tillers and LAI of rice on 60 DAT and number of panicles during *Rabi* season

Treatments	Number of tillers/m²			Leaf Area Index			No. of panicles/m²		
	1992	1993	Pooled	1992	1993	Pooled	1992	1993	Pooled
1. *I. miliacea* 5 plants/m²	263	320	291.5	3.522	3.448	3.490	220.5	272.5	246.5
2. *I. miliacea* 20 plants/m²	232	314	273.0	3.455	3.433	3.440	170.0	247.5	208.8
3. *I. miliacea* 80 plants/m²	227	258	242.5	3.388	3.373	3.380	149.0	190.0	169.5
4. Weed free	296	336	316.0	3.623	3.530	3.577	234.3	280.0	257.1
5. Unweeded	229	263	246.0	3.250	3.312	3.281	160.5	127.5	144.0
6. Weeds other than *I. miliacea*	246	248	247.0	3.265	3.275	3.265	190.0	155.0	172.5
SE±	9.82	9.33	13.36	0.03	0.02	+	11.94	5.60	5.50
CD(0.05)	29.58	28.12	38.58	0.10	0.06		35.98	16.86	11.79

+ Pooled analysis could not be done due to heterogeneity of error mean squares and abscence of interaction effect lowest in unweeded plot. In the study *I. miliacea* significantly decreased the number of panicles per square metre with increasing densities.

4.2.2.4.5 Length of panicle

Length of panicle was also significantly influenced by weed densities (Table 32). Maximum length of panicle was found in weed free plot and the lowest in unweeded plot. Panicle length decreased with increasing densities of *I. miliacea*.

4.2.2.4.6 Number of spikelets and grains per panicle

Number of spikelets and grains per panicle was influenced by crop weed densities (Table 32). Maximum number of spikelets and grains per panicle was found in weed free plot and the least was in unweeded plot. Number of grains per panicle in weed free plot was on par with lowest *I. miliacea* density of five plants per square metre. Higher densities of *I. miliacea* were on par with regard to spikelets and grains per panicle.

4.2.2.4.7 Grain weight

The 1000 grain weight was not influenced by weed densities (Table 33).

4.2.2.5 Grain and straw yields

Both grain and straw yields were significantly influenced by crop-weed densities (Table 33). Maximum grain yield was recorded in weed free control plot and lowest in unweeded plot. Among the different densities of *I. miliacea* maximum yield reduction was at 80 plants per square metre and the least was observed at five plants per square metre. Grain yield of plot where weeds other than *I. miliacea* grew

Table 32. Effect of weed densities on length of panicle, number of spikelets and grains/panicle during *Rabi* season

Treatments	Length of panicle (cm)			No.of spikelets/panicle			No.of grains/panicle		
	1992	1993	Pooled	1992	1993	Pooled	1992	1993	Pooled
1. *I. miliacea* 5 plants/m^2	17.93	20.15	19.04	82.3	77.5	79.88	62.3	57.3	59.8
2. *I. miliacea* 20 plants/m^2	16.95	19.30	18.13	69.8	68.5	69.13	52.8	49.8	51.3
3. *I. miliacea* 80 plants/m^2	16.53	18.80	17.66	68.3	65.3	66.75	50.3	47.5	48.9
4. Weed free	18.48	20.38	19.42	84.5	82.0	83.25	63.0	61.0	62.0
5. Unweeded	15.40	17.88	16.64	58.5	59.0	58.75	42.3	42.0	42.1
6. Weeds other than *I. miliacea*	16.20	18.05	17.13	69.0	67.5	68.13	50.5	49.8	50.1
SE±	0.25	0.32	0.19	4.06	4.22	+	3.17	3.23	2.12
CD (0.05)	0.75	0.96	0.55	12.25	12.71		9.55	9.72	6.08

\+ Pooled analysis could not be done due to heterogeneity of error mean squares and absence of interaction effect

Table 33. Effect of weed densities on 1000 grain weight, grain and straw yield during *Rabi* season

Treatments	1000 grain weight (g)			Grain yield (kg ha^{-1})			Straw yield (kg ha^{-1})		
	1992	1993	Pooled	1992	1993	Pooled	1992	1993	Pooled
1. *I. miliacea* 5 plants/m²	22.38	22.08	22.22	1413	1363	1388	2825	2750	2788
2. *I. miliacea* 20 plants/m²	22.15	22.23	22.19	1013	1138	1075	1900	1825	1863
3. *I. miliacea* 80 plants/m²	22.35	21.75	22.05	988	925	956	1863	1900	1881
4. Weed free	22.60	22.35	22.47	2100	2250	2175	3863	3725	3794
5. Unweeded	22.03	21.88	21.95	800	700	750	1888	1975	1931
6. Weeds other than *I. miliacea*	22.05	21.45	21.75	1438	1463	1450	3150	2775	2963
SE±	0.25	0.22	0.16	54.7	51.7	40.0	125.4	112.7	83.8
CD(0.05)	NS	NS	NS	165.0	155.8	114.8	377.7	339.5	240.6

NS - Not significant

with rice was on par with the yield of plot where *I. miliacea* grew at five plants per square metre.

Straw yield also showed a similar trend as that of grain yield of rice with maximum yield in weed free plot and the lowest in unweeded plot. Straw yield in unweeded plot was on par with the higher densities of *I. miliacea*. Least yield reduction was noticed with the lowest density of *I. miliacea* and in plot where weeds other than *I. miliacea* grew.

4.3 Part III. Integrated weed management in rice based cropping system

4.3.1 *Kharif*

In this trial five pre-emergence herbicides were tested and compared with local practice of hoeing and hand weeding along with a weed free and unweeded control. The results of the trial are presented below and the abstracts of the analysis of variance tables are presented in Appendix-VI.

4.3.1.1 Weed flora

Different species of weeds found in the experiment site were collected and identified. Various species found in the area during *Kharif* season were *I. miliacea*, *Cyperus* spp., *E. colona*, *S. interrupta* and *O. sativa* var. *fatua*, *F. miliacea*, *M. vaginalis* and *S. zeylanica*.

4.3.1.2 Weed count

Data on total weed population, and number of major weed species were recorded on 15 DAS in the experimental plots and are presented in Table 34. Pre-emergence herbicides significantly reduced the weed population.

4.3.1.2.1 *Isachne miliacea*

All the pre-emergence herbicides significantly reduced *I. miliacea* population. Oxyfluorfen was the most effective herbicide which was on par with pretilachlor. Herbicides butachlor, thiobencarb and anilofos also effectively reduced the population of *I. miliacea*. Weed count of *I. miliacea* in non-treated plots ranged from 281-298 m^{-2} whereas the weed count in the herbicide treated plots were less than 29 m^{-2}.

4.3.1.2.2 *Cyperus spp.*

All the pre-emergence herbicides significantly reduced *Cyperus spp.* population during the study. The herbicides in their order of effectiveness in controlling *Cyperus* spp. were oxyfluorfen, pretilachlor, anilofos, thiobencarb and butachlor. Though the weed count of *Cyperus* spp. in untreated plots ranged from 133-138 m^{-2} the count in herbicide treated plots was only two plants per square metre.

4.3.1.2.3 *Echinochloa colona*

Data on weed population of *E. colona* on 15 DAS (Table 34) showed that the pre-emergence herbicides oxyfluorfen, butachlor, thiobencarb and anilofos were only partially effective in reducing the weed count. In pooled analysis, pretilachlor was proved to be the most effective herbicide that controlled the weed. The count of the weed in untreated plots ranged from 26 to 29 m^{-2} and that in herbicide treated plots it was 1.67 to 12.33 m^{-2}.

Table 34. Effect of weed control treatments on the population of weeds (no./m²) at 15 DAS in *Kharif*

Weed control treatments	*Isachne miliacea*			*Cyperus spp.*			*Echinochola colona*		
	1992	1993	Pooled	1992	1993	Pooled	1992	1993	Pooled
1. Anilofos 0.4 kg/ha + HW on 30 DAS	5.11 (26.67)	5.48 (30.00)	5.29 (28.33)	1.38 (2.00)	1.38 (2.00)	1.38 (2.00)	3.15 (10.67)	3.69 (14.00)	3.42 (12.33)
2. Pretilachlor 0.5 kg/ha + HW on 30 DAS	3.01 (11.00)	2.03 (4.33)	2.52 (7.67)	1.00 (1.00)	1.14 (1.33)	1.07 (1.17)	1.33 (2.00)	1.14 (1.33)	1.24 (1.67)
3. Butachlor 1.25 kg/ha + HW on 30 DAS	4.67 (23.67)	4.43 (20.00)	4.55 (21.83)	1.41 (2.00)	1.41 (2.00)	1.41 (2.00)	2.49 (8.00)	3.67 (13.67)	3.08 (10.83)
4. Thiobencarb 1.25 kg/ha + HW on 30 DAS	4.08 (17.00)	5.00 (25.00)	4.54 (21.00)	1.38 (2.00)	1.41 (2.00)	1.40 (2.00)	2.86 (8.67)	3.51 (12.33)	3.18 (10.50)
5. Oxyfluorfen 0.1 kg/ha + HW on 30 DAS	1.0 (1.00)	1.52 (2.33)	1.26 (1.67)	1.00 (1.00)	1.00 (1.00)	1.00 (1.00)	3.09 (10.67)	2.67 (7.33)	2.88 (9.00)
6. Local practice of hoeing on 15 DAS HW on 25 and 40 DAS	16.85 (286.67)	17.56 (310.00)	17.20 (298.33)	9.65 (116.67)	12.62 (160.00)	11.14 (138.33)	5.16 (27.00)	5.03 (25.33)	5.09 (26.17)
7. Unweeded	16.50 (276.00)	17.69 (313.33)	17.09 (294.67)	9.17 (101.33)	12.84 (165.33)	11.01 (133.33)	5.58 (31.67)	5.02 (25.33)	5.30 (28.50)
8. Weed free	16.44 (273.67)	17.01 (290.00)	16.72 (281.83)	9.63 (112.67)	12.34 (155.00)	10.99 (133.83)	5.21 (28.00)	5.46 (30.33)	5.33 (29.17)
SE±	0.93	0.48	+	1.69	0.50	+	0.37	0.31	0.25
CD (0.05)	2.83	1.44		5.12	1.53		1.11	0.94	0.73

+ Pooled analysis could not be done due to heterogeneity of error mean squares and absence of interaction effect

Data in paranthesis are original values

Contd.

Table 34. Continued

Weed control treatments	*Sacciolepis interrupta*			*Oryza sativa* var. *fatua*			Total		
	1992	1993	Pooled	1992	1993'	Pooled	1992	1993	Pooled
1. Anilofos + HW 30 DAS	2.27 (5.67)	3.09 (10.00)	2.68 (7.83)	5.37 (37.00)	5.36 (31.67)	5.37 (34.33)	8.81 (80.00)	9.17 (86.67)	8.89 (82.83)
2. Pretilachlor + ,,	1.00 (1.00)	1.14 (1.33)	1.07 (1.17)	3.92 (20.00)	4.91 (25.33)	4.41 (22.67)	5.38 (35.00)	5.57 (31.67)	5.47 (33.33)
3. Butachlor + ,,	1.38 (2.00)	1.41 (2.00)	1.40 (2.00)	4.83 (29.00)	5.76 (25.33)	5.29 (32.17)	7.78 (64.00)	8.32 (71.00)	8.05 (67.50)
4. Thiobencarb + ,,	1.62 (3.00)	1.14 (1.33)	1.38 (2.17)	5.07 (36.33)	5.19 (28.00)	5.13 (32.17)	7.92 (66.33)	8.12 (66.33)	8.02 (66.33)
5. Oxyfluorfen + ,,	1.00 (1.00)	1.00 (1.00)	1.00 (1.00)	5.12 (35.67)	5.40 (30.67)	5.26 (33.17)	6.76 (49.33)	6.25 (40.67)	6.50 (45.00)
6. Local practice of hoeing + HW	5.36 (31.67)	5.34 (29.00)	5.35 (30.33)	4.72 (29.00)	5.50 (31.33)	5.11 (30.17	22.13 (491.00)	23.56 (555.67)	22.85 (523.33)
7. Unweeded	4.72 (24.00)	5.28 (28.00)	5.00 (26.00)	3.93 (19.33)	5.49 (32.67)	4.71 (26.00)	21.24 (452.33)	23.53 (555.33)	22.38 (503.83)
8. Weed free	5.32 (30.33)	5.30 (28.67)	5.31 (29.50)	5.12 (30.67)	5.31 (31.67)	5.22 (31.17)	21.74 (475.33)	25.01 (629.00)	23.38 (552.17)
SE±	0.50	0.33	0.28	0.64	0.25	+	1.20	0.65	
CD (0.05)	1.52	0.99	0.81	NS	NS		3.64	1.99	

4.3.1.2.4 *Sacciolepis interrupta*

The weed count of *S. interrupta* on 15 DAS (Table 34) proved that all the pre-emergence herbicides significantly reduced its population. In pooled analysis it was found that oxyfluorfen controlled the weed to the maximum and the result was similar to pretilachlor. Other successful herbicides in the order of their effectiveness are thiobencarb, butachlor and anilofos. Weed count of *S. interrupta* in untreated plots ranged from 26 to 30 m^{-2} and that in herbicide treated plots it was between one to 7.83 m^{-2}.

4.3.1.2.5 *Oryza sativa* var. *fatua*

Data on population of *O. sativa* var. *fatua* on 15 DAS (Table 34) proved that none of the herbicides could effectively control the weed. Count of the weed in the experimental field ranged from 22.6 to 31.2 m^{-2}.

4.3.1.2.6 Total weed population

Total weed population on 15 DAS (Table 34) was significantly reduced by all the pre-emergence herbicides tried. Pretilachlor reduced the total weeds to a maximum and was on par with the activity of oxyfluorfen. The order of effectiveness of other herbicides were thiobencarb, followed by butachlor and anilofos. Total weed count in untreated plots ranged from 503 to 552 m^{-2} and that of herbicide treated plots from 33 to 83 m^{-2}.

4.3.1.3 Dry matter production of weeds

Data on total dry weight of weeds and of major weed species recorded on 30 DAS are presented in Table 35 and illustrated in Fig.9.

4.3.1.3.1 *Isachne miliacea*

All the pre-emergence herbicides were effective in checking the DMP of *I. miliacea* as on 30 DAS as in weed free plot and local practice of hoeing and hand weeding. The DMP of *I. miliacea* in unweeded control plot was 62.73 kg ha^{-1}, and that in weed control treatments was 1.04 to 7.40 kg ha^{-1} (Table 35).

4.3.1.3.2 *Cyperus* spp.

Just as in the case of *I. miliacea*, DMP of *Cyperus* spp. as on 30 DAS was significantly reduced by all the pre-emergence herbicides. There was no significant difference in DMP of weed free control; local practice of hoeing and hand weeding and the herbicide treated plots. *Cyperus* spp. produced 52.17 kg ha^{-1} of dry matter on 30 DAS in unweeded check. Whereas it was 0.01 to 7.33 kg ha^{-1} in weed control treatments (Table 35).

4.3.1.3.3 *Echinochloa colona*

All the pre-emergence herbicides significantly reduced DMP of *E. colona* as on 30 DAS; and were on par with weed free control and local practice of hoeing and hand weeding. But in pooled analysis thiobencarb was found to be the least efficient herbicide in checking *E. colona*. Even though all herbicides reduced the weed population pretilachlor was the most efficient herbicide against *E. colona* which was closely followed by local practice (Table 35).

