INTEGRATED WEED MANAGEMENT FOR RICE BASED CROPPING SYSTEM OF ONATTUKARA TRACT

BY

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THESIS

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2000

DECLARATION

I hereby declare that this thesis entitled **"Integrated weed management for rice based cropping system of Onattukara tract"** 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, associateship, fellowship or other similar title, of any other University or Society.

Vellayani,
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CERTIFICATE

Certified that this thesis entitled **"Integrated weed management for rice based cropping system of Onattukara tract"** is a record of research work done independently by **Mr. Rajan. S.** under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to him.

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LIST OF ABBREVIATIONS

@	-	At the rate of
mg	-	Milligram
g	-	Gram
kg	-	Kilogram
ha	-	Hectare
ai	-	Active ingredient
mm	-	Milli metre
cm	-	Centi metre
m	-	Metre
cc	-	Cubic centimetre
%	-	Per cent
°C	-	Degree Celsius
t	-	Tonnes
N	-	Nitrogen
P	-	Phosphorus
K	-	Potassium
DAS	-	Days after sowing
DAT	-	Days after transplanting
EC	-	Emulsifiable concentrate
2,4-D	-	2,4 Dichloro phenoxy acetic acid
Fig.	-	Figure
LAI	-	Leaf Area Index
DMP	-	Dry matter production
CGR	-	Crop growth rate
RGR	-	Relative growth rate

INTRODUCTION

1. INTRODUCTION

Rice (*Oryza sativa* L.) occupying a prime position among cereal food crops is grown under diversified situations. It is an important component of most of the crop rotations practiced in Kerala (Pillai, 1993). Weeds are real menace in such cropping systems. The problem of weeds has become aggravated due to the introduction of early-maturing, photo insensitive and fertilizer responsive varieties coupled with intensive cultural practices. Weeds are supposed to be the foremost factor that inflict heavy yield reduction which varies around 15 to 20 per cent in transplanted rice, 30 to 35 per cent in direct sown puddled rice and more than 50 per cent in direct-seeded rice (Pillai and Rao, 1974). Besides weeds remove considerable amount of nutrients from soil and cause enormous losses in the yield of crop plants (Bhan and Mishra, 1993). Thus weed management is an important practice in the process of cultivation of field crops. Weed problem varies with irrigated and rainfed situations and weed management technology is to be provided accordingly (Bhan, 1992).

The Onattukara tract spread over parts of Mavelikkara, Karunagapally and Karthikapally Taluks of Kollam and Alappuzha districts comes under the humid greyish Onattukara agroclimatic zone of Kerala, designated as a problem area. The soil is sandy loam in texture with low water holding capacity and belongs to order Entisol. The soil is porous, acidic in nature with poor organic matter content and low nutrient status. Water table is high in most of the locations and drainage is a problem. Water table reaches the surface during rainy season and recedes 2 to 3 m during summer. The Onattukara tract consists of a cultivated area of 68340 ha of which 28340 ha is under rice. Rice based cropping system is popular in the tract where farmers raise dry sown rice during first crop season followed by transplanted rice during second crop season and sesamum during third crop season. Weed problem is severe in this system of cultivation causing considerable reduction in crop yield. The age old practice of hoeing and hand weeding are carried out by the farmers of this tract for control of weeds in dry sown rice and sesamum. It is very expensive and nowadays scarcity of labour is an added problem which affects the timely weed control operations. Herbicides are nowadays used extensively for weed control in rice. There is possibility for development of resistant biotypes of weed by continuous use of single herbicide. A combination of heribicides is more effective in controlling wide range of weeds in rice (Rao and Singh, 1994). Research on weed management in individual crop has been done, but information in respect of cropping system is lacking. Weed management becomes more holistic when planned for entire cropping system than for individual crop. The cropping system approach aims at full realization of the residual effects of applied treatments from one crop to another resulting in efficient crop production. Therefore, a system that combines herbicides with cultivation and other good crop husbandry practices viz. "Integrated weed management" should be followed (Fischer, 1974). Integrated weed management reduces losses due to weeds combined with environmental preservation and improved agricultural sustainability.

With this background, an investigation was conducted with the following objectives.

- To find out an effective integrated weed management technology for rice-rice-sesamum cropping sequence of Onattukara tract
- To study the effect of different weed control methods on the growth and persistance of weed flora infesting rice and sesamum
- To assess the effect of weed control treatments on the growth and yield of crops in the cropping system
- To study the persistance and residual effect of herbicides
- To workout the economics of different weed management practices.

REVIEW OF LITERATURE

2. REVIEW OF LITERATURE

The weeds form a serious negative factor in crop production systems. The cultivation of modern rice varieties which are more fertilizer responsive than the traditional varieties and with a different crop geometry and canopy development pattern has drawn attention to the weed control problems in rice based cropping systems. The only universal pest in rice is weeds that exceed tolerable levels in all seasons (Moody and Cordova, 1985). Weeds cause enormous reduction in crop yields, wastage of resources and human energy. With the advent of new intensive and diversified cropping patterns, the concept of controlling weeds in a single crop has been changed to integrated weed management for the entire cropping system. Literature in connection with the integrated weed management in rice based cropping system is reviewed here under.

2.1. Weed spectrum in rice fields

Rice is a facultative hydrophyte and is semiaquatic in nature. It is essentially a short-day and C_3 type of plant. Weeds compete with rice for space, light, water and nutrients. Some of the weeds grow more abundantly while others grow in less density. The dominant weed species among dicots belong to the families Compositae, Scrophulariaceae and Amaranthaceae while monocot weeds belong to the family Gramineae and

Cyperaceae (Singh *et al.*, 1974). Most of the weed flora are of C_4 plant type and are aggressive in nature (Subramanian and Mohamed Ali, 1985).

Weed species such as *Echinochloa* spp, *Caesulia axillaris, Ischaemum rugosum* and *Cyperus* spp. were found to grow in rice nursery (Ramprasad and Singh, 1992). Singh and Rahman (1992) reported that *Echinochloa crusgalli* and *E. colona* were the two grassy weeds in rice nursery.

The most common weeds infesting rice fields are grassy weeds like *Echinochloa colona, E. crusgalli* and *Paspalam* sp., sedges like *Fimbristylis miliacea* and *Cyperus difformis* and broad leaved weeds like *Monochoria vaginalis, Ipomoea reptans* and *Ludwigia parviflora* (Pillai, 1977). Rice fields are colonized by terrestrial, semi aquatic or aquatic plants depending on the type of rice culture and season (Moody and Drost, 1983). Predominant weeds found at Kayamkulam region of Kerala during first crop season are *Brachiaria ramosa, Echinochloa colona, E. crusgalli, Sacciolepis indica, Cyperus rotundus, Cleome viscosa* and *Monochoria vaginalis* (Lakshmi, 1983). Major weeds in rice fields were *Echinochloa crusgalli, E. colona, Cynodon dactylon* and *Panicum repens* among grasses, *Cyperus difformis, C. iria* and *Fimbristylis miliacea* among the sedges and *Ammania baccifera, Ludwigia parviflora, Eclipta alba, Marsilea quadrifoliata, Phyllanthus niruri, Ipomoea reptens, Sphaeranthus indicus* and *Portulaca oleracea* among the broad leaved weeds (Verma *et al.*, 1987, Thirumurugan *et al.*, 1992). In south and south east Asia, *Echinochloa* is the most common weed in rice fields (Moody, 1988). Total weed flora in rice has a proportion of 70 per cent grasses, 25 per cent sedges and five per cent broad leaved weeds (Tomar, 1991).

2.2. Effect on growth and yield of crop

Weaker seedlings are produced as a result of competition effect of weeds in rice nursery (Rao and Moody, 1987). The grassy weeds were highly competitive than sedges and dicots during crop growth. Young seedlings were found to be very sensitive to weed competition (Rao and Moody, 1988).

According to Smith and Shaw (1966), the extent of yield reduction that the weeds cause in rice was around 15-20 per cent in transplanted rice, 30-35 per cent in direct seeded rice under puddled condition and over 50-60 per cent in upland rice. The yield loss of transplanted rice ranged from 15-20 per cent as evidenced by the result of a number of multilocation trials. Ravindran (1976) found that the yield reduction caused by weeds in transplanted rice was 28.7 per cent as shown by weed index. Varughese (1978) reported an yield reduction of 25.47 per cent in transplanted rice due to the presence of weeds. The yield loss could be as high as 46 per cent under unchecked weed growth (De Datta, 1981). Sukumari (1982) stated that weeds caused an yield reduction of 43.47 per cent in direct sown rice under semi dry condition. In semi dry dibbled crop of rice in Onattukara, the extent of yield reduction by the presence of weeds was 18.79 per cent (Lakshmi, 1983). Yield loss of 1.48 tons hectare^{-1} due to weed competition was reported by Sankaran *et al.* (1993). Bhan and Mishra (1993) reported an yield reduction of 70-80 per cent in drilled rice, 30-40 per cent in transplanted rice and 17-41 per cent in sesamum due to weed problem. Reddy and Gautam (1993) reported that uncontrolled weed growth had reduced grain yield of rice by 50 per cent.

Srinivasan and Palaniappan (1994) reported that the growth and yield of rice was reduced considerably by *Echinochloa* sp. and *Marsilea*, with the nature of competition being for light and nutrients respectively.

2.3. Critical period of weed growth

Weeds in rice nursery affected the growth of rice seedlings and even caused complete failure of the nursery (Shahi and Gill, 1979). Rice seedlings emerged five days after sowing, but weed seedlings emerged even earlier indicating early germination than the rice (Biswas *et al.*, 1992).

It has been reported that the critical period of crop-weed competition was between 21 to 40 days after transplanting paddy (Varughese, 1978; Sukumari, 1982). According to Shasidhar (1983), weed competition was critical during the first 40 days after transplanting paddy and yield reduction was not significant by the presence of weeds thereafter. Competition from weeds during the first 15 DAS had no significant effect on the grain yield of rice. Competition beyond 15 DAS caused drastic reduction in grain yield of rice. Density of weeds emerging between 15 and 30 DAS was high and could compete with the crop resulting in reduced grain yield (Singh *et al.*, 1987). Soman (1988) also reported that the weed number and competition was severe upto the 40th day after transplanting. The first 25 to 65 days of rice growth constituted the critical period (Mukhopadhyay *et al.*, 1992).

The available information thus indicated that weed control during the first 3-4 weeks of sowing or planting is critical for rice. Irrespective of the method adopted for weeding, it is the timeliness of this operation that is more important in a cropping system approach.

2.4. Weed management techniques

2.4.1. Manual weeding

Manual weeding methods were most effective in young weeds where as older weeds especially perennials with underground structures were difficult to control (Moody, 1977). Effectiveness of hand weeding in weed management was evidenced in a number of trials (Singh and Sharma, 1981; Raju and Nageshwar Reddy, 1986; Azad *et al.*, 1990). Raju and Nageshwar Reddy (1986) reported that hand weeding reduced weed dry weight by 88 per cent. However the re-emergence of sedges could not be controlled by hand weeding (Verma *et al.*, 1987). Patel and Mehta (1989) indicated the highest reduction of dry weed biomass with soil solarization and hand weeding. Moody (1991) reported manual weeding as the most common method of weed control in rice in Asia. Manual weeding by hand or hand tools is very effective but require more time and labour. Hand weeding registered higher grain yield of rice in a number of experiments (Krishnaswamy *et al.*, 1992; Singh *et al.*, 1992; Singh *et al.*, 1994). Kathiresan and Surendran (1992) observed a higher weed control efficiency of 81.9 per cent by hand weeding twice.

2.4.2. Chemical weeding

The weed control efficiency of various chemicals has been studied extensively and many herbicides are now available for rice growers.

Several workers have evaluated the potential of several herbicides for weed control in rice. Results with herbicides in rice have been inconsistent from site to site and from year to year at the same site. Various weed species, their intensities and soil, moisture and climatic conditions may account for inconsistent results. Despite some problems in making herbicides effective, it seems that herbicides will play major role in controlling weeds in rice culture.

2.4.2.1. Butachlor

Rangiah *et al.* (1974) revealed that machete (Butachlor) granules @ 2.5 kg ai ha^{-1} applied four days after transplanting provided effective weed control. Rethinum and Sankaran (1974) reported that pre-emergence application of butachlor @ 2 kg ai ha^{-1} gave the best and economic weed control under transplanted condition. Singh and Sharma (1981) reported that the effect of butachlor was superior over other herbicides tried. The annual grass weeds were controlled by the application of butachlor (Fajardo and Moody, 1987). Application of butachlor @ 1.5 kg ha^{-1} reduced weed population and increased the grain yield of rice (Singh *et al.*, 1992; Patil, 1994). Maximum WCE was observed in the butachlor treatment @ 1 kg ha^{-1} (Gogoi and Gogoi, 1993). Singh *et al.* (1995) had observed weed control efficiency of 46.1 per cent due to application of butachlor @ 1.5 kg ai ha^{-1} in transplanted rice in rainfed low lands.

However Arceo and Mercado (1981) and Diop and Moody (1989) reported that butachlor controlled weeds poorly and the crop stand reduction caused by butachlor resulted in weed growth.

2.4.2.2. Pretilachlor

Application of pretilachlor was found to be effective in controlling *Cyperus rotundus, C. iria, Echinochloa crusgalli, Eclipta alba* and *Monochoria vaginalis* (Tewari *et al.*, 1986). Cruz (1990) reported pretilachlor as one of the promising herbicides for pre-emergence application in rice. In another study, Purushotham *et al.*, (1990) reported that application of pretilachlor @ 1 kg ai ha^{-1} recorded lower weed dry weight. Pretilachlor applied @ 1.25 kg ha^{-1} on three or seven DAP effectively controlled weed dry weight, increased the number of panicles and recorded higher grain yield of rice (Budhar *et al.*, 1991; Kurmi, 1993). Kurmi (1991) reported that pretilachlor @ 1 kg ha^{-1} enhanced spikelet number, grains panicle^{-1} and grain yield of rice. In Kerala, Joy *et al.* (1992) reported that application of pretilachlor at 1.25 kg ha^{-1} on three DAP registered higher grain yield and gross returns which was on a par with that of weed free control. In another study at Bhuvaneswar, Prusty and Behara (1992) compared the effect of hand weeding and pretilachlor application and recorded higher yield in pretilachlor treated plot compared to two hand weeding treatment.

Gogoi and Gogoi (1993) reported higher weed control efficiency when pretilachlor was applied as pre-emergent herbicide at 0.75 kg ha^{-1}. Muthukrishnan *et al.* (1994) observed that application of pretilachlor at 0.5 kg ha^{-1} controlled weed population, reduced weed dry weight and increased the grain yield of rice.

2.4.2.3. Pendimethalin

In a trial at TNAU, Coimbatore, the herbicide stomp at 1.5 kg ai ha^{-1} was found to be effective in controlling grasses, sedges and broad leaved weeds. Yield increase upto 90 per cent was noticed in the transplanted rice (Mohamed Ali and Sankaran, 1975). Manipon *et al.* (1981) observed increased grain yield of dry seeded rice due to pre-emergence application of pendimethalin. In trials conducted at IRRI, pendimethalin registered lower yields than untreated check during the dry season (IRRI, 1986). Bhattacharya and Mandal (1991) reported excellent control of broad-leaved and grassy weeds with pendimethalin. Joseph and Bridjit (1993) reported that pendimethalin had higher weed control efficiency when compared to thiobencarb and butachlor. Kathiresan *et al.* (1997) reported that pendimethalin at 1 kg ai ha^{-1} as pre-sowing sand mixed, significantly registered higher grain yield of semidry rice through effective reduction of weeds and weed dry matter that resulted in better seedling growth and productive tiller.

2.4.2.4. Thiobencarb

Trials conducted at CRRI, Cuttack, had revealed that thiobencarb was effective in controlling grasses and broad leaved weeds in transplanted and direct seeded rice crop (Dubey, 1976). Application of thiobencarb reduced weed density and improved the grain yield of rice (Singh and Sharma, 1981). In another study at College of Agriculture, Vellayani, Maheswari (1987) reported that application of thiobencarb increased the dry matter accumulation of rice and recorded higher weed control efficiency next to completely weed free treatment. Srinivasan and Pothiraj (1990) reported that thiobencarb controlled 95 per cent grasses, 79 per cent sedges and 78 per cent broad leaved weeds and recorded the lowest grass population of 8 number m^{-2} in rice variety IR-50. Dwivedi *et al.* (1991) reported that thiobencarb at 1.5 kg ha^{-1} proved highly effective in controlling weeds even more than that of one weeding. Increased grain yield of rice due to the application of thiobencarb was also reported by several workers (Siddiqui and Sarkar, 1992; Singh *et al.*, 1992; Patil, 1994). Sankaran *et al.* (1993) reported that application of thiobencarb as pre-emergence herbicide controlled many grasses, cyperaceous and broad leaved weeds in rice. The chemical showed higher selectivity between rice and weed species *E. crusgalli.* Application of thiobencarb at 2 kg ha^{-1} resulted in maximum decrease in weed dry weight and proved more effective in controlling grass weeds (Singh *et al.*, 1994).

2.4.2.5. Oxyfluorfen

Oxyfluorfen is an effective pre-emergence herbicide for transplanted and direct seeded rice (Chauhan and Ramakrishnan, 1981). Oxyfluorfen, a diphenyl ether herbicide is used as a selective pre-emergence herbicide in a variety of crops and is effective for the control of weed species such as *Commelina benghalensis, Digitaria sanguinalis, Echinochloa colonum* etc. (Rao, 1983). Results of advanced trial on upland rice revealed that oxyfluorfen and thiobencarb gave weed counts similar to that of hand weeded check. Oxyfluorfen was moderately toxic to rice (IRRI, 1986). Yasin *et al.* (1988) reported that application of oxyfluorfen controlled weed species such as *Monochoria vaginalis, Marselia arenata, Paspalam* sp, *Echinochloa colonum, Fimbristylis littoralis, Eluesine indica* and *Cyperus iria* in rice. Azad *et al.* (1990) observed that oxyfluorfen at 0.2 kg effectively reduced the population and dry weight of weeds. Grain yield of rice observed was 4.52 to 5.01 t ha^{-1} compared to 2.69 to 3.53 t ha^{-1} obtained with the control.

In a field trial at Bangalore, Mahadevaswamy and Nanjappa (1991) reported that oxyfluorfen is effective for weed control in drilled rice.

2.4.2.6. 2,4-D

The chlorophenoxy herbicide, 2,4-D (2,4-Dichloro phenoxy acetic acid) has been available throughout most of the Asia for the past four or five decades. Many rice growers have been using it routinely for post emergence control of annual broad leaf weeds such as *M. vaginalis, Sphenoclea zeylanica*, sedges such as *Cyperus difformis, C. iria* and *Fimbristylis littoralis* (De Datta, 1980). Most dicotyledonous crops were sensitive to 2,4-D (Rao, 1983). In a field experiment at Bangalore, Mahadevaswamy and Nanjappa (1991) observed reduced weed weight (56.4 q ha^{-1}) compared to unweeded control (83.6 q ha^{-1}) due to the application of 2,4-D @ 1kg 25 DAS in rice variety Jaya. Ramiah and Muthukrishnan (1992) reported better weed control and enhanced tillering of rice through sequential application of pendimethalin followed by 2,4-D Na salt, which resulted in higher grain yield. Brar *et al.* (1997) reported that application of 2,4-D at 0.8 kg ha^{-1} alone or its tank mixed or sequential combination with anilofos @ 0.6 + 0.4 kg ha^{-1} respectively was effective in controlling *Caesulia axillaris* in transplanted rice.

2.4.3. Integrated weed management

Smith and Reynolds (1966) defined integrated weed management as a weed population management that used all suitable methods in a compatible manner to reduce weed populations and maintained them at levels below those causing economic injury. According to Baldwin and Santleman (1980), IWM aimed at maintaining the growth of weed populations at ecologically, agronomically and economically acceptable levels. Slife (1981) defined objective of IWM as to create conditions unfavourable to weeds while maintain suitable for crops or other beneficial vegetation. Integrated weed management thus emphasised the integration of control tactics in a holistic manner with all other practices that influenced the ecosystem and linked weed control to the broader picture of ecosystem management.

Currently the most promising single approach for weed management is the use of manual and mechanical methods in conjunction with herbicides which is effective, economic and environmentally sound.

2.4.3.1. Chemical-cultural integration

Smith and Moody (1979) reported that weed control and grain yield in rice were superior when herbicides were combined with hand weeding than when either practice was used alone. Research on integrated weed management in transplanted medium duration rice at Vellayani revealed that application of thiobencarb at 1 kg ai ha^{-1} as spray followed by one hand weeding given at 35 DAT was quite effective in controlling weeds. The higher grain yield was recorded by the treatment combination of thiobencarb granules at 1 kg ai ha^{-1} as pre-emergence application followed by one hand weeding at 35 DAT (Maheswari, 1987).

Shivamadiah *et al.* (1987) found that herbicide treatment plus hand weeding gave significantly greater yields than herbicides alone. Soman (1988) reported that in rice based cropping system approach, higher grain yield was produced by thiobencarb - hand weeding, nitrofen - hand weeding and butachlor - hand weeding whereas highest net profit was obtained by the repeated application of thiobencarb and butachlor.

In paddy-pulse and paddy-paddy sequences, application of any of the pre-emergence herbicides like butachlor (1.25 kg ha^{-1}), thiobencarb (1.25 kg ha^{-1}), anilofos (0.4 kg ha^{-1}) and pretilachlor (0.75 kg ha^{-1}) within 3 to 4 days after planting followed by one hand weeding at 30 to 35 DAP was found to be very effective in controlling weeds, reducing weed dry matter and increasing grain yield of rice (Ramamoorthy and Mohamed Ali, 1992; Asokaraja, 1994).

From the weed control studies on upland rice by Joseph and Bridjit (1993), it was observed that a pre-emergence application of pendimethalin followed by either a post emergence application of 2,4-D or hand weeding once was as effective as maintaining weed free condition throughout the crop growth.

2.4.3.2. Rotation of herbicides

Kim (1983) reported that a shift in the weed flora from annuals to perennials which were often difficult to control would occur due to the inherent selectivity of the herbicides used in transplanted rice. Janiya and Moody (1987) observed a shift in weed species from annuals to perennials where herbicides were used continuously in rice for a number of years. Continued use of the same herbicide or herbicides on the same piece of land resulted in inevitable increase of tolerant weeds particularly perennials (Moody, 1991). Continuous application of butachlor and thiobencarb + 2,4-D to rice effectively controlled weeds in first crop but they did not control weeds in the 4th crop (IRRI, 1986).

Ahn *et al.* (1975) reported weed population shift due to repeated application of herbicides as a result of successive elimination of the herbicide sensitive species and their gradual replacement by the herbicide tolerant species. Later on herbicide resistance in weeds was reported (Moss and Rubin, 1993).

An alternative to continuous use of a single herbicide, is herbicide rotation which may prevent the build up of tolerant weed species. Smith and Moody (1979) reported that rotating the herbicides or combining two or more herbicides could prevent the build up of tolerant weed species. Crop rotation with related herbicide rotation could effectively hold back hard to control weeds (Klingman *et al.*, 1982). The continuous rotational use of butachlor, alachlor, fluchoralin, nitrofen, metoxuron and atrazine did not cause any adverse effect of residual toxicity in soil and on the productivity of crops grown in sequence viz., rice-wheat, rice-lentil and maize-potato-wheat (AICRPWC, 1988).

In rice-rice-pulse system, at the end of first sequence *Rotala densiflora* and *Echinochloa colona* decreased by the continuous application of pretilachlor. These weeds were suppressed by the domination of *Cyperus iria* in the second sequence and finally *Cyperus rotundus* in blackgram. In butachlor treated plots where *E. colona* is seen as a dominant weed in the first crop was reduced by *C. iria* at the end of the fifth crop (Asokaraja, 1994).

2.5. Residual effect of herbicides

2.5.1. Effect on weeds in succeeding crops

Application of the herbicide, thiobencarb in rice recorded the lowest count and dry matter of weed species such as *E. colona* and *Eclipta alba* in greengram and other succeeding crops in the cropping system (Pawan and Gill, 1981; Srinivasan and Pothiraj, 1990). Maheswari (1987) reported that there was no residual effect of the herbicide thiobencarb applied to rice on the succeeding cowpea crop. Mishra and Singh (1992) reported that herbicides applied to rice had no effect on weeds associated with pea, wheat, gram and lentil. However increase in the population of *Echinochloa* spp. in green gram was noted when herbicide was continously applied to rice.

2.5.2. Effect on succeeding crops

There was no adverse effect on stand, yield and nodulation of the succeeding pulse green gram due to herbicides applied in rice for weed control measures (Vijayaraghavan, 1974). Balu and Sankaran (1978) reported that nitrofen, butachlor, penoxalin, dichlormate and avirosan applied to rice did not affect the germination percentage of the crops raised after its harvest. Ahmed and Hoque (1981) observed that butachlor applied to dry seeded rice had no residual effect on the weed growth in transplanted rice raised after it. Subramanian and Mohamed Ali (1985) also observed no residual effect of butachlor and thiobencarb on succeeding crops like cowpea, blackgram, soybean, gingelly, finger millet and cotton. No residual toxicity of herbicides applied to rice was noted in subsequent cowpea crop (Maheswari, 1987). Similarly residual toxicity of herbicides applied to rice was not observed on the succeeding cowpea crop at Vellayani (Soman, 1988).

According to Srinivasan and Pothiraj (1990) there was no influence on the yield of green gram by the weed control treatments in rice. Mishra and Singh (1992) observed no adverse residual effect of thiobencarb and butachlor on succeeding wheat, gram, pea and lentil. Srivastava *et al.* (1994) reported that application of butachlor, thiobencarb, pendimethalin and 2,4-D sodium salt applied to rice did not cause any variation in germination, plant height and dry matter accumulation of succeeding cucumber. Singh and Vaishya (1994) observed no significant variation in the grain yield of wheat due to the application of thiobencarb (2 kg ha^{-1}), butachlor (1.5 kg ha^{-1}) fluchoralin (1.0 kg ha^{-1}) and pretilachlor (0.75 kg ha^{-1}) to rice crop. Zirpe *et al.* (1994) reported that there was no residual effect of butachlor (1.5 kg ha^{-1}) and anilofos (0.5 kg ha^{-1}) applied to rice on succeeding maize and its weed flora. Veerabhadran *et al.* (1994) reported that pretilachlor plus safener did not cause any adverse residual effect on blackgram and sesamum raised after rice. However Choudhury (1995) reported that application of paraquat spray at pre plant state without N, and molinate after emergence followed by that of 2,4-D sodium salt to rice preceeding summer green gram had significant residual effect in the management of weeds in the latter crop of green gram.

2.5.3. Herbicide residue problem

2.5.3.1. Residues in soil

Herbicides which persist much longer than desired, pose several potential environmental problems. They may also cause injury to succeeding crop in a multiple cropping system. With intensive cropping system repeated application of herbicides for each crop and in cases of gross misapplication and over use, there is potential danger of persistence in the soil and residual accumulation on the crop produce (Sankaran *et al.*, 1993).

The herbicides butachlor and thiobencarb at 1.5 kg ha^{-1} persisted in paddy soil upto 66 days and at harvest, no detectable amount was found in the soil (Sankaran *et al.*, 1993). Asokaraja and Mohamed Ali (1994) reported that application of pretilachlor 0.75 kg ha^{-1} and butachlor 1.25 kg ha^{-1} to rice field showed a residue of 0.0043 and 0.0067 ppm respectively and they were below maximum residue limit. Butachlor at 1 kg ha^{-1} degraded within harvest, but detectable residues were observed at 2 kg ha^{-1} (Rajkumar *et al.*, 1994). In continuous application of butachlor, the residue in soil increased from non-detectable level in the first crop to 0.0188 ppm after seventh crop (Mani *et al.*, 1994).

2.5.3.2. Residues in plants

The problem of herbicide residues in plants is not as serious as that of residues of other pesticides. Residues of several herbicides applied were detected in rice plant parts, by several workers. However they were below maximum residue limit (Jayakumar *et al.*, 1994; Mani *et al.*, 1994; Padmvatidevi *et al.*, 1994a).

2.6. Effect of herbicides on soil organisms

The soil micro organisms have the capacity to detoxify and inactivate the herbicides present in the soil. The micro organisms involved in herbicide detoxification include bacteria, fungi, actinomycetes and algae. Out of these bacteria predominate (Rao, 1983).

Herbicides like propanil, nitrofen, prometryne, 2,4-D and butachlor when applied alone or in combination with insecticides like thimet or furadan in rice crop at their recommended doses and times did not have any adverse effect on soil microflora (bacteria, fungi and actinomycetes). Herbicides such as atrazine, simazine, lorox when applied at field rates in maize showed some adverse effects on soil microflora immediately after application but after 15 days all kinds of soil microorganisms regained their lost population (Mukhopadhyay, 1980). Singh (1990) reported that population of bacteria, fungi and actinomycetes were affected with butachlor application in rice and these adverse effects gradually reduced with passage of time. Nalayini and Sankaran (1992) observed that fungi showed resistance to the herbicides tested. Due to continuous herbicide application, a general reduction in the population of bacteria, fungi and actinomycetes in the soil was noticed (AICRPWC, 1994).