Table 35. Effect of weed control treatments on DMP of weeds (kg ha^{-1}) on 30 DAS in *Kharif*

Weed control treatments	*Isachne miliacea*			*Cyperus spp.*			*Echinochloa colona*		
	1992	1993	Pooled	1992	1993	Pooled	1992	1993	Pooled
1. Anilofos 0.4 kg/ha + H.W. on 30 DAS	4.80	10.00	7.40	3.34	3.00	3.17	3.00	12.00	7.50
2. Pretilachlor 0.5 kg/ha + H.W. on 30 DAS	1.60	1.33	1.47	0.01	0.01	0.01	2.01	4.00	3.00
3. Butachlor 1.25 kg/ha + H.W. on 30 DAS	3.20	3.00	3.10	1.34	2.00	1.67	1.51	10.00	5.75
4. Thiobencarb 1.25 kg/ha + H.W. on 30 DAS	1.60	2.67	2.14	3.34	2.0	2.67	2.67	18.00	10.34
5. Oxyfluorfen 0.1 kg/ha + H.W. on 30 DAS	1.07	1.00	1.04	2.00	1.01	1.51	4.00	8.67	6.34
6. Local practice of hoeing on 15 DAS + H.W. on 25 and 40 DAS	2.40	3.67	3.03	6.67	8.00	7.33	1.50	4.67	3.09
7. Unweed	44.80	80.67	62.73	40.00	64.33	52,17	10.00	34.00	22.00
8. Weed free	1.60	2.00	1.80	1.00	1.33	1.17	0.01	2.00	1.01
SE±	4.86	2.69	3.59	5.99	3.38	+	1.74	2.15	3.85
CD(0.05)	14.73	8.15	12.01	18.19	10.25		5.29	6.53	12.88

\+ Pooled analysis could not be done due to heterogeneity of error mean squares and absence of interaction effect

Contd.

Table 35. Continued

Weed Control treatments	*Sacciolepis interrupta*			*Oryza sativa* var. *fatua*			Total		
	1992	1993	Pooled	1992	1993	Pooled	1992	1993	Pooled
1. Anilofos + HW on 30 DAS	1.00	6.00	3.50	54.00	78.00	66.00	66.13	109.00	87.57
2. Pretilachlor + ,,	0.01	1.33	0.67	22.00	62.67	42.33	25.60	72.00	48.80
3. Butachlor + ,,	0.01	4.00	2.01	33.00	83.00	58.00	39.03	102.00	70.52
4. Thiobencarb + ,,	0.01	8.00	4.01	75.00	76.67	75.83	85.93	107.33	96.63
5. Oxyfluorfen + ,,	0.67	2.00	1.34	33.00	57.00	45.00	39.73	70.00	54.87
6. Local practice of hoeing on 15 DAS + HW on 25 and 40 DAS	1.67	5.67	3.67	7.00	12.00	9.50	19.23	34.00	26.62
7. Unweeded	7.33	27.33	17.33	67.00	164.33	115.67	168.13	404.67	286.40
8. Weed free	0.01	1.00	0.51	2.00	17.00	9.50	4.60	23.67	14.13
SE±	1.21	0.95	3.14	17.36	12.43	11.80	21.51	11.61	21.20
CD(0.05)	3.68	2.88	10.51	NS	37.61	33.87	65.25	35.23	70.89

NS - Not significant

4.3.1.3.4 *Sacciolepis interrupta*

All the pre-emergence herbicides significantly controlled DMP of *S. interrupta* on 30 DAS in both years and was comparable to the weed free plot and local practice. Dry matter production of *S. interrupta* in unweeded plot was 17.33 kg ha^{-1} and that in herbicide applied plots it ranged from 0.5 to 4.0 kg ha^{-1} (Table 35).

4.3.1.3.5 *Oryza sativa* var. *fatua*

Local practice gave maximum control of *O. sativa* var. *fatua* (9.5 kg ha^{-1}) on 30 DAS. None of the herbicides were efficient in controlling the weed. Dry matter production of the weed in unweeded control was 115.67 kg ha^{-1} (Table 35).

4.3.1.3.6 Total DMP of weeds on 30 DAS

All the weed control treatments including pre-emergence herbicides and local practice of hoeing gave satisfactory control of weeds compared to unweeded control plot based on total dry weight of weeds on 30 DAS. Unweeded control plot produced 286.4 kg ha^{-1} of weed dry matter on 30 DAS and that in weed control treatments it was reduced to 26-96 kg ha^{-1}. Local practice proved to be the most effective (26 kg ha^{-1}) when compared to pre-emergence herbicides (48 to 96 kg ha^{-1}). Pretilachlor was the best pre-emergence herbicide followed by oxyfluorfen. Thiobencarb was the least effective (96.63 kg ha^{-1}) herbicide followed by anilofos (Table 35).

4.3.1.3.7 Total DMP of weeds on 60 DAS and at harvest of rice

Data on dry weight of weeds on 60 DAS and at harvest are presented in Table 36. All the weed control treatments significantly reduced the weed dry matter on 60 DAS and at harvest of rice compared to unweeded control. Maximum residual dry weight at harvest time was noticed in local practice of hoeing and hand weeding (1046 kg ha^{-1}). Spraying of oxyfluorfen or pretilachlor followed by one hand weeding on 30 DAS gave best control of DMP of weeds on 60 DAS and even upto harvest.

4.3.1.4 Phytotoxicity of herbicides

The data on toxicity rating of herbicides to rice as on 15 DAS is shown in Table 36. The results showed that all herbicides except pretilachlor was non toxic to rice. Pretilachlor affected the growth of rice at a dose of 0.5 kg ha^{-1}. Pre-emergence spray of oxyfluorfen at 0.1 kg ha^{-1} burned the outer leaves of rice, but recovered soon.

4.3.1.5 Weed Control Efficiency (WCE)

Weed control efficiencies were worked out on 30 and 60 DAS and at harvest of rice and are presented in Table 36. Local practice of hoeing and hand weeding gave maximum efficiency on 30 DAS and its efficiency was least at harvest. All the herbicides plus one hand weeding checked weeds satisfactorily. On 30 DAS application of oxyfluorfen and pretilachlor were the best. When followed by one hand weeding on 30 DAS all the herbicides gave higher WCE on 60 DAS and at harvest.

Table 36. Effect of weed control treatments on total DMP of weeds on 60 DAS and at harvest of rice (kg ha^{-1}), weed control efficiency and phytotoxicity of herbicides to rice in *Kharif*

Weed control treatments	Dry matter production: 60 DAS			Dry matter production: At harvest			Weed control efficiency (%)			Herbicide phytotoxicity to rice on 15 DAS*		
	1992	1993	Pooled	1992	1993	Pooled	30 DAS	60 DAS	At harvest	1992	1993	Pooled
1. Anilophos + HW on 30 DAS	45.00	52.33	48.67	400.0	383.3	391.7	69.45	99.00	92.60	1.0	1.0	1.0
2. Pretilachlor + HW on 30 DAS	2.01	7.33	4.67	73.3	66.6	70.0	82.97	99.90	98.70	6.3	6.3	6.3
3. Butachlor + HW on 30 DAS	47.33	31.33	39.33	333.3	320.0	326.7	75.39	99.27	93.80	1.0	1.0	1.0
4. Thiobencarb + HW on 30 DAS	26.67	60.00	43.33	226.7	300.0	263.3	76.28	99.20	95.00	1.0	1.0	1.0
5. Oxyfluorfen + HW on 30 DAS	8.20	8.67	8.44	73.3	66.7	70.0	88.85	99.80	98.70	1.67	1.33	1.50
6. Local practice of hoeing on 15 DAS + HW on 25 and 40 DAS	79.67	85.33	82.50	1000.0	1093.3	1046.7	91.71	98.41	80.10	1.0	1.0	1.0
7. Unweeded	5116.67	4620.00	4868.33	5433.3	5120.0	4466.7				1.0	1.0	1.0
8. Weed free	8.00	23.33	15.67	500.0	450.0	475.0				1.0	1.0	1.0
SE±	191.48	109.39	+	155.30	110.73	+				0.25	0.15	0.07
CD(0.05)	580.79	331.80		471.02	335.83					0.75	0.47	0.38

+ Pooled analysis could not be done due to heterogeneity of error mean squares and absence of interaction effect

* 0-9 scale of visual rating of injury

4.3.1.6 Growth and yield characters of rice

Growth and yield components of rice plant as influenced by weed control treatments are presented in Tables 37 and 38.

4.3.1.6.1 Height of rice

The height of rice plant was significantly influenced by weed control treatments (Table 37). Maximum plant height of 86.5 cm was observed in oxyfluorfen applied plot and was similar with all other herbicides except pretilachlor. Weed free control plot and local practice also recorded higher plant height. The least plant height was noticed in unweeded plot which was on par with pretilachlor applied plot.

4.3.1.6.2 Number of panicles

The number of panicles were significantly influenced by weed control in 1993 only (Table 37). All the herbicides except pretilachlor were on par with regard to number of panicles and was on par with weed free check. But local practice of hoeing and hand weedings recorded maximum panicles (367 m^{-2}). Among the herbicide applied plots, the treatment of oxyfluorfen and butachlor showed similar results with local practice of hoeing and hand weeding. Unweeded plot had the least number of panicles.

4.3.1.6.3 Length of panicle

Length of panicle was significantly influenced by weed control treatments (Table 37). Higher panicle lengths were recorded with butachlor, oxyfluorfen

Table 37. Effect of weed control treatments on height of rice at harvest, number of panicles and length of panicle in *Kharif*

Weed control treatments	Height (cm)			No.of panicles/m²			Panicle length (cm)		
	1992	1993	Pooled	1992	1993	Pooled	1992	1993	Pooled
1. Anilofos + HW on 30 DAS	84.3	85.7	85.0	308.3	326.7	317.5	18.9	19.2	19.07
2. Pretilachlor + ,,	75.7	83.0	79.3	273.0	246.3	259.7	17.3	18.5	17.88
3. Butachlor + ,,	81.3	85.0	83.2	291.7	346.3	319.0	19.9	20.3	20.08
4. Thiobencarb + ,,	81.0	84.0	82.5	301.0	312.7	306.8	17.3	18.3	17.78
5. Oxyfluorfen + ,,	83.7	89.3	86.5	297.3	342.0	319.7	19.2	20.3	19.73
6. Local practice of hoeing on 15 DAS + HW on 25 and 40 DAS	80.7	84.7	82.7	312.7	367.0	339.8	18.9	20.5	19.70
7. Unweeded	78.3	70.0	74.2	237.0	215.3	226.2	17.0	15.7	16.38
8. Weed free	80.3	86.0	83.2	303.7	311.3	307.5	17.6	19.0	18.27
SE±	2.83	2.09	1.91	19.10	9.33	+	0.71	0.52	0.44
CD (0.05)	NS	6.34	5.49	NS	28.30		NS	1.58	1.28

\+ Pooled analysis could not be done due to heterogeneity of error mean squares and absence of interaction effect

NS - Not significant

Table 38. Effect of weed control treatments on yield attributes of rice in *Kharif*

Weed control treatments	No.of grains/panicle			No.of chaff/panicle			Grain chaff ratio		
	1992	1993	Pooled	1992	1993	Pooled	1992	1993	Pooled
1. Anolofos + HW on 30 DAS	65.0	66.3	65.7	20.67	19.00	19.80	3.23	3.53	3.38
2. Pretilachlor + ,,	56.0	64.0	60.7	18.67	20.70	19.70	3.03	3.10	3.07
3. Butachlor + ,,	67.3	76.7	72.0	20.67	21.00	20.80	3.27	3.70	3.48
4. Thiobencarb + ,,	52.3	58.0	55.2	18.67	19.70	19.20	2.87	3.03	2.95
5. Oxyfluorfen + ,,	68.0	77.7	72.8	21.67	22.30	22.00	3.17	3.50	3.33
6. Local practice of hoeing on 15 DAS + HW on 25 and 40 DAS	64.0	72.3	68.2	18.67	20.00	19.30	3.47	3.63	3.55
7. Unweeded	49.0	48.0	48.5	18.67	20.00	19.30	2.50	2.40	2.45
8. Weed free	59.3	60.7	60.0	18.00	17.70	17.80	3.20	3.50	3.37
SE±	5.20	3.44	2.95	2.67	1.38	+	0.25	0.29	0.23
CD (0.05)	NS	10.43	8.47	NS	NS		NS	NS	0.51

\+ Pooled analysis could not be done due to heterogeneity of error mean squares and absence of interaction effect

NS - Not significant

and anilofos applied plots and with local practice. Unweeded control plot produced the least panicle length.

4.3.1.6.4 Number of filled grains per panicle

Number of grains per panicle was significantly influenced by weed control treatments as shown in Table 38. Oxyfluorfen recorded maximum number of grains per panicle and was on par with butachlor and local practice. Among the herbicides, thiobencarb produced least number of grains per panicle and was on par with pretilachlor and anilofos. However unweeded plot had the least number of grains per panicle.

4.3.1.6.5 Number of chaff per panicle

Number of chaff per panicle was not influenced by any weed control methods in any of the years (Table 38).

4.3.1.6.6 Grain chaff ratio

Maximum grain chaff ratio was in local practice and was on par with all other weed control treatments except thiobencarb. Unweeded control plot recorded the least grain chaff ratio (Table 38).

4.3.1.7 Grain yield

Data on yield of grain as influenced by weed control treatments are presented in Table 39 and illustrated in Fig.10. Significant influence was noticed in both years. Local practice of weed control recorded maximum grain yield, which was on par with oxyfluorfen and butachlor treated plots and weed free plot. Among

Table 39. Grain and straw yield of rice and weed index (WI) as influenced by weed control treatments in *Kharif*

Weed control treatments	Grain (kg ha^{-1})			Straw (kg ha^{-1})			Total yield	
	1992	1993	Pooled	1992	1993	Pooled	Grain + Straw (kg ha^{-1})	WI (%)
1. Anilofos + HW on 30 DAS	2779	3148	2964	4478	4583	4531	7495	8.66
2. Pretilachlor + ,,	2376	3115	2746	3809	4537	4173	6919	15.68
3. Butachlor + ,,	2936	3259	3098	4630	4583	4606	7704	6.12
4. Thiobencarb + ,,	2820	3069	2945	4325	4213	4269	7214	12.09
5. Oxyfluorfen + ,,	3148	3417	3282	5079	4769	4924	8206	0.00
6. Local practice of hoeing on 15 DAS + HW on 25 and 40 DAS	3182	3495	3339	4742	4861	4801	8140	0.80
7. Unweeded	1041	1709	1375	1658	2778	2218	3593	56.19
8. Weed free	3094	3435	3265	4658	4815	4736	8001	1.28
SE±	270.76	83.86	+	363.45	125.72	+		
CD(0.05)	821.2	254.3		1102.3	381.3			

+ Pooled analysis could not be done due to heterogeneity of error mean squares and absence of interaction effect

the herbicides pretilachlor gave the minimum yield. But unweeded control recorded the lowest yield of grain.

4.3.1.8 Straw yield

Yield of straw as influenced by weed control treatments is furnished in Table 39 and illustrated in Fig.10. Yield of straw was significantly influenced by weed control treatments. Maximum straw yield was observed in oxyfluorfen applied plot and was on par with local practice and other herbicides such as butachlor and anilofos and weed free control plot. Among herbicides pretilachlor recorded least straw yield. Lowest straw yield was recorded in unweeded control plot.

4.3.1.9 Weed index

Weed index was worked out based on total dry matter of crop and presented in Table 39. Maximum DMP by crop was in oxyfluorfen applied plot. Unweeded control plot recorded maximum weed index of 56.15 per cent. Among the herbicides studied pretilachlor recorded highest weed index of 15.68 per cent followed by thiobencarb (12.09). The least weed index of 0.80 was found in local practice.

4.3.2 *Rabi*

4.3.2.1 Weed flora

Major weed found in the experimental fields during second crop season was *I. miliacea*. It accounted for more than 90 per cent of the total weeds in the experimental fields. The remaining ten per cent or less consisted of *Cyperus* spp and *Fimbristylis miliacea*.

4.3.2.2 Dry matter production of weeds

Data on weed dry weight at harvest of rice are presented in Table 40. The *Kharif* treatments showed significant effect on DMP of weeds at harvest of *Rabi* rice. Among the *Kharif* treatments pretilachlor showed the maximum weed control efficiency in *Rabi*. Weed control treatments given to the *Rabi* crop influenced DMP of *I. miliacea* significantly. Glyphosate applied on residual weeds after the harvest of *Kharif* proved to be the most effective in checking *I. miliacea* growth till harvest of the *Rabi* crop. Hand weeding was found to be less effective in checking *I. miliacea* growth.

4.3.2.3 Growth and yield characters

4.3.2.3.1 Plant height

Height of plants during *Rabi* was not influenced by weed control treatments of *Kharif* or *Rabi* crop.

4.3.2.3.2 Number of panicles

Both *Kharif* and *Rabi* treatments were found to be insignificant on number of panicles.

4.3.2.4 Grain yield

Data on grain yield of *Rabi* crop are presented in Table 41 and depicted in Fig.11. The *Kharif* weed control treatments showed no significant influence on grain yield during *Rabi* season. The *Rabi* weed control treatments significantly influenced the grain yield of rice. Maximum grain yield was recorded in weed free plot which was on par with application of glyphosate on residual weeds immediately after the harvest of *Kharif* crop. One hand weeding on 30th day alone did not satis-

Table 40. Weed dry weight (kg ha^{-1}) at harvest as influenced by weed control treatments during *Rabi* season

Main plot	1992 Subplot							1993 Subplot						
	t_1	t_2	t_3	t_4	t_5	t_6	Mean	t_1	t_2	t_3	t_4	t_5	t_6	Mean
Anilofos	1.23 (3.33)	1.35 (3.67)	11.12 (124.67)	6.71 (37.00)	20.03 (1066.7)	9.08 (71.30)	8.28 (217.7)	1.13 (3.00)	1.45 (4.00)	12.07 (114.00)	7.22 (43.30)	21.66 (1460.00)	9.06 (70.70)	8.77 (338.70)
Pretilachlor	0.65 (1.67)	0.79 (2.00)	11.47 (130.3)	6.16 (31.33)	17.58 (593.3)	8.12 (55.7)	7.46 (135.7)	0.91 (2.33)	1.02 (2.67)	10.97 (115.50)	6.40 (34.00)	20.90 (1230.00)	11.84 (65.09)	8.68 (241.50)
Butachlor	0.78 (2.00)	0.79 (2.00)	11.49 (131.0)	6.52 (35.00)	20.63 (1306.7)	9.02 (70.00)	8.21 (257.8)	1.23 (3.30)	1.24 (3.30)	11.86 (144.30)	7.99 (22.10)	22.09 (1610.00)	9.25 (74.00)	8.95 (342.80)
Thiobencarb	0.54 (1.33)	0.67 (1.67)	11.47 (130.3)	6.12 (31.00)	20.61 (1240.0)	8.43 (64.0)	7.97 (244.7)	0.91 (2.33)	1.24 (3.33)	12.39 (163.50)	6.52 (35.00)	22.38 (1720.00)	9.23 (74.00)	8.78 (333.30)
Oxyfluorfen	1.13 (3.00)	1.13 (3.00)	11.41 (128.66)	6.69 (37.00)	18.63 (813.3)	8.19 (56.3)	7.87 (173.5)	1.35 (3.67)	1.02 (2.67)	11.00 (116.30)	7.15 (42.30)	21.05 (1263.30)	9.10 (71.30)	8.45 (250.00)
Local practice	0.78 (2.00)	0.91 (2.00)	11.47 (130.3)	6.05 (30.3)	20.9 (1333.3)	8.13 (55.3)	8.04 (258.9)	1.13 (3.00)	1.02 (2.67)	11.49 (131.00)	6.57 (26.70)	21.86 (1530.00)	8.47 (63.00)	8.42 (292.80)
Unweeded	0.90 (2.33)	0.67 (1.66)	11.43 (129.0)	6.37 (33.6)	20.8 (1026.7)	8.00 (53.3)	8.04 (207.7)	1.13 (3.00)	1.25 (3.33)	12.17 (156.67)	6.97 (40.00)	21.97 (1573.30)	9.23 (74.00)	8.79 (308.20)
Weed free	0.78 (2.00)	0.79 (2.00)	11.51 (131.67)	6.27 (32.67)	20.26 (1123.3)	9.28 (75.0)	8.15 (227.8)	0.78 (2.00)	1.02 (2.67)	12.35 (162.00)	6.44 (34.30)	22.12 (1626.70)	8.92 (68.00)	8.61 (315.90)
Mean	0.85 (2.21)	0.89 (2.29)	11.44 (129.50)	6.36 (33.50)	19.94 (1062.9)	8.54 (67.60)		1.07 (2.83)	1.16 (3.08)	11.79 (179.90)	6.91 (59.60)	21.76 (1501.70)	9.39 (70.00)	

1992	SE±	CD(0.05)	1993	SE±	CD(0.05)
T	0.1023	0.3103	T	0.2528	0.7679
t	0.2006	0.5656	t	0.2071	0.5838
Tt	0.5676	1.5998	Tt	0.5859	1.6513

Data in parenthesis are original values

t_1 - glyphosate 0.75 kg/ha
t_2 - glyphosate 1.50 kg/ha
t_3 - HW on 30 DAT
t_4 - HW on 20 and 40 DAT
t_5 - Unweeded
t_6 - Weed free

Table 41. Grain yield of rice (kg ha^{-1}) as influenced by weed control treatments during *Rabi* season

	1992 Subplot							1993 Subplot						
	t_1	t_2	t_3	t_4	t_5	t_6	Mean	t_1	t_2	t_3	t_4	t_5	t_6	Mean
Anilofos	3027	2917	2500	2693	2250	2710	2683	2237	2267	2043	2353	1653	2237	2132
Pretilachlor	2917	2807	2417	2693	1860	2833	2588	2447	2537	2103	2393	1653	2517	2275
Butachlor	2917	2747	2417	2750	2057	2890	2629	2127	2253	1867	2253	1547	2283	2055
Thiobencarb	2780	2750	2527	2720	2170	2887	2639	2022	2193	1893	2177	1760	2093	2023
Oxyfluorfen	2550	2750	2280	2750	2140	2890	2593	2220	2327	2083	2290	1970	2357	2208
Local practice	2860	2887	2413	2693	2140	2833	2638	2347	2380	1920	2390	1877	2433	2224
Unweeded	2860	2943	2360	2557	1970	2890	2593	2100	2290	1890	2053	1800	2307	2073
Weed free	2887	2890	2640	2750	2027	2940	2689	2260	2437	1897	2553	1873	2640	2263
Mean	2830	2836	2444	2701	2077	2859		2220	2335	1975	2308	1767	2336	

	1992 SE±	1992 CD(0.05)		1993 SE±	1993 CD(0.05)
T	301.3	NS	T	108.59	NS
t	28.51	80.3	t	40.52	114.2
Tt	80.65	NS	Tt	114.62	NS

t_1 - glyphosate 0.75 kg/ha
t_2 - glyphosate 1.50 kg/ha
t_3 - HW on 30 DAT
t_4 - HW on 20 and 40 DAT
t_5 - Unweeded
t_6 - Weed free

Table 42. Straw yield of rice (kg ha^{-1}) as influenced by weed control treatments during *Rabi* season

Main plot	1992 Subplot t_1	t_2	t_3	t_4	t_5	t_6	Mean	1993 Subplot t_1	t_2	t_3	t_4	t_5	t_6	Mean
Anilofos	4337	4170	3223	3443	2890	3973	3673	3280	3427	3127	3433	2863	3353	3247
Pretilachlor	4113	3947	3193	3640	2667	3887	3574	3660	3767	3223	3687	2820	3440	3423
Butachlor	4083	4027	3470	3747	2890	4173	3732	3307	3443	2850	3430	2907	3610	3258
Thiobencarb	3917	3947	3417	3890	2973	4083	3704	3043	3343	2987	3000	2737	3240	3058
Oxyfluorfen	3860	3917	3167	3807	2747	4137	3606	3387	3557	3200	3437	2987	3627	3367
Local practice	4083	4110	3390	3693	2753	4000	3672	3597	3670	2930	3663	2890	3723	3412
Unweeded	3860	4167	3250	3527	2750	4083	3606	3070	3390	2880	3210	2737	3513	3133
Weed free	4083	4110	3333	3943	2553	3807	3639	3510	3697	3097	3763	2943	3790	3467
Mean	4042	4049	3305	3711	2778	4018		3349	3537	3037	3453	2860	3537	

1992	SE±	CD(0.05)	1993	SE±	CD(0.05)
T	174.90	NS	T	178.7	NS
t	57.66	162.50	t	43.30	122.1
Tr	163.10	NS	Tt	122.50	NS

t_1 - glyphosate 0.75 kg/ha
t_2 - glyphosate 1.50 kg/ha
t_3 - HW on 30 DAT
t_4 - HW 20 and 40 DAT
t_5 - Unweeded
t_6 - Weed free

Table 43. Economics of weed control

(a) *Kharif*

Treatments		Value of produce Rs.	Cost of weed control Rs.	Total cost of cultivation Rs.	Benefit/cost ratio
T_1	Anilofos (0.4 kg) + HW on 30 DAS	19,351	1600	11,600	1.67
T_2	Pretilachlor (0.5 kg) + ,,	17,903	1675	11,675	1.53
T_3	Butachlor (1.25 kg) + ,,	20,096	1600	11,600	1.73
T_4	Thiobencarb (1.25 kg) + ,,	18,994	1650	11,650	1.63
T_5	Oxyfluorfen (0.1 kg) + ,,	21,334	1850	11,850	1.80
T_6	Hoeing on 15 DAS + 2 HW on 25 and 40 DAS	21,496	4350	14,350	1.49
T_7	Unweeded	9,093	-	10,000	0.90
T_8	Weed free	21,061	4800	14,800	1.42

(b) *Rabi*

t_1	Glyphosate 0.75 kg (pre-plant)	16,431	1800	11,200	1.47
t_2	Glyphosate 1.50 kg (pre-plant)	16,723	1750	11,750	1.42
t_3	One HW 30 DAT	14,216	1600	11,600	1.23
t_4	Two HW 20 and 40 DAT	16,102	2600	12,600	1.28
t_5	Unweeded	12,429	-	10,000	1.24
t_6	Weed free	16,767	3200	13,200	1.27

Cost of paddy Rs.5/- per kg. Straw Rs.1/- per kg
Wages Rs.70/- per man and Rs.40/- per woman
Norms for spraying 50 cents/man, for hoeing 10 cents/man
First hand weeding 40 women/ha. Second hand weeding 25 women/ha
For weed free crop 120 women for *Kharif* and 80 women for *Rabi*
Cost of cultivation excluding weeding Rs.10000/ha per season
Cost of herbicides/litre of product

Anilogaurd - 30 EC Rs.200/-
Thiobencarb - 50 EC Rs.250/-
Oxyfluorfen - 23.5 EC Rs.1250/-
Butachlor - 50 EC Rs.200/-
Rifit - 50 EC Rs.375/-
Roundup - 41 SL Rs.400/-

factorily increase the grain yield. At least two hand weedings on 20 and 40 DAT were needed for good yield. Least grain yield was in unweeded plot. Interaction of *Kharif* and *Rabi* weed control treatments was not found to influence grain yield of *Rabi* crop significantly.

4.3.2.5 Straw yield

Data on *Rabi* crop straw yield are presented in Table 42 and illustrated in Fig.11. Just as in the case of grain yield, straw yield during *Rabi* crop was also unaffected by *Kharif* season weed control treatments. The *Rabi* weed control treatments significantly influenced straw yield of rice. Highest straw yield was recorded by application of glyphosate (1.50 kg ha^{-1}) on weed residues immediately after harvest of *Kharif* crop which was on par with weed free plot and glyphosate 0.75 kg ha^{-1}. Hand weeding on 30th DAT alone was not able to increase straw yield satisfactorily compared to two hand weedings on 20 and 40 DAT. Least straw yield of 2819 kg ha^{-1} was recorded in unweeded plot. Interaction of *Kharif* and *Rabi* weed control treatments was not significant on straw yield of *Rabi* crop.

4.3.3 Economics of weed control

Economic analysis of weed control treatments for *Kharif* and *Rabi* are presented in Table 43. In *Kharif* oxyfluorfen (0.1 kg ha^{-1}) followed by hand weeding on 30 DAS was found to be most economic giving maximum return per rupee invested, eventhough local practice of hoeing and hand weeding gave maximum grain yield. Herbicides butachlor, anilofos and thiobencarb also gave economic yield in *Kharif* season when followed by one hand weeding on 30 DAS. In *Rabi* 0.75 kg ha^{-1} of glyphosate application after harvest of *Kharif* crop gave maximum economic yield of rice compared to hand weeded plots.

Discussion

DISCUSSION

The results of various trials conducted on the biology and control *Isachne miliacea* are discussed in this chapter.

5.1 Part I. Ecophysiology of *I. miliacea*

5.1.1 Weed flora in rice fields of Onattukara

The survey of low land rice fields of Onattukara has brought out information on the major weeds of rice. In the dry sown *Kharif* crop seven species formed bulk of the population (Table 2 and Fig.4). Of these weeds, *Cyperus difformis, Cyperus iria, Echinochloa colona, Monochoria vaginalis* and *Oryza sativa* var. *fatua* are of world wide importance (Holm *et al.*, 1977 and Reissig *et al.*, 1985). Other three species viz. *Isachne miliacea, Sacciolepis interrupta* and *Ludwigia parviflora* are of local importance (KAU, 1990). The survey clearly showed that *I. miliacea* was the major weed in rice with maximum density and highest relative dominance towards the second half of the *Kharif* and throughout the *Rabi* crop (Fig.4 and 5). The results reported by All India Co-ordinated Research Programme on Weed Control, Thrissur centre also showed similar results (KAU, 1988 and 1990).

Among the seven species reported, *I. miliacea* and *Cyperus* spp. were the most predominant weeds during *Kharif* season. *Cyperus* dominated upto 60 DAS and thereafter *I. miliacea* became dominant. *Cyperus* spp. grew fast and attained its maximum growth by 60 DAS whereas the growth of *I. miliacea* was slow in the early stages upto 30 DAS. Thereafter *I. miliacea* showed a faster growth. Mimicry

Legend

IM - *Isachne miliacea*

CY - *Cyperus* spp.

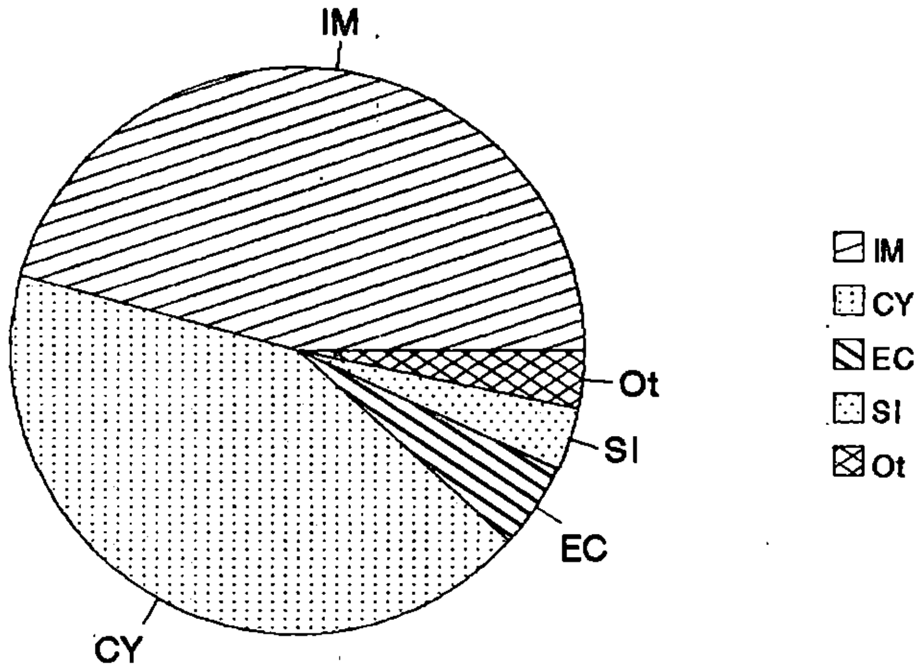
EC - *Echinochloa colona*

SI - *Sacciolepis interrupta*

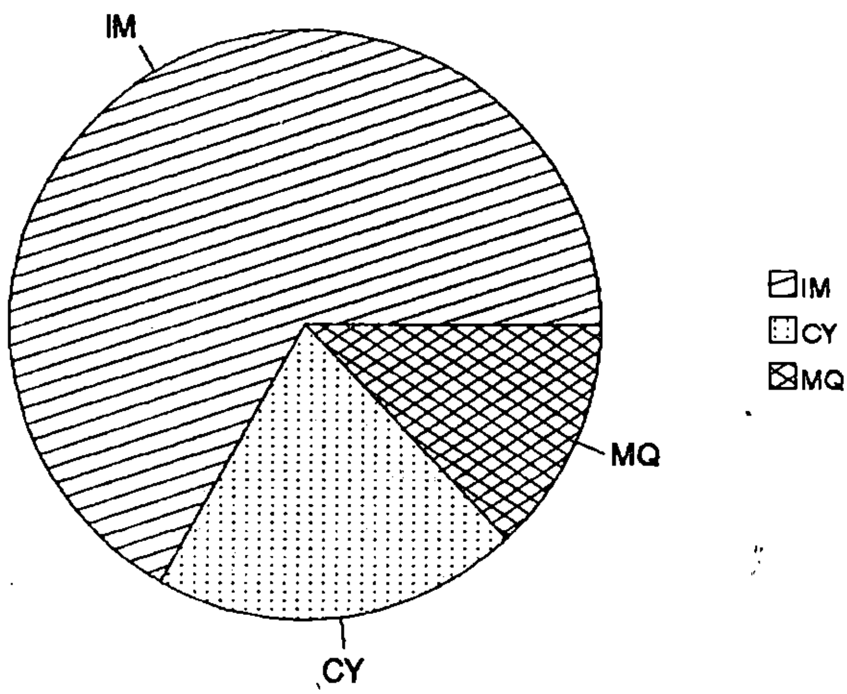
Ot - Others

MQ - *Marsilea quadrifolia*

Fig. 4 Relative density of weeds in the rice fields of Onattukara at 30 DAS/DAT



Kharif season



Rabi season

Legend

IM - *Isachne miliacea*

CY - *Cyperus* spp.