Mohamed Ali and Asokaraja (1994) reported that continuous application of pre-emergence herbicide pretilachlor at 0.75 kg ha^{-1} and butachlor at 1.25 kg ha^{-1} in rice-rice-pulse system showed a little suppression of soil bacteria as compared to hand weeding in rice post harvest soil. Kumar and Kandaswamy (1994) reported that suppression of soil microflora was noted upto 30 days after application of herbicides after which soil microflora recovered once again. In succeeding black gram the variations in soil bacteria, fungi and actinomycetes due to continuous application of herbicides in rice were narrowed down (Mohamed Ali and Asokaraja, 1994). Gopalaswamy *et al.* (1994) reported a decrease in bacteria, fungi and actinomycetes population upto 20 days after application of pre-emergence herbicides in rice. The soil microflora recovered after 30 days. The herbicide thiobencarb was inhibitory to soil fungi and actinomycetes while butachlor and thiobencarb were inhibitory to soil bacteria, fungi and actinomycetes and anilofos was inhibitory to bacterial population.

2.7. Bioassay of herbicide residues

For quick determination of herbicide residues bioassay studies are used as an alternative method to the expensive, labourious and time consuming chemical methods. A number of test plants viz., cucumber, barley, oats, soybean, finger millet and corn were proposed as indicator plants suitable for determination of various herbicide residues by bioassay. Leela (1981) reported cucumber var. white long and french bean variety contender as useful indicator plants for detection of soil residues of bromacil while cowpea and green gram for diuron and atrazine respectively. Jayakumar *et al.* (1985) studied the residual effect of fluchloralin and pendimethalin using various indicator plants and found that cucumber was the most sensitive indicator plant. Fluchloralin and pendimethalin at 1.0 and 1.5 kg ai ha^{-1} respectively affected the germination, plant height and dry matter production of indicator plants. The results of sensitive bioassay for detection of pendimethalin residues in soil indicated that germination was affected beyond 0.1 ppm on ragi, beyond 0.5 ppm in *Setaria italica,* bajra and wheat and beyond 2 ppm in maize, sunflower and green gram (Padmavatidevi *et al.*, 1994b).

MATERIALS AND METHODS

3. MATERIALS AND METHODS

Field experiments were carried out at Rice Research Station, Kayamkulam to study the response of integrated weed management practices in rice-rice-sesamum cropping system of Onattukara region. Trials were conducted consecutively for two years from the first crop season of 1996-97 to third crop season of 1997-98. The materials used and methods adopted for the study are briefly described below.

3.1. Materials

3.1.1. Experimental site

The field experiments were conducted at Rice Research Station, Kayamkulam. This location is situated at 9°30'N latitude and 76°20'E longitude at an altitude of 3.05m above mean sea level with facilities for controlled irrigation and drainage.

3.1.2. Soil

The soil of experimental site was sandy loam in texture with low water holding capacity. The important physical, chemical and biological properties of the soil are given in Table 1.

Table 1. Soil characteristics of the experimental site

A. Mechanical composition

Constituent	Content in soil (%)	Method used
Coarse sand	56.6	
Fine sand	30.2	Bouyoucos Hydrometer method (Bouyoucos, 1962)
Silt	5.8	
Clay	5.6	
Textural class : Sandy loam		

B. Physical properties

Property		Method used
Bulk density (gcc^{-1})	1.540	Core Method (Gupta and Dakshinamoorthi, 1980)
Particle density (gcc^{-1})	2.625	
WHC (%)	17.6	

C. Chemical composition

Constituent	Content in soil	Rating	Method used
Available N (kg ha^{-1})	164.3	Low	Alkaline potassium permanganate method (Subbiah and Asija, 1956)
Available P_2O_5 (kg ha^{-1})	48	Low	Bray Colorimetric method (Jackson, 1973)

Available K_2O (kg ha^{-1})	86	Low	Ammonium acetate method (Jackson, 1973)
Total N (%)	0.042	Low	Microkjeldahl method (Jackson, 1973)
Organic carbon (%)	0.41	Low	Walkely and Black rapid titration method (Jackson, 1973)
pH	5.2	Moderately acidic	1:2 soil solution using pH meter (Jackson, 1973)

D. Biological properties

Organisms	Population count	Method used
Fungus (10^4)	6 g^{-1} of soil	Plating in Rose Bengal Agar Medium (Martin, 1950)
Bacteria (10^6)	11 g^{-1} of soil	Soil Extract Agar Medium (Allen, 1953)
Actinomycetes (10^5)	1 g^{-1} of soil	Plating in Agar Medium (Kuster and Williams, 1964)
Earthworms	3 m^{-2} of soil	Hand sorting method (Van Rhee, 1967)

3.1.3. Cropping history of the field

The location of the experiment in Block E of RRS, Kayamkulam was under a bulk crop of sesamum before the commencement of the experiment. The typical rice-rice-sesamum cropping pattern of the Onattukara region was practised in the field.

3.1.4. Season

The experiment was conducted consecutively for two years from the first crop season of 1996-97 to third crop season of 1997-98.

3.1.5. Weather conditions

The monthly averages of temperature, relatively humidity and rainfall during the cropping period, collected from the meteorological observatory at CPCRI, Kayamkulam are presented in Appendix 1 and Fig. 1.

3.1.6. Cultivar

3.1.6.1. Bhagya (Kayamkulam-2)

It is a dwarf photo insensitive non lodging short duration red rice having 95-100 days duration. It is released from RRS, Kayamkulam from the parents Tadukkan and Jaya by combination breeding methodology. The variety is fairly tolerant to sheath blight, BPH and drought in early stages.

3.1.6.2. Dhanya (Kayamkulam-4)

It is a tall photo sensitive non-lodging red rice having 160-165 days duration. It is released from RRS, Kayamkulam from the parents Jaya and Ptb-4 by combination breeding method. It is moderately resistant to stem borer, gall midge, leaf roller, sheath blight and blast.

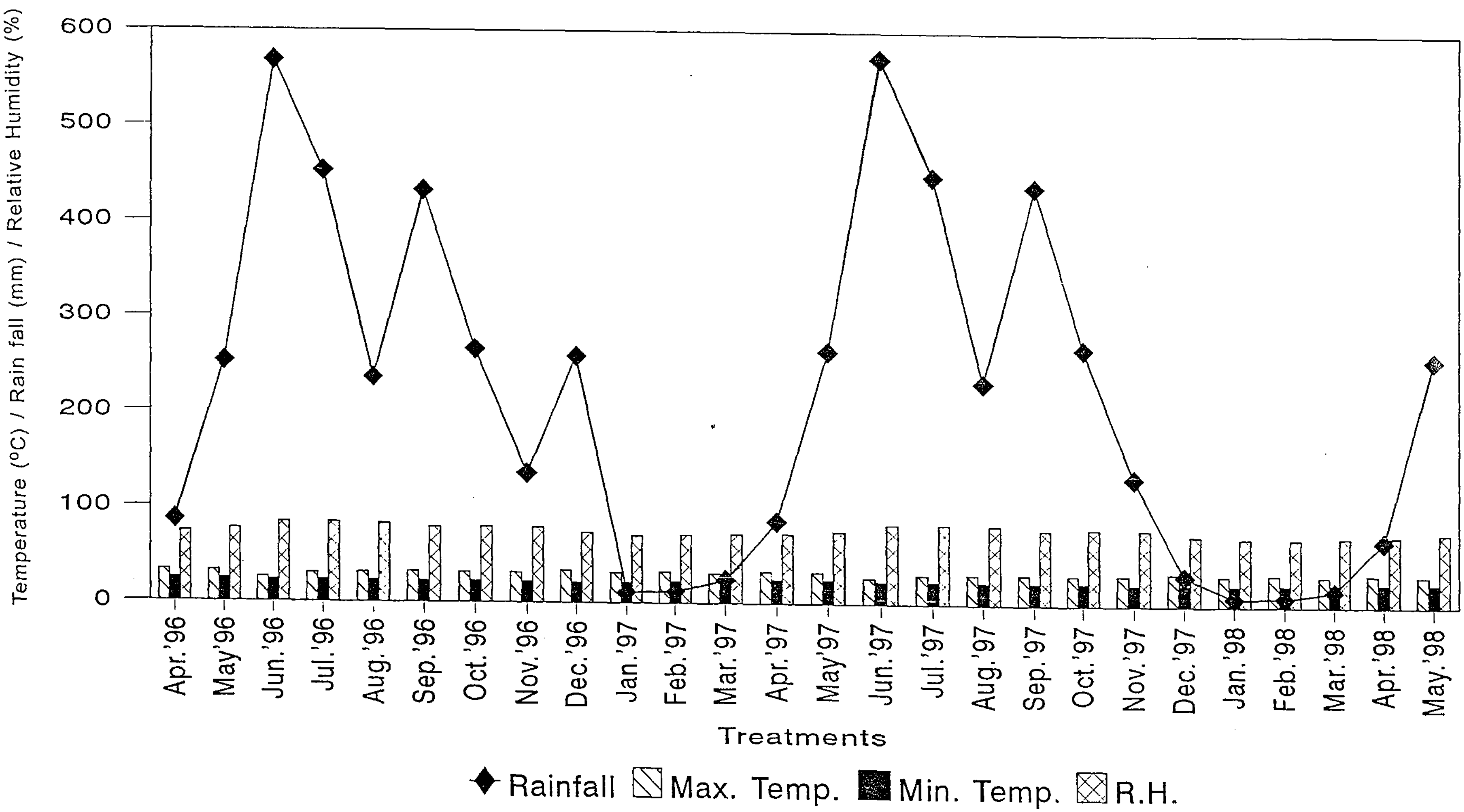


Fig. 1. Weather data during the cropping period

3.1.6.3. Thilak (ACV-3)

It is a pureline selection of sesamum having a duration of 80-90 days and suitable for summer rice fallows of Onattukara.

The above three cultivars were raised during the first crop, second crop and third crop seasons respectively.

3.1.7. Herbicides

3.1.7.1. Pendimethalin

The chemical structure of the active ingredient penoxalin is N - (1-Ethyl propyl) 2,6-dinitro - 3,4-xylidine. It is a pre-emergent herbicide which control grasses and broad leaf weeds. Commercial formulation is available as pendimethalin 50 EC.

3.1.7.2. Butachlor

It is a pre-emergent herbicide containing active ingredient 2-chloro- 2, 6 diethyl-N-butoxy methyl acetanilide, available in the form of 50 per cent EC. It has good efficiency for controlling annual grasses and broad leaf weeds.

3.1.7.3. Oxyfluorfen

It is a diphenyl ether herbicide with the active ingredient 2-Chloro-1-1 (3-ethoxy 4-nitro phenoxy) - 4-(trifluoromethyl) benzene, used as a pre-emergent herbicide available in the commercial form as 23.5 per cent EC.

3.1.7.4. Pretilachlor

It is a broad spectrum herbicide with the active ingredient 2-Chloro-2, 6-diethyl-N-(2 propoxyethyl) acetanilide available at 50 per cent EC. The chemical is used as a pre-emergent herbicide for dry sown low land conditions.

3.1.7.5. Thiobencarb

It is a pre-emergent herbicide containing the active ingredient benthiocarb S-(4-chlorobenzyl) - N-diethyl thio carbamate which gives excellent control of annual grasses and sedges. Commercial formulation is available as 50 per cent EC.

3.1.7.6. 2,4-D

It is a selective systemic post emergent herbicide used for the control of many annual broad leaf weeds. The active ingredient 2,4-Dichloro phenoxy acetic acid is available in salt (sodium) and ester formulation.

3.1.8. Source of seed material

The rice and sesamum seeds for the experiment were obtained from RRS, Kayamkulam.

3.1.9. Manures and Fertilizers

Farm Yard Manure (0.4 N : 0.3 P_2O_5 : 0.2 K_2O per cent) obtained from RRS, Kayamkulam was used for the experiment. Urea containing

46 per cent N, Mussoriephos 16 per cent P_2O_5 and Muriate of Potash 60 per cent K_2O were used as the source of N, P and K respectively in the experiment.

3.2. Methods

3.2.1. Details of the field experiments

Field experiments were laid out in Randomised Block Design during the first crop season. During second crop season and third crop season, field experiments were laid out as split-plot in Randomised Block Design. The layout of the experiments are given in Fig. 2a and Fig. 2b.

3.2.1.2. Treatment details

First crop (semi dry paddy) (April-July)

T_1 - Weed free

T_2 - No weeding

T_3 - Farmers practice (hoeing) at 15 DAS and hand weeding at 25 and 45 DAS

T_4 - Pendimethalin (pre-em) @ 1.5 kg ai ha^{-1}

T_5 - Butachlor (pre-em) @ 1.25 kg ai ha^{-1}

T_6 - Oxyfluorfen (pre-em) @ 0.15 kg ai ha^{-1}

T_7 - Pendimethalin (pre-em) 1.5 kg ai ha^{-1} + hand weeding at 25 DAS

T_8 - Butachlor (pre-em) @ 1.25 kg ai ha^{-1} + hand weeding at 25 DAS

T_9 - Oxyfluorfen (pre-em) 0.15 kg ai ha^{-1} + hand weeding at 25 DAS

T_{10} - Pendimethalin (pre-em) 1.5 kg ai ha^{-1} + 2,4-D (post-em) 1 kg ai ha^{-1}

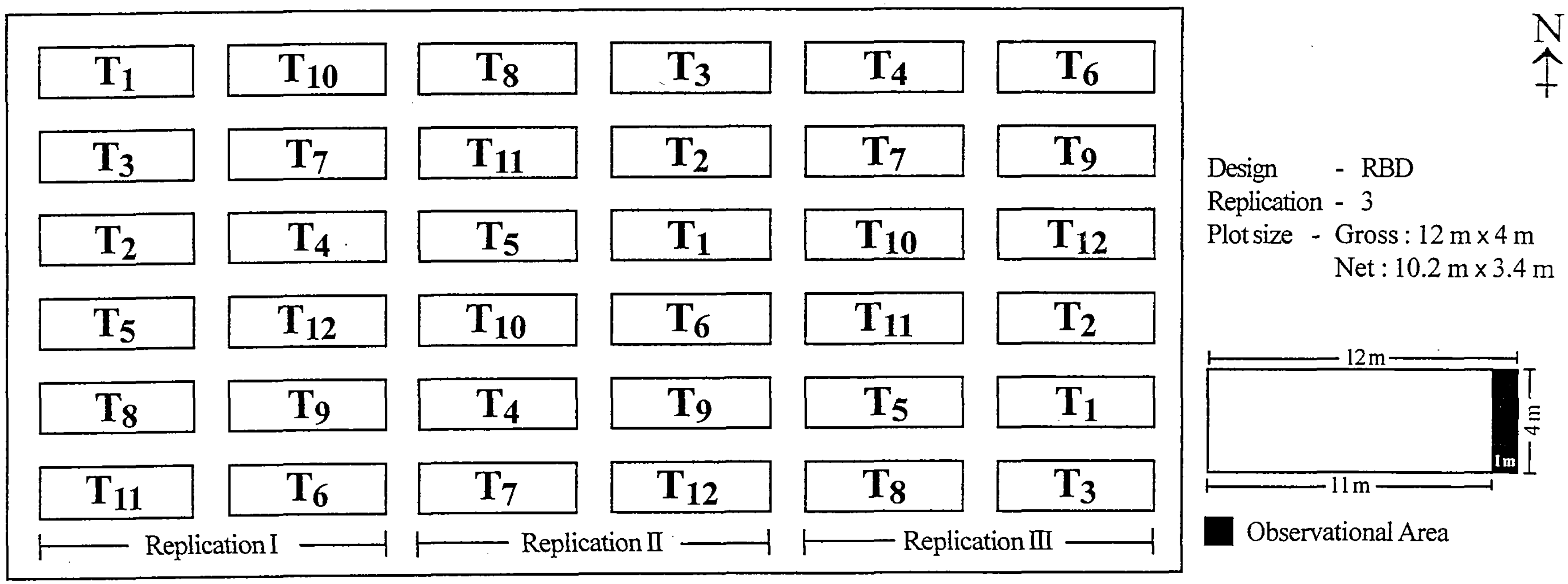


Fig. 2a. LAYOUT PLAN (First crop season)

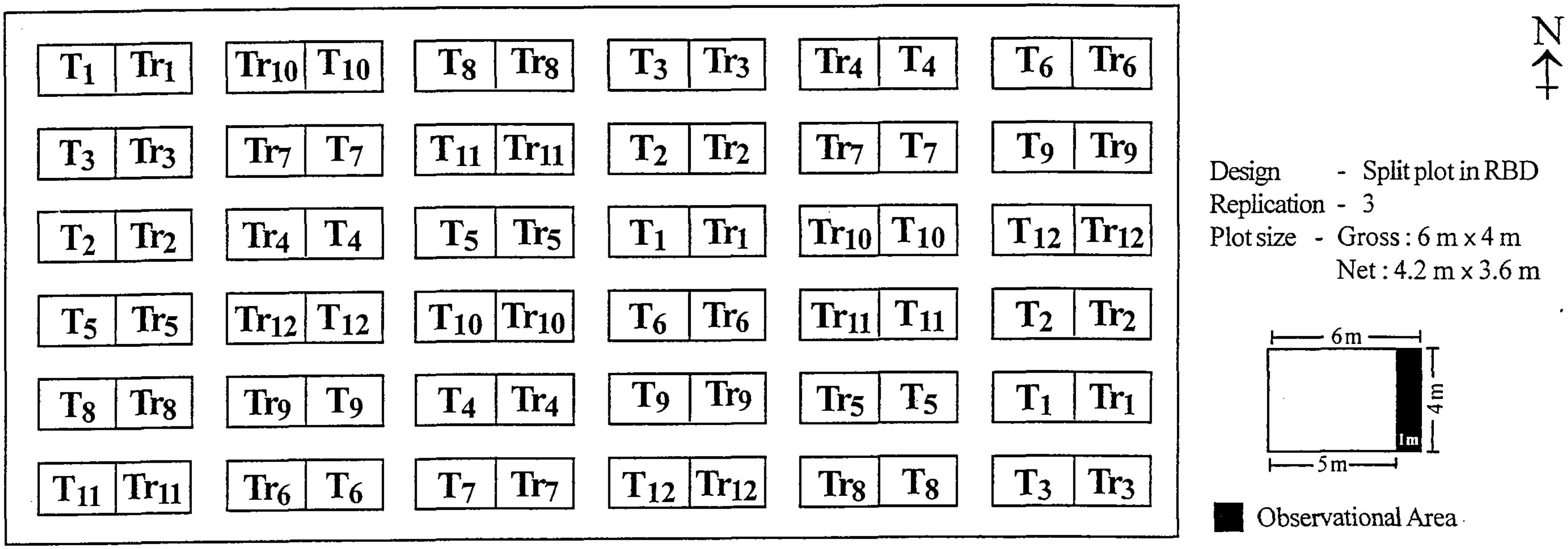


Fig. 2b. LAYOUT PLAN (Second crop and Third crop seasons)

T_{11} - Butachlor (pre-em) 1.25 kg ai ha^{-1} + 2,4-D (post-em) 1 kg ai ha^{-1}

T_{12} - Oxyfluorfen (pre-em) 0.15 kg ai ha^{-1} + 2,4-D (post-em) 1 kg ai ha^{-1}

Total number of treatments	-	12
Replication	-	3
Number of plots	-	36
Design	-	RBD
Plot size	-	Gross - 12 x 4 m Net 10.20 x 3.40 m
Border rows	-	2
Sampling area	-	One metre strip along the 4m side inside the border area
Paddy variety	-	Bhagya

Second crop (Transplanted paddy) (August-December)

T_1 - Weed free

T_2 - No weeding

T_3 - Farmers' practice (hand weeding) at 30 DAT

T_4 - Pendimethalin (pre-em) @ 1.5 kg ai ha^{-1}

T_5 - Pretilachlor (pre-em) @ 0.75 kg ai ha^{-1}

T_6 - Thiobencarb (pre-em) @ 1.5 kg ai ha^{-1}

T_7 - Pendimethalin (pre-em) @ 1.5 kg ai ha^{-1} + hand weeding at 30 DAT

T_8 - Pretilachlor (pre-em) @ 0.75 kg ai ha^{-1} + hand weeding at 30 DAT

T_9 - Thiobencarb (pre-em) @ 1.5 kg ai ha^{-1} + hand weeding at 30 DAT

T_{10} - Pendimethalin (pre-em) @ 1.5 kg ai ha^{-1} + 2,4-D (post-em) @ 1 kg ai ha^{-1}

T_{11} - Pretilachlor (pre-em) @ 0.75 kg ai ha^{-1} + 2,4-D (post-em) @ 1 kg ai ha^{-1}

T_{12} - Thiobencarb (pre-em) @ 1.5 kg ai ha^{-1} + 2,4-D (post-em) @ 1 kg ai ha^{-1}

No. of treatments	-	12
Replications	-	3
No. of plots	-	36 x 2 = 72
Design	-	Split plot in RBD

Each first crop plot was divided into equal halves and the treatments applied on one half. The remaining half was used to measure the residual effects of treatments in first crop.

Plots size

Gross	-	6 x 4m
Net	-	4.2 x 3.6m
Spacing	-	20 x 10cm
Border rows	-	2
Paddy variety	-	Dhanya

Third crop (Sesamum) (January-April)

During the third crop season, sesamum variety Thilak was raised in the treated and untreated plots of the second crop giving uniform management practices. The farmer's practice of weeding ie., hoeing at 15 and 25 DAS was done in sesamum.

The effect of herbicide application during first crop paddy alone and continuous application during first and second crop of paddy on the weed flora of sesamum was assessed.

3.2.2 Bio assay studies

The indicator plant seeds (cucumber) were sown in the soil taken from the experimental plots immediately after the harvest of the crop and the residual concentration of the herbicides in the soil was assessed from the response of the indicator plant by noting the germination percentage and weight of seedlings at three weeks after sowing.

3.3. Field culture

3.3.1. First crop season (Paddy)

3.3.1.1. Land preparation

The experimental area was ploughed twice. Plots of size 12 x 4m were laid out with 12 plots in each block. The plots were separated with bunds of 30 cm width and blocks with bunds of 50cm width. Individual plots were dug and levelled perfectly. Irrigation channels of 50cm width were provided between plots.

3.3.1.2 Manures and fertilizers

Farm yard manure @ 5 t ha^{-1} was applied uniformly to all the plots and mixed well with the top soil while ploughing. Nitrogen, phosphorus and potash were applied to the plots @ 70:35:35 kg ha^{-1} in the form of urea, mussoriephos and muriate of potash respectively. 50 per cent N, 50 per cent K and full dose of P were applied as basal dressing, 25 per cent N in the tillering stage and 25 per cent N and 50 per cent K at 5-7 days prior to the panicle initiation stage.

3.3.1.3. Sowing

Seeds were dibbled @ 80 kg ha^{-1} at a spacing of 15 x 10 cm and covered with soil.

3.3.1.4. Pre-emergence application of herbicides

A pre-planting light irrigation was given uniformly to all the plots. The liquid formulation of the herbicides were made into an emulsion with water at the required dose. The herbicide solutions were sprayed uniformly on the soil surface using knapsack sprayers fitted with flood jet nozzle.

3.3.1.5. Irrigation and drainage

The crop was mainly rainfed. However irrigation and drainage were provided as and when required.

3.3.1.6. Plant protection

One protective spraying with quinalphos on 30th day after sowing was given.

3.3.1.7. Harvest

The crops were harvested at maturity on 100th day after sowing.

3.3.2. Second crop season (Paddy)

3.3.2.1. Nursery

Field was ploughed, puddled and levelled. Cowdung @ 1 kg m^{-2} was applied to the nursery bed. Germinated seeds of paddy variety Dhanya was sown on the 3rd day. Recommended water management practices were adopted to produce healthy seedlings. Seedlings were transplanted in the main field at 4-5 leaf stage.

3.3.2.2. Main field

The individual plots of the first experiment were dug, puddled and levelled. The plots were separated into two equal halves of size 6 x 4 m by providing narrow bunds. Irrigation / Drainage channel provided were strengthened.

3.3.2.3. Manures and fertilizers

Farm yard manure @ 5 t ha^{-1} was applied uniformly to all plots and mixed well with top soil. Nitrogen, phosphorus and potash were applied to the plots @ 60:30:30 kg ha^{-1} in the form of urea, mussoriephos and muriate of potash respectively. 50 per cent of N, 50 per cent of K and full dose of P were applied as basal dressing, 25 per cent of N in the tillering stage and 25 per cent of N and 50 per cent of K just before panicle initiation stage.

3.3.2.4. Transplanting

Seedlings were uprooted and transplanted in the main field with two seedlings per hill in lines at a spacing of 20 x 10 cm.

3.3.2.5. Irrigation and drainage

After transplanting controlled irrigation and drainage were given to the crop as and when required.

3.3.2.6. Pre-emergence application of herbicide

The liquid formulations of the herbicides pendimethalin, pretilachlor and benthiocarb were made with water at the required dose and applied on the soil surface on the next day after transplantation.

3.3.2.7. Post emergence application of herbicide

The 2,4-D sodium salt was applied as post-emergent herbicide 25 days after transplantation as per the treatments.

3.3.2.8. Plant protection

One protective spraying with quinalphos on 30th day after transplanting was given to the crop.

3.3.2.9. Harvest

The crops were harvested on 17.1.1997 and 14.1.1998 during the first year (1996-97) and second year (1997-98) respectively.

3.3.3. Third crop season (Sesamum)

3.3.3.1. Land preparation

Individual plots of the second crop were dug and soil prepared to a fine tilth.

3.3.3.2. Manures and fertilizers

Farm yard manure @ 5 t ha^{-1} was applied uniformly to all the plots as basal dressing. Nitrogen, phosphorus and potash were applied @ 30:15:30 kg ha^{-1} in the form of urea, mussoriephos and muriate of potash respectively. 75 per cent N, full P and K were applied as basal dressing 25 per cent of N was given as foliar spray at 3 per cent concentration 30 days after sowing, keeping the discharge rate at 500 l ha^{-1}.

3.3.3.3. Sowing

Sesamum seeds were sown in lines 20 cm apart @ 5 kg ha^{-1}, and pressed with wooden plank to cover the seeds in the soil.

3.3.3.4. Interculture

When the plants were about 15cm in height, thinning was done to give a spacing of 20 cm between plants.

3.3.3.5. Irrigation

The crops were grown under rainfed conditions. However irrigations were given at vegetative and reproductive phases based on the soil moisture content.

3.3.3.6. Plant protection

Generally the crops were free from pests and diseases. Leaf caterpillars sporadically occurred were destroyed by physical methods.

3.3.3.7. Harvesting

The crops were harvested when the capsules turned yellowish by pulling out the plants, the root portions cut off and staked the plants in bundles for 3-4 days to facilitate threshing operation.

3.4. Observations on weeds

3.4.1. Important weed species in each season

The different species of weeds belonging to grasses, broad leaved weeds and sedges were collected and identified from the experimental plot during each cropping season.

3.4.2. Weed count

Weed samples were collected on 15th, 30th, 45th DAS or DAT and at harvest. Monocot, dicot and total weed populations were observed and recorded.

3.4.3. Dry weight of weeds

Dry weight of weeds collected on 15th, 30th, 45th DAS/DAT and at harvest were observed and recorded.

3.4.4. Weed control efficiency

Weed control efficiency was calculated using the following formula (Mani *et al.,* 1973).

$$WCE = \frac{(x - y)}{x} \times 100$$ where

x - weed count from unweeded control plot

y - weed count from treatment plot

WCE - weed control efficiency

3.4.5. Herbicide efficiency index

Herbicide efficiency index was worked out using the following formula (Krishnamurthy *et al.*, 1975).

$$HEI = \frac{\dfrac{\text{Yield from treatment} - \text{Yield from control}}{\text{Yield from control}}}{\text{Weed weight in treatment (\%)}} \times 100$$

3.5. Biometric observations on crops

3.5.1. Paddy

3.5.1.1. Height of plant

The plant height in cm was recorded at 15th, 30th and 45th DAS/ DAT and at harvest. Plant height was measured from the ground level to the tip of the longest leaf or to the tip of the earhead whichever was the tallest.

3.5.1.2. Number of tillers m^{-2}

The tillers from each sampling unit were counted on 15th, 30th and 45th DAS/DAT and at harvest and the values per square metre were calculated.

3.5.1.3. Leaf area index

Leaf area of plants from each plot was measured at 15th, 30th and 45th DAS / DAT using LI-3100 leaf area meter and expressed in square centimetre. Leaf area index was then worked out using the following equation (Watson, 1947).

$$LAI = \frac{\text{Total leaf area of the plant } (cm^2)}{\text{Land area occupied by the plant } (cm^2)}$$

3.5.1.4. Productive tillers m^{-2}

Number of productive tillers from each sampling unit of 0.5 m^2 area was counted and the value per square metre computed.

3.5.1.5. Weight of panicle

From the sampling area, all the panicles from the sample hills were weighed and weight per panicle worked out and expressed in g.

3.5.1.6. Percentage of filled grains per panicle

Completely filled and unfilled grains in each panicle were separately recorded and the percentage of filled grains calculated.

3.5.1.7. Grain yield

The grain harvested from net area of each plot was dried, cleaned, winnowed and weighed. From this yield of grain in kg ha^{-1} was worked out.

3.5.1.8. Straw yield

The weight of sun dried straw was recorded plot wise and from this, the yield of straw in kg ha^{-1} was computed.

3.5.1.9. RGR

RGR was worked out using the relationship and expressed as $gg^{-1}day^{-1}$ (Blackman, 1919)

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

where W_1 and W_2 are dry weights of crop at time t_1 and t_2.

3.5.1.10. CGR

CGR between stages was worked out using the following relationship (Hunt, 1982) and expressed in g m^{-2} day^{-1}

$$CGR = \frac{W_2 - W_1}{t_2 - t_1} \times \frac{1}{P} \quad \text{where}$$

W_1 and W_2 dry weight of crops at time t_1 and t_2

P - ground area

3.5.1.11. Harvest index

From the grain yield and straw yield, the harvest index was worked out using the following relationship

$$\text{Harvest index} = \frac{\text{Economic yield}}{\text{Biological yield}}$$

3.5.1.12. Weed index

Weed index was calculated using the following formula (Gill and Vijaya kumar, 1969).

$$WI = \frac{(x - y)}{x} \times 100$$

x - yield from weed free plot
y - yield from the plot
WI - weed index

3.5.2. Sesamum

3.5.2.1. Height of plant

The height of ten observational plants was recorded from the ground level to the growing tip, mean worked out and expressed in cm.