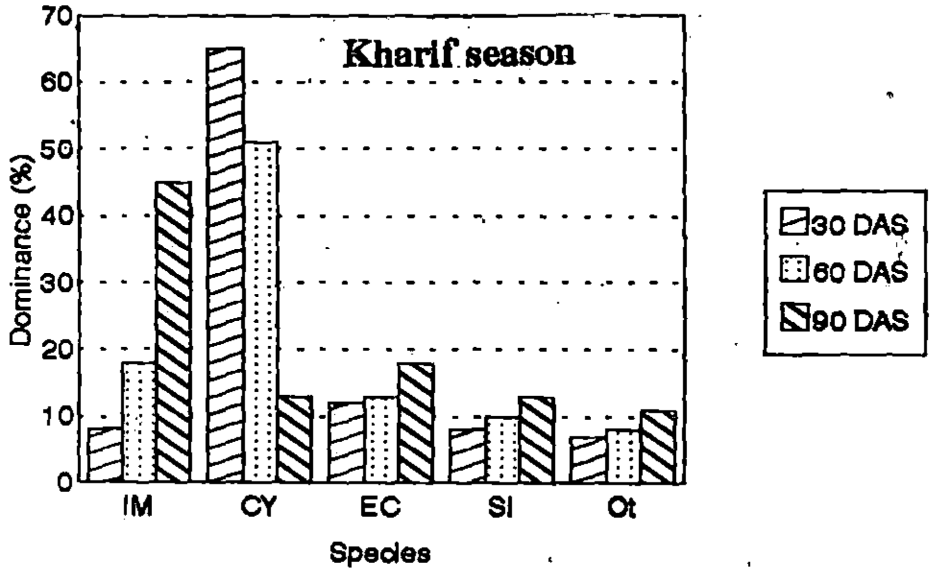
EC - *Echinochloa colona*

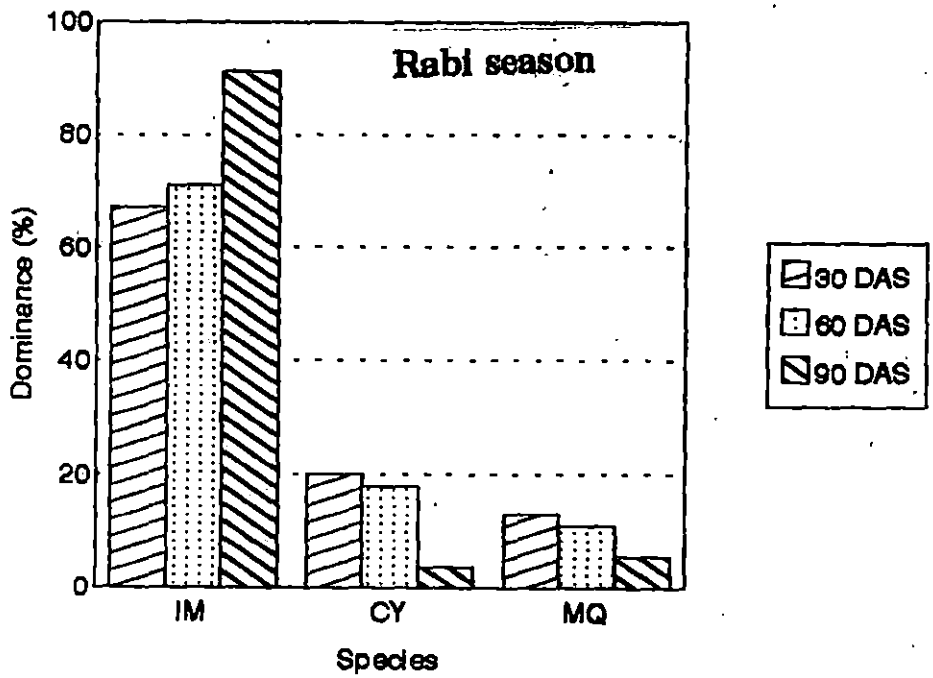
SI - *Sacciolepis interrupta*

Ot - Others

MQ - *Marsilea quadrifolia*

Fig. 5 Dominance of weed species in rice fields of Onattukara





weeds of rice, viz. *E. colona* and *S. interrupta* showed steady dominance throughout the growth phases of the rice crop (Fig.5).

Throughout the *Rabi* season *I. miliacea* was the most dominant weed (Fig.5). The other two important weed species of the season were *Cyperus* spp. and *Marsilea quadrifolia*. Seeds of *I. miliacea* seldom germinate in *Rabi* because the field is submerged and the germination studies have also shown that seeds do not germinate when submerged in water. But the weed is carried on to *Rabi* from residual weeds of *Kharif* by vegetative multiplication of broken slips formed during the ploughing. Budd *et al.* (1979) have also reported similar multiplication of *C. benghalensis* from broken slips.

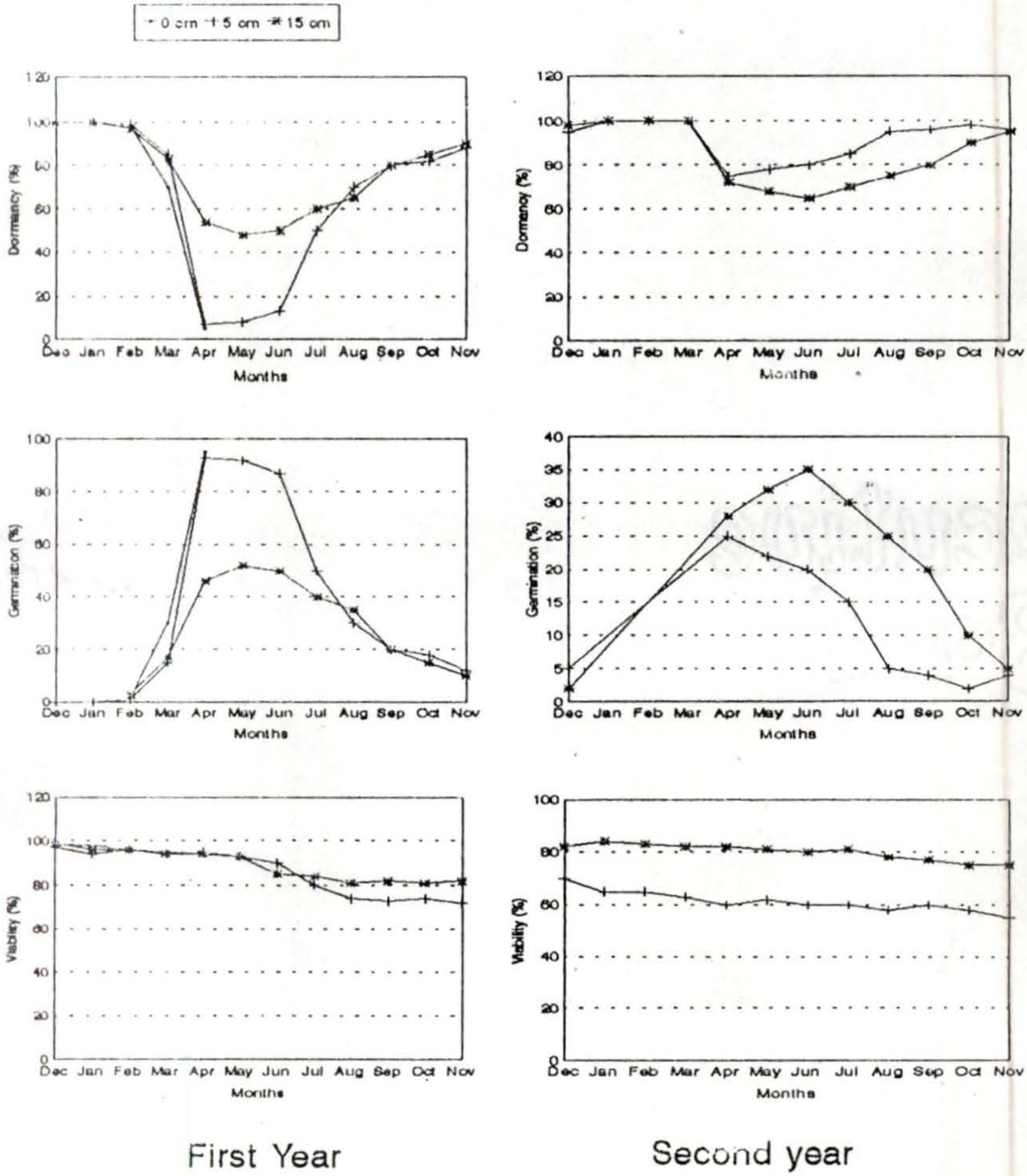
5.1.2 Biology, phenology and ecology of *I. miliacea*

The species of *Isachne* found in Onattukara has been identified as *I. miliacea* Roth. Two types of *I. miliacea* were noticed; the predominant type with brown stem and a less important type with green stem (Plate 1). This weed is confined to wet lands only. Seeds of *I. miliacea* germinate, at field capacity moisture on receipt of pre-monsoon showers in April-May along with dry sown rice and other weeds. It is slow growing upto 30 DAS and thereafter spread rapidly creeping along the ground, rooting at nodes and form a mat along the ground. The peculiar nature of growth suppresses the growth of other weeds and rice crop, both above the ground and below the soil.

Dry matter accumulation of *I. miliacea* was low ranging from 10 to 12 per cent (Table 6). The observed low dry matter content of *I. miliacea* is due to its

Plate 1. Brown stemmed (A) and Green stemmed (B) types of *Isachne miliacea*

Fig 6 Seed dormancy, germination and viability of Isachne at different depths of burial



succulent nature. The weed grows to a maximum of 45 cm in height. Therefore the weed appears not to be a serious competitor for sunlight.

The flowering of *I. miliacea* was two months earlier when grown in open condition compared to that grown in rice crop canopy. This might be due to the difference in availability of sunlight and resultant photosynthetic efficiency of plants growing inside the rice canopy and that grow outside. Since *I. miliacea* is a water loving weed with shallow rooting nature, it dries off quickly with the onset of the summer in the sandy region of Onattukara.

The observed delay in flowering (Table 7) of *I. miliacea* when seeded during March to May might be due to the slow growth resulting from the unfavourable high temperature and low humidity during that period. The early flowering of stem cuttings within 45 days of planting might be due to the physiological maturity of the vegetative shoots.

5.1.3 Propagation of *I. miliacea*

The field capacity moisture was the best for the germination of seeds of *I. miliacea* and even a thin film of one centimetre standing water prevented the germination (Table 8). The lack of germination might be due to non availability of oxygen and optimum temperature under submerged condition. Similar studies on the germination of weed seeds have been reported by Smith and Fox (1973) and Vamadevan *et al.* (1974). The observed decrease in germination with increasing depth might be due to lack of light. Wesson and Wareing (1969a and b) have reported similar findings wherein they found that seeds buried 50 weeks needed light for germination. Similar results were obtained in the case of *I. miliacea* also.

King (1966) observed that maximum emergence of most weed seeds was at two to six centimetre depth. Seeds buried deeper during ploughing are added to the seed bank of the soil. Elgey and Duke (1985) have also supported this theory.

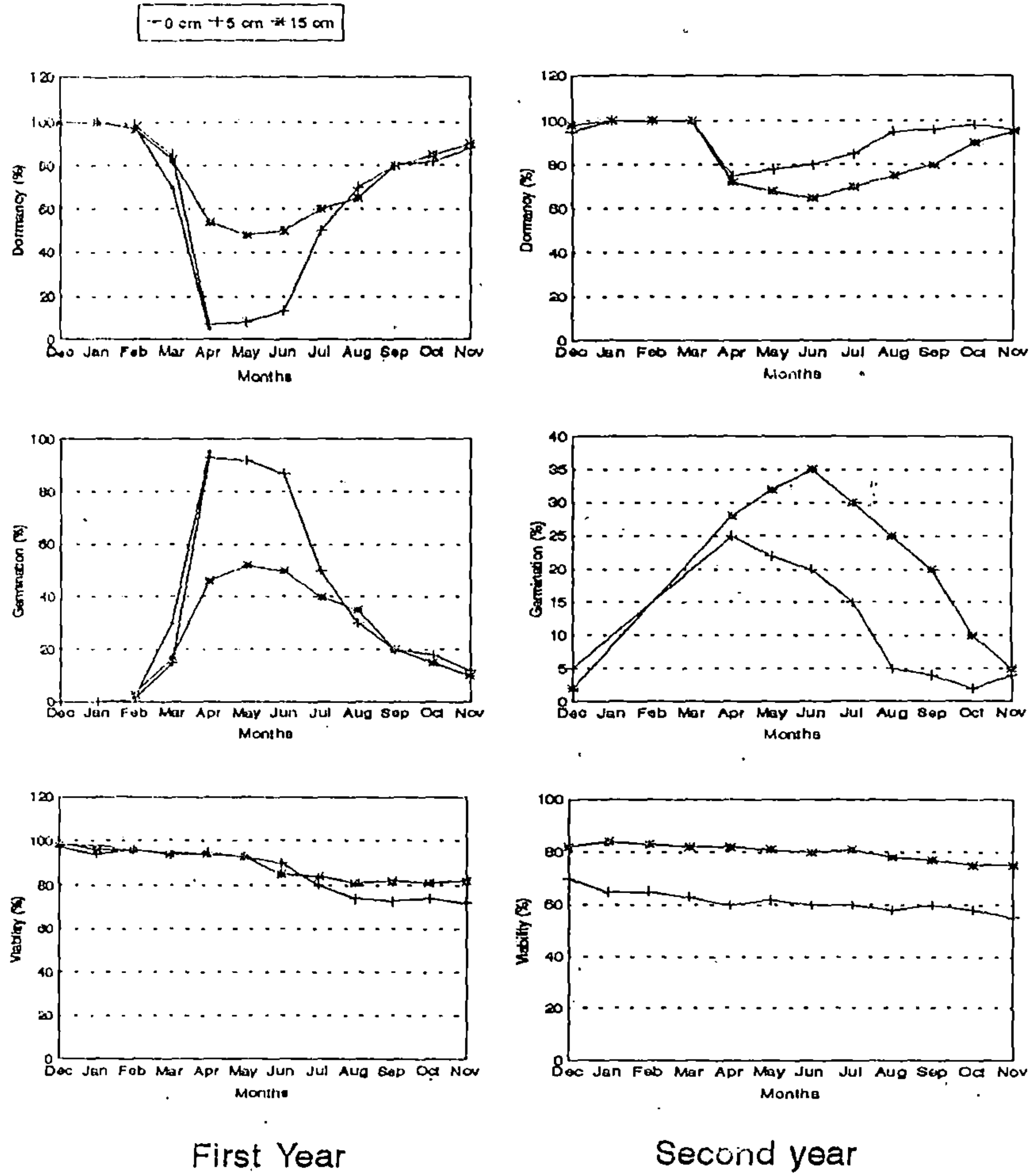
The results indicated that the stem cuttings of *I. miliacea* cannot establish well at field capacity moisture level but it requires a thin film of one to 2.5 cm standing water (Table 9). *Isachne miliacea* is a water loving weed and hence the cuttings did not establish well even at field capacity. At deeper submergence the stem cuttings could not root as it floated on water at zero depth of planting. The results indicate that this weed can be controlled by ploughing the field and burying the cuttings into deeper soil depth more than five centimetre and maintaining soil under submergence of more than five centimetre water. Budd *et al.* (1979) with *Commelina* and Reissig *et al.* (1985) with *Paspalum* got similar results.