3.5.2.2. Number of branches

Total number of branches of each observational plant was counted, and the mean worked out at three stages of growth *viz.,* 30 and 60 DAS and at harvest.

3.5.2.3. Leaf area index

Leaf area of plants from each plot was measured using LI-3100 leaf area meter and expressed in cm^2. Leaf area index was then worked out using the equation (Watson, 1947).

$$LAI = \frac{\text{Total leaf area of the plant } (cm^2)}{\text{Land area occupied by the plant } (cm^2)}$$

3.5.2.4. Days to 50 per cent flowering

Total number of days from the date of sowing to the date at which 50 per cent of plants flowered were counted per plot and recorded.

3.5.2.5. Number of capsules per plant

The number of capsules of all observational plants per plot were counted, mean worked out and expressed as number of capsules per plant.

3.5.2.6. Seed yield per plot

Plants in the net plot area were harvested separately, seeds threshed out, dried to constant moisture content and expressed in kg ha^{-1}.

3.5.2.7. Harvest index

The harvest index was worked out from the following relationship

$$\text{Harvest index} = \frac{\text{Economic yield}}{\text{Biological yield}}$$

3.6. Analytical procedures

3.6.1. Soil analysis

3.6.1.1. Physical properties

Mechanical analysis of the soil was carried out by Bouyoucos Hydrometer method (Bouyoucos, 1962). Soil was classified into textural group using ISSS system.

3.6.1.2. Chemical properties

Soil samples were collected from the experimental area before and after the experiment. The air dried soil samples were analysed for available nitrogen, available phosphorus and available potash contents. Available nitrogen content was estimated by alkaline potassium permanganate method (Subbiah and Asija, 1956). Available phosphorus content was estimated by Bray colorimetric method (Jackson, 1973) and available potash by ammonium acetate method (Jackson, 1973).

3.6.1.3. Biological properties

Soil samples were collected after the experiment for assessing the changes in population of soil micro and macro flora and fauna due to application of herbicides. The soil water extract was prepared by serial dilution method. Inoculation was done at a concentration of 10^{-6} for bacteria in Soil Extract agar medium (Allen, 1953). Inoculation for fungi was done at a concentration of 10^{-4} in Rose Bengal agar medium (Martin, 1950). Inoculation for actinomycetes was done at a concentration of 10^{-5} in agar medium (Kuster and Williams, 1964). The population count was taken at third day for bacteria, fifth day for fungi and seventh day for actinomycetes after inoculation and expressed as population g^{-1} of oven dry soil.

3.6.2. Plant analysis

The crop and weed samples were chemically analysed for nitrogen, phosphorus and potassium at the final harvest. The plants were dried in an air oven at 80 ± 5°C separately till constant weights were achieved. Samples were then ground to pass throught a 0.5 mm mesh in a Wiley mill. The required quantity of samples were then weighed out accurately in a physical balance and analysed.

3.6.2.1. Uptake of nitrogen

The nitrogen in crop and weeds was estimated by modified microkjeldahl method (Jackson, 1973) and the uptake of nitrogen was calculated based on the content of the nutrient in plants and the dry matter produced.

3.6.2.2. Uptake of phosphorus

The phosphorus content in crop and weeds was estimated colorimetrically (Jackson, 1973) after wet digestion of the sample using 2:1 mixture of nitric acid and perchloric acid and developing colour by Vanodomolydo phosphoric yellow colour method and read in a spectronic 20 spectrophotometer. Based on the phosphorus content in plants and the dry matter produced at harvest, the uptake was worked out.

3.6.2.3. Uptake of potassium

The potassium content in crop and weeds was estimated by the flame photometric method after wet digestion of the sample using diacid mixture (Jackson, 1973). The uptake of potassium was calculated based on the potassium content in plants and dry matter produced.

3.6.3. Residual toxicity in soil

Soil samples were collected from experimental plots in polyethene bags and 10 seeds of indicator plant cucumber were sown to each bag. The germination percentage and dry weight were estimated three weeks after sowing to assess the residual effect of herbicides in soil.

3.7. Economics of different weed management treatments

The economics of different weed management treatments was worked out and the net profit and benefit cost ratio were calculated as follows

$$\text{Net profit (Rs ha}^{-1}\text{)} = \text{Gross income} - \text{Cost of cultivation}$$

$$\text{B:C ratio} = \frac{\text{Gross income}}{\text{Cost of cultivation}}$$

3.8. Statistical analysis

The data were subjected to statistical analysis by the analysis of variance method (Cochran and Cox, 1965). Data on weed counts and population counts of soil organisms were analysed after square root transformation ($\sqrt{x+1}$). Significant results were compared by working out critical difference at 5 per cent.

RESULTS

4. RESULTS

The experimental data recorded were statistically analysed and the results of the experiments are presented in this chapter under the following sections.

1. Observations on weeds
2. Growth and growth characters of crop
3. Yield and yield attributes of crop
4. Uptake of nutrients by crop
5. Uptake of nutrients by weeds
6. Soil nutrient status
7. Population dynamics of soil organisms
8. Economics
9. Pooled analysis of crop yield

4.1. First crop season

4.1.1. Observations on weeds

4.1.1.1. Important weed species of the season

The different weed species found in the experimental field were collected before and during the period of experimentation and identified. The weeds were classified into grasses, sedges and broad-leaved weeds and are presented in Table 2.

Table 2. Major weed flora of the experimental field during first crop season

Group	Name of weed	Family
I. Grasses	*Echinochloa crus-galli*	Gramineae
	Echinochloa colonum	Gramineae
	Brachiaria ramosa	Gramineae
	Cynadon dactylon	Gramineae
	Panicum spp.	Gramineae
II. Sedges	*Cyperus rotundus*	Cyperaceae
	Cyperus iria	Cyperaceae
	Cyperus difformis	Cyperaceae
	Scirpus juncoides	Cyperaceae
	Fimbristylis miliacea	Cyperaceae
III. Broad-leaved weeds	*Ammania baccifera*	Lytheraceae
	Ludwigia parviflora	Onagraceae
	Marsilea quadrifoliata	Marsileaceae
	Cleome viscosa	Capparaceae
	Monochoria vaginalis	Pontederiaceae
	Leucas aspera	Labiatae

4.1.1.2. Monocot weed population

The data on monocot weed count at 15, 30 and 45 DAS and at harvest were analysed statistically after square root transformation ($\sqrt{x+1}$) and the mean values are presented in Table 3.

4.1.1.2a. 15 days after sowing

Analysis of the data revealed significant effect of weed control treatments on the monocot weed population m^{-2} at 15 DAS during first crop season of both the years. During the first crop season of 1996-97, all the herbicide treatments recorded lesser number of monocot weed population than the unweeded check (T_2) and farmers practice (T_3). Among the herbicide treaments, pendimethalin pre-emergence (T_4) recorded the lowest monocot weed population. Weedy check (T_2) and farmers' practice (T_3) recorded the highest number of monocot weeds which were inferior to all other herbicide treatments. During the first crop season of 1997-98, oxyfluorfen pre-emergence + 2,4-D post-emergence (T_{12}) recorded the highest number of monocot weeds and minimum under oxyfluorfen pre-emergence + hand weeding (T_9) which was superior.

4.1.1.2b. 30 days after sowing

During first crop season of both the years, herbicide treatments recorded significantly lower number of monocots than the unweeded check (T_2) at 30 days after sowing. During the first year, farmer's practice (T_3) recorded the lowest monocot weed count which was on a par with

Table 3. Effect of weed management practices on monocot weed count during first crop season (number m^{-2})

Treatments	First crop 1996-97				First crop 1997-98			
	15 DAS	30 DAS	45 DAS	At harvest	15 DAS	30 DAS	45 DAS	At harvest
T_1	0 (1)	0 (1)	0 (1)	0 (1)	0 (1)	0 (1)	0 (1)	0 (1)
T_2	46.14 (6.86)	82.57 (9.14)	103.64 (10.23)	124.84 (11.22)	60.33 (7.83)	73.24 (8.62)	106.63 (10.37)	113.31 (10.69)
T_3	38.38 (6.27)	10.58 (3.40)	41.53 (6.52)	55.31 (7.50)	41.00 (6.48)	9.25 (3.20)	39.69 (6.38)	51.68 (7.26)
T_4	17.18 (4.26)	23.69 (4.97)	47.24 (6.95)	48.65 (7.05)	18.33 (4.39)	18.73 (4.44)	46.60 (6.89)	37.78 (6.23)
T_5	23.97 (4.99)	27.68 (5.36)	42.01 (6.56)	49.41 (7.10)	16.65 (4.20)	23.89 (4.99)	43.17 (6.65)	48.46 (7.03)
T_6	18.51 (4.42)	35.94 (6.08)	58.61 (7.72)	41.34 (6.51)	17.32 (4.28)	27.98 (5.38)	53.95 (7.41)	40.84 (6.47)
T_7	19.91 (4.57)	11.26 (3.50)	30.02 (5.57)	38.46 (6.28)	19.14 (4.49)	13.85 (3.85)	31.48 (5.69)	31.86 (5.73)
T_8	22.60 (4.86)	14.57 (3.94)	39.30 (6.35)	44.88 (6.77)	15.84 (4.10)	11.19 (3.49)	33.76 (5.89)	34.94 (5.99)
T_9	17.18 (4.26)	16.49 (4.18)	33.85 (5.90)	41.34 (6.51)	12.65 (3.69)	21.88 (4.78)	34.19 (5.93)	34.62 (5.97)
T_{10}	20.53 (4.64)	55.68 (7.53)	36.53 (6.13)	33.07 (5.84)	18.51 (4.41)	35.52 (6.04)	21.42 (5.12)	29.24 (5.49)
T_{11}	23.80 (4.98)	47.24 (6.94)	46.79 (6.91)	44.39 (6.74)	15.96 (4.11)	39.15 (6.34)	41.66 (6.53)	36.96 (6.16)
T_{12}	26.51 (5.25)	47.18 (6.94)	51.18 (7.22)	45.30 (6.80)	22.66 (4.86)	41.12 (6.49)	41.93 (6.55)	33.21 (5.85)
$F_{11,22}$	37.355**	29.381**	9.636**	17.769**	38.797**	33.215**	17.648**	28.318**
CD(0.05)	0.68	1.20	1.97	1.55	0.76	0.99	1.45	1.17
SE	0.231	0.409	0.672	0.529	0.258	0.336	0.495	0.400

** Significant at 1% level

Figures in paranthesis are transformed values

pendimethalin pre-emergence + hand weeding (T_7), butachlor pre-emergence + hand weeding (T_8) and oxyfluorfen pre-emergence + hand weeding (T_9). Among the herbicide treatments, pendimethalin pre-emergence + 2,4-D post-emergence (T_{10}) recorded the highest monocot weed count m^{-2} which was statistically on a par with butachlor pre-emergence + 2,4-D post-emergence (T_{11}) and oxyfluorfen pre-emergence + 2,4-D post-emergence (T_{12}). During the second year of experimentation, farmer's practice (T_3) recorded the lowest monocot weed count which was on a par with butachlor pre-emergence + hand weeding (T_8) and pendimethalin pre-emergence + hand weeding (T_7) and superior to the other treatments. Unweeded check recorded the highest monocot weed count which was inferior to all the treatments. The next higher monocot weed counts were recorded by pre-emergence application of oxyfluorfen, butachlor and pendimethalin followed by post-emergence application of 2,4-D treatments *viz.*, T_{12}, T_{11} and T_{10}.

4.1.1.2c. 45 days after sowing

The data revealed significant effect of weed control treatments on monocot weed count at this stage also. During the first crop season of 1996-97, the lowest weed count among the different herbicide treatments was recorded by pendimethalin pre-emergence + hand weeding (T_7) which was statistically at par with other herbicide treatments except oxyfluorfen pre-emergence alone (T_6) which was inferior. The monocot weed count was maximum in the unweeded check. During the first crop season of 1997-98 also, the unweeded check (T_2) was inferior to all other treatments. Monocot weed population was the least in pendimethalin pre-emergence + 2,4-D post-emergence (T_{10}).

4.1.1.2d. At harvest

Monocot weed population differed significantly at the stage of harvest of the crop during both the seasons. Unweeded check recorded the highest number of monocot weeds during both the seasons which was inferior to all the other treatments. Among the herbicide treatments, lowest monocot weed count was recorded under the pendimethalin pre-emergence + 2,4-D post-emergence (T_{10}) during the first crop season of first year which was statistically at par with the other herbicide treatments. During the first crop season of 1997-98, monocot weed population was higher in unweeded check (T_2) which was significantly inferior to all other treatments. This was followed by farmers' practice (T_3). Pendimethalin pre-emergence + 2,4-D post-emergence (T_{10}) recorded the minimum number of monocot weeds which was on a par with other herbicide treatments except butachlor pre-emergence alone (T_5).

4.1.1.3. Dicot weed population

The data on dicot weed count at 15, 30 and 45 DAS and at harvest were analysed statistically after square root transformation ($\sqrt{x+1}$) and are presented in Table 4.

Table 4. Effect of weed management practices on dicot weed count during first crop season (number m^{-2})

Treatments	First crop 1996-97				First crop 1997-98			
	15 DAS	30 DAS	45 DAS	At harvest	15 DAS	30 DAS	45 DAS	At harvest
T_1	0 (1)	0 (1)	0 (1)	0 (1)	0 (1)	0 (1)	0 (1)	0 (1)
T_2	83.76 (9.2)	42.48 (6.59)	53.18 (7.36)	72.67 (8.58)	59.29 (7.76)	51.85 (7.27)	53.74 (7.39)	65.96 (8.18)
T_3	37.95 (6.24)	3.28 (2.07)	31.11 (5.67)	40.84 (6.47)	33.16 (5.84)	5.90 (2.63)	29.24 (5.49)	37.95 (6.24)
T_4	27.98 (5.38)	10.64 (3.41)	23.45 (4.95)	29.65 (5.54)	22.54 (4.85)	13.14 (3.76)	23.92 (5.00)	20.62 (4.65)
T_5	46.66 (6.90)	24.55 (5.05)	19.71 (4.55)	25.21 (5.12)	28.61 (5.44)	24.01 (5.00)	21.91 (4.78)	29.13 (5.49)
T_6	28.61 (5.44)	31.86 (5.73)	25.01 (5.09)	28.32 (5.41)	24.61 (5.06)	35.25 (6.02)	25.97 (5.19)	27.20 (5.31)
T_7	32.88 (5.82)	11.77 (3.58)	14.91 (3.98)	21.36 (4.73)	27.53 (5.34)	9.31 (3.21)	21.73 (4.77)	19.79 (4.56)
T_8	34.44 (5.95)	7.92 (2.98)	11.70 (3.56)	25.27 (5.12)	28.65 (5.45)	15.63 (4.08)	17.09 (4.25)	17.86 (4.34)
T_9	41.58 (6.52)	5.05 (2.46)	20.46 (4.63)	22.03 (4.79)	26.76 (5.27)	6.54 (2.75)	17.76 (4.33)	23.76 (4.98)
T_{10}	35.47 (6.04)	32.47 (5.78)	7.12 (2.85)	20.12 (4.59)	32.72 (5.81)	16.39 (4.17)	7.31 (2.88)	14.22 (3.90)
T_{11}	25.23 (5.12)	29.98 (5.57)	17.27 (4.27)	15.41 (4.05)	17.00 (4.24)	9.31 (3.21)	18.59 (4.43)	17.56 (4.31)
T_{12}	39.06 (6.33)	26.83 (5.28)	13.44 (3.80)	13.35 (3.79)	28.97 (5.47)	15.74 (4.09)	15.23 (4.03)	13.65 (3.83)
$F_{11,22}$	9.064**	22.861**	6.809**	10.991**	11.037**	16.917**	40.783**	27.073**
SE	0.615	0.371	0.593	0.531	0.464	0.398	0.238	0.322
CD (0.05)	1.80	1.08	1.74	1.55	1.36	1.17	0.69	0.94

** Significant at 1% level

Figures in paranthesis are transformed values

4.1.1.3a. 15 days after sowing

All the herbicide treatments recorded lower dicot weeds than the unweeded check (T_2). During the first crop season of 1996-97, butachlor pre-emergence + 2,4-D post-emergence (T_{11}) recorded the lowest number of dicot weeds which was on a par with other herbicide treatments and differed significantly from unweeded check (T_2). During the first crop season of 1997-98 also, butachlor pre-emergence + 2,4-D post-emergence (T_{11}) recorded the lowest number of dicot weeds, closely followed by pendimethalin pre-emergence (T_4) and oxyfluorfen pre-emergence (T_6). Dicot weed count was high in farmers' practice (T_3) and was on a par with the other herbicide treatments except butachlor pre-emergence + 2,4-D post-emergence (T_{11}).

4.1.1.3b. 30 Days after sowing

Dicot weed count m^{-2} was significantly influenced by the weed control treatments. Dicot weed population was the highest in unweeded check and the minimum in the completely weed free treatment. During the first crop season of 1996-97, lowest dicot weed count m^{-2} was recorded by farmers' practice (T_3) which was on par with oxyfluorfen pre-emergence + hand weeding (T_9) and butachlor pre-emergence + hand weeding (T_8). Dicot weed population was higher in pendimethalin pre-emergence + 2,4-D post-emergence (T_{10}) which was statistically at par with oxyfluorfen pre-emergence (T_6), butachlor pre-emergence + 2,4-D post-emergence (T_{11}), oxyfluorfen pre-emergence + 2,4-D post-emergence (T_{12}) and butachlor pre-emergence alone (T_5). During the second year of experimentation, dicot weed population was low in farmers' practice (T_3) which was on par with oxyfluorfen pre-emergence + hand weeding (T_9), butachlor pre-emergence + 2,4-D post-emergence (T_{11}), pendimethalin pre-emergence + hand weeding (T_7) and pendimethalin pre-emergence (T_4). Oxyfluorfen pre-emergence (T_6) was inferior to other herbicide treatments.

4.1.1.3c. 45 Days after sowing

The completely weed free plots were superior to all other treatments. During the first crop season of 1996-97, no weeding (T_2) recorded the maximum dicot weed count which was on a par with farmers' practice (T_3). Next to completely weed free treatment, dicot weed count was the lowest in pendimethalin pre-emergence + 2,4-D post-emergence (T_{10}) , which was statistically at par with butachlor pre-emergence + hand weeding (T_8), oxyfluorfen pre-emergence + 2,4-D post-emergence (T_{12}), pendimethalin pre-emergence + hand weeding (T_7), butachlor pre-emergence + 2,4-D post-emergence (T_{11}) and butachlor pre-emergence (T_5). During the second year of experimentation, unweeded check recorded the highest dicot weed count which was inferior. Farmers' practice (T_3) recorded the next higher weed count which was on a par with oxyfluorfen pre-emergence (T_6) and pendimethalin pre-emergence (T_4) treatments. Lowest weed count was recorded by the treatment pendimethalin pre-emergence + 2,4-D post-emergence (T_{10}).

4.1.1.3d. At harvest

During the first crop season of 1996, oxyfluorfen pre-emergence + 2,4-D post-emergence (T_{12}) recorded lower dicot weed count which was on a par with the other integrated weed control treatments. No weeding (T_2) was inferior to all other treatments. During the second year, oxyfluorfen pre-emergence + 2,4-D post-emergence (T_{12}) recorded the lowest weed count which was on a par with pendimethalin pre-emergence + 2,4-D post-emergence (T_{10}), butachlor pre-emergence + 2,4-D post-emergence (T_{11}), butachlor pre-emergence + hand weeding (T_8), pendimethalin pre-emergence + hand weeding (T_7) and pendimethalin pre-emergence (T_4). Farmers' practice (T_3) recorded the highest dicot weed count at harvest which was on a par with butachlor pre-emergence (T_5) and oxyfluorfen pre-emergence (T_6) treatments.

4.1.1.4. Total weed count m^{-2}

The data on total weed count recorded at 15, 30 and 45 DAS and at harvest were analysed statistically after square root transformation ($\sqrt{x+1}$) and the mean data are presented in Table 5.

4.1.1.4a. 15 days after sowing

Total weed count m^{-2} was maximum in the no weeding (T_2). Herbicidal treatments differed significantly over no weeding (T_2). During the first crop season of 1996, farmers practice (T_3) recorded the maximum total weed count. Next to completely weed free treatment (T_1)

Table 5. Effect of weed management practices on total weed count during first crop season (number m^{-2})

Treatments	First crop 1996-97				First crop 1997-98			
	15 DAS	30 DAS	45 DAS	At harvest	15 DAS	30 DAS	45 DAS	At harvest
T_1	0 (1)	0 (1)	0 (1)	0 (1)	0 (1)	0 (1)	0 (1)	0 (1)
T_2	130.15 (11.45)	125.13 (11.23)	156.94 (12.57)	198.18 (14.11)	119.72 (10.98)	125.47 (11.25)	160.65 (12.71)	179.53 (13.44)
T_3	76.41 (8.79)	15.23 (4.03)	85.18 (9.28)	96.32 (9.86)	88.27 (9.45)	15.32 (4.04)	69.31 (8.39)	89.79 (9.53)
T_4	45.29 (6.80)	34.63 (5.97)	70.98 (8.48)	78.31 (8.90)	44.00 (6.71)	32.30 (5.77)	70.58 (8.46)	58.44 (7.71)
T_5	70.97 (8.48)	52.48 (7.31)	62.54 (7.97)	75.73 (8.76)	38.41 (6.28)	48.03 (7.00)	65.27 (8.14)	77.71 (8.87)
T_6	47.16 (6.94)	68.44 (8.33)	83.94 (9.21)	70.61 (8.46)	41.95 (6.55)	63.25 (8.02)	79.97 (8.99)	68.26 (8.32)
T_7	52.94 (7.34)	23.29 (4.93)	46.24 (6.87)	60.03 (7.81)	46.73 (6.91)	23.27 (4.93)	53.43 (7.38)	51.84 (7.27)
T_8	57.05 (7.62)	22.52 (4.85)	51.20 (7.22)	70.43 (8.45)	36.75 (6.14)	27.15 (5.30)	51.13 (7.22)	52.80 (7.33)
T_9	59.39 (7.77)	21.59 (4.75)	56.59 (7.59)	64.64 (8.10)	40.03 (6.41)	28.64 (5.44)	52.37 (7.30)	58.57 (7.72)
T_{10}	56.48 (7.58)	88.86 (9.48)	45.28 (6.80)	53.39 (7.37)	50.59 (7.18)	52.37 (7.31)	39.69 (6.38)	43.69 (6.68)
T_{11}	49.12 (7.08)	77.31 (8.85)	64.04 (8.06)	60.67 (7.85)	33.09 (5.84)	48.46 (7.03)	60.26 (7.82)	54.61 (7.45)
T_{12}	65.95 (8.12)	73.99 (8.66)	64.66 (8.10)	62.62 (7.98)	52.08 (7.29)	56.89 (7.61)	57.44 (7.64)	47.14 (6.94)
$F_{11,22}$	16.784**	41.005**	13.186**	26.417**	14.193**	34.842**	33.831**	41.454**
SE	0.579	0.447	0.724	0.561	0.622	0.422	0.449	0.431
CD (0.05)	1.69	1.31	2.12	1.65	1.82	1.24	1.32	1.26

** Significant at 1% level

Figures in paranthesis are transformed values

lowest total weed count m^{-2} was recorded under pendimethalin (T_4) which was on a par with the other herbicide treatments and was superior to farmers practice (T_3). During the first crop season of 1997, farmers practice (T_3) recorded higher total weed count m^{-2} which was at par with no weeding (T_2). Among the herbicide treatments butachlor pre-emergence + 2,4-D post-emergence (T_{11}) recorded the lowest total weed count which was on a par with other herbicide treatments and differed significantly from farmers practice (T_3) and no weeding (T_2).

4.1.1.4b. 30 Days after sowing

At this stage of crop growth, maximum number of weeds was recorded in the weedy check (T_2). During the first year of experimentation farmers practice (T_3) recorded the lowest total weed count which was on a par with oxyfluorfen pre-emergence + hand weeding (T_9), butachlor pre-emergence + hand weeding (T_8), pendimethalin pre-emergence + hand weeding (T_7). Pendimethalin pre-emergence + 2,4-D post-emergence (T_{10}) recorded the highest weed count next to no weeding (T_2) which was on a par with butachlor pre-emergence + 2,4-D post-emergence (T_{11}), oxyfluorfen pre-emergence + 2,4-D post-emergence (T_{12}) and oxyfluorfen pre-emergence (T_6). During the first crop season of 1997-98 also, lowest total weed count was observed in farmers practice (T_3) after completely weed free treatment (T_1) which was as good as pendimethalin pre-emergence + hand weeding (T_7). Oxyfluorfen pre-emergence (T_6) recorded the highest weed count after no weeding (T_2) and it was on a par with oxyfluorfen pre-emergence + 2,4-D post-emergence (T_{12}), pendimethalin pre-emergence + 2,4-D post-emergence (T_{10}), butachlor pre-emergence + 2,4-D post-emergence (T_{11}) and butachlor pre-emergence (T_5).

4.1.1.4c. 45 Days after sowing

At this stage of crop growth, pendimethalin pre-emergence + 2,4-D post-emergence (T_{10}) recorded the lowest weed count next to completely weed free treatment and was on a par with other herbicide treatments except oxyfluorfen pre-emergence (T_6) which was inferior. Oxyfluorfen pre-emergence (T_6) was on a par with farmers practice (T_3) during the first crop season of 1996. In the second year of experimentation also, the effects of different weed control treatment were significant. Completely weed free treatment (T_1) recorded the lowest weed count which was superior. Pendimethalin pre-emergence + 2,4-D post-emergence (T_{10}) recorded the next lower weed count. The total number of weeds m^{-2} was higher under oxyfluorfen pre-emergence (T_6), which was on par with pendimethalin pre-emergence (T_4), farmers practice (T_3), butachlor pre-emergence (T_5) and butachlor pre-emergence + 2,4-D post-emergence (T_{11}).

4.1.1.4d. At harvest

The data revealed significant effect of weed control treatments on total number of weeds m^{-2} at this stage during both the seasons. During first crop season of 1996-97, pendimethalin pre-emergence + 2,4-D post-emergence (T_{10}) recorded the lowest weed count among the herbicide treatments which was on a par with all other herbicide treatments. Total weed count was high in the no weeding (T_2), followed by farmers practice (T_3) which were inferior. During the second year of experimentation also completely weed free treatment (T_1) was superior. The weedy check recorded the highest number of total weeds which was inferior to all other treatments. Farmers practice (T_3) was as good as butachlor pre-emergence (T_5) and oxyfluorfen pre-emergence (T_6). Lowest weed count was recorded by pendimethalin pre-emergence + 2,4-D post-emergence (T_{10}) which was statistically at par with all other herbicide treatments except oxyfluorfen pre-emergence (T_6) and butachlor pre-emergence (T_5) which were inferior.

4.1.1.5. Dry weight of weeds

The data on dry weight of weeds recorded at 15, 30 and 45 DAS and at harvest were statistically analysed and the mean values are given in Table 6.

4.1.1.5a. 15 Days after sowing

The data revealed the significant effect of weed control treatments during the first crop season of 1997-98 only. Pendimethalin pre-emergence + hand weeding (T_7) recorded the maximum dry weight of weeds which was on a par with no weeding (T_2), butachlor pre-emergence + hand weeding (T_8) and pendimethalin pre-emergence (T_4). Completely weed free treatment was superior to all other treatments.

Table 6. Effect of weed control treatments on weed dry matter accumulation (g m^{-2}) during first crop season

Treatments	First crop 1996-97				First crop 1997-98			
	15 DAS	30 DAS	45 DAS	At harvest	15 DAS	30 DAS	45 DAS	At harvest
T_1	0	0	0	0	0	0	0	0
T_2	1.20	18.24	27.87	57.97	1.18	22.44	29.09	49.81
T_3	0.29	2.59	15.45	30.15	0.54	2.24	16.69	28.98
T_4	0.24	5.09	8.57	24.25	0.69	5.07	7.45	22.24
T_5	0.30	3.65	10.32	22.99	0.34	3.55	8.80	21.23
T_6	0.41	6.33	11.69	29.58	0.51	5.71	11.78	28.62
T_7	0.90	2.14	7.25	22.45	1.36	1.83	5.53	19.99
T_8	0.56	3.37	7.93	36.91	0.71	3.06	8.09	36.75
T_9	0.26	5.37	5.21	44.63	0.29	4.75	5.41	43.45
T_{10}	0.43	6.02	4.69	29.81	0.50	5.97	4.10	30.95
T_{11}	0.57	5.20	4.17	41.57	0.57	4.13	3.69	42.24
T_{12}	0.35	3.87	13.03	33.33	0.42	3.49	9.59	30.72
$F_{11,22}$	1.29^{NS}	13.55^{**}	5.57^{**}	8.67^{**}	2.67^{**}	35.08^{**}	13.76^{**}	14.68^{**}
SE	0.28	1.22	3.01	4.82	0.23	0.96	2.04	3.44
CD(0.05)	NS	3.58	8.85	14.13	0.66	2.82	5.99	10.08

** Significant at 1% level NS - Not significant

4.1.1.5b. 30 Days after sowing

The effect of different weed control treatments was significant at 30 DAS. Weedy check (T_2) recorded significantly higher dry weight of weeds during both the seasons. During the first crop season of 1996-97, pendimethalin pre-emergence + hand weeding (T_7) recorded the lowest dry weight of weeds. During the first crop season of 1997-98, pendimethalin pre-emergence + hand weeding (T_7) recorded lowest weed count next to weed free treatment and it was as good as farmers practice (T_3). The highest weed dry weight was recorded by pendimethalin pre-emergence + 2,4-D post-emergence (T_{10}) at this stage of crop growth.

4.1.1.5c. 45 Days after sowing

The highest weed dry matter production was noted in no weeding (T_2) and was inferior. During the first crop season of both the years, weed dry weight under farmers practice (T_3) was the highest after the weedy check. During the first year, pendimethalin pre-emergence (T_4), butachlor pre-emergence + hand weeding (T_8), pendimethalin pre-emergence + hand weeding (T_7), oxyfluorfen pre-emergence + hand weeding (T_9), pendimethalin pre-emergence + 2,4-D post-emergence (T_{10}) and butachlor pre-emergence + 2,4-D post-emergence (T_{11}) were on a par and were as good as weed free treatment. In the second year of experimentation, pendimethalin pre-emergence + hand weeding (T_7), oxyfluorfen pre-emergence + hand weeding (T_9), pendimethalin pre-emergence + 2,4-D post-emergence (T_{10}) and butachlor pre-emergence + 2,4-D post-emergence (T_{11}) were on a par and were as good as completely weed free treatment.

4.1.1.5d. At harvest

The weed control treatments had significant effect on dry weight of weeds at this stage also. Among the herbicide treatments, pendimethalin pre-emergence + hand weeding (T_7) recorded the lowest weed dry weight of 22.45 g m^{-2} and 19.99 g m^{-2} during the first and second year respectively. Unweeded treatment recorded the highest weed dry weight and it was on a par with oxyfluorfen pre-emergence + hand weeding (T_9) during the first year and with oxyfluorfen pre-emergence + hand weeding (T_9) and butachlor pre-emergence + 2,4-D post-emergence (T_{11}) during the second year.

4.1.1.6. Weed control efficiency

The data on weed control efficiency are presented in Table 7.

The data revealed significant difference between the treatments during both the seasons. Among the herbicide treatments, pendimethalin pre-emergence + 2,4-D post-emergence (T_{10}) recorded the highest weed control efficiency during both the seasons. During the first crop season of 1996-97, pendimethalin pre-emergence + 2,4-D post-emergence (T_{10}) recorded the highest weed control efficiency after the weed free treatment (T_1) which was statistically at par with all other herbicide treatments and superior over farmers practice (T_3) and no weeding (T_2). During the first crop season of 1997-98 also, pendimethalin pre-emergence + 2,4-D post-emergence (T_{10}) recorded the next higher weed control efficiency after the weed free treatment which was on a par with other integrated methods tried in the experiment. Weedy check recorded the lowest weed control efficiency which was inferior to all other treatments.

Table 7. Effect of weed control treatments on weed index, weed control efficiency and herbicide efficiency index during first crop season

Treatments	Weed index		Weed control efficiency		Herbicide efficiency index	
	First crop 1996-97	First crop 1997-98	First crop 1996-97	First crop 1997-98	First crop 1996-97	First crop 1997-98
T_1	0	0	100	100	0	0
T_2	58.11	58.53	0	0	0	0
T_3	36.48	25.60	60.05	55.0	0	0
T_4	39.19	26.70	67.22	70.67	11.60 (19.90)	12.70 (20.80)
T_5	40.20	37.60	68.32	60.67	11.60 (19.90)	11.30 (19.60)
T_6	43.92	37.30	70.79	65.67	9.60 (18.00)	8.50 (16.90)
T_7	28.71	16.30	74.93	74.00	14.20 (22.10)	16.20 (23.70)
T_8	32.65	36.90	70.79	73.33	8.40 (16.80)	6.60 (14.80)
T_9	36.49	39.20	73.28	70.67	6.50 (14.80)	5.30 (13.30)
T_{10}	33.11	30.40	77.68	78.00	10.30 (18.70)	8.50 (16.90)
T_{11}	40.02	28.50	74.65	72.33	6.90 (15.20)	6.30 (14.50)
T_{12}	37.39	33.90	73.55	76.33	8.60 (17.00)	8.30 (16.70)
$F_{11,22}$	4.881**	3.545**	18.050**	30.997**	14.846**	30.058**
SE	4.69	6.67	4.41	3.78	1.52	1.10
CD(0.05)	13.76	19.57	12.95	11.09	4.45	3.23

** - Significant at 1 % level   Figures in paranthesis are angular transformed values

4.1.1.8. Herbicide efficiency index

The data on herbicide efficiency index of weed control treatments were analysed statistically after angular transformation and the mean values are presented in Table 7.

There was significant difference among the weed control treatments during both the seasons. During the first crop season of 1996-97, the herbicide efficiency index was the highest for pendimethalin pre-emergence + hand weeding (T_7) and the lowest for oxyfluorfen pre-emergence + hand weeding (T_9). During the second year of experimentation also, pendimethalin pre-emergence + hand weeding (T_7) recorded the highest herbicide efficiency index which was on a par with pendimethalin pre-emergence (T_4). Among the herbicidal control, oxyfluorfen pre-emergence + hand weeding (T_9) recorded the lowest herbicide efficiency index value.

4.1.2. Observation on crop growth characters

4.1.2.1. Height of plant

The results are presented in Table 8.

4.1.2.1a 15 Days after sowing

There was no significant effect of the treatments on the height of plant at 15 DAS during the first crop season of the year 1996-97. However significant effect on the height of plant was observed during

Table 8. Effect of weed control treatments on the height of plant (cm) during first crop season

Treatments	First crop 1996-97				First crop 1997-98			
	15 DAS	30 DAS	45 DAS	At harvest	15 DAS	30 DAS	45 DAS	At harvest
T_1	18.5	25.6	52.6	93.4	11.8	25.6	56.2	93.6
T_2	18.0	23.8	49.0	80.7	12.6	22.7	46.3	84.9
T_3	16.5	25.3	51.7	85.9	10.9	24.4	53.5	85.8
T_4	17.2	25.0	51.2	88.9	11.4	27.4	52.7	89.4
T_5	18.0	25.4	49.9	85.8	11.9	24.8	52.6	86.0
T_6	16.9	25.2	51.7	86.2	13.4	25.9	52.2	86.5
T_7	16.8	26.2	51.7	91.3	15.1	28.5	55.1	91.7
T_8	17.0	26.0	53.4	86.4	13.9	26.6	52.8	86.8
T_9	19.2	27.8	54.4	84.8	15.4	27.9	54.6	85.2
T_{10}	17.2	25.9	53.0	87.5	14.6	27.6	53.8	87.8
T_{11}	16.0	24.4	51.1	84.4	14.6	27.3	54.9	86.6
T_{12}	19.5	27.0	53.6	83.7	16.6	27.6	54.2	87.4
$F_{11,22}$	0.394^{NS}	0.494^{NS}	0.993^{NS}	12.288^{**}	11.133^{**}	2.470^{*}	6.504^{**}	5.788^{**}
SE	1.71	1.53	1.54	0.97	0.54	1.09	0.98	1.10
CD(0.05)	NS	NS	NS	2.85	1.59	3.21	2.87	3.23

* Significant at 5% level   ** Significant at 1% level   NS - Not significant

the second year of experimentation. Oxyfluorfen pre-emergence + 2,4-D post-emergence (T_{12}) recorded the maximum height which was on a par with oxyfluorfen pre-emergence + hand weeding (T_9) and pendimethalin pre-emergence + hand weeding (T_7) treatments. The plant height was lowest in the farmers practice (T_3) which was statistically on a par with butachlor pre-emergence (T_5), completely weed free treatment (T_1) and pendimethalin pre-emergence alone (T_4).

4.1.2.1b. 30 Days after sowing

There was no significant effect of the treatments on the height of plants at 30 DAS during the first year of experimentation.

During the second year of experimentation, the effect of treatments on plant height was significant. The maximum height of 28.5 cm was recorded by the treatment pendimethalin pre-emergence + hand weeding (T_7) which was statistically at par with other integrated methods and weed free treatment. The lowest height of 22.7 cm was recorded by no weeding (T_2) followed by the farmers practice (T_3).

4.1.2.1c. 45 Days after sowing

At this stage also, there was no significant difference among the treatments regarding the plant height during the first year of experimentation.

The effect of the treatments on plant height was significant during the first crop season of the year 1997-98. Plant height was maximum in the weed free treatment which was on a par with other herbicidal treatments involving combination of pre and post-emergence herbicides and pre-emergence herbicides followed by hand-weeding. Height was significantly low for plants grown in no weeding (T_2) and was inferior to all the other treatments.

4.1.2.1d. At harvest

During both the years significant difference in this character was observed among the treatments tried in the experiment. Weed free treatment (T_1) recorded the maximum plant height followed by pendimethalin pre-emergence + hand weeding (T_7) during both the years and were on a par. Pendimethalin pre-emergence + hand weeding (T_7) was on a par with pendimethalin pre-emergence (T_4) during both the seasons. The lowest plant height was recorded by no weeding (T_2) which was inferior to all other treatments during the first year and with other treatments except weed free treatment (T_1), pendimethalin pre-emergence (T_4) and pendimethalin pre-emergence + hand weeding (T_7) during the second year of experimentation.

4.1.2.2. Number of tillers m^{-2}

The data were analysed statistically and the mean values are presented in Table 9.

4.1.2.2a. 30 Days after sowing

Weed free treatment (T_1) recorded the maximum number of tillers followed by pendimethalin pre-emergence + hand weeding (T_7).

Table 9. Effect of weed control treatments on number of tillers m^{-2} during first crop season

Treatments	First crop 1996-97			First crop 1997-98		
	30 DAS	45 DAS	At harvest	30 DAS	45 DAS	At harvest
T_1	261.3	370.7	343.0	246.0	377.3	372.0
T_2	120.7	222.0	227.3	121.3	216.0	224.7
T_3	220.0	330.7	327.3	206.0	312.3	309.3
T_4	210.7	320.0	326.0	229.3	324.0	310.6
T_5	174.7	312.7	313.7	176.7	319.3	311.3
T_6	202.0	332.0	334.0	210.7	352.7	320.3
T_7	252.0	362.0	353.3	246.0	367.3	340.0
T_8	198.7	360.0	341.3	212.0	368.7	345.3
T_9	198.0	372.0	352.7	194.7	382.0	343.0
T_{10}	221.3	399.3	382.0	222.3	400.0	351.3
T_{11}	186.7	350.7	345.3	188.7	395.3	345.7
T_{12}	170.0	372.7	356.3	181.3	378.0	343.3
$F_{11,22}$	3.759**	3.802**	5.093**	5.714**	9.008**	11.229**
SE	19.42	23.31	16.73	14.41	17.03	11.14
CD(0.05)	56.95	68.36	49.07	42.28	49.96	32.67

** Significant at 1% level

All the weed control treatments were superior to no weeding (T_2). The effect of pendimethalin pre-emergence + hand weeding (T_7), pendimethalin pre-emergence + 2,4-D post-emergence (T_{10}), farmers practice (T_3) and pendimethalin pre-emergence (T_4) were as good as weed free treatment during both the seasons.

4.1.2.2b. 45 Days after sowing

At this stage, pendimethalin pre-emergence + 2,4-D post-emergence (T_{10}) recorded the highest tiller number and the weedy check (T_2) recorded the lowest tiller number, which was inferior to all other treatments. The effect of pre-emergence application of oxyfluorfen alone (T_6) was on a par with the pre-emergence application of other herbicide such as pendimethalin pre-emergence (T_4), butachlor pre-emergence (T_5) and farmers practice (T_3), during both the years.

4.1.2.2c. At harvest

The effect of treatments on tiller number m^{-2} was significant at the stage of harvest of the crop. Pendimethalin pre-emergence + 2,4-D post-emergence (T_{10}) treatment recorded the maximum number of tillers m^{-2} during the first year of experimentation which was on a par with other integrated weed control methods and completely weed free plot. During the second year of experimentation the weed free treatment (T_1) recorded the maximum tiller number which was on a par with the other integrated methods tried in the experiment. No weeding (T_2) recorded the lowest tiller number which was statistically inferior to all other treatments.

4.1.2.3. Leaf areaindex

The data are presented in Table 10.

4.1.2.3a. 15 Days after sowing

The effect of different treatments on LAI was significant at 15 DAS during both the years. During the first crop season of 1996-97, maximum LAI was recorded by pendimethalin pre-emergence + hand weeding (T_7). However it was on a par with weed free treatment (T_1) and no weeding (T_2). During the second year of experimentation, completely weed free treatment recorded the highest LAI which was on a par with pendimethalin pre-emergence + hand weeding (T_7) and was superior to all other treatments. Farmers practice (T_3) recorded the next higher LAI and the minimum LAI by pendimethalin pre-emergence + 2,4-D post-emergence (T_{10}).

4.1.2.3b. 30 Days after sowing

The LAI recorded at 30 DAS revealed the superiority of pendimethalin pre-emergence + hand weeding (T_7) during the first year of experimentation. The no weeding (T_2) recorded the lowest LAI. The effect of pendimethalin pre-emergence + hand weeding (T_7) was on a par with weed free treatment (T_1), pendimethalin pre-emergence + 2,4-D post-emergence (T_{10}), farmers practice (T_3) and butachlor pre-emergence + hand weeding (T_8). However LAI due to weed control treatments did not vary significantly during the second year.

Table 10. Effect of weed control treatments on LAI of rice during first crop season

Treatments	First crop 1996-97			First crop 1997-98		
	15 DAS	30 DAS	45 DAS	15 DAS	30 DAS	45 DAS
T_1	0.19	3.13	4.35	0.19	3.11	4.14
T_2	0.17	2.71	3.11	0.17	2.73	3.11
T_3	0.15	3.09	4.11	0.17	3.15	4.13
T_4	0.15	2.88	3.95	0.15	3.07	4.10
T_5	0.14	2.86	3.85	0.15	2.97	3.93
T_6	0.13	2.72	3.47	0.14	2.83	3.51
T_7	0.19	3.16	4.16	0.19	3.10	4.12
T_8	0.14	3.08	3.76	0.14	3.16	3.85
T_9	0.14	2.92	3.70	0.14	3.06	3.84
T_{10}	0.14	3.11	3.99	0.13	3.07	4.00
T_{11}	0.14	2.85	3.73	0.15	3.04	3.79
T_{12}	0.16	2.87	3.95	0.16	3.04	4.02
$F_{11,22}$	5.658^{**}	4.905^{**}	24.745^{**}	9.648^{**}	1.775^{NS}	11.267^{**}
SE	0.009	0.072	0.066	0.006	0.095	0.089
CD(0.05)	0.027	0.210	0.194	0.019	NS	0.263

** Significant at 1% level NS - Not significant

4.1.2.3c. 45 Days after sowing

At this stage of crop growth, weed free treatment (T_1) recorded the maximum LAI of 4.35 and 4.14 during the first and second year respectively. Pendimethalin pre-emergence + hand weeding (T_7) recorded higher LAI values which were as good as the completely weed free treatment. No weeding treatment recorded the lowest LAI values of 3.10 and 3.11 during the first and second year respectively which were inferior to all other weed control treatments.

4.1.2.4 Crop growth rate (CGR)

The data are presented in Table 11.

The results revealed that the weed control treatments had no significant influence on the CGR of the crop during both the years.

4.1.2.5 Relative growth rate (RGR)

The data are presented in Table 12

The weed control treatments had significantly influenced the RGR of the crop between 15 and 30 DAS during the first year of experimentation only. At all other stages, the RGR was not significantly affected by the weed control treatments. During the first year RGR between 15 and 30 DAS was maximum under completely weed free treatment which was closely followed by pendimethalin pre emergence + hand weeding (T_7).

Table 11. Crop growth rate (CGR) of rice during first crop season as influenced by different weed control treatments (g m^{-2} day^{-1})

Treatments	First crop 1996 (DAS)			First crop 1997 (DAS)		
	15-30	30-45	45-harvest	15-30	30-45	45-harvest
T_1	24.34	13.01	3.67	26.86	13.46	3.39
T_2	15.59	6.73	1.03	15.78	4.82	1.55
T_3	16.93	12.05	1.62	17.83	15.61	0.99
T_4	18.74	13.29	2.76	19.81	14.70	3.19
T_5	15.51	9.96	1.75	17.00	14.87	1.77
T_6	15.84	9.82	1.54	16.27	11.16	2.95
T_7	23.45	4.84	5.21	22.64	7.70	4.94
T_8	22.08	4.26	2.83	25.28	2.47	2.91
T_9	17.42	7.64	2.99	17.26	9.45	2.92
T_{10}	22.83	6.66	4.86	23.74	5.28	4.81
T_{11}	18.52	11.38	25.74	18.80	10.56	4.19
T_{12}	17.95	10.59	3.98	18.39	10.14	4.61
$F_{11,22}$	1.658^{NS}	0.777^{NS}	1.579^{NS}	1.834^{NS}	1.370^{NS}	2.202^{NS}
SE	2.57	3.51	1.05	2.75	3.66	0.87
CD(0.05)	NS	NS	NS	NS	NS	NS

NS - Not significant

Table 12. Relative growth rate (RGR) of rice during first crop season as influenced by different weed control treatments (g g^{-1} day^{-1})

Treatments	First crop 1996 (DAS)			First crop 1997 (DAS)		
	15-30	30-45	45-harvest	15-30	30-45	45-harvest
T_1	0.29	0.028	0.0054	0.29	0.028	0.0048
T_2	0.23	0.027	0.0027	0.24	0.018	0.0043
T_3	0.24	0.036	0.0032	0.26	0.042	0.0019
T_4	0.25	0.035	0.0051	0.25	0.039	0.0053
T_5	0.24	0.033	0.0036	0.25	0.043	0.0033
T_6	0.24	0.030	0.0037	0.24	0.034	0.0065
T_7	0.28	0.013	0.0097	0.27	0.019	0.0086
T_8	0.27	0.012	0.0060	0.28	0.006	0.0062
T_9	0.24	0.024	0.0065	0.25	0.028	0.0061
T_{10}	0.26	0.016	0.0084	0.27	0.012	0.0084
T_{11}	0.27	0.031	0.0052	0.27	0.029	0.0075
T_{12}	0.24	0.029	0.0063	0.25	0.027	0.0085
$F_{11,22}$	2.585*	6.955^{NS}	1.123^{NS}	2.047^{NS}	1.373^{NS}	1.646^{NS}
SE	0.010	0.009	0.002	0.010	0.009	0.002
CD(0.05)	0.03	NS	NS	NS	NS	NS

* - Significant at 5 % level NS - Not significant

4.1.3. Yield and yield attributes of crop

4.1.3.1. Number of productive tillers m^{-2}

The data recorded on productive tillers m^{-2} were statistically analysed and the mean values are given in Table 13.

The weed control treatments had significant effect on the number of productive tillers m^{-2} during both the years. Completely weed free (T_1) recorded the highest number of productive tillers followed by pendimethalin pre-emergence + hand weeding (T_7) which were on a par. The number of productive tillers in no weeding (T_2) was the lowest and inferior to all other herbicide treatments.

4.1.3.2. Weight of panicle

The data on weight of panicle recorded at the stage of harvest of the crop are presented in Table 13.

Effects of weed control treatments were found to be not significant on this parameter during both the years.

4.1.3.3. Total spikelets panicle^{-1}

The data on total spikelets panicle^{-1} are presented in Table 14.

The data revealed that there was significant difference between the treatments during the first year of experimentation only. Completely weed free (T_1) recorded the maximum number of spikelets panicle^{-1}

Table 13. Effect of weed control treatments on number of productive tillers m^{-2} and weight of panicle (g) during first crop season

Treatments	First crop 1996-97		First crop 1997-98	
	Number of productive tillers	Weight of panicle (g)	Number of productive tillers	Weight of panicle (g)
T_1	298.7	2.55	304.3	2.36
T_2	190.3	1.93	188.0	1.64
T_3	276.7	2.25	281.3	2.08
T_4	281.3	2.13	287.7	2.09
T_5	272.0	2.07	271.3	2.02
T_6	279.7	2.12	234.0	1.99
T_7	294.7	2.24	290.3	2.24
T_8	276.0	2.07	270.0	2.13
T_9	275.0	1.73	272.7	1.89
T_{10}	272.0	1.85	263.3	1.82
T_{11}	260.0	1.91	260.7	1.94
T_{12}	256.0	2.05	253.0	2.10
$F_{11,22}$	6.011^{**}	2.159^{NS}	4.700^{**}	1.659^{NS}
SE	11.46	0.15	14.01	0.15
CD(0.05)	33.60	NS	41.09	NS

** Significant at 1% level NS - Not significant

Table 14. Effect of weed control treatments on total number of spikelets panicle^{-1}, number of filled grains panicle^{-1} and percentage of filled grains

Treatments	First crop 1996-97			First crop 1997-98		
	No. of spikelet panicle^{-1}	No. of filled grains	Percentage of filled grains	No. of spikelet panicle^{-1}	No. of filled grains	Percentage of filled grains
T_1	107.0	91.7	85.3	110.3	96.7	87.6
T_2	82.7	59.3	71.8	86.0	69.7	80.6
T_3	96.0	71.3	74.2	94.3	80.0	84.8
T_4	104.7	81.3	78.0	102.7	80.0	78.2
T_5	94.0	78.0	82.6	94.3	76.7	80.9
T_6	85.0	77.0	90.2	87.0	65.7	75.2
T_7	104.7	96.7	92.6	107.3	84.0	78.5
T_8	100.3	91.7	91.2	96.7	80.7	83.2
T_9	94.0	72.7	77.2	91.3	57.7	63.7
T_{10}	97.7	74.7	76.4	93.7	72.7	77.7
T_{11}	99.0	88.7	89.4	93.7	71.7	76.7
T_{12}	90.0	78.3	87.1	91.7	77.0	83.8
$F_{11,22}$	2.959*	3.862**	4.869**	2.118^{NS}	3.441**	2.750*
SE	4.44	5.37	3.29	5.14	5.29	3.68
CD (0.05)	13.04	15.76	9.64	NS	15.52	10.8

* Significant at 5% level ** Significant at 1% level NS - Not significant

followed by pendimethalin pre-emergence (T_4) and pendimethalin pre-emergence + hand weeding (T_7). No weeding (T_2) recorded the lowest number of total spikelets panicle^{-1} during the season. Among the herbicide treatments oxyfluorfen pre-emergence (T_6) and oxyfluorfen pre-emergence + 2,4-D post-emergence (T_{12}) were found inferior. However during the second year of experimentation, the treatments did not show any significant difference on this character.

4.1.3.4. Number of filled grains panicle^{-1}

The data on the number of filled grains panicle^{-1} recorded at the time of harvest of the crop are presented in Table 14.

The effect of weed control treatments on this aspect was found to be significant during both the seasons. During the first crop season of 1996, pendimethalin pre-emergence + hand weeding (T_7) recorded the maximum number of filled grains panicle^{-1} (96.7) and minimum (59.3) by the no weeding (T_2). Completely weed free (T_1) and butachlor pre-emergence + hand weeding (T_8) recorded the next higher number of filled grains panicle^{-1}. During the first crop season of 1997, number of filled grains panicle^{-1} was maximum in completely weed free (T_1) and minimum in oxyfluorfen pre-emergence + hand weeding (T_9). Among the weed control treatments, integrated methods of weed control, pendimethalin pre-emergence + hand weeding (T_7) and butachlor pre-emergence + hand weeding (T_8) recorded higher number of filled grains compared to farmers practice (T_3).

4.1.3.5. Percentage of filled grains

The data on percentage of filled grains are given in Table 14.

There was significant effect of different weed control treatments on percentage of filled grains during both the seasons. During the first crop season of 1996-97 highest percentage of filled grains (92.6 per cent) was recorded by pendimethalin pre-emergence + hand weeding (T_7) followed by butachlor pre-emergence + hand weeding (T_8). Percentage of filled grains was the lowest in no weeding (T_2). All the herbicide treatments recorded higher percentage of filled grains compared to farmers practice (T_3). During the second year of experimentation, highest percentage of filled grains was recorded by weed free (T_1) closely followed by farmers practice (T_3). Lowest percentage of filled grains was recorded by the treatment oxyfluorfen pre-emergence + hand weeding (T_9) which was significantly lower than other treatments.

4.1.3.6. Grain yield

The data on grain yield recorded at harvest of the crop are presented in Table 15.

The grain yield of the crop was significantly influenced by the weed control treatments during both the seasons. During the first crop season of 1996-97, the maximum grain yield of 3889 kg ha^{-1} was recorded by weed free (T_1) and was superior to all other treatments. Next highest grain yield of 3197 kg ha^{-1} was recorded by pendimethalin pre-emergence + hand weeding (T_7). Grain yield was the lowest in the no weeding (T_2)

Table 15. Effect of weed control treatments on Grain yield, Straw yield and Harvest index of rice during first crop season

Treatments	First crop 1996-97			First crop 1997-98		
	Grain yield kg ha^{-1}	Straw yield kg ha^{-1}	Harvest index	Grain yield kg ha^{-1}	Straw yield kg ha^{-1}	Harvest index
T_1	3888.8	4232.3	0.48	3474.7	3787.8	0.48
T_2	1878.7	2383.8	0.44	1570.7	2020.1	0.44
T_3	2848.4	3686.8	0.44	2818.1	3121.2	0.48
T_4	2727.2	3121.2	0.47	2777.7	2999.9	0.48
T_5	2681.8	3020.2	0.47	2363.6	2636.3	0.47
T_6	2515.1	2676.7	0.48	2373.7	2636.3	0.47
T_7	3196.9	3282.8	0.52	3171.7	3474.7	0.48
T_8	3020.2	3202.0	0.48	2387.2	2696.9	0.47
T_9	2848.4	3550.5	0.45	2303.0	2550.8	0.47
T_{10}	3000.0	3323.2	0.47	2636.3	2939.3	0.47
T_{11}	2690.0	3202.0	0.45	2707.0	3050.5	0.47
T_{12}	2808.0	3141.4	0.47	2505.0	2712.1	0.48
$F_{11,22}$	4.881^{**}	3.548^{**}	2.563^{*}	3.545^{**}	2.178^{NS}	4.116^{**}
SE	210.38	248.72	0.014	252.81	310.57	0.0052
CD(0.05)	617.05	729.51	0.042	741.51	NS	0.015

* Significant at 5% level ** Significant at 1% level NS - Not significant

and was inferior to all other treatments. During the first crop season of 1997-98 also, completely weed free (T_1) recorded the highest grain yield of 3475 kg ha^{-1} which was statistically at par with pendimethalin pre-emergence + hand weeding (T_7), farmers practice (T_3) and pendimethalin pre-emergence (T_4). No weeding (T_2) recorded the lowest grain yield which was on a par with oxyfluorfen pre-emergence + hand weeding (T_9).

4.1.3.7. Straw yield

The data on straw yield are presented in Table 15.

The effect of different weed control treatments was found to be significant on the straw yield of the crop during the first crop season of 1996-97 only. During the first season, weed free (T_1) recorded the highest straw yield and the lowest by the no weeding (T_2). Farmers practice (T_3) and oxyfluorfen pre-emergence + hand weeding (T_9) were on a par with completely weed free plots. During the first crop season of 1997-98 also weed free (T_1) recorded the highest straw yield but the effect of different treatments were statistically at par.

4.1.3.8. Harvest index

The data on harvest index of the crop are presented in Table 15.

Analysis of the data revealed significant effect of weed control treatments on the harvest index of the crop during both the seasons. During the first crop season of 1996-97, pendimethalin pre-emergence + hand weeding (T_7) recorded the highest harvest index value followed by butachlor pre-emergence + hand weeding (T_8), oxyfluorfen pre-emergence (T_6) and weed free (T_1), which were on a par. The harvest index was the lowest in no weeding (T_2) and farmers practice (T_3). During the second year of experimentation also, the harvest index in unweeded treatment was the lowest while all other treatments were superior.

4.1.3.9. Dry matter production

The data on crop dry matter production were analysed statistically and the mean values are presented in Table 16.

4.1.3.9a. 15 Days after sowing

The effect of weed control treatments on dry matter production of crop was not significant during both the years.

4.1.3.9b. 30 Days after sowing

The effect of weed control treatments on dry matter production of crop was not significant at this stage also during both the seasons.

4.1.3.9c. 45 Days after sowing

The effect of weed control treatments on this parameter was significant only during the second year of experimentation. Completely weed free treatment recorded the maximum dry matter production which was statistically at par with pendimethalin pre-emergence and farmers's practice. Dry matter production was the lowest in the no weeding (T_2) treatment.