5.1.4 Seed physiology of *I. miliacea*

The maximum germination of seeds on soil surface achieved during April by breaking dormancy fully was resulted due to the higher exposure of seeds to light when the field was left unploughed and the availability of optimum moisture obtained from pre-monsoon showers (Table 12 and Fig.6). Similar results were obtained on the importance of light for germination by Wesson and Wareing (1969a and b) in seeds buried in pastures.

The observed high percentage of germination of seeds on the surface and the induced dormancy of the seed buried deep corroborate with the work of Woolley and Stoller (1978) and Karssen (1980), wherein they observed maximum weed germination from proximity to soil surface. Ploughing increases the chance of

Fig 6 Seed dormancy, germination and viability of <u>Isachne</u> at different depths of burial



inducing secondary dormancy to seeds by burial and also break the secondary dormancy of deep buried seeds by exposure.

Thus the weed could be controlled by leaving the field unploughed upto April, allowing the entire seeds of the season to germinate and later on killing the new sprouts by spraying a contact herbicide. Thus the carrying over of the seeds of a season to succeeding crops could be prevented.

The faster loss of viability of seeds at shallow depths of burial (5 cm) compared to that at 15 cm depth might be due to the effect of temperature as observed by Schafer and Chilcote (1970). Similar results have been reported by Toole (1946) with other weeds.

The *I. miliacea* seeds exhibited a seasonal rhythm in germination through breaking the dormancy in the month of April and by inducing secondary dormancy due to water stagnation from July to November (Fig.6). This might be due to the effect of temperature resulting from the seasonal changes as reported by Elgey and Duke (1985).

5.1.5 Allelopathic effects of *I. miliacea*

The whole plant extracts of *I. miliacea* did not show any appreciable effect on the germination of any rice variety tested. Whereas whole plant extracts of associated weeds such as *Cyperus* spp., *O. sativa* var. *fatua* and *M. vaginalis* allelopathically reduced seed germination of *I. miliacea* (Table 13). Jayakumar *et al.* (1988) got similar results on *E. colona* seeds using water extracts of *Amaranthus viridis* and *Boerhaavia diffusa*.

5.2 Part II. Rice-weed competition

5.2.1 Dry matter production of weeds and rice

In unweeded plots the DMP of rice and weed together was significantly lower than that of the crop or weed grown separately. This proved that competition prevented either the weeds or the crop to produce maximum possible dry matter.

Weeds produced more dry matter in *Kharif*, dry sown crop than that in *Rabi*, wet transplanted crop (Fig.7). This might be due to the peculiar ecological conditions of both seasons. A mixed population of weeds emerged along with the dry dibbled rice due to the prevalence of field capacity moisture level favourable for germination of most weed seeds. These weeds have the competitive advantage over rice since they can grow faster and smother the direct sown rice. This view is supported by many workers (Okafor and De Datta, 1974; Pillai and Rao, 1974 and De Datta, 1981).

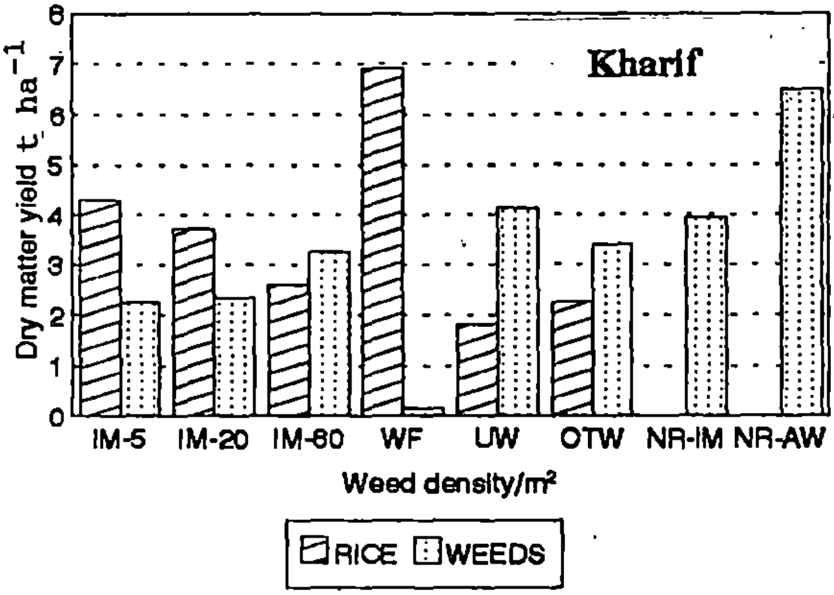
During *Rabi* due to the standing water in the field very few weeds germinated. Only *I. miliacea* grew from the broken slips from the residual weeds of *Kharif* season. When the water level receded this weed spread fast creeping on the ground. Moreover, in transplanted rice the crop is at a competitive advantage over the weeds.

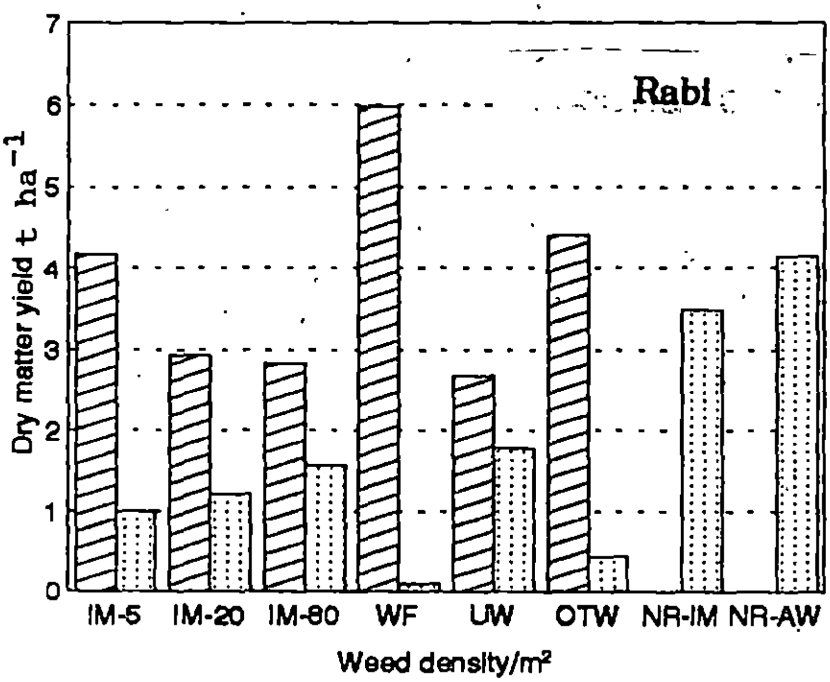
From the ratio of dry weight to fresh weight of various weeds it could be concluded that the fresh biomass produced by *I. miliacea* was double that of other weeds for every unit of dry matter produced. Along with the higher biomass production, the peculiar rooting nature of the weed, created much pressure on the crop as well as on other weeds.

Legend

IM-5	- *Isachne miliacea* 5 plants/m^2
IM-20	- *Isachne miliacea* 20 plants/m^2
IM-80	- *Isachne miliacea* 80 plants/m^2
WF	- Weed free
UW	- Unweeded
OTW	- Weeds other than *Isachne*
NR-IM	- No rice, *Isachne miliacea* alone
NR-AW	- No rice, all weeds

Fig. 7 Influence of weed densities on dry matter yield of rice and weeds at harvest





This result could be further substantiated by the observed reduction in rice DMP at various densities of *I. miliacea*. A low population density (5 plants m^{-2}) of *I. miliacea* reducing rice yield shows the seriousness of the situation created by this weed in rice production.

The growth rate of weeds other than *I. miliacea* was very fast during the first 60 days in the *Kharif* season, thereafter it fell drastically. The population of weeds other than *I. miliacea* was less in the *Rabi* crop and hence the yield reduction was also low.

The DMP of crop and weed was found to be directly related to their nutrient uptake (NPK). Since the crop and weeds competed for nutrients the yield of rice decreased with increased weed dry matter (Fig.8). In unweeded plots weeds accounted for 70 per cent of nutrient uptake in *Kharif* and only 40 per cent in *Rabi* and uptake by rice was 30 and 60 per cent in *Kharif* and *Rabi* respectively.

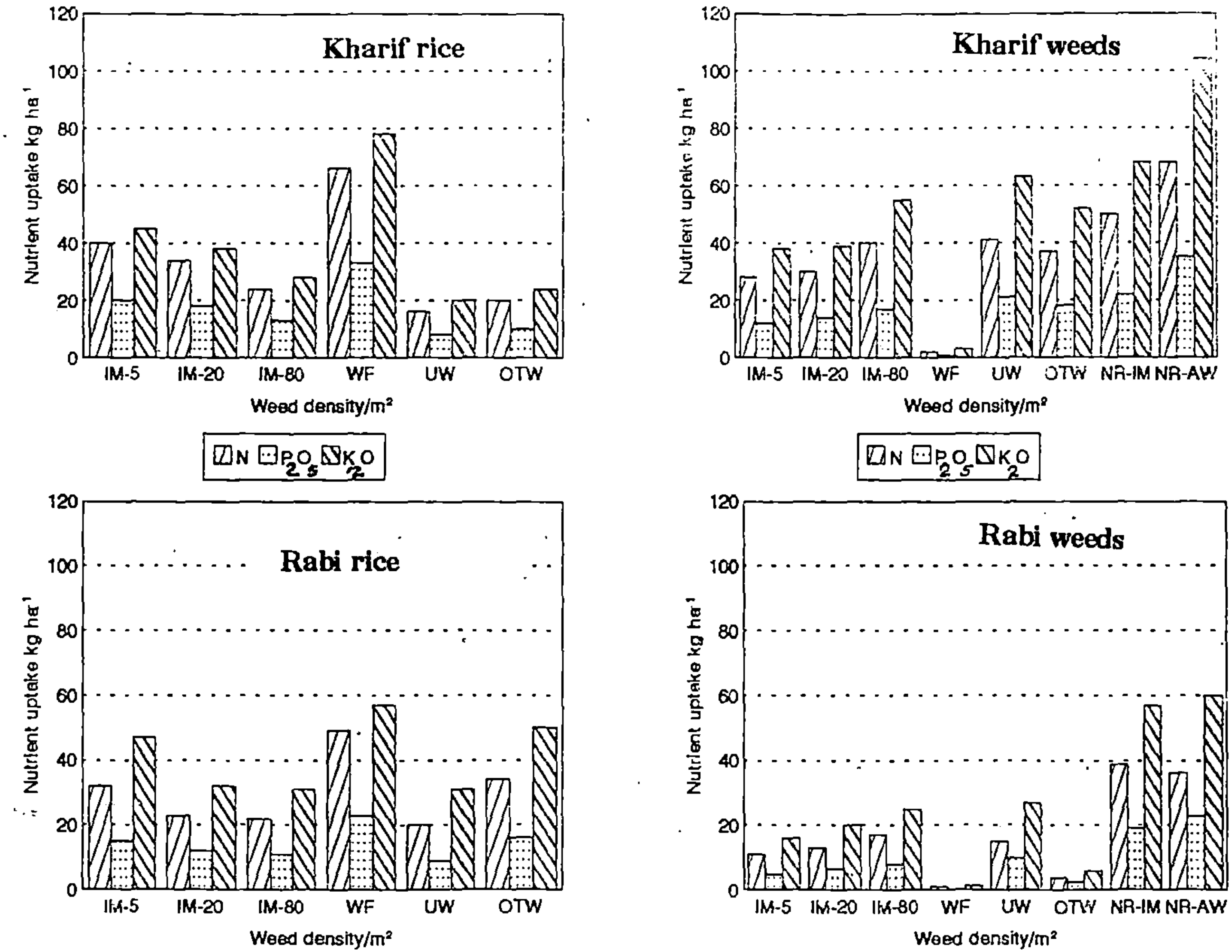
5.2.2 Crop characters as influenced by weed densities

There are controversial reports about the influence of weed competition on plant height of rice. Increase in height due to weed competition was reported by Noda *et al*. (1968) and Zimdahl (1980). Whereas, reduction in plant height due to weed competition was reported by Sreedevi (1979) and Wells and Cabradilla (1981). In the present study there was no appreciable difference in the height of rice even at high densities of *I. miliacea*, whereas the competition of other weeds increased the height of rice plants. This might be due to the competition generated for sunlight between rice and taller weed species.

Legend

IM-5	- *Isachne miliacea* 5 plants/m²
IM-20	- *Isachne miliacea* 20 plants/m²
IM-80	- *Isachne miliacea* 80 plants/m²
WF	- Weed free
UW	- Unweeded
OTW	- Weeds other than *Isachne*
NR-IM	- No rice, *Isachne miliacea* alone
NR-AW	- No rice, all weeds

Fig 8 Nutrient uptake by rice and weeds at harvest



Though the higher densities of *I. miliacea* influenced tillering and LAI of rice, the influence of lower densities were not appreciable in both seasons. This might be due to the increased physical choking by the weed biomass at higher densities. Other weed species were more competitive in *Kharif* at early stages and hence suppressed tillering and LAI of rice. Similar results have been reported by many workers (Okafor and De.Datta, 1974; Sharma *et al.*, 1977; Sreedevi, 1979 and Jayasree, 1987).

Panicle number, length of panicle and number of grains per panicle and 1000 grain weight of rice were reduced by weeds other than *I. miliacea* and *I. miliacea* at 80 plants per square metre in *Kharif* season. Higher densities of *I. miliacea* (20 and 80 m^{-2}) reduced panicle number and length and grains per panicle in *Rabi* crop. Similar results due to weed competition has been reported by Okafor and De Datta (1974), Sharma *et al.* (1977), Sreedevi (1979), Jayasree (1987) and Sahai *et al.* (1983).

5.2.3 Grain and straw yield of rice as influenced by weed densities

Lowest yield of grain and straw was obtained in unweeded plot in both seasons. Yield was low in plots where weeds other than *I. miliacea* grew in *Kharif*. Since weeds other than *I. miliacea* were few in *Rabi* crop, they could not influence yield of rice as in *Kharif*. In *Rabi* the higher densities (20 or 80 m^{-2}) of *I. miliacea* and unweeded conditions had more or less similar effect on the yield reduction of rice. In *Kharif* season a density of 80 *I. miliacea* per square metre was required to reduce the yield to a level of the unweeded control. This was because of the slow growth rate of *I. miliacea* from seeds during first 30 DAS of rice. Whereas during *Rabi* crop the growth of *I. miliacea* was faster from stem cuttings compared to seedlings. These yield reduction were due to less number of panicles and number of grains per panicle. Straw yield of rice also followed the same pattern of grain yield. Similar results have been reported by other workers also (Zimdahl, 1980; Sahai *et al.*, 1983 and Singh *et al.*, 1987).

5.3 Part III. Integrated weed management in rice based cropping system

5.3.1 *Kharif*

5.3.1.1 Effect of weed control treatments on weeds

As evidenced by the weed count on 15 DAS and weed DMP on 30 DAS, it was found that most of the pre-emergence herbicides could effectively control weeds except *O. sativa* var.*fatua*, *E. colona* and *S. interrupta* (Fig.9 and Plates 2 to 9). Pretilachlor was the only chemical that could effectively control *E. colona*, but it was phytotoxic to rice.

Local practice of one hoeing on 15 DAS and HW on 25 DAS, gave maximum weed control efficiency as on 30 DAS, because it controlled the growth of weeds like *E. colona, S. interrupta* and *O. sativa* var. *fatua* which were resistant to herbicides. Though the weed control efficiency in local practice was the highest upto 60 DAS it became the least at harvest time. The high emergence of *I. miliacea* through vegetative multiplication from the broken slips resulting from hoeing or HW, formed the maximum contribution of weed biomass by the end of the cropping season. The pre-emergence herbicides reduced the emergence of *I. miliacea* from seeds itself giving no room for further growth (Plates 2 to 6).