Table 16. Effect of weed control treatments on dry weight of rice crop during first crop season (g m^{-2})

Treatments	First crop 1996-97				First crop 1997-98			
	15 DAS	30 DAS	45 DAS	At harvest	15 DAS	30 DAS	45 DAS	At harvest
T_1	4.73	369.93	565.07	770.10	4.51	407.44	609.4	799.59
T_2	6.82	242.11	340.45	358.72	6.38	243.10	315.37	402.49
T_3	6.49	260.48	507.94	532.18	5.94	273.46	507.65	533.06
T_4	7.26	301.73	487.85	642.95	7.04	304.26	524.81	703.78
T_5	6.71	239.16	487.19	486.86	6.16	261.25	484.33	583.55
T_6	6.71	244.31	391.71	478.28	6.60	250.69	420.20	513.22
T_7	5.39	357.17	429.88	721.71	5.72	345.40	451.11	727.98
T_8	5.61	370.26	400.95	559.86	6.05	385.33	386.98	550.00
T_9	6.93	268.29	382.91	550.55	6.71	265.65	407.44	571.45
T_{10}	6.93	366.19	449.46	721.93	6.71	362.78	441.98	711.70
T_{11}	4.62	282.48	453.20	606.87	5.28	287.32	445.83	680.90
T_{12}	7.37	276.76	435.71	605.11	6.94	287.37	434.50	693.22
$F_{11,22}$	1.895^{NS}	1.762^{NS}	1.791^{NS}	2.064^{NS}	1.159^{NS}	1.819^{NS}	3.731^{**}	5.390^{**}
SE	0.69	40.00	46.15	82.03	0.65	41.19	38.41	49.14
CD(0.05)	NS	NS	NS	NS	NS	NS	112.67	144.14

** Significant at 1% level NS - Not significant

4.1.3.9d. At harvest

The effect of different weed control treatments on dry matter production at harvest stage was significant only during the second year. Completely weed free plot recorded the maximum crop dry matter production which was followed by pendimethalin pre-emergence + hand weeding (T_7) and pendimethalin pre-emergence + 2,4-D post-emergence (T_{10}). The minimum dry matter production was recorded under unweeded check (T_2) which was statistically at par with oxyfluorfen pre-emergence (T_6) and farmers practice (T_3). The effect of pendimethalin pre-emergence + hand weeding (T_7) was on a par with other treatments except no weeding treatment, which was inferior.

4.1.3.10. Weed index

The data on weed index are presented in Table 7.

The data showed significant effect of weed control treatments on weed index during both the seasons. Next to completely weed free treatment, pendimethalin pre-emergence + hand weeding (T_7) treatment recorded the lowest weed index. Unweeded check recorded the highest weed index during both the seasons.

4.1.4 Uptake of nutrients by crop

4.1.4.1 Uptake of nitrogen

The data on uptake of nitrogen by the crop are presented in Table 17.

Table 17. Effect of weed control treatments on N, P, K uptake by rice crop during first crop season (kg ha^{-1})

Treatments	First crop 1996-97			First crop 1997-98		
	Uptake of N	Uptake of P	Uptake of K	Uptake of N	Uptake of P	Uptake of K
T_1	131.01	56.55	140.57	145.44	57.48	157.78
T_2	50.13	21.18	45.06	55.64	23.07	52.86
T_3	83.17	32.70	75.28	68.35	31.85	80.40
T_4	99.77	39.65	95.49	108.52	42.74	108.66
T_5	75.32	28.91	75.49	93.40	34.97	93.33
T_6	76.33	29.11	75.99	63.95	31.19	82.34
T_7	118.48	49.93	117.75	120.16	46.15	119.82
T_8	88.79	34.31	90.64	89.56	33.70	89.23
T_9	89.12	32.72	90.01	91.84	34.63	92.98
T_{10}	118.29	43.89	118.07	117.63	42.40	114.10
T_{11}	95.16	37.70	99.42	108.79	41.30	109.38
T_{12}	97.94	37.75	98.35	111.07	42.03	112.19
$F_{11,22}$	2.907**	3.524**	3.655**	6.397**	8.623**	11.288**
SE	12.95	5.14	13.00	10.31	3.01	7.69
CD(0.05)	37.97	15.09	38.14	30.25	8.82	22.57

** - Significant at 1 % level

There was significant influence of the weed control treatments on this aspect. Nitrogen uptake by the crop was the highest in completely weed free treatment while it was the lowest in the weedy check. Uptake of nitrogen was higher in pendimethalin pre-emergence + hand weeding (T_7) and pendimethalin pre-emergence + 2,4-D post-emergence (T_{10}) treatment which were also on a par with weed free treatment.

4.1.4.2 Uptake of phosphorus

The data on phosphorus uptake by crop at harvest are presented in Table 17.

The data revealed significant difference among the weed control treatments on this aspect. Completely weed free plots (T_1) were superior to the other treatments and recorded the highest phosphorus uptake by the crop. During the first crop season of 1996-97, pendimethalin pre-emergence + hand weeding (T_7) and pendimethalin pre-emergence + 2,4-D post-emergence (T_{10}) could produce similar effects as that of weed free treatment. During the first crop season of 1997-98, weed free treatment recorded the highest phosphorus uptake followed by pendimethalin pre-emergence + hand weeding. Unweeded check recorded the lowest phosphorus uptake by crop during both the seasons.

4.1.4.3 Uptake of potassium

The data on potassium uptake by the crop at harvest were analysed statistically and the mean values are presented in Table 17.

Weed control treatments significantly influenced the potassium uptake by the crop during both the seasons. Completely weed free treatment (T_1) was superior to herbicide treatments. During the first crop season of 1996-97, pendimethalin pre-emergence + 2,4-D post-emergence (T_{10}) and pendimethalin pre-emergence + hand weeding (T_7) were on a par with weed free treatment. During the second year of experimentation, pendimethalin pre-emergence + hand weeding (T_7) recorded the next higher uptake of potassium after weed free treatment. Unweeded check (T_2) recorded the lowest potassium uptake values and was inferior to all the treatments.

4.1.5 Uptake of nutrients by weeds

4.1.5.1 Uptake of nitrogen

The data on nitrogen uptake by weeds at the stage of harvest of the crop are presented in Table 18.

There were significant variations on the uptake of nitrogen by the weeds during both the years. The weedy check recorded the highest nitrogen uptake by the weeds. Among the herbicide treatments, pendimethalin pre-emergence + hand weeding (T_7) recorded the lowest nitrogen uptake by weeds. Oxyfluorfen pre-emerence + hand weeding (T_9) recorded higher nitrogen uptake by weeds.

4.1.5.2 Uptake of phosphorus

The data on phosphorus uptake by weeds at harvest stage of the crop are presented in Table 18.

Table 18. Effect of weed control treatments on N, P, K uptake by weeds at harvest (kg ha^{-1}) during the first crop season

Treatments	First crop 1996-97			First crop 1997-98		
	Uptake of N	Uptake of P	Uptake of K	Uptake of N	Uptake of P	Uptake of K
T_1	0	0	0	0	0	0
T_2	9.93	4.74	12.76	8.61	3.79	8.90
T_3	4.89	1.84	5.48	4.67	2.03	5.16
T_4	3.77	1.44	4.10	3.55	1.54	3.81
T_5	3.69	1.38	3.97	3.38	1.46	3.69
T_6	4.58	2.05	5.48	4.62	2.04	5.17
T_7	3.35	1.29	3.13	3.00	1.18	3.07
T_8	5.91	2.23	6.06	5.89	2.25	5.93
T_9	7.21	2.92	7.57	6.98	2.79	7.02
T_{10}	4.79	1.81	4.44	4.99	1.96	4.86
T_{11}	6.68	2.48	6.63	6.86	2.69	6.85
T_{12}	5.34	2.02	5.50	5.05	1.90	4.99
$F_{11,22}$	9.715**	13.502**	12.542**	15.394**	14.583**	14.684**
SE	0.777	0.306	0.851	0.568	0.244	0.586
CD(0.05)	2.27	0.89	2.49	1.67	0.72	1.72

** Significant at 1 per cent level

The effect of weed control treatments was significant on this aspect. During the first crop season of 1996-97, unweeded check (T_2) recorded significantly higher P-uptake (4.74 kg ha^{-1}) followed by oxyfluorfen pre-emergence + hand weeding (T_9). Among the herbicide treatments pendimethalin pre-emergence + hand weeding (T_7) recorded the lowest P-uptake by weeds. During the first crop season of 1997-98 also, unweeded check (T_2) recorded the highest P-uptake by weeds (3.79 kg ha^{-1}). Oxyfluorfen pre-emergence + hand weeding (T_9) recorded the next higher uptake which was on a par with butachlor pre-emergence + 2,4-D post-emergence (T_{11}) and butachlor pre-emergence + hand weeding (T_8) treatments. The uptake of phosphorus by weeds was the lowest in pendimethalin pre-emergence + hand weeding (T_7) treatment.

4.1.5.3 Uptake of potassium

The data on uptake of potassium by weeds at the stage of harvest of the crop are presented in Table 18.

The results indicated that the uptake of potassium by weeds was significantly influenced by the weed control treatments. During both the years completely weed free treatment was superior owing to the season long weed free condition maintained in the plots. The weedy check (T_2) recorded the highest potassium uptake by weeds compared to other herbicide treatments during both the season. This was followed by oxyfluorfen pre-emergence + hand weeding (T_9) during both the years of experimentation. Potassium uptake by weeds was the lowest in pendimethalin pre-emergence + hand weeding (T_7) treatment compared to other herbicide treatments.

4.1.6 Soil nutrient status

4.1.6.1 Available nitrogen content in soil

The data on available nitrogen content of soil after the first crop season are presented in Table 19.

The results revealed significant difference on this aspect between the weed control treatments during both the seasons.

During the first year of experimentation, completely weed free treatment recorded the lowest available nitrogen content which was on a par with pendimethalin pre-emergence + hand weeding (T_7) and pendimethalin pre-emergence + 2,4-D post-emergence (T_{10}). Available N-content was higher under unweeded check (T_2) which was on a par with farmers' practice (T_3) and other herbicide treatments involving butachlor and oxyfluorfen. During the second year of experimentation, completely weed free treatment recorded the lowest available N-content which was on a par with pendimethalin pre-emergence + 2,4-D post-emergence (T_{10}) and pendimethalin pre-emergence + hand weeding (T_7). Other treatments differed significantly.

4.1.6.2 Available P_2O_5 content in soil

The data are presented in Table 19.

Table 19. Effect of weed control treatments on available N, P_2O_5 and K_2O status of the soil after first crop season (kg ha^{-1})

Treatments	First crop 1996-97			First crop 1997-98		
	Available N	Available P_2O_5	Available K_2O	Available N	Available P_2O_5	Available K_2O
T_1	133.13	20.77	32.20	96.20	22.10	28.00
T_2	196.23	34.66	72.07	168.83	41.53	47.77
T_3	175.23	30.40	56.05	165.40	32.40	24.93
T_4	164.93	27.86	40.17	128.70	29.36	27.13
T_5	184.90	31.70	55.43	145.43	30.30	29.80
T_6	183.20	28.70	31.00	172.10	29.67	30.43
T_7	143.63	22.53	27.63	118.93	27.63	24.33
T_8	174.07	29.33	37.43	144.63	32.00	37.00
T_9	171.70	29.07	34.27	141.46	32.10	34.23
T_{10}	149.77	26.00	25.80	118.23	29.73	33.63
T_{11}	166.30	28.96	27.87	128.30	28.90	30.47
T_{12}	166.23	27.60	37.82	131.50	29.40	31.00
$F_{11,22}$	3.071^{*}	3.502^{**}	2.897^{*}	5.549^{**}	17.319^{**}	6.835^{**}
SE	10.28	2.00	8.33	9.66	1.06	2.41
CD(0.05)	30.15	5.87	24.43	28.34	3.12	7.07

* - Significant at 5 % level   ** - Significant at 1 % level

The available phosphorus content in soil was significantly influenced by the weed control treatments. During the first year, highest available P_2O_5 content of 34.67 kg ha^{-1} was recorded under unweeded check (T_2). The lowest available P_2O_5 content was recorded under completely weed free treatment (T_1) which was statistically at par with pendimethalin pre-emergence + hand weeding (T_7) and pendimethalin pre-emergence + 2,4-D post-emergence (T_{10}). T_{10} was on a par with all other herbicide treatments. During the second year also, completely weed free treatment (T_1) recorded the lowest available P_2O_5 content (22.1 kg ha^{-1}) and weedy check recorded the highest content which differed significantly from other treatments. Pendimethalin pre-emergence + hand weeding (T_7) recorded the next lower P_2O_5 content which was on a par with other herbicide treatments except butachlor pre-emergence + hand weeding (T_8) and oxyfluorfen pre-emergence + hand weeding (T_9).

4.1.6.3 Available K_2O content in soil

The results are presented in Table 19.

The weedy check recorded the highest content of the nutrient during both the seasons which was on a par with farmers' practice (T_3) and butachlor pre-emergence alone (T_5) during the first year. The available K_2O status of the soil was the lowest under pendimethalin pre-emergence + 2, 4-D post-emergence (T_{10}) and pendimethalin pre-emergence + hand weeding (T_7) during the first and second year of experimentation respectively.

4.1.7 Population dynamics of soil organisms

4.1.7.1 Soil fungal population

The counts of soil fungi after the first crop rice were analysed statistically after square root transformation ($\sqrt{x + 1}$) and the data are presented in Table 20.

There was no significant difference in the soil fungal population between the treatments during both the years.

4.1.7.2 Soil bacterial population

The counts of soil bacterial population after the first crop of rice were analysed statistically after square root transformation ($\sqrt{x +1}$) and the data are presented in Table 20.

Soil bacterial population remained unaffected and there was no significant difference in both the years due to the weed control treatments tried in the experiment.

4.1.7.3 Soil actinomycetes population

The soil actinomycetes population after the first crop rice were analysed statistically after square root transformation ($\sqrt{x + 1}$) and the mean values are presented in Table 20.

The data revealed no significant difference in the soil actinomycetes population due to various herbicide treatments during both the years.

Table 20. Effect of weed control treatments on soil microbial population after first crop season

Treatments	First crop 1996-97			First crop 1997-98		
	Soil fungi 1×10^4 g^{-1}	Soil bacteria 1×10^6 g^{-1}	Soil actinomycetes 1×10^5 g^{-1}	Soil fungi 1×10^4 g^{-1}	Soil bacteria 1×10^6 g^{-1}	Soil actinomycetes 1×10^5 g^{-1}
T_1	9.31 (3.21)	9.32 (3.21)	0.63 (1.27)	9.98 (3.31)	8.93 (3.15)	0.44 (1.20)
T_2	8.62 (3.10)	8.66 (3.11)	0.55 (1.24)	8.25 (3.04)	9.60 (3.26)	0.54 (1.24)
T_3	7.98 (2.99)	8.62 (3.10)	0.38 (1.17)	8.93 (3.15)	10.31 (3.36)	0.66 (1.29)
T_4	7.98 (2.99)	9.32 (3.21)	0.63 (1.27)	9.17 (3.19)	9.56 (3.25)	0.43 (1.19)
T_5	9.00 (3.16)	7.87 (2.97)	0.65 (1.28)	10.98 (3.46)	10.32 (3.36)	0.49 (1.22)
T_6	8.29 (3.05)	8.94 (3.15)	0.49 (1.22)	8.98 (3.16)	7.98 (2.99)	0.66 (1.29)
T_7	9.25 (3.20)	7.98 (2.99)	0.33 (1.15)	9.57 (3.25)	9.32 (3.21)	0.44 (1.20)
T_8	8.00 (3.00)	10.32 (3.36)	0.55 (1.24)	9.25 (3.20)	8.53 (3.08)	0.66 (1.28)
T_9	8.15 (3.02)	9.98 (3.31)	0.63 (1.27)	10.31 (3.36)	9.66 (3.26)	0.65 (1.29)
T_{10}	8.55 (3.09)	8.32 (3.05)	0.61 (1.26)	7.77 (2.96)	8.95 (3.15)	0.54 (1.24)
T_{11}	7.66 (2.94)	8.53 (3.08)	0.43 (1.19)	8.93 (3.15)	9.66 (3.26)	0.54 (1.25)
T_{12}	8.25 (3.04)	9.33 (3.21)	0.63 (1.27)	9.00 (3.16)	9.60 (3.25)	0.65 (1.28)
$F_{11,22}$	0.199^{NS}	0.822^{NS}	0.300^{NS}	0.496^{NS}	0.477^{NS}	0.744^{NS}
SE	0.193	0.131	0.081	0.192	0.154	0.043
CD(0.05)	NS	NS	NS	NS	NS	NS

NS - Not significant   Figures in paranthesis are transformed means

4.1.8 Economics

4.1.8.1 Benefit : cost ratio

The data on benefit : cost ratio are presented in Table 21.

There was significant difference in the benefit cost ratio between the weed control treatments during the first crop season of 1996-97 only. Among the treatments, completely weed free plots recorded the highest BCR of 1.75 and the minimum of 1.03 by unweeded check. Butachlor pre-emergence + hand weeding (T_8) recorded the next highest BCR which was on a par with all other herbicide treatments except pendimethalin pre-emergence + 2,4-D post-emergence (T_{10}).

4.1.8.2 Net profit

The data on net profit during the first crop season are presented in Table 21.

There was significant difference in the net profit for various weed control treatments during the first season only. Completely weed free check was superior while the unweeded check was inferior to all other treatments. Among the herbicide treatments, butachlor pre-emergence + hand weeding (T_8) recorded higher net profit of Rs.8137.80 ha^{-1} which was on a par with completely weed free treatment. Butachlor pre-emergence + hand weeding treatment was on a par with farmer's practice (T_3) and other herbicide treatments except oxyfluorfen pre-emergence alone (T_6).

Table 21. Economics of weed control treatments during the first crop season

Treatments	Benefit : Cost ratio		Net profit (Rs ha^{-1})	
	1996-97	1997-98	1996-97	1997-98
T_1	1.75	1.57	11875.70	8946.30
T_2	1.03	0.87	466.40	-1745.60
T_3	1.36	1.31	5487.80	4740.30
T_4	1.33	1.29	4784.70	4366.70
T_5	1.40	1.23	5471.00	3178.20
T_6	1.26	1.19	3658.70	2760.80
T_7	1.43	1.43	6764.70	6805.10
T_8	1.56	1.16	8137.80	2380.60
T_9	1.37	1.08	5532.40	1260.00
T_{10}	1.11	1.24	6198.30	3632.60
T_{11}	1.39	1.38	5377.00	5327.90
T_{12}	1.38	1.23	5555.90	3308.40
$F_{11,22}$	3.283^{**}	1.946^{NS}	3.590^{**}	2.1758^{NS}
SE	0.093	0.127	1405.70	1827.80
CD(0.05)	0.27	NS	4123.20	NS

** Significant at 1 % level NS - Not significant

4.2. Second crop rice

4.2.1. Observation on weeds

4.2.1.1. Important weed species of the season

The important weed species found in the experimental field during the second crop season are presented in Table 22. Predominant species during the season were *Echinochloa crus-galli*, *Cyperus iria*, *Monochoria vaginalis, Fimbristylis miliacea* and *Marsilea quadrifoliata*.

4.2.1.2. Monocot weed population

The results on monocot weed population m^{-2} are presented in Table 23 and 24.

4.2.1.2a. 15 Days after transplanting

The data revealed significant difference in the monocot weed count due to the weed control treatments applied to the second crop and the residual effect of weed control treatments applied to the first crop of rice. The unweeded treatment (T_2) recorded the highest count of 9.13 and 7.07 during the first and second year respectively. Thiobencarb pre-emergence application recorded the lowest monocot weed count at 15 DAT. Farmers practice (T_3) was significantly inferior to all other treatments in respect of weed control.

Table 22. Major weed flora in the experimental field during second crop season

Group	Name of weed	Family
Grasses	*Echinochloa crus-galli*	Gramineae
	Echinochloa colonum	Gramineae
	Cynodon dactylon	Gramineae
	Brachiaria ramosa	Gramineae
Sedges	*Cyperus iria*	Cyperaceae
	Cyperus rotundus	Cyperaceae
	Cyperus difformis	Cyperaceae
	Fimbristylis miliacea	Cyperaceae
	Scirpus juncoides	Cyperaceae
Broad-leaved weeds	*Marsilea quadrifoliata*	Marsileaceae
	Monochoria vaginalis	Pontederiaceae
	Ludwigia parviflora	Onograceae
	Ammania baccifera	Lytheraceae
	Andrographis paniculata	Acanthaceae
	Centella asiatica	Umbelliferae

Table 23. Effect of weed control treatments on monocot weed population (number m^{-2}) during second crop season (1996-97)

Treatments	15 DAT	30 DAT	45 DAT	At harvest
Treatment effect				
T_1	0 (1.00)	0 (1.00)	0 1.00)	0 1.00)
T_2	82.33 (9.13)	81.48 (9.08)	122.32 (11.10)	156.63 (12.56)
T_3	37.75 (6.23)	37.77 (6.23)	39.03 (6.33)	58.65 (7.72)
T_4	34.97 (5.99)	29.96 (5.56)	24.65 (5.06)	29.62 (5.53)
T_5	27.23 (5.31)	26.99 (5.29)	19.66 (4.54)	24.65 (5.06)
T_6	27.08 (5.29)	23.30 (4.92)	16.64 (4.20)	22.65 (4.86)
T_7	19.97 (4.58)	19.31 (4.51)	16.31 (4.16)	32.98 (5.83)
T_8	25.32 (5.13)	21.32 (4.72)	17.25 (4.27)	26.87 (5.28)
T_9	14.09 3.88)	15.62 (4.08)	8.98 (3.15)	14.96 (3.99)
T_{10}	17.99 4.36)	14.99 (3.99)	21.21 (4.71)	24.92 (5.09)
T_{11}	18.42 (4.41)	19.28 (4.50)	12.64 (3.69)	16.24 (4.15)
T_{12}	16.11 (4.14)	18.40 (4.40)	13.31 (3.78)	17.22 (4.27)
$F_{11,22}$	35.079^{**}	30.333^{**}	49.749^{**}	118.899^{**}
SE	0.15	0.16	0.17	0.12
CD(0.05)	0.45	0.47	0.51	0.37

Contd...

Treatments	15 DAT	30 DAT	45 DAT	At harvest
First crop residual effect				
Tr_1	39.45 (6.36)	33.78 (5.89)	29.57 (5.53)	59.64 (7.79)
Tr_2	33.59 (5.88)	30.17 (5.58)	33.23 (5.85)	59.99 (7.81)
Tr_3	36.86 (6.15)	30.57 (5.62)	38.59 (6.29)	60.92 (7.87)
Tr_4	34.99 (5.99)	33.62 (5.88)	32.33 (5.77)	59.46 (7.77)
Tr_5	33.31 (5.86)	33.83 (5.90)	28.52 (5.43)	58.99 (7.74)
Tr_6	32.42 (5.78)	35.16 (6.01)	30.99 (5.66)	61.22 (7.89)
Tr_7	33.65 (5.89)	33.06 (5.83)	33.05 (5.83)	60.53 (7.84)
Tr_8	34.98 (5.99)	31.32 (5.68)	37.22 (6.18)	59.29 (7.76)
Tr_9	34.97 (5.99)	31.59 (5.71)	32.17 (5.76)	59.98 (7.81)
Tr_{10}	31.55 (5.71)	33.12 (5.84)	34.35 (5.94)	61.92 (7.93)
Tr_{11}	34.22 (5.94)	34.49 (5.96)	32.41 (5.78)	60.18 (7.82)
Tr_{12}	33.97 (5.91)	32.96 (5.83)	32.60 (5.79)	64.28 (8.08)
$F_{1,24}$	131.648**	81.544**	111.064**	1018.53**
SE	0.06	0.07	0.08	0.05
CD (0.05)	0.18	0.22	0.23	0.16

** - Significant at 1 % level   Figures in parenthesis are transformed values

Table 24. Effect of weed control treatments on monocot weed population (number m^{-2}) during second crop season (1997-98)

Treatments	15 DAT	30 DAT	45 DAT	At harvest
Treatment effect				
T_1	0 (1)	0 (1)	0 (1)	0 (1)
T_2	48.97 (7.07)	71.63 (8.52)	110.99 (10.58)	143.66 (12.03)
T_3	26.11 (5.21)	36.64 (6.13)	35.98 (6.08)	53.27 (7.37)
T_4	18.99 (4.47)	21.93 (4.79)	19.97 (4.58)	26.64 (5.26)
T_5	19.71 (4.55)	20.61 (4.65)	16.66 (4.20)	20.97 (4.69)
T_6	16.61 (4.19)	19.66 (4.54)	15.97 (4.12)	21.93 (4.79)
T_7	18.89 (4.46)	20.29 (4.61)	15.57 (4.07)	18.66 (4.43)
T_8	16.93 (4.23)	19.66 (4.54)	16.56 (4.19)	20.58 (4.64)
T_9	7.66 (2.94)	11.98 (3.60)	8.24 (3.04)	10.33 (3.37)
T_{10}	24.29 (5.03)	19.99 (4.58)	18.25 (4.39)	21.26 (4.72)
T_{11}	17.59 (4.31)	18.66 (4.43)	12.33 (3.65)	17.99 (4.36)
T_{12}	15.97 (4.12)	14.98 (3.99)	11.91 (3.59)	18.86 (4.46)
$F_{11,22}$	13.401**	31.152**	69.775**	131.638**
SE	0.19	0.16	0.13	0.11
CD(0.05)	0.56	0.47	0.39	0.32

Contd...

Treatments	15 DAT	30 DAT	45 DAT	At harvest
First crop residual effect				
Tr_1	23.65 (4.96)	28.52 (5.43)	32.60 (5.79)	48.93 (7.07)
Tr_2	22.55 (4.85)	32.30 (5.77)	29.83 (5.55)	43.97 (6.71)
Tr_3	22.26 (4.82)	30.63 (5.62)	28.76 (5.45)	50.97 (7.21)
Tr_4	20.93 (4.68)	27.48 (5.33)	31.53 (5.70)	49.97 (7.14)
Tr_5	22.29 (4.82)	28.88 (5.46)	31.31 (5.68)	49.99 (7.14)
Tr_6	26.31 (5.22)	31.82 (5.73)	29.65 (5.54)	51.61 (7.25)
Tr_7	22.11 (4.80)	30.96 (5.65)	31.58 (5.71)	55.98 (7.55)
Tr_8	23.08 (4.91)	28.98 (5.47)	30.32 (5.59)	51.60 (7.25)
Tr_9	21.29 (4.72)	31.25 (5.68)	31.11 (5.67)	50.65 (7.18)
Tr_{10}	21.92 (4.79)	26.29 (5.22)	30.64 (5.62)	52.30 (7.30)
Tr_{11}	22.68 (4.87)	28.55 (5.44)	30.87 (5.64)	50.29 (7.16)
Tr_{12}	20.95 (4.68)	28.37 (5.42)	30.53 (5.61)	52.60 (7.32)
$F_{1,24}$	45.626**	83.624**	150.561**	1476.682**
SE	0.06	0.07	0.07	0.04
CD (0.05)	0.17	0.20	0.19	0.11

** - Significant at 1 % level

Figures in parenthesis are transformed values

The residual effect of treatments applied to the first crop of rice was significant during the second crop season during both the years. Lowest weed count was observed under the residual effect of pendimethalin pre-emergence + 2,4-D post-emergence (Tr_{10}) and pendimethalin pre-emergence (Tr_4) applied to the first crop during the first and second year of experimentation respectively. The monocot weed counts were lower than the weedy check under all residual effects.

4.2.1.2b. 30 Days after transplanting

The weed control treatments applied to the second crop rice had significant influence on monocot weed population. All the herbicide treatments were superior to weedy check and farmers practice of weeding. Among the weed control treatments thiobencarb pre-emergence + hand weeding (T_9) gave the best result during both the years.

The residual effect of previous weed control treatments significantly influenced the monocot weed population at this stage of crop growth. However the results were inconsistent. During the first year of experimentation Tr_2 (residual effect of weedy treatment) and during the second year, Tr_{10} (residual effect of pendimethalin pre-emergence + 2,4-D post emergence treatment) recorded the lowest weed count.

4.2.1.2c. 45 Days after transplanting

At this stage also, thiobencarb pre-emergence + hand weeding (T_9) recorded the lowest monocot weed population during both the years which was superior over the weedy check and farmers practice.

The residual effect of treatments applied to previous crop was significant and were superior to the weedy check during both the years. The monocot weed count was the lowest under Tr_5 (residual effect of butachlor pre-emergence applied to the first crop of rice) during the first year and under Tr_3 (carry over effect of farmers practice from previous crop of rice) in the second year of experimentation.

4.2.1.2d. At harvest

At this stage also thiobencarb pre-emergence + hand weeding (T_9) remained superior over other treatments by recording the lowest monocot weed population. T_9 was on par with T_{11} (pretilachlor pre-emergence + 2,4-D post-emergence) and T_{12} (thiobencarb pre-emergence + 2,4-D post-emergence) during the first year of experimentation.

The residual effect of previous crop treatments on monocot weed population during second crop season was significant. During the first year, the monocot weed population was high under Tr_{12} (residual effect of oxyfluorfen, pre-emergence + 2,4-D post-emergence applied to the first crop) and Tr_{10} (residual effect of pendimethalin pre-emergence + 2,4-D post-emergence). During the second year of experimentation, the monocot weed population was the highest under Tr_7 (residual effect of pendimethalin pre-emergence + hand weeding applied to the first crop of rice).

4.2.1.3. Dicot weed population

The results are presented in Tables 25 and 26. .

Table 25. Effect of weed control treatments on dicot weed population (number m^{-2}) during secnd crop season (1996-97)

Treatments	15 DAT	30 DAT	45 DAT	At harvest
Treatment effect				
T_1	0 (1)	0 (1)	0 (1)	0 (1)
T_2	33.98 (5.91)	31.98 (5.74)	31.32 (5.68)	50.65 (7.18)
T_3	20.06 (4.59)	17.99 (4.36)	14.98 (3.99)	22.60 (4.86)
T_4	18.66 (4.43)	17.24 (4.27)	11.94 (3.59)	15.97 (4.12)
T_5	17.99 (4.36)	16.32 (4.16)	11.98 (3.60)	15.99 (4.12)
T_6	16.65 (4.20)	14.64 (3.95)	12.30 (3.65)	19.31 (4.51)
T_7	21.66 (4.76)	17.97 (4.36)	11.65 (3.56)	17.19 (4.26)
T_8	17.97 (4.36)	14.98 (3.99)	10.96 (3.46)	16.96 (4.24)
T_9	14.99 (3.99)	10.63 (3.41)	9.29 (3.21)	11.96 (3.60)
T_{10}	17.64 (4.32)	11.90 (3.59)	10.65 (3.41)	14.31 (3.91)
T_{11}	15.64 (4.08)	11.98 (3.60)	10.63 (3.41)	13.62 (3.82)
T_{12}	15.99 (4.12)	9.31 (3.21)	10.96 (3.46)	13.71 (3.83)
$F_{11,22}$	16.449**	11.967**	19.012**	20.874**
SE	0.14	0.16	0.12	0.15
CD(0.05)	0.41	0.46	0.34	0.45

Contd...

Treatments	15 DAT	30 DAT	45 DAT	At harvest
First crop residual effect				
Tr_1	26.51 (5.24)	19.63 (4.54)	12.66 (3.69)	22.32 (4.83)
Tr_2	25.93 (5.19)	19.91 (4.57)	12.30 (3.45)	23.32 (4.93)
Tr_3	25.18 (5.12)	20.26 (4.61)	12.95 (3.74)	24.59 (5.06)
Tr_4	27.88 (5.37)	20.51 (4.64)	12.26 (3.64)	23.54 (4.95)
Tr_5	26.96 (5.29)	20.97 (4.69)	12.21 (3.63)	28.86 (5.46)
Tr_6	28.61 (5.44)	22.91 (4.89)	13.33 (3.78)	26.99 (5.29)
Tr_7	27.61 (5.35)	20.56 (4.64)	13.65 (3.83)	27.91 (5.38)
Tr_8	26.26 (5.22)	21.59 (4.75)	11.61 (3.55)	24.98 (5.09)
Tr_9	26.19 (5.21)	22.16 (4.81)	12.76 (3.71)	27.63 (5.35)
Tr_{10}	25.27 (5.12)	22.59 (4.86)	11.25 (3.49)	24.95 (5.09)
Tr_{11}	25.97 (5.19)	23.95 (4.99)	12.99 (3.74)	26.96 (5.29)
Tr_{12}	27.96 (5.38)	23.43 (4.94)	11.84 (3.58)	26.92 (5.28)
$F_{1,24}$	197.950**	116.858**	8.588**	229.806**
SE	0.05	0.06	0.04	0.05
CD (0.05)	0.16	0.18	0.12	0.14

** - Significant at 1 % level

Figures in parenthesis are transformed values

Table 26. Effect of weed control treatments on dicot weed population (number m^{-2}) during second crop season (1997-98)

Treatments	15 DAT	30 DAT	45 DAT	At harvest
Treatment effect				
T_1	0 (1)	0 (1)	0 (1)	0 (1)
T_2	20.59 (4.65)	26.27 (5.22)	23.55 (4.95)	41.32 (6.50)
T_3	22.60 (4.86)	10.27 (3.36)	12.66 (3.69)	21.99 (4.79)
T_4	12.65 (3.69)	18.66 (4.43)	9.29 (3.21)	17.99 (4.36)
T_5	11.98 (3.60)	16.63 (4.19)	15.99 (4.12)	20.31 (4.62)
T_6	12.64 (3.69)	13.64 (3.82)	14.97 (3.99)	20.26 (4.61)
T_7	12.98 (3.74)	15.60 (4.07)	16.56 (4.19)	23.59 (4.96)
T_8	11.61 (3.55)	12.99 (3.74)	13.33 (3.78)	19.66 (4.54)
T_9	13.28 (3.78)	9.65 (3.26)	9.33 (3.21)	13.64 (3.83)
T_{10}	12.30 (3.65)	7.981 (2.99)	10.87 (3.44)	15.99 (4.12)
T_{11}	12.33 (3.65)	6.84 (2.79)	9.52 (3.24)	11.98 (3.60)
T_{12}	12.30 (3.65)	6.66 (2.77)	9.23 (3.19)	14.49 (3.94)
$F_{11,22}$	13.327**	15.410**	28.687**	25.666**
SE	0.14	0.14	0.002	0.12
CD(0.05)	0.41	0.41	0.26	0.36

Contd....

Treatments	15 DAT	30 DAT	45 DAT	At harvest
First crop residual effect				
Tr_1	21.26 (4.72)	9.94 (3.31)	11.64 (3.56)	21.58 (4.75)
Tr_2	20.86 (4.67)	10.48 (3.39)	11.31 (3.51)	21.28 (4.72)
Tr_3	21.97 (4.79)	9.13 (3.18)	11.31 (3.51)	20.31 (4.62)
Tr_4	23.65 (4.96)	11.26 (3.50)	12.95 (3.73)	20.29 (4.61)
Tr_5	22.62 (4.86)	10.26 (3.35)	12.33 (3.65)	22.30 (4.83)
Tr_6	24.59 (5.06)	10.63 (3.41)	11.30 (3.51)	22.64 (4.86)
Tr_7	21.56 (4.75)	10.24 (3.35)	12.89 (3.73)	21.56 (4.75)
Tr_8	23.94 (4.99)	10.19 (3.34)	12.98 (3.74)	20.88 (4.68)
Tr_9	21.92 (4.79)	9.88 (3.29)	11.61 (3.55)	21.65 (4.76)
Tr_{10}	20.59 (4.65)	9.41 (3.23)	11.95 (3.59)	20.56 (4.64)
Tr_{11}	22.89 (4.89)	10.98 (3.46)	12.33 (3.65)	21.59 (4.75)
Tr_{12}	23.22 (4.92)	10.15 (3.34)	10.29 (3.36)	22.61 (4.86)
$F_{1,24}$	211.284^{**}	2.364^{NS}	1.471^{NS}	79.619^{**}
SE	0.06	0.06	0.05	0.04
CD (0.05)	0.17	NS	NS	0.11

NS - Not significant ** - Significant at 1 % level

Figures in parenthesis are transformed values

4.2.1.3a. 15 Days after transplanting

The data revealed significant difference in dicot weed population due to the weed control treatments applied to the second crop and also due to the residual effect of previous treatments. Farmers practice (T_3) and weedy check (T_2) recorded higher dicot weed count and were inferior to the herbicide treatments during both the years.

Among the carry over effects of weed control treatments applied to previous crop, pendimethalin pre-emergence + 2,4-D post-emergence (Tr_{10}) recorded the lowest dicot weed count at this stage of crop growth.

4.2.1.3b. 30 Days after transplanting

At this stage maximum control of dicot weed population was achieved by thiobencarb pre-emergence + 2,4-D post-emergence (T_{12}) during both the seasons. The weedy check (T_2) recorded maximum dicot weed population at this stage also.

The residual effect of previous season weed control treatments on dicot weed count during the second crop season was significant only during the first year. The dicot weed count was the lowest in plots having the residual effect of completely weed free treatment applied to the first crop of rice.

4.2.1.3c. 45 days after transplanting

All the herbicide treatments were superior to the unweeded check. Thiobencarb pre-emergence integrated with hand weeding recorded the lowest number of dicot weeds during the first year and its integration with 2,4-D post emergence treatment recorded the lowest number of dicot weeds during the second year.

The residual effects of previous weed control treatments were significant only during the first year. Among the carry over effect of herbicide treatments applied to the first crop of rice, that of pendimethalin pre-emergence + 2,4-D post-emergence was superior which recorded the lowest dicot weed population in second crop rice.

4.2.1.3d. At harvest

The weed control treatments significantly influenced the dicot weed population during both the seasons. Thiobencarb pre-emergence + hand weeding (T_9) and pretilachlor pre-emergence + 2,4-D post-emergence (T_{11}) were found superior at this stage. The weedy check recorded higher weed population.

The residual effects of previous crop treatment were found significant. The lowest dicot weed population at harvest was recorded under residual effect of weed free treatment (Tr_1) during the first year and under residual effect of pendimethalin pre-emergence (Tr_4) during the second year of experimentation respectively.

4.2.1.4. Total weed count

The data are presented in Tables 27 and 28.

Table 27. Effect of weed control treatments on total weed count (number m^{-2}) during second crop season (1996-97)

Treatments	15 DAT	30 DAT	45 DAT	At harvest
Treatment effect				
T_1	0 (1)	0 (1)	0 (1)	0 (1)
T_2	116.32 (10.83)	113.47 (10.69)	153.66 (12.44)	207.28 (14.43)
T_3	57.98 (7.68)	56.01 (7.55)	54.16 (7.43)	81.32 (9.07)
T_4	53.66 (7.39)	47.32 (6.95)	36.66 (6.13)	45.63 (6.83)
T_5	45.28 (6.80)	43.32 (6.65)	31.66 (5.71)	40.66 (6.45)
T_6	43.79 (6.69)	37.95 (6.24)	28.96 (5.47)	41.97 (6.55)
T_7	41.64 (6.53)	37.31 (6.19)	27.99 (5.38)	50.27 (7.16)
T_8	43.29 (6.65)	36.31 (6.11)	28.24 (5.41)	43.95 (6.70)
T_9	29.20 (5.49)	26.33 (5.23)	18.28 (4.39)	26.92 (5.28)
T_{10}	35.65 (6.05)	26.98 (5.29)	31.86 (5.73)	39.23 (6.34)
T_{11}	34.13 (5.93)	31.27 (5.68)	23.29 (4.93)	29.89 (5.56)
T_{12}	32.26 (5.77)	27.74 (5.36)	24.29 (5.03)	31.26 (5.68)
$F_{11,22}$	37.057**	54.940**	56.155**	140.665**
SE	0.17	0.14	0.18	0.13
CD(0.05)	0.51	0.42	0.52	0.38

Contd...

Treatments	15 DAT	30 DAT	45 DAT	At harvest
First crop residual effect				
Tr_1	66.03 (8.18)	53.57 (7.39)	42.28 (6.58)	81.99 (9.11)
Tr_2	59.65 (7.79)	50.30 (7.16)	45.54 (6.82)	83.33 (9.18)
Tr_3	62.09 (7.94)	50.96 (7.21)	51.64 (7.26)	85.63 (9.31)
Tr_4	62.97 (7.99)	54.20 (7.43)	44.80 (6.77)	83.56 (9.19)
Tr_5	60.32 (7.83)	54.94 (7.48)	41.20 (6.49)	87.98 (9.43)
Tr_6	61.25 (7.89)	58.07 (7.68)	44.33 (6.73)	88.25 (9.44)
Tr_7	61.50 (7.90)	53.82 (7.40)	46.86 (6.92)	88.60 (9.46)
Tr_8	61.26 (7.89)	52.95 (7.34)	48.91 (7.06)	84.32 (9.24)
Tr_9	61.21 (7.88)	53.87 (7.41)	44.97 (6.78)	87.67 (9.41)
Tr_{10}	56.91 (7.61)	55.76 (7.53)	45.68 (6.83)	86.88 (9.37)
Tr_{11}	60.30 (7.83)	58.81 (7.73)	45.46 (6.82)	87.27 (9.39)
Tr_{12}	61.99 (7.94)	56.80 (7.60)	44.64 (6.75)	87.95 (9.43)
$F_{1,24}$	431.86**	174.505**	125.502**	2243.528**
SE	0.05	0.07	0.07	0.04
CD (0.05)	0.15	0.21	0.19	0.11

** - Significant at 1 % level

Figures in parenthesis are transformed values

Table 28. Effect of weed control treatments on total weed count (number m^{-2}) during second crop season (1997-98)

Treatments	15 DAT	30 DAT	45 DAT	At harvest
Treatment effect				
T_1	0 (1)	0 (1)	0 (1)	0 (1)
T_2	69.63 (8.40)	97.91 (9.94)	134.66 (11.65)	184.98 (13.64)
T_3	48.91 (7.06)	46.99 (6.93)	48.65 (7.04)	75.28 (8.73)
T_4	31.66 (5.71)	40.64 (6.45)	29.28 (5.50)	44.64 (6.76)
T_5	32.12 (5.75)	37.24 (6.18)	32.66 (5.80)	41.33 (6.51)
T_6	29.25 (5.50)	33.30 (5.86)	31.33 (5.69)	42.19 (6.57)
T_7	31.90 (5.73)	35.91 (6.07)	32.16 (5.76)	42.30 (6.58)
T_8	28.66 (5.44)	32.66 (5.80)	29.96 (5.56)	40.31 (6.43)
T_9	20.97 (4.69)	21.63 (4.76)	17.63 (4.32)	23.99 (4.99)
T_{10}	36.59 (6.13)	27.98 (5.38)	29.20 (5.49)	37.28 (6.18)
T_{11}	29.94 (5.56)	25.65 (5.16)	21.93 (4.79)	29.98 (5.57)
T_{12}	28.27 (5.41)	21.66 (4.76)	21.30 (4.72)	33.44 (5.87)
$F_{11,22}$	19.837**	45.696**	82.310**	109.652**
SE	0.19	0.16	0.13	0.13
CD(0.05)	0.56	0.46	0.38	0.39

Contd...

Treatments	15 DAT	30 DAT	45 DAT	At harvest
First crop residual effect				
Tr_1	44.95 (6.77)	38.12 (6.25)	44.31 (6.73)	70.63 (8.46)
Tr_2	43.43 (6.66)	42.95 (6.63)	44.20 (6.49)	65.27 (8.14)
Tr_3	44.25 (6.73)	39.99 (6.40)	40.18 (6.42)	71.29 (8.50)
Tr_4	44.59 (6.75)	39.12 (6.33)	44.53 (6.75)	70.31 (8.44)
Tr_5	44.93 (6.78)	39.29 (6.35)	43.65 (6.68)	72.32 (8.56)
Tr_6	50.98 (7.21)	42.50 (6.59)	40.99 (6.48)	74.27 (8.67)
Tr_7	43.68 (6.68)	41.23 (6.49)	44.57 (6.75)	77.65 (8.87)
Tr_8	47.06 (6.93)	39.23 (6.34)	43.31 (6.65)	72.51 (8.57)
Tr_9	43.33 (6.66)	41.43 (6.51)	42.78 (6.62)	72.30 (8.56)
Tr_{10}	42.86 (6.62)	36.26 (6.10)	42.60 (6.60)	72.97 (8.60)
Tr_{11}	45.92 (6.85)	39.59 (6.37)	43.24 (6.65)	71.99 (8.54)
Tr_{12}	44.18 (6.72)	38.69 (6.29)	40.95 (6.48)	75.22 (8.73)
$F_{1,24}$	178.967**	79.376**	128.999**	1478.97**
SE	0.07	0.06	0.06	0.04
CD (0.05)	0.19	0.16	0.18	0.11

** - Significant at 1 % level

Figures in parenthesis are transformed values

4.2.1.4a. 15 Days after transplanting

Thiobencarb treatment (T_9) recorded the lowest number of weeds during both the season. T_9 was on a par with pretilachlor treatment (T_{11}) during the first year.

The residual effects of previous season treatments significantly influenced the total weed count. The carry over effect of pendimethalin pre-emergence + 2,4-D post-emergence applied to the first crop of rice significantly reduced the total weed population m^{-2} in the second crop season.

4.2.1.4b. 30 Days after transplanting

Among the second crop treatments thiobencarb pre-emergence + hand weeding (T_9) continued to be the superior treatment with the lowest weed count. During both the seasons, weedy check (T_2) recorded the highest number of weeds which was inferior to all the herbicide treatments tried in the experiment.

The residual effect of previous season treatments on total weed count during the second crop season was significant. Lowest total weed count was recorded under the carry over effect of weed free treatment (Tr_1) and pendimethalin pre-emergence + 2,4-D post-emergence (Tr_{10}) during the first and second year of experimentation respectively.

4.2.1.4c. 45 Days after transplanting

The weedy check (T_2) recorded the maximum number of weeds which was inferior. The lowest weed count of 4.39 and 4.32 were recorded during the first and second year respectively under thiobencarb pre-emergence + hand weeding (T_9). Farmer's practice (T_3) recorded a weed count which was significantly inferior to all other herbicide treatments but superior to unweeded control.

The total weed count was significantly low in plots having the carry over effect of previous weed control treatments. Residual effect of butachlor pre-emergence treatment (Tr_5) recorded the lowest weed count during the first year. In the second year, the weed count was low in the plots having the carry over effect of farmers practice of weeding (Tr_3).

4.2.1.4d. At harvest

The weed control treatments influenced the total number of weeds significantly during both the seasons. Thiobencarb pre-emergence integrated with hand weeding (T_9) recorded the lowest number of weeds. During the first year, pretilachlor pre-emergence + 2,4-D post-emergence (T_{11}) was on a par with T_9.

The residual effect of previous season treatments on the number of weeds m^{-2} was significant. The total weed population was low under the carry over effect of completely weed free treatment (Tr_1) followed by the carry over effect of pendimethalin pre-emergence (Tr_4) applied to the first crop of rice.

4.2.1.5. Dry weight of weeds

The data are presented in Tables 29 and 30.

Table 29. Effect of weed control treatments on dry weight of weeds (g m^{-2}) during second crop season (1996-97)

Treatment	15 DAT	30 DAT	45 DAT	At harvest
Treatment effect				
T_1	0	0	0	0
T_2	2.93	23.28	31.41	50.17
T_3	2.13	11.16	15.86	27.15
T_4	1.18	6.80	8.98	21.97
T_5	1.06	6.68	10.18	26.87
T_6	0.69	6.11	9.31	28.60
T_7	0.79	6.78	11.87	22.59
T_8	1.07	6.09	9.77	26.65
T_9	0.78	5.54	7.84	18.58
T_{10}	0.93	6.82	9.99	21.11
T_{11}	0.86	5.37	10.94	20.49
T_{12}	0.71	6.09	11.07	21.27
$F_{11,22}$	6.400**	68.283**	33.155**	17.579**
SE	0.15	0.35	0.63	1.35
CD (0.05)	0.45	1.02	1.85	3.96
First crop residual effect				
Tr_1	2.17	10.76	15.78	25.97
Tr_2	2.23	11.13	15.49	26.31
Tr_3	2.11	10.53	16.24	27.79
Tr_4	1.95	10.53	15.87	25.32
Tr_5	2.08	10.17	15.76	25.93
Tr_6	2.17	11.80	15.99	25.37
Tr_7	2.13	10.28	16.13	25.90
Tr_8	2.18	9.68	14.42	25.26
Tr_9	2.11	10.36	15.63	25.40
Tr_{10}	2.06	10.12	15.77	26.17
Tr_{11}	2.30	10.03	14.87	25.63
Tr_{12}	2.07	10.13	16.10	24.88
$F_{1,24}$	114.196**	216.222**	121.983**	15.942**
SE	0.07	0.14	0.27	0.36
CD (0.05)	0.20	0.41	0.79	1.06

** - Significant at 1 % level

Table 30. Effect of weed control treatments on dry weight of weeds ($g\ m^{-2}$) during second crop season (1997-98)

Treatments	15 DAT	30 DAT	45 DAT	At harvest
Treatment effect				
T_1	0	0	0	0
T_2	2.75	20.71	25.68	45.47
T_3	2.37	10.24	12.31	28.55
T_4	1.21	6.75	11.71	21.71
T_5	1.27	5.82	11.76	25.75
T_6	1.38	6.53	10.39	23.14
T_7	1.51	7.08	10.89	23.18
T_8	1.39	6.38	10.71	23.91
T_9	0.87	5.78	10.05	18.22
T_{10}	1.55	5.83	8.43	21.61
T_{11}	1.51	5.69	8.86	21.25
T_{12}	1.91	5.82	8.53	19.39
$F_{11,22}$	9.82**	63.268**	52.060**	58.639**
SE	0.11	0.29	0.39	0.68
CD (0.05)	0.32	0.87	1.17	1.98
First crop residual effect				
Tr_1	2.09	10.69	11.98	28.48
Tr_2	2.11	10.24	12.23	29.83
Tr_3	1.99	10.65	11.99	28.49
Tr_4	2.07	10.25	12.03	29.25
Tr_5	2.17	10.20	12.51	29.30
Tr_6	1.97	11.41	12.27	29.69
Tr_7	2.06	10.57	12.76	29.69
Tr_8	2.12	10.51	12.21	29.40
Tr_9	2.08	11.11	12.13	30.52
Tr_{10}	2.13	10.17	11.84	26.78
Tr_{11}	2.07	10.20	12.04	27.26
Tr_{12}	2.10	11.13	12.37	29.41
$F_{1,24}$	86.721**	275.504**	32.116**	160.552**
SE	0.05	0.14	0.18	0.35
CD (0.05)	0.13	0.42	0.52	1.03

** - Significant at 1 % level

4.2.1.5a. 15 Days after transplanting

The results revealed that weed control treatments significantly influenced the dry weight of weeds. Weed dry weight was high in weedy check and low in completely weed free treatment. Farmer's practice recorded significantly lower weed dry weight but was inferior to herbicide treatments. During the first year of experimentation, all the herbicide treatments except T_4 (pendimethalin pre-emergence alone) were on a par. During the second year of experimentation, weed dry weight was significantly lower in T_9 (thiobencarb pre-emergence + hand weeding).

The residual effect of weed control treatments applied to the first crop of rice significantly influenced the weed dry weight during the second crop season. However they were at par.

4.2.1.5b. 30 Days after transplanting

Weed free treatment was superior among the weed management methods studied in the experiment. The maximum weed dry weight of 23.28 and 20.71 gm^{-2} were recorded by the weedy check during the first and second year respectively. Among the herbicide treatments, pretilachlor pre-emergence + 2,4-D post-emergence (T_{11}) recorded the lowest weed dry weight.

The carryover effect of previous season weed control treatments on total weed dry weight was significant at 30 DAT. During the first year, Tr_8 (residual effect of butachlor pre-emergence + hand weeding) recorded the lowest weed dry weight which was on a par with Tr_{11} (residual effect of butachlor pre-emergence + 2,4-D post-emergence). During the second year of experimentation, residual effect of pendimethalin pre-emergence + 2,4-D post-emergence (Tr_{10}) recorded the lowest weed dry weight.

4.2.1.5c. 45 Days after transplanting

Among the herbicide treatments thiobencarb pre-emergence + hand weeding (T_9) recorded lowest weed dry weight during the first year and pendimethalin pre-emergence + 2,4-D post-emergence (T_{10}) during the second year.

The residual effect of previous season treatments was significant on weed dry matter production in the second crop season of both the years. During the first year residual effect of butachlor pre-emergence + hand weeding (Tr_8) recorded the lowest weed dry weight which was on a par with the residual effect of butachlor pre-emergence + 2,4-D post-emergence (Tr_{11}). During the second year, lowest weed dry weight was recorded under Tr_{10} (residual effect of pendimethalin pre-emergence + 2,4-D post-emergence).

4.2.1.5d. At harvest

The data indicated that the weed control treatments recorded lower weed dry matter accumulation compared to the residual effect. Among the herbicidal treatments, thiobencarb pre-emergence + hand weeding (T_9) recorded the lowest weed dry matter accumulation.

During the first year of experimentation, the residual effect of oxyfluorfen pre-emergence + 2,4-D post-emergence Tr_{12} recorded the lowest weed dry weight which was on a par with other residual effects except Tr_1, Tr_2, Tr_3 and Tr_{11}. In the second crop of the year 1997-98, the lowest weed dry weight was recorded under the residual effect of pendimethalin pre-emergence + 2,4-D post-emergence treatment (Tr_{10}) which was on a par with the residual effect of butachlor pre-emergence + 2,4-D post-emergence (Tr_{11}).

4.2.1.6. Weed control efficiency

The results are presented in Table 31.

The weedy check showed the lowest weed control efficiency indicating its inferiority. Among the herbicide treatments applied to the second crop, thiobencarb pre-emergence + hand weeding (T_9) recorded the highest WCE. The farmer's practice of hand weeding was inferior to all the herbicide treatments.

The data on residual effect of previous treatments on WCE revealed that during the first year, all residual effects were on a par and inferior to Tr_4 (pendimethalin pre-emergence applied to the first crop of rice). During the second year also, Tr_4 (residual effect of pendimethalin pre-emergence) recorded the highest WCE among the residual effect of previous herbicide treatments.

4.2.1.7. Herbicide efficiency index

The results are presented in Table 32.

Table 31. Effect of weed control treatments on weed index and weed control efficiency during second crop season

Treatments	Weed index		WCE	
	1996-97	1997-98	1996-97	1997-98
Treatment effect				
T_1	0 (0)	0 (0)	99.99 (90.00)	99.99 (90.00)
T_2	60.61 (51.11)	64.57 (53.45)	0 (0)	0 (0)
T_3	43.93 (41.49)	51.06 (45.59)	62.35 (52.13)	60.36 (50.96)
T_4	34.54 (35.98)	41.83 (40.28)	78.87 (62.61)	76.49 (60.97)
T_5	36.40 (37.09)	42.53 (40.68)	81.17 (64.26)	78.24 (62.17)
T_6	34.21 (35.78)	38.28 (38.21)	80.56 (63.82)	77.77 (61.85)
T_7	33.98 (35.64)	31.83 (34.33)	76.72 (61.12)	77.73 (61.81)
T_8	37.60 (37.81)	34.69 (36.07)	79.65 (63.16)	78.78 (62.54)
T_9	16.91 (24.27)	19.79 (26.40)	87.53 (69.29)	87.36 (69.15)
T_{10}	27.19 (31.41)	36.15 (36.94)	81.82 (64.74)	80.37 (63.67)
T_{11}	27.02 (31.31)	32.59 (34.79)	86.15 (68.12)	84.21 (66.56)
T_{12}	25.85 (30.55)	30.47 (33.49)	85.52 (67.61)	82.37 (65.15)
$F_{11,22}$	3.772^{**}	15.023^{**}	84.910^{**}	94.971^{**}
SE	2.48	1.32	0.99	0.94
CD(0.05)	7.28	3.86	2.92	2.76

Contd...

Treatments	Weed index		WCE	
	1996-97	1997-98	1996-97	1997-98
First crop residual effect				
Tr_1	44.69 (41.94)	48.93 (44.37)	62.04 (51.94)	62.82 (52.41)
Tr_2	47.72 (43.68)	52.48 (46.40)	61.42 (51.58)	65.63 (54.08)
Tr_3	43.93 (41.49)	46.04 (42.71)	65.13 (53.78)	62.46 (52.19)
Tr_4	46.96 (43.24)	49.64 (44.77)	61.28 (51.49)	62.98 (52.51)
Tr_5	44.68 (41.93)	48.93 (44.36)	59.19 (50.28)	61.93 (51.88)
Tr_6	43.81 (41.42)	50.32 (45.17)	59.11 (50.23)	60.88 (51.27)
Tr_7	36.69 (37.27)	46.80 (43.15)	58.96 (50.14)	59.13 (50.24)
Tr_8	42.99 (40.95)	48.93 (44.36)	60.75 (51.19)	61.78 (51.79)
Tr_9	43.14 (41.04)	49.64 (44.77)	59.41 (50.41)	61.93 (51.88)
Tr_{10}	43.17 (41.06)	44.67 (41.92)	59.74 (50.59)	61.58 (51.68)
Tr_{11}	44.68 (41.93)	48.93 (44.37)	59.58 (50.50)	62.10 (51.98)
Tr_{12}	44.64 (41.91)	48.93 (44.37)	59.26 (50.32)	60.37 (50.96)
$F_{1,24}$	42.073**	84.231**	360.535**	546.525**
SE	0.84	0.63	0.38	0.25
CD (0.05)	2.45	1.83	1.12	0.73

** - Significant at 1 % level

Figures in parentheis indicate transformed values

Table 32. Effect of weed control treatments on herbicide efficiency index during second crop season

Treatments	1996-97	1997-98
Treatment effect		
T_1	0 (0)	0 (0)
T_2	0 (0)	0 (0)
T_3	0 (0)	0 (0)
T_4	10.79 (19.17)	10.41 (18.81)
T_5	8.48 (16.92)	8.62 (17.06)
T_6	8.16 (16.59)	10.31 (18.72)
T_7	10.61 (19.00)	11.48 (19.79)
T_8	8.41 (16.85)	10.53 (18.93)
T_9	16.26 (23.77)	17.42 (24.66)
T_{10}	12.54 (20.73)	11.42 (19.74)
T_{11}	12.94 (21.08)	12.36 (20.58)
T_{12}	12.70 (20.87)	13.87 (21.86)
$F_{11,22}$	16.617^{**}	44.438^{**}
SE	0.80	0.48
CD(0.05)	2.35	1.41

Contd...

Treatments	1996-97	1997-98
First crop residual effect		
Tr_1	7.70 (16.10)	6.95 (15.28)
Tr_2	7.18 (15.53)	7.02 (15.36)
Tr_3	7.58 (15.97)	7.38 (15.76)
Tr_4	7.60 (15.99)	6.66 (14.94)
Tr_5	7.70 (16.11)	6.73 (15.03)
Tr_6	7.99 (16.42)	6.42 (14.67)
Tr_7	8.79 (17.25)	6.92 (15.24)
Tr_8	8.11 (16.54)	6.71 (15.00)
Tr_9	8.08 (16.51)	6.37 (14.61)
Tr_{10}	7.86 (16.27)	7.99 (16.42)
Tr_{11}	8.00 (16.42)	7.24 (15.60)
Tr_{12}	8.08 (16.51)	6.69 (14.99)
$F_{1,24}$	1.994^{NS}	38.182^{**}
SE	0.20	0.21
CD(0.05)	NS	0.62

** - Significant at 1 % level

NS - Not significant

Figures in parentheis indicate angular transformed values

The weed control treatments applied to the second crop rice showed significant variation in the herbicide efficiency index. T_9 (Thiobencarb pre-emergence + hand weeding) recorded the highest herbicide efficiency index of 23.77 and 24.66 during the first and second year respectively. Pretilachlor pre-emergence + 2,4-D post-emergence (T_{11}) and thiobencarb pre-emergence + 2,4-D post-emergence (T_{12}) were also superior as indicated by the herbicide efficiency index.