Fig 9 Efficiency of weed control treatments at 30 DAS

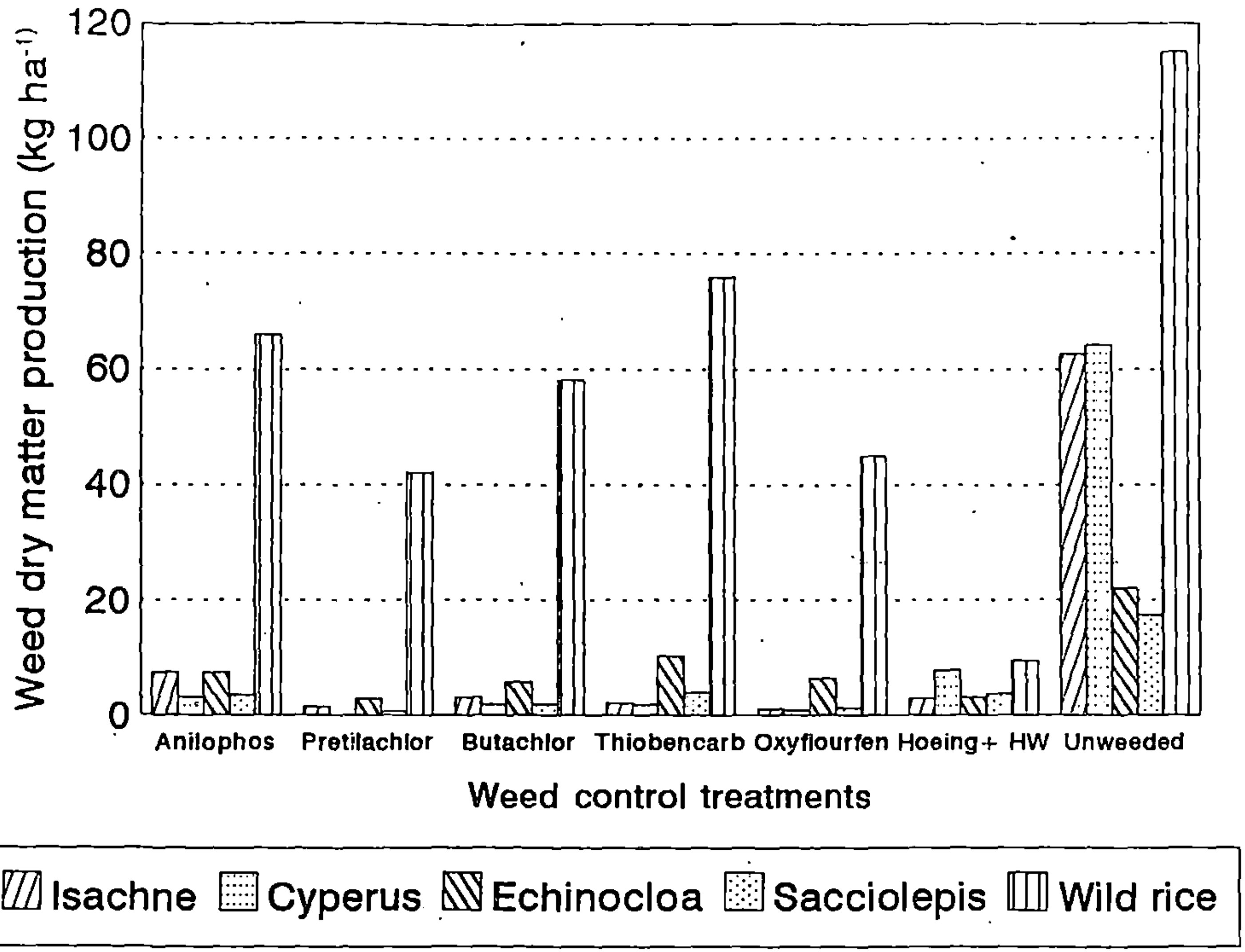
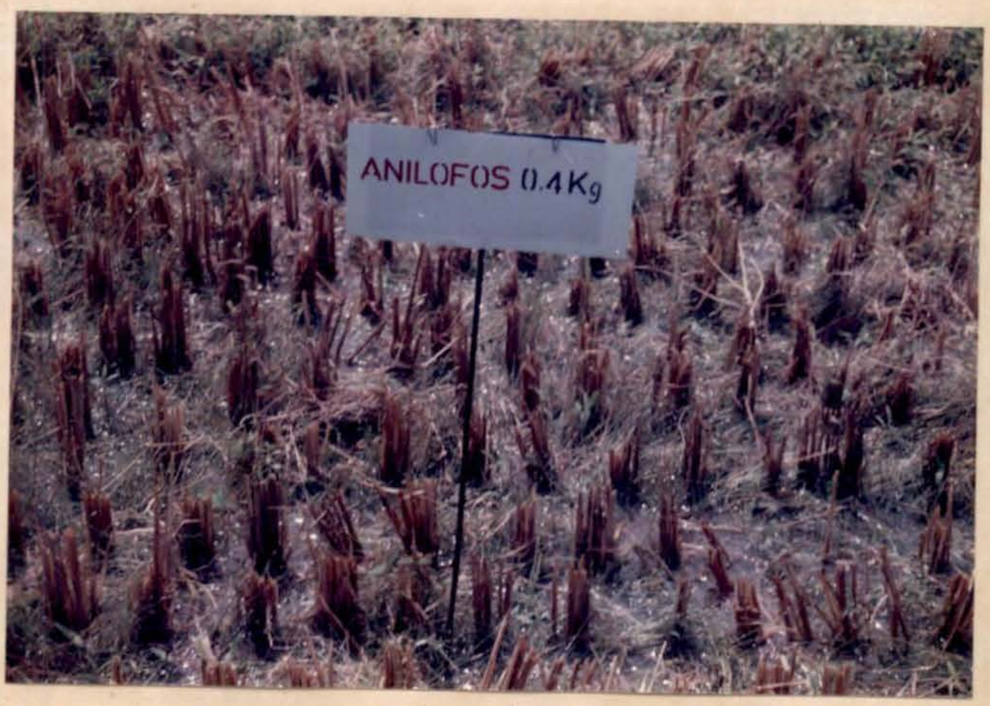


Plate 2. Effect of pre-emergence application of anilofos 0.40 kg ha^{-1} on weed growth

(a) at 20 DAS



(b) at harvest

Plate 3. Effect of pre-emergence application of pretilachlor 0.50 kg ha^{-1} on weed growth

(a) at 20 DAS

(b) at harvest

Plate 4. Effect of pre-emergence application of butachlor 1.25 kg ha^{-1} on weed growth

(a) at 20 DAS

(b) at harvest

Plate 5. Effect of pre-emergence application of thiobencarb 1.25 kg ha^{-1} on weed growth

(a) at 20 DAS

(b) at harvest

Plate 6. Effect of pre-emergence application of oxyfluorfen 0.10 kg ha^{-1} on weed growth

(a) at 20 DAS

(b) at harvest

Plate 7. Effect of local practice of hoeing on 15 DAS and hand weeding on 25 and 40 DAS on weed growth

(a) at 20 DAS

(b) at harvest

Plate 8. Effect of unweeded condition on weed growth

(a) at 20 DAS

(b) at harvest

Plate 9. Effect of weed free condition on weed growth

(a) at 20 DAS

(b) at harvest

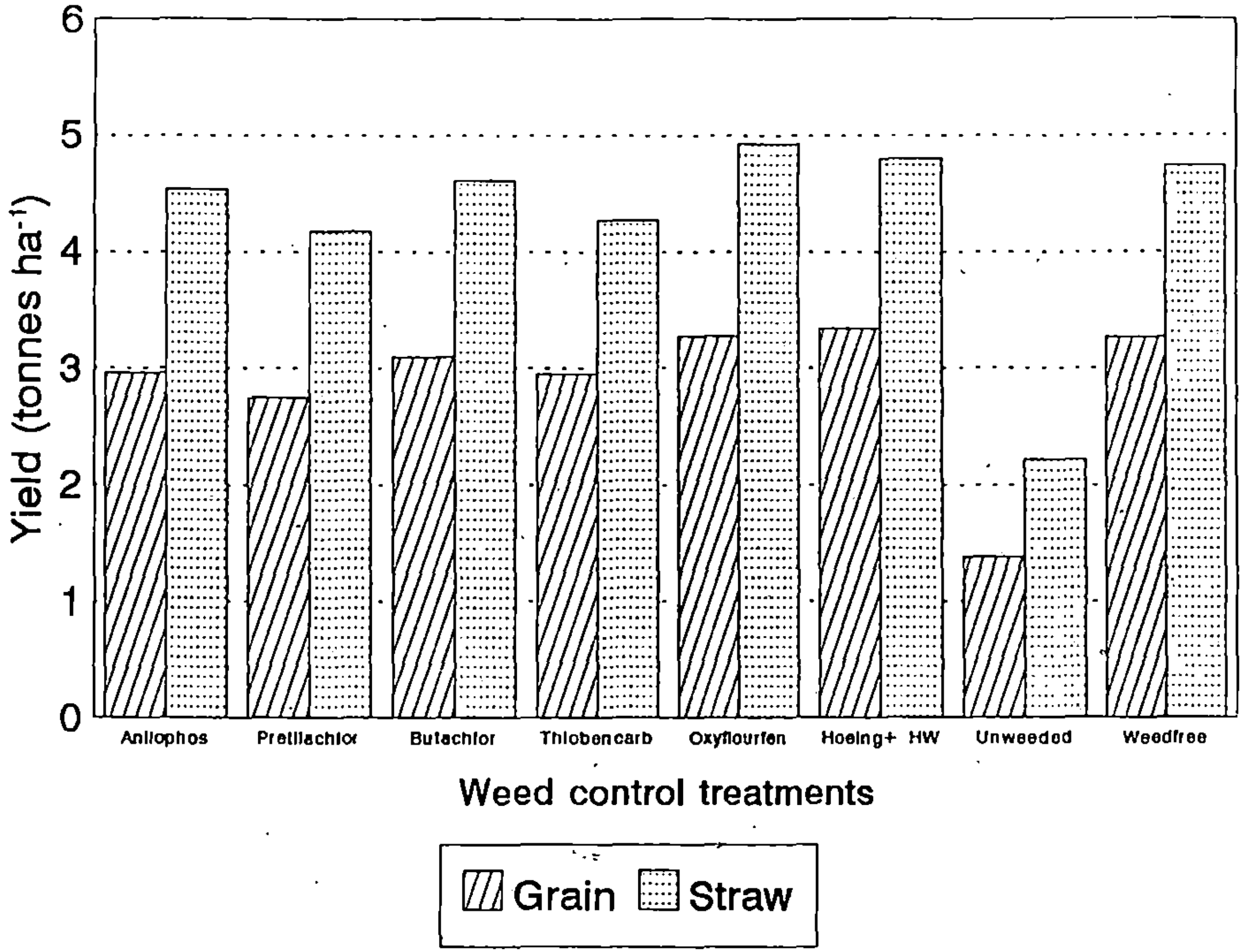
The application of herbicides or the local practice alone could not provide good control over all the weeds studied. And as shown in the results the herbicide spray at pre-emergence followed by HW on 30 DAS gave very good control of all the weeds especially *I. miliacea* upto the harvest time. Similar results have been observed by many workers, where a combination of pre-emergence herbicide followed by HW gave maximum weed control (Misra and Roy, 1971, Bhan *et al.*, 1980, Manipan *et al.*, 1981, Pandey and Singh, 1982, Balyan *et al.*, 1983, Singh and Singh, 1985, Deshmukh *et al.*, 1987 and Vijayaraghavan *et al.*, 1988).

5.3.1.2 Influence of weed control treatments on yield and yield components of rice

The maximum grain and straw yield obtained in the local practice was due to the better weed control efficiency upto 60 DAS which produced maximum tillers, panicles and more number of grains per panicle contributing to higher yields (Fig. 10). Even though oxyfluorfen gave high weed control efficiency on 30 and 60 DAS and at harvest it could not produce the grain yield as obtained in local practice. The local practice of hoeing might have given a dust mulching effect on soil in the dry sown crop and enhanced soil aeration for better root growth and thereby increased the tillering and the number of panicles (340 m^{-2}) resulting in higher yields. Reissig *et al.* (1985) and Sharma *et al.* (1986) also got maximum grain yield with three hand weedings.

Herbicides anilofos, butachlor, oxyfluorfen and thiobencarb were effective in controlling weeds and producing good yields when followed by one HW on 30 DAS. Similar results showing economic yield of rice were obtained by many

Fig 10 Effect of weed control treatments on grain and straw yield of rice during the *Kharif* season



workers (Misra and Roy, 1971, Bhan *et al.*, 1980, Manipan *et al.*, 1981, Pandey and Singh, 1982 and Balyan *et al.*, 1983). The herbicides may be rotated year after year to reduce the resistance developed by weeds. Wherever family labour is available or labour is in plenty, hoeing and HW is still the better method for getting more yield. Since in Kerala labour is costly and weed control being the most expensive operation in rice, only herbicides can help the farmers for economic weed management.

5.3.2 *Rabi*

Though there was no influence on grain and straw yield of *Rabi* rice by the *Kharif* treatments, pretilachlor showed significant control of *I. miliacea* upto harvest of *Rabi* rice. Since the *Rabi* is featured by the stagnant water, the systemic herbicide glyphosate was found to be more useful for controlling *I. miliacea* upto the harvest of rice. This treatment could give the maximum yield of grain and straw (Fig.11). Similar results on the effectiveness of glyphosate have been reported for controlling *Paspalum* in rice (IRRI, 1976, Corbetta *et al.*, 1979, Manuel *et al.*, 1979).

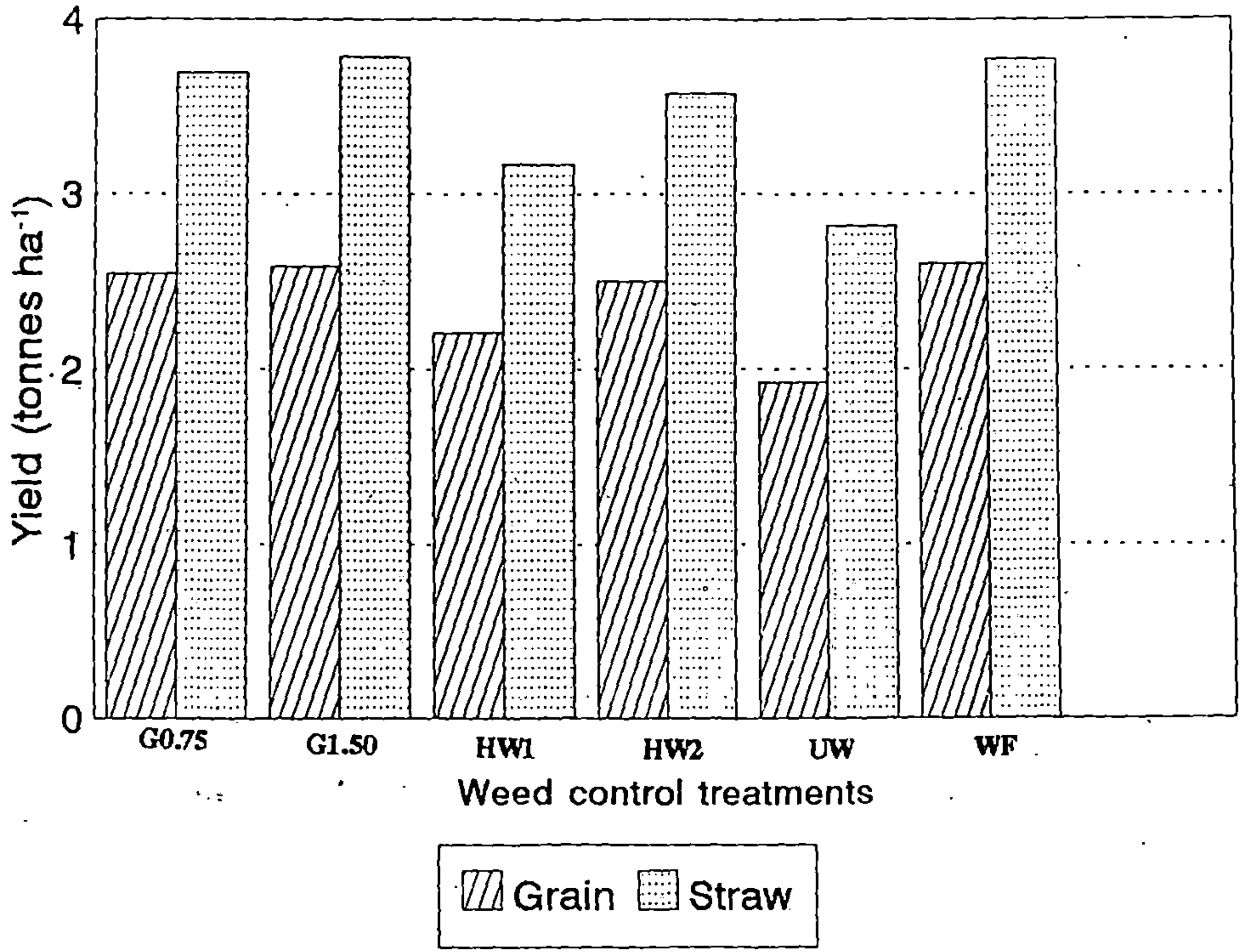
Eventhough two hand weedings were also seen effective as glyphosate treatment in controlling weeds and producing satisfactory yields, glyphosate (0.75 kg ha^{-1}) treatment was found to be more economic (Table 43). In case small bits of weed appear here and there it can be hand picked which will provide a clean crop free from *I. miliacea*. When labour is in plenty or family labour is available HW on 20 and 40 DAT too can be recommended for good yields.