The residual effect of previous season treatment was significant only during the second year of experimentation. Tr_{10} (residual effect of pendimethalin pre-emergence + 2,4-D post-emergence) recorded the highest herbicide efficiency index.

4.2.2 Observations on crop growth characters

4.2.2.1 Height of plant

The effect of treatments on height of plant are presented in Tables 33 and 34.

4.2.2.1a 15 Days after transplanting

Weed control treatments applied to second crop rice had significant influence on height of plant at 15 DAT. Weed free treatment (T_1) recorded a plant height of 40 and 42 cm during the first and second year respectively. All the herbicide treatments significantly influenced the plant height and were superior to the unweeded check. Among the herbicides, thiobencarb pre-emergence application recorded maximum plant height during both the years.

Table 33. Effect of weed control treatments on plant height (cm) during second crop season (1996-97)

Treatments	15 DAT	30 DAT	45 DAT	At harvest
Treatment effect				
T_1	40.2	51.5	65.2	116.1
T_2	29.5	40.4	53.4	100.7
T_3	34.7	43.2	58.8	106.6
T_4	32.0	42.5	57.1	106.4
T_5	33.2	43.5	54.7	107.0
T_6	33.9	42.5	56.8	108.2
T_7	33.4	41.9	57.9	107.9
T_8	33.9	41.5	55.1	107.2
T_9	40.7	47.2	61.1	109.5
T_{10}	36.4	42.2	58.9	106.9
T_{11}	37.2	42.5	55.9	107.9
T_{12}	38.9	44.6	58.6	108.2
$F_{11,22}$	10.837**	12.192**	6.287**	13.733**
SE	0.56	0.46	0.80	0.52
CD (0.05)	1.65	1.34	2.35	1.52
First crop residual effect				
Tr_1	35.9	42.7	59.3	106.9
Tr_2	35.9	43.2	54.1	104.6
Tr_3	35.1	42.7	56.2	107.9
Tr_4	36.5	42.6	58.3	107.9
Tr_5	36.1	42.3	57.3	106.9
Tr_6	38.6	42.5	57.7	107.4
Tr_7	35.7	42.6	57.9	107.2
Tr_8	36.3	42.9	58.6	107.4
Tr_9	37.9	44.7	57.7	106.9
Tr_{10}	35.9	42.9	57.7	107.1
Tr_{11}	36.8	42.9	58.8	107.3
Tr_{12}	35.9	42.2	58.4	107.0
$F_{1,24}$	6.947*	9.309**	0.004NS	3.475NS
SE	0.28	0.18	0.35	0.26
CD (0.05)	0.83	0.53	NS	NS

NS - Not significant   * - Significant at 5 % level   ** - Significant at 1 % level

Table 34. Effect of weed control treatments on plant height (cm) during second crop season (1997-98)

Treatments	15 DAT	30 DAT	45 DAT	At harvest
Treatment effect				
T_1	42.4	49.9	71.6	121.1
T_2	30.2	39.3	58.2	104.4
T_3	34.0	42.9	63.4	112.9
T_4	32.1	41.9	61.9	112.7
T_5	33.9	42.7	62.8	113.0
T_6	34.6	42.9	64.2	113.4
T_7	33.2	40.5	62.7	113.5
T_8	34.0	42.0	62.9	113.7
T_9	40.6	47.9	67.4	116.4
T_{10}	35.0	43.7	62.9	114.5
T_{11}	37.8	44.4	63.5	115.3
T_{12}	36.2	46.3	64.4	115.9
$F_{11,22}$	8.779^{**}	11.864^{**}	8.408^{**}	4.920^{**}
SE	0.67	0.50	0.60	0.86
CD (0.05)	1.96	1.47	1.76	2.52
First crop residual effect				
Tr_1	35.8	42.9	63.2	113.5
Tr_2	36.3	42.6	63.9	113.5
Tr_3	34.5	42.9	64.4	112.9
Tr_4	34.4	42.8	64.2	111.9
Tr_5	35.1	43.0	64.4	113.4
Tr_6	36.1	43.2	64.4	113.9
Tr_7	35.4	43.5	63.2	113.9
Tr_8	35.7	44.1	64.4	113.1
Tr_9	37.8	44.9	66.3	112.9
Tr_{10}	35.5	43.7	63.1	112.9
Tr_{11}	35.9	42.9	63.8	112.5
Tr_{12}	34.9	44.9	66.2	113.2
$F_{1,24}$	0.606^{NS}	0.372^{NS}	1.493^{NS}	2.130^{NS}
SE	0.25	0.29	0.27	0.36
CD (0.05)	NS	NS	NS	NS

NS - Not significant ** - Significant at 1 % level

The residual effect of previous season treatments was significant during the second crop season of first year only. The carry over effect of oxyfluorfen pre-emergence (Tr_6) and oxyfluorfen pre-emergence + hand weeding (Tr_9) were on a par and superior to other residual effects.

4.2.2.1b 30 Days after transplanting

Next to weed free treatment, thiobencarb pre-emergence + hand weeding recorded the maximum plant height among the weed control treatments studied in the experiment. Thiobencarb pre-emergence + 2,4-D post-emergence treatment was the next superior one.

The residual effect of treatments applied to the previous crop was significant during the first year only and maximum plant height was recorded under Tr_9 (residual effect of oxyfluorfen pre-emergence + hand weeding applied to the first crop).

4.2.2.1c. 45 Days after transplanting

All the herbicide treatments were superior in influencing the height of plant as compared to unweeded check. Unweeded check (T_2) recorded the lowest plant height during both the years. At this stage also, thiobencarb pre-emergence + hand weeding recorded the maximum plant height among the herbicide treatments which was on a par with thiobencarb pre-emergence +2,4-D post-emergence (T_{12}).

The residual effect of treatments applied to the previous crop of rice was not significant during both the years.

4.2.2.1d. At harvest

Weed free treatment recorded the maximum plant height of 116 and 121 cm and weedy check recorded the plant height of 100 and 104 cm during the first and second year respectively. Thiobencarb pre-emergence + hand weeding (T_9) recorded the maximum plant height among the herbicide treatments.

The residual effect of treatments applied to the first crop was not significant during both the years.

4.2.2.2 Number of tillers m^{-2}

The data are presented in Tables 35 and 36.

4.2.2.2a 15 Days after transplanting

Maximum number of tillers was recorded under weed free treatment (T_1) and the minimum under weedy check (T_2). Pre-emergence application of thiobencarb (T_9) increased the number of tillers m^{-2}.

The residual effect of treatments applied to the previous crop was significant during both the years. The residual effect of oxyfluorfen pre-emergence + 2,4-D post-emergence (Tr_{12}) recorded the maximum number of tillers. The residual effect of oxyfluorfen pre-emergence + hand weeding (Tr_9) was equal to that of Tr_{12} during the first year of experimentation. The tiller number was the lowest under the residual effect of pendimethalin pre-emergence + 2,4-D post-emergence (Tr_{10})

Table 35. Effect of weed control treatments on number of tillers m^{-2} during second crop season (1996-97)

Treatments	15 DAT	30 DAT	45 DAT	At harvest
Treatment effect				
T_1	260.0	420.7	456.7	456.7
T_2	153.3	302.7	318.7	336.0
T_3	168.7	345.3	384.0	385.7
T_4	166.7	330.0	394.7	394.0
T_5	166.0	344.0	392.7	404.7
T_6	195.3	366.0	403.0	400.7
T_7	170.0	339.3	405.3	401.7
T_8	190.6	348.7	396.7	407.0
T_9	232.7	364.7	423.3	417.3
T_{10}	192.0	342.7	404.7	418.0
T_{11}	172.0	349.3	416.0	421.7
T_{12}	169.3	336.0	416.0	413.7
$F_{11,22}$	25.791**	7.006**	9.155**	46.533**
SE	3.03	5.33	5.67	2.03
CD (0.05)	8.88	15.62	16.62	5.95
First crop residual effect				
Tr_1	163.3	344.7	391.3	394.0
Tr_2	168.7	348.7	390.7	394.7
Tr_3	168.7	346.7	402.7	395.0
Tr_4	168.7	345.3	396.7	396.3
Tr_5	173.3	356.7	399.3	398.0
Tr_6	173.3	351.3	400.7	402.0
Tr_7	168.3	345.3	408.7	400.0
Tr_8	169.3	357.3	414.7	391.1
Tr_9	177.3	357.3	404.7	393.7
Tr_{10}	162.0	358.7	401.3	393.3
Tr_{11}	171.3	346.7	398.7	393.0
Tr_{12}	177.3	355.3	412.7	397.0
$F_{1,24}$	106.391**	0.011^{NS}	0.049^{NS}	31.715**
SE	1.11	2.77	2.80	1.14
CD (0.05)	3.25	NS	NS	3.33

NS - Not significant ** - Significant at 1 % level

Table 36. Effect of weed control treatments on number of tillers m^{-2} during second crop season (1997-98)

Treatments	15 DAT	30 DAT	45 DAT	At harvest
Treatment effect				
T_1	263.3	438.0	442.7	458.3
T_2	167.3	305.3	332.7	343.0
T_3	182.0	351.3	390.7	385.0
T_4	174.7	334.0	392.0	394.6
T_5	170.7	354.7	393.3	400.6
T_6	206.7	363.3	407.3	401.6
T_7	173.3	343.3	400.7	408.0
T_8	185.3	350.0	400.7	414.0
T_9	223.3	364.7	422.0	427.0
T_{10}	180.3	345.3	410.7	425.0
T_{11}	180.7	351.3	415.3	424.6
T_{12}	180.7	364.0	422.7	414.6
$F_{11,22}$	9.278^{**}	16.538^{**}	4.196^{**}	62.627^{**}
SE	4.59	3.54	6.77	1.72
CD (0.05)	13.46	10.38	19.86	5.05
First crop residual effect				
Tr_1	172.0	342.0	408.7	390.0
Tr_2	179.3	351.3	406.7	390.0
Tr_3	172.7	348.0	407.3	396.6
Tr_4	174.7	347.3	403.3	388.0
Tr_5	173.3	352.7	406.0	389.6
Tr_6	181.3	348.0	404.6	392.6
Tr_7	175.3	348.7	412.7	397.3
Tr_8	164.7	356.0	410.7	387.6
Tr_9	176.0	354.7	405.3	387.0
Tr_{10}	168.0	356.0	407.3	388.0
Tr_{11}	177.3	357.3	410.0	388.0
Tr_{12}	187.3	353.3	413.3	393.0
$F_{1,24}$	49.671^{**}	3.272^{NS}	4.593^{*}	157.198^{**}
SE	1.56	1.63	1.79	0.98
CD (0.05)	4.55	NS	5.25	2.86

NS - Not significant ** - Significant at 1 % level * - Significant at 5 % level during the first year and in Tr_6 (residual effect of oxyfluorfen pre-emergence alone) during the second year.

4.2.2.2b 30 Days after transplanting

The treatments were significant during this stage also. Weed free treatment (T_1) recorded maximum number of tillers (420 and 438 during the first and second year respectively). During the first year, thiobencarb pre-emergence (T_6) and thiobencarb pre-emergence + 2,4-D post emergence (T_{12}) were equal. During the second year thiobencarb pre-emergence + hand weeding (T_9) recorded maximum number of tillers.

The residual effect of previous crop treatments was found to be non significant at this stage of crop growth during both the seasons.

4.2.2.2c 45 Days after transplanting

The data revealed significant difference in the number of tillers between the weed control treatments. Next to weed free treatment thiobencarb pre-emergence + hand weeding (T_9) during the first year and thiobencarb pre-emergence + 2,4-D post emergence (T_{12}) during the second year significantly increased the number of tillers.

The residual effects of previous season treatments were significant only during the second crop season of 1997-98. The residual effect of oxyfluorfen pre-emergence + 2,4-D post-emergence (Tr_{12}) recorded the maximum number of tillers m^{-2} followed by the residual effect of pendimethalin pre-emergence + hand weeding (Tr_7) which were on a par with the residual effect of completely weed free treatment of the previous season (Tr_1).

4.2.2.2d At harvest

All the herbicide treatments tried in the experiment were superior to unweeded check. Among the herbicide treatments, maximum number of tillers was recorded under pretilachlor pre-emergence + 2,4-D post emergence (T_{11}) and thiobencarb pre-emergence + hand weeding (T_9) during the first and second year respectively.

The number of tillers were significantly influenced by the residual effect of previous crop treatments during both the years. The carry over effect of pendimethalin pre-emergence + hand weeding treatment (Tr_7) was significant which recorded greater number of tillers during both the years. The residual effect of oxyfluorfen pre-emergence (Tr_6) and the carry over effect of farmers practice of weed control applied to the first crop (Tr_3) were on a par with Tr_7 during the first and second year respectively.

4.2.2.3 Leaf area Index

The results are presented in Tables 37 and 38.

4.2.2.3a 15 Days after transplanting

Results revealed the significant effect of weed control treatments on LAI of crop during the first year only. Weed free treatment (T_1)

Table 37. Effect of weed control treatments of LAI on rice during second crop season (1996-97)

Treatments	15 DAT	30 DAT	45 DAT
Treatment effect			
T_1	1.07	2.86	5.22
T_2	1.02	2.62	3.70
T_3	1.03	2.75	4.32
T_4	1.02	2.76	4.51
T_5	1.04	2.73	4.06
T_6	1.05	2.83	5.00
T_7	1.06	2.75	4.35
T_8	1.03	2.76	4.41
T_9	1.06	2.81	4.73
T_{10}	1.06	2.75	3.80
T_{11}	1.05	2.77	4.31
T_{12}	1.04	2.82	4.15
$F_{11,22}$	12.527^{**}	5.244^{**}	6.678^{**}
SE	0.003	0.01	0.08
CD (0.05)	0.008	0.04	0.23
First crop residual effect			
Tr_1	1.02	2.75	4.32
Tr_2	1.03	2.76	5.14
Tr_3	1.02	2.79	4.99
Tr_4	1.03	2.76	4.51
Tr_5	1.02	2.75	4.40
Tr_6	1.03	2.73	4.30
Tr_7	1.03	2.74	4.33
Tr_8	1.03	2.74	4.45
Tr_9	1.03	2.77	4.29
Tr_{10}	1.03	2.75	4.39
Tr_{11}	1.02	2.80	4.16
Tr_{12}	1.03	2.76	4.31
$F_{1,24}$	94.262^{**}	0.685^{NS}	1.637^{NS}
SE	0.001	0.007	0.05
CD (0.05)	0.004	NS	NS

NS - Not significant　　** - Significant at 1 % level

Table 38. Effect of weed control treatments on LAI of rice during second crop season (1997-98)

Treatments	15 DAT	30 DAT	45 DAT
Treatment effect			
T_1	1.08	2.89	5.37
T_2	1.00	2.65	3.81
T_3	1.03	2.79	4.50
T_4	1.02	2.77	4.79
T_5	1.03	2.78	4.31
T_6	1.06	2.80	5.20
T_7	1.01	2.75	4.57
T_8	1.00	2.78	4.74
T_9	1.02	2.81	4.66
T_{10}	1.06	2.74	4.43
T_{11}	1.06	2.77	4.51
T_{12}	1.05	2.82	4.32
$F_{11,22}$	0.974^{NS}	2.158^{NS}	1.636^{NS}
SE	0.45	0.02	0.17
CD (0.05)	NS	NS	NS
First crop residual effect			
Tr_1	1.02	2.75	4.33
Tr_2	1.02	2.75	4.35
Tr_3	1.03	2.77	4.35
Tr_4	1.02	2.80	4.01
Tr_5	1.02	2.78	4.44
Tr_6	1.02	2.81	4.37
Tr_7	1.02	2.78	4.28
Tr_8	1.03	2.78	4.21
Tr_9	1.02	2.78	4.45
Tr_{10}	1.02	2.77	4.05
Tr_{11}	1.02	2.79	4.15
Tr_{12}	1.02	2.78	4.39
$F_{1,24}$	0.909^{NS}	0.024^{NS}	15.37^{**}
SE	0.18	0.008	0.06
CD (0.05)	NS	NS	0.17

NS - Not significant ** - Signficant at 1 % level recorded the maximum LAI and weedy check (T_2) registered the lowest LAI value. All other herbicide treatments were superior to weedy check. Pre-emergence treatments of pendimethalin and thiobencarb were superior and equal in effect (T_7, T_{10} and T_9). The data were not significant during the second year.

The residual effects of treatments applied to the previous crop of rice were significant only during the first year. However the results were not conclusive.

4.2.2.3b 30 Days after transplanting

There was significant difference between the treatments on the LAI of the crop during the first year only. Thiobencarb treatments (T_6, T_9 and T_{12}) were on a par with weed free treatment during the first year.

The results also indicated that the residual effect of previous treatments were not significant on the LAI of the crop.

4.2.2.3c 45 Days after transplanting

The results indicated that all the herbicide treatments and farmer's practice were superior to the weedy check (T_2). During the first year, thiobencarb pre-emergence (T_6) recorded the highest LAI among the herbicide treatments which was on a par with completely weed free treatment (T_1). During the second year the data were not significant.

The residual effect of previous season treatment was not significant during the first year. However during the second year, the data showed significant difference in the LAI among the residual effect of weed control treatment practiced in the previous crop of rice. Among the residual effects, Tr_9 (residual effect of oxyfluorfen pre-emergence + hand weeding applied to first crop) recorded the maximum LAI.

4.2.2.4 Crop growth rate (CGR)

The results are presented in Table 39.

The CGR of the crop was influenced by the weed control treatments studied in the experiment at 15-30 DAT during both the years and at 45 DAT-harvest period during the first year only. Thiobencarb treatments recorded higher CGR values at 15-30 DAT interval. Among the residual effects, the CGR values were the maximum for Tr_{12} (oxyfluorfen pre-emergence + 2,4-D post-emergence applied to first crop) and Tr_1 (residual effect of weed free treatment of the first crop) during the first and second year of experimentation respectively.

At 30-45 DAT period, the CGR was unaffected by the weed control treatments. The residual effect of previous crop treatment was also significant during the first year only. Tr_6 (residual effect of oxyfluorfen pre-emergence) recorded the highest CGR value which was on a par with Tr_{11} (residual effect of butachlor pre-emergence + 2,4-D post-emergence treatment) at the stage of crop growth.

Table 39. Crop growth rate (CGR) of rice during second crop season as influenced by different weed control treatments (g m^{-2} day^{-1})

Treatments	1996-97 (DAT)			1997-98 (DAT)		
	15-30	30-45	45-Harvest	15-30	30-45	45-Harvest
Treatments						
T_1	12.32	14.13	4.90	15.23	8.57	7.43
T_2	4.23	7.49	1.32	5.47	4.49	3.02
T_3	6.32	7.45	3.51	6.57	5.45	4.73
T_4	6.59	6.38	4.41	7.05	3.42	6.03
T_5	6.98	7.26	4.23	7.11	5.72	5.10
T_6	7.12	6.75	4.44	7.41	5.02	6.73
T_7	11.56	5.01	4.27	8.88	6.57	6.18
T_8	11.59	6.99	4.25	10.44	6.50	6.46
T_9	12.58	6.43	4.67	11.13	8.38	6.03
T_{10}	10.16	7.68	4.36	10.25	7.66	5.93
T_{11}	9.62	7.54	4.48	8.47	9.78	5.82
T_{12}	5.42	10.66	5.11	11.49	6.72	5.49
$F_{11,22}$	11.632**	1.972^{NS}	2.842*	3.344**	0.856^{NS}	1.251^{NS}
SE	0.44	0.67	0.28	0.79	1.09	0.46
CD(0.05)	1.28	NS	0.83	2.31	NS	NS
First crop residual effect						
Tr_1	6.51	7.38	3.81	7.33	5.46	4.81
Tr_2	5.77	8.50	3.75	6.89	4.58	5.56
Tr_3	6.56	8.50	3.54	6.19	5.69	5.07
Tr_4	6.46	8.82	3.19	6.63	5.23	5.26
Tr_5	6.84	8.88	3.37	6.67	4.89	5.19
Tr_6	5.61	10.45	3.16	6.33	6.01	4.88
Tr_7	6.32	9.23	3.33	7.07	4.77	5.35
Tr_8	6.57	9.22	3.52	6.46	4.64	5.16
Tr_9	6.63	9.24	3.33	6.54	5.63	4.86
Tr_{10}	6.45	8.49	3.44	6.42	4.77	5.04
Tr_{11}	6.21	10.32	3.25	6.70	5.27	4.67
Tr_{12}	7.39	7.91	3.80	6.65	6.90	4.14
$F_{1,24}$	87.377**	6.052**	37.973**	33.597**	3.708^{NS}	6.214*
SE	0.17	0.32	0.08	0.30	0.44	0.21
CD(0.05)	0.50	0.92	0.24	0.88	NS	0.62

NS - Not significant   * - Significant at 5 % level   ** - Significant at 1 % level

During the first year, next to weed free treatment (T_1) the CGR value was high in thiobencarb pre-emergence + hand weeding treatment (T_9) at 45 DAT - harvest interval. The weed control treatments had no significant effect on CGR during the second year. The residual effects of previous season treatments were found significant. In the first year, the CGR values were higher under Tr_1 (weed free treatment applied to first crop). In the second year, the CGR value was high under Tr_2 (residual effect of weedy check).

4.2.2.5 Relative growth rate (RGR)

The data are presented in Table 40.

The results indicated significant difference in the RGR values for the intervals 15-30 DAT and 30-45 DAT during the first year of experimentation only. At 15-30 DAT, thiobencarb pre-emergence + hand weeding (T_9) recorded the maximum RGR followed by pretilachlor pre-emergence + hand weeding (T_8). Among the residual effect, Tr_7 (pendimethalin pre-emergence + hand weeding applied to the first crop of rice) was comparable with that of weed free treatment of the first crop (Tr_1) during the second year of experimentation. However the data were not significant during the second crop season of 1996-97. At 30-45 DAT interval, weedy check (T_2) recorded higher RGR value. Among the residual effects, Tr_6 (oxyfluorfen per-emergence applied to the first crop) produced greater RGR.

Table 40. Relative growth rate (RGR) of rice during second crop season as influenced by different weed control treatments (g g^{-1} day^{-1})

Treatments	1996-97 (DAT)			1997-98 (DAT)		
	15-30	30-45	45-Harvest	15-30	30-45	45-Harvest
Treatments						
T_1	0.080	0.039	0.008	0.112	0.025	0.012
T_2	0.081	0.054	0.005	0.115	0.034	0.012
T_3	0.069	0.037	0.010	0.088	0.032	0.014
T_4	0.062	0.031	0.034	0.089	0.019	0.017
T_5	0.063	0.033	0.010	0.091	0.031	0.014
T_6	0.065	0.031	0.011	0.089	0.027	0.017
T_7	0.087	0.019	0.010	0.097	0.033	0.015
T_8	0.089	0.025	0.009	0.107	0.026	0.014
T_9	0.094	0.022	0.010	0.109	0.033	0.012
T_{10}	0.084	0.029	0.010	0.109	0.033	0.013
T_{11}	0.081	0.028	0.010	0.098	0.043	0.012
T_{12}	0.056	0.050	0.011	0.112	0.026	0.012
$F_{11,22}$	4.392^{**}	2.977^{**}	1.169^{NS}	0.864^{NS}	0.302^{NS}	1.212^{NS}
SE	0.0028	0.003	0.003	0.006	0.006	0.001
CD(0.05)	0.0082	0.008	NS	NS	NS	NS
First crop residual effect						
Tr_1	0.072	0.037	0.010	0.093	0.029	0.014
Tr_2	0.067	0.044	0.010	0.092	0.028	0.016
Tr_3	0.074	0.042	0.009	0.086	0.034	0.015
Tr_4	0.072	0.040	0.008	0.090	0.031	0.015
Tr_5	0.077	0.043	0.009	0.090	0.029	0.015
Tr_6	0.067	0.052	0.008	0.087	0.035	0.014
Tr_7	0.072	0.045	0.009	0.093	0.028	0.015
Tr_8	0.076	0.045	0.009	0.086	0.028	0.015
Tr_9	0.071	0.044	0.009	0.085	0.033	0.014
Tr_{10}	0.072	0.042	0.009	0.086	0.029	0.015
Tr_{11}	0.068	0.049	0.008	0.089	0.032	0.014
Tr_{12}	0.078	0.037	0.009	0.088	0.036	0.012
$F_{1,24}$	3.381^{NS}	32.369^{**}	1.592^{NS}	18.819^{**}	0.074^{NS}	0.930^{NS}
SE	0.001	0.0013	0.0014	0.0021	0.0022	0.0006
CD(0.05)	NS	0.0037	NS	0.0061	NS	NS

NS - Not significant ** - Significant at 1 % level

4.2.3 Yield and yield attributes of crop

4.2.3.1 Number of productive tillers m^{-2}

The data are presented in Table 41.

Among the treatments applied to second crop maximum number of productive tillers was recorded by completely weed free treatment (335 and 359) during the first and second year respectively. All the herbicide treatments were superior to T_3 (farmer's practice) and T_2 (weedy check). Among the herbicide treatments T_9 (thiobencarb pre-emergence + hand weeding) recorded the maximum number of productive tillers and the lowest by T_4 (pendimethalin pre-emergence). During the first year, all the residual effects except Tr_4 (pendimethalin pre-emergence) and Tr_5 (butachlor pre-emergence) were on a par.

The residual effect of treatments applied to the first crop of rice were found to be significant. In the second crop season of 1996-97, the residual effect of butachlor pre-emergence (Tr_5) and residual effect of oxyfluorfen pre-emergence + hand weeding treatment (Tr_9) recorded higher number of productive tillers which were on a par with each other. In the second crop season of 1997-98, the residual effects of pendimethalin pre-emergence + hand weeding (Tr_7), oxyfluorfen pre-emergence + hand weeding (Tr_9), weed free treatment (Tr_1), pendimethalin pre-emergence (Tr_4) and oxyfluorfen pre-emergence treatment (Tr_6) recorded higher number of productive tillers and were on a par.

Table 41. Effect of weed control treatments on productive tillers m^{-2} and weight of panicle (g) during second crop season

Treatment	Productive tillers m^{-2}		Weight of panicle	
	1996-97	1997-98	1996-97	1997-98
Treatment effect				
T_1	335.7	359.0	2.71	2.72
T_2	230.3	293.3	2.07	2.03
T_3	281.7	291.3	2.36	2.29
T_4	292.0	297.3	2.36	2.33
T_5	293.3	302.7	2.33	2.28
T_6	297.3	302.7	2.35	2.35
T_7	298.6	308.7	2.43	2.48
T_8	300.7	317.0	2.42	2.46
T_9	314.3	329.7	2.54	2.59
T_{10}	305.7	328.3	2.52	2.54
T_{11}	307.7	329.0	2.48	2.49
T_{12}	310.7	315.3	2.45	2.46
$F_{11,22}$	25.462**	37.661**	7.069**	5.424**
SE	2.38	2.39	0.003	0.038
CD (0.05)	6.99	7.02	0.085	0.111
First crop residual effect				
Tr_1	283.7	294.3	2.35	2.34
Tr_2	288.0	292.3	2.38	2.34
Tr_3	288.0	290.3	2.34	2.32
Tr_4	289.7	294.0	2.35	2.32
Tr_5	290.0	292.0	2.35	2.31
Tr_6	282.7	293.7	2.37	2.35
Tr_7	283.3	297.3	2.35	2.33
Tr_8	283.7	292.6	2.36	2.35
Tr_9	287.7	294.7	2.34	2.31
Tr_{10}	284.0	292.0	2.42	2.31
Tr_{11}	286.6	292.0	2.42	2.31
Tr_{12}	284.3	292.6	2.38	2.32
$F_{1,24}$	88.84**	76.76**	9.631**	23.609**
SE	0.85	1.36	0.012	0.014
CD (0.05)	2.49	3.97	0.033	0.040

** - Significant at 1 % level

4.2.3.2 Weight of panicle

The results are presented in Table 41.

The data indicated the difference in the weight of panicle due to weed control treatments applied to the second crop and the residual effect of treatments applied to the previous crop. Next to the weed free treatment (T_1), thiobencarb pre-emergence + hand weeding (T_9) recorded higher weight of panicle which was statistically at par with T_{10} (pendimethalin pre-emergence + 2,4-D post-emergence) and T_{11} (pretilachlor pre-emergence + 2,4-D post-emergence). Unweeded check (T_2) and farmers' practice (T_3) were inferior to herbicide treatments.

The residual effect of previous treatments was found to be significant. Maximum weight of panicle was noted under the residual effect of pre-emergence application of pendimethalin and butachlor integrated with 2,4-D post-emergence application (Tr_{10} and Tr_{11}) during the first year and under pre-emergence application of oxyfluorfen (Tr_6) and pre-emergence application of butachlor + hand weeding (Tr_8) during the second year respectively.

4.2.3.3 Total spikelets panicle^{-1}

The data are presented in Tables 42 and 43.

The results revealed no significant difference in the total number of spikelets panicle^{-1} due to the weed control treatments applied to the second crop and the residual effect of treatments applied to the previous crop.