From the study it can be concluded that pre-emergence spray of oxyfluorfen (0.1 kg ha^{-1}) followed by one HW on 30 DAS in *Kharif* season and pre

Legand

G 0.75	- Glyphosate 0.75 kg ha^{-1} pre-plant application
G 1.5	- Glyphosate 1.50 kg ha^{-1} pre-plant application
HW-1	- Hand weeding on 30 DAT
HW-2	- Hand weeing on 20 and 40 DAT
UW	- Unweeded
WF	- Weed free

Fig11 Effect of weed control treatments on grain and straw yield of rice during the Rabi season



plant application of glyphosate (0.75 kg ha^{-1}) on residual weeds after the harvest of the *Kharif* crop could give efficient weed control and economic yield of rice in the rice based cropping system involving 'rice-rice-fallow' of Onattukara region.

5.4 Future line of work

Similar studies on the ecophysiology of weeds like *Echinochloa, Sacciolepis*, wild rice etc. in the various rice ecosystems of the state could be of use for developing the measures to control the mimicry weeds of rice, which are more difficult to control.

Summary

SUMMARY

Isachne miliacea Roth. is the most serious weed in the 28,000 ha of low land rice fields of the coastal sandy Onattukara region, situated in Kollam and Alapuzha districts of Kerala. No work to chalk out methods of controlling this serious weed that affects the rice ecosystem was undertaken. Hence a series of investigations focussing on the ecophysiology and management of *I. miliacea*, were undertaken at the Rice Research Station, Kayamkulam during 1991 to 1994 with the following objectives:

1. Survey the weed flora of the rice ecosystem
2. Study the biology, phenology and ecology of *I. miliacea*
3. Study the seed physiology of *I. miliacea*
4. Study the competitive efficiency of *I. miliacea* in rice and
5. Develop a management strategy for controlling the weeds in the rice based cropping system

The study was undertaken in three parts to achieve the objectives.

Part I. Ecophysiology of *Isachne miliacea*

Weed flora of the rice fields and pests and diseases of *I. miliacea* were studied by survey of the low lands of Onattukara. Germination and propagation studies were done in pots. Germination behaviour of the buried seeds was studied by burying the seeds in terylene bags in rice fields. Allelopathic effects on germination were tested in Petri dishes.

The survey of Onattukara region identified seven weed species that dominated the weed flora in the *Kharif* season. *Isachne miliacea* and *Cyperus* spp.

were the most dominant weeds. More than 90 per cent of the weed population was *I. miliacea* in the *Rabi* season. Two ecotypes of *I. miliacea* were noticed; the pre-dominant one being brown stemmed and the other was green in colour.

Isachne miliacea germinated in April-May with the pre-monsoon showers. Though the weed was slow growing in the beginning, it exhibited faster growth later, by creeping along the ground, rooting at nodes and covering the rice fields. It is a water loving weed with shallow root system and low dry matter content. The weed dries off quickly with the onset of summer in January.

Studies on propagation revealed that submergence of field with water even upto one centimetre prevented the germination of seeds. Seeds germinated only at field capacity moisture and from a maximum depth of five centimetre. Vegetative multiplication of *I. miliacea* can be controlled by plunging the stem cuttings more than five centimetre deep in soil or by maintaining the water level in the field over five centimetre depth.

Seeds of *I. miliacea* had innate dormancy from December to April. Since the full dormancy was found to be breaking in April, the entire seeds of one season will germinate if left undisturbed on soil surface. The weed growth can be controlled very well by spraying a contact herbicide on the fresh sprouts. Burying of the seeds by ploughing induces secondary dormancy and can create weed problem in succeeding crops. Water stagnation from July to November also induced secondary dormancy to seeds. Water stagnation and temperature play a major role in inducing secondary dormancy and the breaking of dormancy. The viability of seeds buried at shallow depths was found to be lost faster compared to those buried deeper.

The aqueous extracts of *I. miliacea* exhibited no allelopathic effect on germination of rice seeds whereas the extracts of *Cyperus* spp., *O. sativa* var. *fatua* and *M. vaginalis* reduced the germination of seeds of *I. miliacea*.

No serious pests and diseases were noticed on *I. miliacea*. A grass hopper (*Oxya chinensis*) and a plant hopper (*Nephotetix* sp.) was found feeding on the weed.

Part II. Rice-weed competition

Crop weed competition studies were conducted in *Kharif* and *Rabi* for two years using a randomised block design. The analysis of the impact of weeds suggest that the reduction in the DMP of rice was much higher in *Kharif* (74%) compared to *Rabi* (55%) with a mixed weed population. Even a low infestation of five plants per metre square of *I. miliacea* could produce appreciable biomass causing a substantial reduction in rice DMP. The DMP of crop and weed was found to be related to the uptake of nutrients N, P and K. The grain and straw yield reduction of rice was due to reduced number of tillers, panicles and grains per panicle.

Part III. Integrated weed management in rice based cropping system

Integrated weed management trial was conducted in a split plot design in three randomised blocks. *Kharif* season treatments formed main plots for *Rabi* trial. In *Kharif* five pre-emergence herbicides followed by one HW on 30 DAS were compared with local practice and unweeded control.

The pre-emergence herbicides anilofos 0.40 kg, butachlor 1.25 kg, thiobencarb 1.25 kg and oxyfluorfen 0.10 kg per hectare followed by HW on 30 DAS produced satisfactory rice yields. But maximum grain yield was obtained from local practice of one hoeing on 15 DAS and two hand weedings on 25 and 40 DAS. The spraying of oxyfluorfen followed by HW on 30 DAP ranked next in yield.

Local practice of hoeing and HW was not effective in checking the build up of *I. miliacea* towards the latter half of the *Kharif* season. But the herbicides were found to be more effective in controlling this weed. Pretilachlor, though caused phytotoxicity, was the efficient herbicide against *E. colona*. None of the herbicides was effective against wild rice.

During *Rabi* pre-plant spray of glyphosate and hand weedings were compared in six sub plots. Pre-plant application of glyphosate immediately after the harvest of *Kharif* gave good control of *I. miliacea* and produced maximum grain and straw yield in *Rabi* crop. Eventhough the *Kharif* treatments had no influence on grain yield of *Rabi* crop, pretilachlor 0.50 kg ha^{-1} could reduce to DMP of *I. miliacea* upto harvest of *Rabi* rice.

From the study it can be concluded that pre-emergence spraying of oxyfluorfen at the rate of 0.1 kg ha^{-1} followed by one HW on 30 DAS in *Kharif* and pre plant application of glyphosate at the rate of 0.75 kg ha^{-1} on residual weed flora immediately after the harvest of the *Kharif* crop controls the weeds effectively and gives an economic return of rice in a rice based cropping system involving 'rice-rice-fallow' of Onattukara.

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Appendices

APPENDIX-I

Weather data during 1992, 1993 and sixteen years mean from 1975-1991

	Temperature (°C)					
	Maximum			Minimum		
	1992	1993	16 year	1992	1993	16 year
January	33.44	32.90	33.32	16.58	14.12	18.34
February	32.88	32.93	34.01	19.83	16.48	20.17
March	34.10	34.08	34.58	20.05	18.45	22.23
April	34.34	33.96	33.99	21.58	19.70	23.13
May	32.10	32.53	33.08	21.40	19.33	22.85
June	30.48	29.88	30.88	20.68	18.30	21.73
July	29.20	29.70	30.45	19.18	17.58	21.25
August	29.80	30.15	30.69	19.86	18.03	21.39
September	30.48	30.95	31.28	19.55	22.78	21.33
October	30.86	30.88	31.53	19.38	22.96	21.17
November	31.30	31.05	32.22	18.88	22.93	20.06
December	32.90	31.80	33.12	16.13	22.05	18.79
	Rain (mm)			RH (%)		
January	-	-	7.81	68.4	67.2	68.4
February	2.6	2.0	12.46	71.3	72.8	70.8
March	-	13.5	28.82	72.3	72.8	73.5
April	140.1	63.0	101.68	73.4	73.8	76.4
May	313.2	251.2	293.38	83.8	81.8	81.0
June	807.3	895.4	612.38	85.2	86.2	86.4
July	425.2	424.7	321.17	86.5	86.5	85.3
August	227.9	137.0	245.05	87.0	83.8	84.8
September	280.6	90.4	238.86	83.8	80.3	82.3
October	345.1	502.0	294.50	84.0	83.2	82.2
November	290.8	347.3	91.95	81.8	81.5	77.8
December	-	61.0	27.38	66.8	76.8	71.8

APPENDIX-II

Mean weed count m^{-2} on 30 DAS in *Kharif* in different locations of Onattukara

Locations/ Weed species	1	2	3	4	5	6	7	8	9	10
I. miliacea	280	187	177	115	95	134	140	210	70	78
Cyperus spp.	140	165	203	158	160	140	118	142	108	125
E. colona	30	11	10	15	16	23	19	19	12	15
S. interrupta	26	11	8	17	7	18	17	14	12	12
O. sativa var. *fatua*	10	10	1	1	2	8	-	3	9	10
M. vaginalis	11	5	3	3	4	4	5	3	4	14
L. parviflora	8	3	2	-	3	3	2	4	2	6
Total	505	392	404	309	287	330	301	395	217	260

1. Kayamkulam
2. Chettikulangara
3. Thekkekara
4. Chepad
5. Haripad
6. Ochira
7. Thazhava
8. Karunagapally
9. Karthikapally
10. Pathiyoor

APPENDIX-III

Soil test data of Onattukara

Locations	Variables				
	pH	Electrical conductivity (millimhos/cm)	Organic carbon (%)	Average P_2O_5 (kg/ha)	Average K_2O (kg/ha)
Haripad	5.8	0.20	0.18	31	80
Pallipad	5.8	0.21	0.17	32	83
Pathiyoor	6.0	0.10	0.11	31	67
Muthukulam	6.1	0.20	0.19	31	53
Kayamkulam	4.8	0.22	0.24	31	61
Bharanikavu	6.1	0.30	0.34	31	67
Mavelikara	5.9	0.28	0.20	31	67
Karunagapally	5.8	0.33	0.20	33	60
Manapally	6.0	0.29	0.21	32	62
Krishnapuram	6.0	0.28	0.19	33	66

APPENDIX-IVa

Nutrient content NPK(%) of crop and weed at harvest of rice during *Kharif*

Treatments	N		P_2O_5		K_2O	
	1992	1993	1992	1993	1992	1993
			Crop - Grain			
1	1.188	1.188	0.755	0.678	0.492	0.475
2	1.193	1.177	0.773	0.715	0.460	0.448
3	1.175	1.190	0.743	0.698	0.450	0.440
4	1.223	1.195	0.760	0.713	0.527	0.490
5	1.177	1.185	0.705	0.688	0.460	0.430
6	1.183	1.177	0.735	0.665	0.483	0.447
			Crop - Straw			
1	0.685	0.670	0.270	0.255	1.52	1.58
2	0.655	0.663	0.275	0.252	1.51	1.56
3	0.632	0.680	0.255	0.253	1.50	1.53
4	0.722	0.767	0.255	0.273	1.64	1.66
5	0.668	0.635	0.258	0.255	1.51	1.60
6	0.653	0.638	0.265	0.265	1.51	1.51
			Weed			
1	1.240	1.262	0.523	0.538	1.695	1.688
2	1.255	1.290	0.573	0.522	1.683	1.683
3	1.230	1.250	0.510	0.525	1.678	1.685
4	1.300	1.310	0.515	0.515	1.528	1.525
5	1.008	0.980	0.502	0.522	1.503	1.522
6	1.078	1.072	0.515	0.543	1.548	1.543
7	1.267	1.290	0.538	0.585	1.748	1.715
8	1.045	1.065	0.532	0.532	1.603	1.582

APPENDIX-IVb

Nutrient content NPK(%) of crop and weed at harvest of rice during *Rabi*

Treatments	N		P_2O_5		K_2O	
	1992	1993	1992	1993	1992	1993
			Crop - Grain			
1	1.162	1.150	0.653	0.573	0.477	0.390
2	1.167	1.165	0.670	0.653	0.462	0.400
3	1.175	1.170	0.642	0.612	0.460	0.410
4	1.198	1.188	0.657	0.640	0.462	0.405
5	1.172	1.155	0.633	0.598	0.452	0.412
6	1.178	1.171	0.633	0.588	0.475	0.415
			Crop - Straw			
1	0.573	0.563	0.247	0.230	1.480	1.442
2	0.553	0.565	0.250	0.227	1.463	1.442
3	0.530	0.573	0.245	0.225	1.452	1.403
4	0.617	0.605	0.238	0.242	1.450	1.412
5	0.597	0.570	0.242	0.237	1.455	1.415
6	0.593	0.575	0.240	0.230	1.470	1.420
			Weeds			
1	1.085	1.088	0.560	0.520	1.630	1.620
2	1.073	1.077	0.563	0.505	1.640	1.630
3	1.053	1.083	0.567	0.500	1.643	1.595
4	1.135	1.150	0.578	0.520	1.417	1.565
5	0.853	0.847	0.560	0.535	1.520	1.475
6	0.835	0.845	0.552	0.553	1.447	1.437
7	1.155	1.093	0.563	0.547	1.645	1.625
8	0.875	0.840	0.547	0.542	1.490	1.382

Crop weed competition - Rabi

Character Rice Source	Df Individual	Df Pooled	30 DAT 1992	30 DAT 1993	30 DAT Pooled
Dry matter					
Year		1			14008.0
Treatment	5	5	16976.7*	22407.5*	38811.6*
Interaction		5			572.0
Error/P. error	15	30	602.8	1167.50	885.17
Rate of DMP					
Year		1			5.20
Treatment	5	5	5.507*	7.426*	12.67*
Interaction		5			0.27
Error/P. error	15	30	0.207	0.383	0.30
Uptake of nutrients				Nitrogen	
Year		1			4.39
Treatment	5	5	495.1*	403.24*	974.41*
Interaction		5			3.93
Error/P. error	15	30	7.13	3.57	5.35

Contd.

APPENDIX-V

Details of herbicides used in this trial

1. Anilofos

Chemical name	S[N-(4 chlorophenyl)-N-isopropyl carbomoyl methyl]-0,0-dimethyl dithiophosphate
Herbicide family	Organo phosphorus
Manufacturer	Gharda Chemicals Ltd.
Trade name	Anilogaurd
Formulation	30 EC

2. Pretilachlor

Chemical name	2, chloro-2,6 diethyl-N-(2 propoxy ethyl acetanilide)
Herbicide family	Anilides
Manufacturer	CIBA GEIGY
Trade name	Rifit
Formulation	50 EC

3. Butachlor

Chemical name	N-(butoxy methyl)-2 chloro-2',6'-diethyl acetanilide
Herbicide family	Amides
Manufacturer	Pest Control Co.
Trade name	Butachlor
Formulation	50 EC

Source:

WSSA, 1983. *Herbicide Handbook of the Weed Science Society of America*. pp.515

4. Thiobencarb

Chemical name	S[C4-chlorophenyl) methyl] diethyl carbamothiate
Herbicide family	Thiocarbomates
Manufacturer	Pesticides India Ltd.
Trade name	Saturn
Formulation	50 EC

5. Oxyfluorfen

Chemical name	2-Chloro-1-(3-ethoxy-4 nitrophenoxy)-4-(trifluor methyl) benzene
Herbicide family	Diphenyl ethers
Manufacturer	Indofil Chemicals
Trade name	Goal
Formulation	23.5 EC

6. Glyphosate

Chemical	N-phospho-methyl glycine isopropyl amine salt of glyphosate
Manufacturer	Monsanto
Trade name	Roundup
Formulation	41. S.L

APPENDIX-VI

Abstractsof analysis of variance tables

Crop weed competition - Kharif

Character weeds	Df		Mean sum of squares		
			30 DAS		
	Individual	Pooled	1992	1993	Pooled
Source Dry matter					
Year		1			1914.00
Treatment	7	7	102467.4*	12404.07*	225837.3*
Interaction		7			671.21
Error/P error	21	42	1112.65	1664.88	1388.76
Rate of weed DMP					
Year		1			2.14
Treatment	7	7	113.88*	137.83*	250.97*
Interaction		7			0.74
Error/P error	21	42	1.236	1.85	1.54
Uptake of nutrients				Nitrogen	
Year		1			52.55
Treatment	7	7	1512.44*	1399.52*	2906.42*
Interaction		7			5.54
Error/P Error	21	42	19.32	15.92	17.62
Highest of weeds at harvest					
Year		1			6.89
Treatment	7	7	7784.91*	8123.85*	15887.8*
Interaction		7			20.93
Error/P Error	21	42	19.49	17.23	18.36

Contd.

Mean sum of squres					
60 DAS			At harvest		
1992	1993	Pooled	1992	1993	Pooled
		752.00			553088.0
6370828.6*	5248698.2*	11441500.0*	13955233.9*	2764939199.5*	26529740.0*
		178032.00			49792.0
30146.4	38877.97	34512.00	136354.2	275583148.7	111643.40
		0.06			374.18
5474.436*	4302.18*	9586.01*	1472.97	1681.14*	3036.85*
		190.60			117.26
30.158	44.50	37.33	111.64	130.56	121.10
Phosphorus			Potash		
		2.54			167.33
389.46*	358.42*	746.11*	3560.48*	3130.45*	6673.67*
		1.77			17.26
5.69	5.68	5.68	36.92	23.49	30.20

Contd.

Character Rice source	Df Individual	Df Pooled	30 DAS 1992	30 DAS 1993	30 DAS Pooled
Dry matter					
Year		1	5621.04*	419.37	
Treatment	5	5			
Interaction		5			
Error/P. error	15	30	1817.71	342.71	
Rate of DMP					
Year		1			
Treatment	5	5	4.535*	0.464	
Interaction		5			
Error/P. error	15	30	1.223	0.382	
Uptake of nutrients				Nitrogen	
Year		1			
Treatment	5	5	1272.01*	1423.06*	
Interaction		5			
Error/P. error	15	39	32.31	5.140	

Contd.

60 DAP			At harvest		
1992	1993	Pooled	1992	1993	Pooled
		396944.0			
2449856.67*	4163676.04*	637712.30*	13430574.2*	15088976.7*	
		236409.6			
90756.67	52043.8	71399.87	425827.5	84103.33	
		577.77			1220.12
2480.39*	4570.34*	6766.97**	2764.97	2207.54	28.42*
		283.77			23.01
107.29	60.57	83.93	143.94	9.33	76.64
Phosphorus			Potassium		
326.88*	342.12*		1780.81*	1879.99*	
9.45	2.190		42.54	6.07	

Contd.

Character	Df		Height of crop at harvest		
Source	Individual	Pooled	1992	1993	Pooled
Year		1			58.50
Treatment	5	5	25.80*	24.04*	205.59*
Interaction		5			43.63
Error/P. error	15	30	6.89	6.55	7.01
			No. of panicles/m^2		
Year		1			
Treatment	5	5	4007.84*	6894.2*	
Interaction		5			
Error/P. error	15	30	1376.91	339.7	
			Number of grains/panicle		
Year		1			70.08
Treatment	5	5	200.10*	1313.67*	311.95
Interaction		5			19.53
Error/P.error	15	30	37.01	33.88	35.44

Contd.

Total tiller on 60 DAS			LAI on 60 DAS		
1992	1993	Pooled	1992	1993	Pooled
					0.02
1079.24	1796.97*		0.162*	0.232*	0.37*
					0.02
832.62	177.50		0.007	0.007	0.01
Length of panicle			**No.of spikelets/panicle**		
		1.40			52.09
2.728*	3.653*	6.14*	266.26*	212.30*	457.68*
		0.25			20.88
0.795	0.281	0.54	59.53	52.30	55.92
Grain yield			**Straw yield**		
2871357.5*	3277196.7*		3735500.0*	4087666.7*	
91566.4	26574.4		113222.2	33233.3	

Crop-weed competition - Rabi

Character Weeds Sources	Df Individual	Df Pooled	60 DAT 1992	60 DAT 1993	60 DAT Pooled
Dry matter					
Year		1			
Treatment	7	7	194025.38*	220351.5*	
Interaction		7			
Error/P. error	21	42	1127.14	339.5	
Rate of weeds DMP					
Year		1			7.56
Treatment	7	7	251.61*	251.69*	466.43*
Interaction		7			0.87
Error/P. error	21	42	1.251	0.594	0.92
Uptake of nutrients			Nitrogen		
Year		1			
Treatment	7	7	755.19*	770.327*	
Interaction		7			
Error/P. error	21	42	2.112	10.486	
Height of weeds at harvest					
Year		1			74.39
Treatment	7	7	3147.55*	2870.10*	6012.48*
Interaction		7			5.18
Error/P. error	21	42	11.06	8.69	9.88

Contd.

60 DAT			At harvest		
1992	1993	Pooled	1992	1993	Pooled
		20848.0			
2434616.85*	2662655.3*	5196206.0*	7702769.64*	8511506.7*	
		1065.1			
6305.54	6868.7	6587.3	8575.60	41417.4	
		2.59			13.17
1558.01*	1585.63*	3143.33*	744.058*	843.152*	1578.72*
		0.31			8.50
6.377	6.589	6.48	10.12	10.607	10.36
Phosphorus			Potash		
235.645*	255.40*		1839.86*	1860.05*	
0.736	1.804		2.911	14.09	

Contd.

60 DAT			At harvest		
1992	1993	Pooled	1992	1993	Pooled
		341712.0			67456.0
1888876.7*	2122284.1*	4006451.10*	6707104.2*	6349854.2*	13013840.0*
		4710.4			43136.0
16303.3	18937.5	17620.27	95381.9	61298.6	78337.07
		247.47			
1759.71*	1937.54*	3692.09*	776.3*	631.07*	
		5.16			
15.74	16.34	16.02	43.93	9.95	
Phosphorus			Potash		
		9.85			
99.87*	103.23*	201.73*	514.0*	626.8*	
		1.37			
1.66	1.45	1.56	119.0	10.11	

Contd.

Character Crop Sources	Df Individual	Df Pooled	Height of crop at harvest 1992	1993	Pooled
Dry matter					
Year		1			14.09
Treatment	5	5	23.94*	13.475*	29.73
Interaction		5			7.68
Error/P. error	15	30	6.59	1.364	3.98
			No. of panicle/m²		
Year		1			4129.66
Treatment	5	5	4638.57*	16334.17*	1831.5*
Interaction		5			1113.53
Error/P. error	15	30	570.31	125.28	347.79
			No. of grains/plant		
Year		1			63.03
Treatment	5	5	250.80*	188.14*	433.07*
Interaction		5			5.87
Error/P. error	15	30	40.20	41.63	40.92

Contd.

Total tiller on 60 DAT			LAI on DAT		
1992	1993	Pooled	1992	1993	Pooled
		20008.5			
2873.10*	5650.07*	7094.85*	0.085*	0.035*	
		1428.3			
385.34	348.31	366.83	0.005	0.002	
Length of panicle			No. of spikelets/panicle		
		56.98			
5.131*	4.369*	9.37*	377.34*	282.86*	
		0.13			
0.246	0.406	0.33	66.08	71.20	
Grain yield			Straw yield		
		2552.0			96320.00
881166.67*	1167687.5*	2027301.0*	2789187.5*	2183666.7*	4920179.00*
		21522.0			52672.00
12000.0	10687.5	11344.0	62854.2	50777.8	56815.47

Integrated Weed Management in rice in Onattukara - Kharif

Characters Weed count 15 DAS Source	Df Individual	 Pooled	Isachne miliacea 1992	 1993	 Pooled
Year		1			
Treatment	7	7	55767.3*	67103.1*	
Interaction		7			
Error/P. error	14	28	1781.7	590.2	
			Sacciolepis interrupta		
			1992	1993	Pooled
Year		1			0.20
Treatment	7	7	569.2*	545.05*	23.01*
Interaction		7			0.24
Error/P. error	14	28	102.99	27.17	0.53
Weed dry weight on 30 DAS			**Isachne miliacea**		
			1992	1993	Pooled
Year		1			904.30
Treatment	7	7	680.84*	2264.04*	116.95*
Interaction		7			77.33
Error/P. error	14	28	70.73	21.685	46.21

Contd.

Cyperus spp			Echinochloa colona		
1992	1993	Pooled	1992	1993	Pooled
					0.32
9535.9*	20196.6*		377.52*	296.76*	12.56*
					0.53
3414.9	435.5		17.80	24.11	0.35

Oriyza sativa var. fatua			Total weeds		
1992	1993	Pooled	1992	1993	Pooled
144.14	27.238		138533.24*	220463.7*	
216.60	30.113		2849.58	2344.03	

Cuperus spp			Echinochloa colona		
1992	1993	Pooled	1992	1993	Pooled
					883.14
538.89*	1452.21*		27.62*	322.286*	260.98*
					88.93
107.94	34.22		9.11	13.93	11.52

Contd.

Weed dry weight 30 DAS Source	Df Individual	Df Pooled	Sacceolepis intrrupta 1992	1993	Pooled
Year		1			373.25
Treatment	7	7	18.71*	222.55*	182.03*
Interaction		7			57.23
Error/P. error	14	28	4.42	2.71	3.56
			Dry weight of weeds 60 DAS		
			1992	1993	Pooled
Year		1			
Treatment	7	7	9701100.3*	7874014.4*	
Interaction		7			
Error/P. error	14	28	110002.8	35904.0	
			No. of panicle/m²		
			1992	1993	Pooled
Year		1			
Treatment	7	7	1846.9*	8089.7*	
Interaction		7			
Error/P. error	14	28	1094.4	261.2	

Contd.

Oryza sativa var. fatua			Total weeds		
1992	1993	Pooled	1992	1993	Pooled
		12447.5			14731.1
2148.6	6669.1*	7374.7*	8161.26*	44119.9*	14058.1*
		1442.9			2655.9
904.12	463.5	683.8	1388.63	404.6	896.6
Weed Dry Weight			**At harvest**		
1992	1993	Pooled	1992	1993	Pooled
					93.53
9867495.2*	8723790.5*		22.952	99.137*	86.67*
					35.42
75352.4	36781.6		24.01	13.137	18.57
Length of panicle			**No. of grains/panicle**		
1992	1993	Pooled	1992	1993	Pooled
		6.02			520.09
3.551	7.270*	9.53*	196.37	303.5*	471.91*
		1.29			27.99
1.495	0.819	1.16	81.23	35.5	58.34

Contd.

Characters	Df		No. of chaff/panicle		
Source	Individual	Pooled	1992	1993	Pooled
Year		1			
Treatment	7	7	5.327	5.75	
Interaction		7			
Error/P. error	14	28	21.310	5.72	

			Grain yield		
			1992	1993	Pooled
Year		1			
Treatment	7	7	1507463.4*	998785.5*	
Interaction		7			
Error/P. error	14	28	219937.5	21099.2	

Contd.

Grain chaff ratio			Straw yield		
1992	1993	Pooled	1992	1993	Pooled
		0.39			
0.305	0.569	0.83	3497139.5*	1402088.6*	
		0.49			
0.194	0.262	0.23	396233.3	47423.1	

Disease score			Herbicide toxicity rating		
1992	1993	Pooled	1992	1993	Pooled
					0.02
2.232*	0.952*		10.452*	10.518*	20.95*
					0.02
0.768	0.167		0.185	0.071	0.13

Integrated weed management - Rabi

	Df	DMP of weeds at harvest		Grain yield	
		1992	1993	1992	1993
Replication	2	0.0635986	0.0004425	243.0586	12.92578
T (Mainplot)	7	0.01168387	0.0057754	2.725447	17.55357
Error-1	14	0.00188391	0.0115051	17.7673	21.22824
t (Subplot)	5	12.43961	14.34009	240.2797	132.5703
Tt	35	0.009012278	0.010861	2.488616	2.58928
Error-2	80	0.009666157	0.010298	1.95166	3.9409

	Df	Straw yield	
		1992	1993
Replication	2	793.3985	13.34375
T (Mainplot)	7	5.23437	38.65625
Error-1	14	55.0904	37.48996
t (Subplot)	5	638.7406	192.2281
Tt	35	5.7084	4.396875
Error-2	80	7.98105	4.504102

ABSTRACT

Isachne miliacea Roth is the most dominant weed in the 28,000 ha of low land rice fields of the coastal sandy Onattukara region, situated in Kollam and Alapuzha districts of Kerala. A series of investigations were undertaken at Rice Research Station, Kayamkulam, during 1991 to 1994 with the objective to identify the major weeds in the rice ecosystem and to bring out the ecophysiology of *I. miliacea* and to find out a suitable weed management strategy for the rice based cropping system of Onattukara.

Isachne miliacea was found to be the dominant weed in rice during *Kharif* and *Rabi* seasons. The weed seeds germinate in April-May, attains its peak vegetative growth in July and flowers in October. The seeds mature in November and the plants dry off in January with the onset of summer.

The weed is propagated by seeds and stem cuttings. Germination of seeds can be prevented by submerging the seeds in the area in water even to a depth of one centimetre. The forcing of the stem cuttings of *I. miliacea* to a depth of five centimetre below the soil surface or maintaining a submergence for more than five centimetre can effectively check the vegetative multiplication of the weed.

Seeds attained physiological maturity in November and remained dormant upto March. Seeds of the season that remain on the surface germinate fully in April-May with the pre-monsoon showers while the buried seeds remain dormant. Burying the seeds to more than five centimetre depth and water stagnation in July to November induced secondary dormancy. Viability of the seeds was lost faster at shallow depth of burial.

Crop weed competition studies were conducted in *Kharif* and *Rabi* for two years with different densities of *I. miliacea*. Weed competition was severe in dry dibbled *Kharif* compared to wet transplanted *Rabi*. Even a small density of five *I. miliacea* plants per square metre produced appreciable biomass and reduced the DMP of rice substantially.

Integrated weed management study was conducted in *Kharif* and *Rabi* for two years in a split-plot design in three randomised blocks. *Kharif* season treatments formed the main plots for *Rabi* trial. In *Kharif* five pre-emergence herbicides were compared with local practice. Local practice of hoeing on 15 DAS and HW twice on 25 and 40 DAS gave maximum grain yield. Application of oxyfluorfen 0.1 kg ha^{-1} followed by HW on 30 DAS was on par with local practice and ranked second. The performance of other herbicides anilofos 0.40 kg, butachlor 1.25 kg and thiobencarb 1.25 kg per hectare were also satisfactory when followed by one HW on 30 DAS. Pretilachlor 0.50 kg ha^{-1} was phytotoxic to rice. The tested herbicides effectively controlled *I. miliacea* upto harvest of rice compared to local practice.

During *Rabi* the effect of pre-plant spray of glyphosate and hand weedings were compared. Among the treatments a pre-plant spray of glyphosate after harvest of *Kharif* controlled *I. miliacea* best and gave maximum rice yield in *Rabi* season. *Kharif* treatments did not show any significant influence on yield of rice during *Rabi*.

From the study it could be concluded that pre-emergence spray of oxyfluorfen 0.1 kg ha^{-1} followed by one HW on 30 DAS in *Kharif* and pre-plant application of glyphosate 0.75 kg ha^{-1} on residual weeds immediately after the harvest of the *Kharif* crop gave efficient weed control and economic yield of rice in the rice based cropping system involving rice-rice-fallow of Onattukara region.