Table 42. Effect of weed control treatments on total number of spikelets panicle^{-1}, number of filled grains and percentage of filled grains (1996-97)

Treatments	No. of spikelets / panicle	No. of filled grains	Percentage of filled grains
Treatment effect			
T_1	102.3	94.6	92.5
T_2	88.7	62.9	70.9
T_3	97.0	77.8	80.2
T_4	103.0	84.0	81.6
T_5	104.0	85.5	82.2
T_6	99.3	81.7	82.2
T_7	101.7	86.1	84.7
T_8	98.7	81.4	82.4
T_9	90.3	78.1	86.5
T_{10}	98.3	81.0	82.5
T_{11}	100.0	82.8	82.9
T_{12}	99.0	82.9	83.8
$F_{11,22}$	1.003^{NS}	3.417^{**}	13.746^{**}
SE	2.61	2.12	0.66
CD (0.05)	NS	6.21	1.93
First crop residual effect			
Tr_1	99.7	80.9	81.2
Tr_2	98.7	80.3	81.4
Tr_3	96.3	77.9	80.9
Tr_4	98.0	78.6	80.2
Tr_5	100.7	82.1	81.5
Tr_6	100.0	80.7	80.7
Tr_7	100.3	81.8	81.5
Tr_8	101.3	83.2	82.1
Tr_9	99.7	80.0	80.3
Tr_{10}	97.3	78.8	80.9
Tr_{11}	95.0	76.7	80.8
Tr_{12}	98.3	81.0	82.4
$F_{1,24}$	0.042^{NS}	2.049^{NS}	12.758^{**}
SE	0.84	0.69	0.30
CD (0.05)	NS	NS	0.89

NS - Not significant ** - Significant at 1 % level

Table 43. Effect of weed control treatments on total number of spikelets panicle^{-1}, number of filled grains and percentage of filled grains during second crop season (1997-98)

Treatments	No. of spikelets / panicle	No. of filled grains	Percentage of filled grains
Treatment effect			
T_1	99.7	91.8	92.1
T_2	96.3	66.8	69.4
T_3	96.0	76.6	79.8
T_4	101.0	82.7	81.9
T_5	103.0	82.0	79.7
T_6	98.0	82.6	85.5
T_7	97.7	81.1	83.0
T_8	99.3	82.0	82.5
T_9	102.3	85.0	83.1
T_{10}	97.7	81.2	83.2
T_{11}	96.3	80.6	83.6
T_{12}	97.7	82.2	84.3
$F_{11,22}$	0.771^{NS}	3.647^{**}	13.035^{**}
SE	2.10	1.57	0.79
CD (0.05)	NS	4.59	2.33
First crop residual effect			
Tr_1	100.7	81.4	80.9
Tr_2	103.0	80.9	78.6
Tr_3	99.6	79.3	79.6
Tr_4	98.3	76.5	77.9
Tr_5	95.0	75.0	79.0
Tr_6	91.7	72.9	79.5
Tr_7	99.7	80.1	80.4
Tr_8	97.6	78.8	80.6
Tr_9	96.0	76.9	80.1
Tr_{10}	102.0	81.2	79.7
Tr_{11}	98.3	78.8	80.2
Tr_{12}	91.7	73.2	79.9
$F_{1,24}$	0.813^{NS}	14.198^{**}	51.076^{**}
SE	0.74	0.62	0.26
CD (0.05)	NS	1.81	0.76

NS - Not significant ** - Significant at 1 % level

4.2.3.4 Number of filled grains panicle^{-1}

The results are presented in Tables 42 and 43.

Maximum number of filled grains (94.6 and 91.8) was recorded under completely weed free treatment. All the herbicide treatments recorded higher number of filled grains as compared to the farmers' practice (T_3) and unweeded treatment (T_2). During the first year of experimentation, pendimethalin pre-emergence + hand weeding (T_7) recorded the highest number of filled grains which was on a par with other herbicide treatments except T_9 (thiobencarb pre-emergence + hand weeding). During the second year, T_9 (thiobencarb pre-emergence + hand weeding) recorded maximum number of filled grains which was at par with all other herbicide treatments.

The residual effect of weed control treatments applied to the previous crop was significant only during the second year of experimentation. The residual effect of pendimethalin pre-emergence integrated with 2,4-D post-emergence treatment (Tr_{10}) recorded the maximum number of filled grains followed by the integration of pendimethalin pre-emergence with the hand weeding (Tr_7).

4.2.3.5 Percentage of filled grains

The data are presented in Tables 42 and 43.

Results revealed that the application of weed control treatments had increased the percentage of filled grains compared to the residual effect of previous treatments. All the herbicide treatments were superior to the farmers' practice (T_3). Among the herbicide treatments, thiobencarb pre-emergence + hand weeding (T_9) recorded the highest percentage of filled grains during the first year. Pendimethalin pre-emergence + hand weeding (T_7) was on a par with T_9. Thiobencarb pre-emergence alone (T_6) recorded the highest percentage of filled grains during the second year. T_6 was on a par with other pre-emergence herbicide treatments integrated with 2,4-D post-emergence (T_{12}, T_{11} and T_{10}). Highest percentage of filled grains was recorded under completely weed free treatment (T_1).

The residual effect of treatments applied to the previous crop was significant. Tr_{12} (residual effect of oxyfluorfen pre-emergence + 2,4-D post-emergence) recorded the highest percentage of filled grains during the first year which was on a par with Tr_8 (residual effect of butachlor pre-emergence + hand weeding) whereas in the second year Tr_1 (carry over effect of completely weed free treatment) recorded the highest percentage. Tr_8, Tr_7 and Tr_{11} (residual effects of butachlor pre-emergence + hand weeding, pendimethalin pre-emergence + hand weeding and butachlor pre-emergence + 2,4-D post-emergence) were on a par with Tr_1.

4.2.3.6 Grain yield

The results are presented in Tables 44 and 45.

Maximum grain yield was recorded under weed free treatment (3.34 t ha^{-1} and 3.59 t ha^{-1}) during the first and second year respectively. Weedy check (T_2) recorded the lowest grain yield. All the herbicide

Table 44. Effect of weed control treatments on grain yield, straw yield and harvest index of rice during second crop season (1996-97)

Treatments	Grain yield (kg ha^{-1})	Straw yield (kg ha^{-1})	Harvest index
Treatment effect			
T_1	3344.30	4002.19	0.46
T_2	1425.44	2110.75	0.40
T_3	2028.51	2713.81	0.43
T_4	2357.46	3042.76	0.44
T_5	2302.63	2987.94	0.43
T_6	2357.46	2960.53	0.44
T_7	2384.87	2987.94	0.44
T_8	2247.81	2987.94	0.43
T_9	2987.94	3557.48	0.44
T_{10}	2631.58	3426.53	0.43
T_{11}	2631.58	3553.95	0.43
T_{12}	2658.99	3426.93	0.44
$F_{11,22}$	3.493**	5.851**	1.106^{NS}
SE	135.97	113.43	0.007
CD (0.05)	398.82	332.71	NS
First crop residual effect			
Tr_1	2001.10	2713.81	0.42
Tr_2	1891.45	2549.34	0.43
Tr_3	2028.51	2713.81	0.43
Tr_4	1918.86	2576.75	0.43
Tr_5	2001.10	2741.23	0.42
Tr_6	2028.50	2768.64	0.42
Tr_7	2275.22	2768.64	0.45
Tr_8	2055.92	2823.46	0.42
Tr_9	2055.92	2823.46	0.42
Tr_{10}	2001.10	2741.23	0.43
Tr_{11}	2001.10	2741.23	0.42
Tr_{12}	2026.20	2796.05	0.42
$F_{1,24}$	44.842**	52.903**	8.324**
SE	44.38	41.31	0.002
CD (0.05)	129.55	120.57	0.007

NS - Not significant ** - Significant at 1 % level

Table 45. Effect of weed control treatments on the grain yield, straw yield and harvest index of rice during second crop season (1997-98)

Treatments	Grain yield (kg ha^{-1})	Straw yield (kg ha^{-1})	Harvest index
Treatment effect			
T_1	3591.01	4248.90	0.46
T_2	1370.61	2330.04	0.37
T_3	1891.45	2768.64	0.41
T_4	2247.81	2933.11	0.43
T_5	2220.39	2960.53	0.43
T_6	2384.87	3152.41	0.43
T_7	2631.60	3207.24	0.43
T_8	2521.93	3316.88	0.43
T_9	3097.59	3837.72	0.45
T_{10}	2467.11	3536.18	0.41
T_{11}	2604.16	3508.77	0.43
T_{12}	2686.40	3453.95	0.44
$F_{11,22}$	15.719**	10.797**	4.183**
SE	72.74	85.14	0.02
CD (0.05)	213.36	249.72	0.006
First crop residual effect			
Tr_1	1973.68	2796.05	0.41
Tr_2	1836.62	2658.99	0.41
Tr_3	2083.33	2960.53	0.41
Tr_4	1946.27	2686.40	0.42
Tr_5	1973.68	2713.82	0.42
Tr_6	1918.86	2686.40	0.41
Tr_7	2055.92	2933.11	0.41
Tr_8	1973.68	2768.64	0.42
Tr_9	1946.27	2878.29	0.40
Tr_{10}	2138.16	2987.94	0.42
Tr_{11}	1973.68	2933.11	0.40
Tr_{12}	1973.68	2796.05	0.41
$F_{1,24}$	119.938**	105.319**	24.132**
SE	31.86	31.32	0.002
CD (0.05)	92.99	91.43	0.005

NS - Not significant ** - Significant at 1 % level

treatments were superior to farmers practice (T_3). Thiobencarb pre-emergence + hand weeding (T_9) top ranked on this aspect. T_9 was on a par with the pre-emergence herbicide treatments integrated with 2,4-D post-emergence application (T_{10} to T_{12}) during the first year of experimentation.

The residual effects of previous treatments on grain yield of rice during second crop season were significant but the results were inconsistent. During the first year Tr_7 (residual effect of pendimethalin + hand weeding applied to the first crop of rice) recorded the maximum grain yield. During the second year, maximum grain yield was observed under the residual effect of Tr_{10} (pendimethalin pre-emergence + 2,4-D post-emergence) which was on par with the carry over effect of farmers practice (Tr_3) and pendimethalin pre-emergence + hand weeding (Tr_7).

4.2.3.7 Straw yield

The data are presented in Tables 44 and 45.

Weed free treatment was superior. All the herbicide treatments recorded higher straw yield compared to farmer's practice (T_3). Thiobencarb pre-emergence + hand weeding (T_9) recorded the highest straw yield during both the seasons which was on a par with 2,4-D post-emergence integrated treatments viz. T_{10}, T_{11} and T_{12} during the first year of experimentation only.

All the residual effects was superior to weedy check. During the first year the residual effects were on a par except Tr_2 and Tr_4 (carry over effect of weedy check and pendimethalin pre-emergence from first crop season) which recorded lower straw yields. During the second year, maximum straw yield was recorded under the residual effects of pendimethalin pre-emergence + 2,4-D post-emergence (Tr_{10}). Tr_{10} was on a par with the carry over effect of pendimethalin pre-emergence + hand weeding (Tr_7) and butachlor pre-emergence + 2,4-D post-emergence (Tr_{11}).

4.2.3.8 Harvest Index

The data are presented in Tables 44 and 45.

There was no significant difference during the first year. In the second year harvest index differed significantly. Completely weed free treatment (T_1) recorded the highest harvest index followed by T_9 (thiobencarb pre-emergence + hand weeding).

The residual effects of treatments applied to the first crop of rice were significant. During the first year Tr_7 (residual effect of pendimethalin pre-emergence + hand weeding) and during the second year, the residual effect of pendimethalin pre-emergence (Tr_4), residual effect of butachlor pre-emergence (Tr_5), carry over effect of butachlor pre-emergence + hand weeding (Tr_8) and pendimethalin pre-emergence + 2,4-D post-emergence (Tr_{10}) recorded higher harvest indices.

4.2.3.9 Dry matter production

The data are presented in Tables 46 and 47.

Table 46. Effect of weed control treatments on dry matter production ($g\ m^{-2}$) of the crop during second crop season (1996-97)

Treatments	15 DAT	30 DAT	45 DAT	At harvest
Treatment effect				
T_1	79.4	264.3	476.3	804.6
T_2	27.2	90.7	203.2	291.8
T_3	51.3	146.1	257.8	493.7
T_4	65.1	164.0	259.7	555.8
T_5	66.2	171.0	279.9	563.9
T_6	65.1	171.9	273.2	570.8
T_7	64.1	237.6	312.7	599.3
T_8	61.4	235.3	340.2	625.2
T_9	61.4	250.3	346.8	660.4
T_{10}	60.9	213.3	295.4	621.3
T_{11}	61.4	205.7	285.6	619.5
T_{12}	61.4	142.8	302.7	645.7
$F_{11,22}$	15.329**	14.986**	11.895**	10.901**
SE	1.58	6.87	9.42	18.37
CD (0.05)	4.64	20.12	27.63	53.90
First crop residual effect				
Tr_1	49.9	147.6	258.4	514.4
Tr_2	49.7	136.4	264.0	515.7
Tr_3	48.5	146.9	274.6	512.1
Tr_4	52.2	145.7	278.1	492.1
Tr_5	47.2	149.8	283.1	509.3
Tr_6	49.6	132.9	289.7	501.5
Tr_7	49.1	143.9	282.5	505.8
Tr_8	47.3	145.9	284.2	520.3
Tr_9	48.6	148.1	286.8	510.2
Tr_{10}	49.4	146.2	273.7	504.1
Tr_{11}	51.4	144.7	299.5	517.3
Tr_{12}	50.2	161.1	279.8	534.6
$F_{1,24}$	84.883**	164.778**	23.980**	85.106**
SE	0.84	2.49	3.36	5.84
CD (0.05)	2.46	7.29	9.80	17.04

** - Significant at 1 % level

Table 47. Effect of weed control treatments on dry matter production ($g\ m^{-2}$) of the crop during second crop season (1997-98)

Treatments	15 DAT	30 DAT	45 DAT	At harvest
Treatment effect				
T_1	52.7	281.2	409.7	870.6
T_2	18.0	100.2	167.6	355.1
T_3	36.1	134.6	216.5	510.4
T_4	37.1	142.8	194.3	568.7
T_5	36.6	143.3	229.1	545.9
T_6	38.6	149.8	225.3	642.8
T_7	37.7	170.9	269.5	652.7
T_8	39.5	196.2	293.8	685.7
T_9	39.3	206.4	332.2	706.5
T_{10}	36.4	190.3	305.2	673.4
T_{11}	37.4	164.6	311.3	672.2
T_{12}	39.2	211.6	312.5	653.4
$F_{11,22}$	13.495**	4.587**	8.050**	5.404**
SE	1.08	11.56	13.06	25.57
CD (0.05)	3.15	33.92	38.31	75.00
First crop residual effect				
Tr_1	35.3	145.4	227.4	525.60
Tr_2	34.2	137.6	201.5	546.80
Tr_3	35.2	128.3	213.7	528.20
Tr_4	34.6	134.1	212.6	539.00
Tr_5	34.9	135.1	208.6	530.90
Tr_6	35.5	130.6	220.8	523.60
Tr_7	34.2	139.4	210.9	542.90
Tr_8	36.5	133.5	203.2	523.50
Tr_9	36.9	134.9	217.0	518.80
Tr_{10}	36.3	132.7	204.3	516.70
Tr_{11}	35.4	136.1	215.1	504.90
Tr_{12}	35.7	135.5	239.1	496.10
$F_{1,24}$	13.607**	39.158**	29.475**	45.806**
SE	0.38	4.42	7.52	10.30
CD (0.05)	1.11	12.89	21.95	81.53

** - Significant at 1 % level

4.2.3.9a 15 Days after transplanting

Weed control treatments had significant influence on dry matter production at this stage. Maximum dry matter production was noted in weed free treatment and minimum in the weedy check. During the first year, T_5 (pretilachlor pre-emergence alone) recorded the maximum dry weight. All other herbicide treatments were on a par and recorded higher dry matter production than T_3 (Farmer's practice).

The residual effects were found to be significant. The data indicated higher dry matter accumulation in Tr_4 (residual effect of pendimethalin pre-emergence) and Tr_9 (residual effect of oxyfluorfen pre-emergence + hand wedding) during the first and second year respectively. Tr_4 was on a par with 2,4-D integrated treatments viz., Tr_{11} and Tr_{12} during the first year of experimentation.

4.2.3.9b 30 Days after transplanting

Among the herbicides thiobencarb pre-emergence + hand weeding (T_9) recorded the maximum dry matter accumulation during the first year and thiobencarb pre-emergence + 2,4-D post-emergence (T_{12}) during the second year.

The residual effect of previous season treatment was found to be significant. The dry matter accumulation by the second crop of rice were the maximum under the carry over effect of oxyfluorfen per-emergence + 2,4-D post emergence (Tr_{12}) and completely weed free treatment (Tr_1) during the first and second year respectively.

4.2.3.9c 45 Days after transplanting

Completely weed free treatment (T_1) recorded the highest drymatter accumulation followed by thiobencarb pre-emergence + hand weeding (T_9). Farmers practice of weeding (T_3) recorded higher dry matter production than the weedy check but it was inferior to all the herbicide treatments.

The residual effects were significant. The data showed that the carry over effect of butachlor pre-emergence + 2,4-D post-emergence (Tr_{11}) and that of oxyfluorfen pre-emergence alone (Tr_6) were on a par and superior to other weed control treatments, during the first year. In the second year, Tr_{12} (residual effect of oxyfluorfen pre-emergence + 2,4-D post-emergence) recorded the maximum dry matter production which were on a par with residual effects of completely weed free treatment and oxyfluorfen alone (Tr_1 and Tr_6).

4.2.3.9d At harvest

Weed free treatment (T_1) recorded the maximum dry matter accumulation and the minimum was observed in the weedy check (T_2). Thiobencarb pre-emergence + hand weeding (T_9) recorded maximum dry matter among the herbicide treatments studied in the experiment. The dry matter accumulation by crop was significantly higher in the treatments T_8 to T_{12} during the first year and T_6 to T_{12} during the second year.

The residual effect of treatments applied to the first crop of rice significantly influenced the dry matter accumulation by the rice crop during the second crop season also. Compared to the weedy check, all the residual effects recorded significantly higher dry matter accumulation during both the year.

4.2.3.10 Weed index

The data on weed index during second crop season are presented in Table 31 (Page No. 123).

Treatments differed significantly in the weed index. The weed index was invariably low in the second crop treatments. Among the treatments the lowest weed index values were noted under thiobencarb pre-emergence + hand weeding (T_9). Farmer's practice (T_3) recorded weed indices of 41.49 and 45.59 during the first and second year respectively where as it was higher in weedy check.

The results revealed that the residual effect of previous crop treatments on weed index was significant. During the first year, lowest weed index was recorded in Tr_7 (residual effect of pendimethalin pre-emergence + hand weeding) whereas all other residual effects except residual effect of weedy check (Tr_2) were on a par. During the second year of experimentation lowest weed indices were recorded under Tr_{10} (residual effect of pendimethalin pre-emergence + 2,4-D post-emergence) Tr_3 (carry over effect of farmers practice of weeding applied to the first crop) and Tr_7 (residual effect of pendimethalin + hand weeding) which were on a par.

4.2.4 Uptake of nutrients by second crop rice

4.2.4.1 Uptake of Nitrogen

The results of the experiments are presented in Tables 48 and 49.

The highest N-uptake was recorded under weed free (T_1) and minimum under weedy check (T_2). Farmers practice (T_3) was superior to weedy check but inferior to all the herbicide treatments. Thiobencarb pre-emergence + hand weeding (T_9) recorded the highest N-uptake by crop during both the years of experimentation.

The residual effect of first crop treatments on second crop rice was significant. Among the residual effect of first crop treatments, maximum N-uptake by crop was observed in Tr_{12} (residual effect of oxyfluorfen pre-emergence + 2,4-D post-emergence treatment) during the first year and in Tr_7 (residual effect of pendimethalin pre-emergence + hand weeding treatment) during the second year.

4.2.4.2 Uptake of phosphorus

Results are presented in Tables 48 and 49.

The uptake of phosphorus was the highest in weed free treatment (T_1). All the herbicide treatments were superior to weedy check and farmer's practice. Uptake of the nutrient was maximum under thiobencarb pre-emergence + hand weeding (T_9) during both the seasons.

Table 48. Effect of weed control treatments on NPK uptake by rice crop (kg ha^{-1}) during the second crop season (1996-97)

Treatments	N	P	K
Treatment effect			
T_1	126.32	54.98	128.24
T_2	35.83	15.21	40.42
T_3	74.17	28.83	69.06
T_4	85.12	32.31	85.12
T_5	86.51	35.69	91.26
T_6	91.33	32.32	90.39
T_7	89.89	36.07	94.08
T_8	102.09	37.51	99.03
T_9	109.03	41.82	104.54
T_{10}	101.56	37.21	101.41
T_{11}	101.26	38.13	98.29
T_{12}	101.21	40.99	103.03
$F_{11,22}$	13.084**	9.336**	7.019**
SE	3.28	1.49	3.98
CD (0.05)	9.62	4.36	11.67
First crop residual effect			
Tr_1	78.81	28.28	84.04
Tr_2	75.74	29.28	86.05
Tr_3	76.46	31.73	84.54
Tr_4	78.83	28.81	78.76
Tr_5	83.13	31.38	81.52
Tr_6	83.46	28.17	80.39
Tr_7	79.35	27.65	82.57
Tr_8	81.62	29.43	81.28
Tr_9	83.17	29.06	83.41
Tr_{10}	78.82	32.84	79.74
Tr_{11}	79.24	30.15	84.39
Tr_{12}	85.25	28.54	87.34
$F_{1,24}$	45.332**	54.690**	23.949**
SE	1.23	0.60	1.34
CD (0.05)	3.59	1.76	3.90

** - Significant at 1 % level

Table 49. Effect of weed control treatments on NPK uptake by the crop ($kg\ ha^{-1}$) during the second crop season (1997-98)

Treatments	N	P	K
Treatment effect			
T_1	142.64	63.77	130.59
T_2	56.38	21.74	53.07
T_3	82.02	31.79	78.71
T_4	93.05	34.83	90.32
T_5	89.34	32.42	86.30
T_6	103.91	39.43	101.62
T_7	106.56	40.89	102.68
T_8	110.17	43.53	110.67
T_9	114.48	46.21	114.94
T_{10}	109.87	42.26	106.23
T_{11}	105.97	42.08	104.23
T_{12}	99.65	40.41	103.49
$F_{11,22}$	6.602**	6.667**	5.687**
SE	3.88	1.92	3.97
CD (0.05)	11.37	5.63	11.64
First crop residual effect			
Tr_1	85.27	31.93	79.23
Tr_2	87.86	32.78	82.74
Tr_3	86.17	33.11	79.70
Tr_4	87.69	32.31	81.55
Tr_5	86.74	32.23	80.87
Tr_6	85.85	31.51	81.13
Tr_7	88.08	35.20	83.75
Tr_8	85.72	33.29	79.92
Tr_9	83.88	31.84	79.89
Tr_{10}	84.07	32.76	79.67
Tr_{11}	81.61	31.66	77.65
Tr_{12}	80.89	31.90	77.00
$F_{1,24}$	42.330**	63.522**	61.241**
SE	1.72	0.66	1.66
CD (0.05)	5.02	1.92	4.83

** - Significant at 1 % level

The residual effect of previous season treatments were significant. During the first year of experimentation, Tr_{10} (residual effect of pendimethalin pre-emergence + 2,4-D post-emergence treatment) and in the second year, Tr_7 (residual effect of pendimethalin pre-emergence + hand weeding treatment) recorded the maximum P - uptake by the crop.

4.2.4.3 Uptake of potassium

The data are presented in Tables 48 and 49.

Among the treatments, maximum potassium uptake was recorded by the weed free treatment (T_1) followed by thiobencarb pre-emergence + hand weeding treatment (T_9). Farmers practice (T_3) was superior to weedy check but inferior to all the herbicide treatments studied in the experiment.

The residual effects of previous season treatments were found to be significant during the first year of experimentation. Tr_{12} (residual effect of oxyfluorfen pre-emergence + 2,4-D post-emergence treatment) recorded the maximum potassium uptake by the crop during the second crop season. In the second year of experimentation Tr_7 (residual effect of pendimethalin pre-emergence + hand weeding) recorded the maximum uptake of potassium by the rice crop.

4.2.5 Uptake of nutrients by weeds

The data on N, P, K uptake by weed at the stage of harvest of the crop are presented in Tables 50 and 51.

Table 50. Effect of weed control treatments on NPK uptake by weeds (kg ha^{-1}) at harvest during second crop season (1996-97)

Treatments	N uptake	P uptake	K uptake
Treatment effect			
T_1	0.00	0.00	0.00
T_2	8.53	4.18	9.26
T_3	4.36	2.62	4.74
T_4	3.53	2.02	3.51
T_5	4.34	2.74	4.32
T_6	4.61	2.35	4.73
T_7	3.66	2.10	3.62
T_8	4.29	1.93	4.33
T_9	3.07	1.66	2.92
T_{10}	3.39	2.15	3.43
T_{11}	3.29	2.29	3.36
T_{12}	3.40	2.18	3.43
$F_{11,22}$	17.437**	4.323**	19.234**
SE	0.23	0.23	0.24
CD (0.05)	0.68	0.66	0.69
First crop residual effect			
Tr_1	4.15	2.48	4.31
Tr_2	4.22	2.49	4.19
Tr_3	4.46	2.55	4.46
Tr_4	4.05	2.70	4.13
Tr_5	4.30	2.26	4.25
Tr_6	4.06	2.56	4.16
Tr_7	4.20	2.39	4.21
Tr_8	4.09	2.20	4.17
Tr_9	4.05	2.75	4.12
Tr_{10}	4.26	2.55	4.25
Tr_{11}	4.12	2.53	4.13
Tr_{12}	4.05	2.83	3.98
$F_{1,24}$	11.166**	11.464**	5.149*
SE	0.06	0.07	0.07
CD (0.05)	0.18	0.21	0.21

* - Significant at 5 % level ** - Significant at 1 % level

Table 51. Effect of weed control treatments on NPK uptake by weeds ($kg\ ha^{-1}$) at harvest during the second crop season (1997-98)

Treatments	N uptake	P uptake	K uptake
Treatment effect			
T_1	0.00	0.00	0.00
T_2	7.30	3.51	8.54
T_3	4.60	2.02	5.09
T_4	3.55	1.39	3.79
T_5	4.16	1.64	4.47
T_6	3.75	1.49	4.02
T_7	3.70	1.42	3.78
T_8	3.91	1.48	4.19
T_9	3.02	1.11	3.00
T_{10}	3.48	1.35	3.63
T_{11}	3.45	1.30	3.43
T_{12}	3.12	1.15	3.12
$F_{11,22}$	57.332**	85.792**	57.002**
SE	0.11	0.04	0.13
CD (0.05)	0.33	0.13	0.38
First crop residual effect			
Tr_1	4.54	1.78	4.47
Tr_2	5.01	1.81	4.64
Tr_3	4.63	1.73	4.53
Tr_4	4.76	1.83	4.54
Tr_5	4.79	1.82	4.59
Tr_6	4.85	1.78	4.70
Tr_7	4.87	1.77	4.67
Tr_8	4.79	1.74	4.74
Tr_9	4.97	1.93	4.82
Tr_{10}	4.29	1.64	4.31
Tr_{11}	4.39	1.67	4.25
Tr_{12}	4.72	1.87	4.63
$F_{1,24}$	156.602**	62.665**	59.917**
SE	0.06	0.03	0.06
CD (0.05)	0.17	0.08	0.17

** - Significant at 1 % level

4.2.5.1 Uptake of nitrogen

The weed control treatments applied to the second crop had significant reduction in the weed uptake of nitrogen. Next to weed free treatment, thiobencarb pre-emergence + hand weeding recorded the lowest uptake of nitrogen by weeds. The weedy check (T_2) recorded the highest N-uptake of 8.53 and 7.30 kg ha^{-1} during the first and second year respectively.

There was significant carry over effect from the treatments applied to the previous crop of rice on the uptake of nitrogen by the weeds in the second crop season. The data revealed highest uptake of N in the carry over effect from farmers practice (Tr_3) and weedy treatment (Tr_2) during the first and second year respectively. The uptake of nitrogen by weeds was significantly reduced by the carry over effect of herbicide treatments viz., pendimethalin pre-emergence (Tr_4), oxyfluorfen pre-emergence + hand weeding (Tr_9), oxyfluorfen pre-emergence + 2,4-D post-emergence (Tr_{12}) during the first year and pendimethalin pre-emergence + 2,4-D post-emergence (Tr_{10}) during the second year of experimentation.

4.2.5.2 Uptake of phosphorus

The weedy check (T_2) recorded the highest P-uptake (4.18 and 3.51 kg ha^{-1}). Among the herbicides, application of thiobencarb pre-emergence + hand weeding (T_9) recorded the lowest P-uptake by weeds which was superior next to weed free treatment (T_1).

The uptake of phosphorus significantly differed in the residual effect of previous treatments. However, the results were not conclusive. During the first year, maximum phosphorus uptake was noted in Tr_{12} (residual effect of oxyfluorfen pre-emergence + 2,4-D post-emergence) and minimum P-uptake was noted in Tr_8 (residual effect of butachlor pre-emergence + hand weeding). During the second year of experimentation, maximum P - uptake was recorded in Tr_9 (residual effect of oxyfluorfen pre-emergence + hand weeding) and minimum in Tr_{10} (residual effect of pendimethalin pre-emergence + 2,4-D post-emergence treatment).

4.2.5.3 Uptake of potassium

The results indicated that the K-uptake by weeds was significantly influenced by the control treatments applied. The weedy check (T_2) recorded the highest K-uptake by weeds during both the seasons (9.26 and 8.54 kg ha^{-1}). The farmer's practice of weeding (T_3) recorded higher K-uptake than the herbicide treatments but superior to weedy check (T_2). Thiobencarb pre-emergence + hand weeding (T_9) recorded the lowest K-uptake by weeds.

Among the residual effect of previous season treatments, the lower K-uptake by weeds was recorded by Tr_{12} (residual effect of oxyfluorfen pre-emergence + 2,4-D post-emergence) and Tr_{11} (residual effect of butachlor pre-emergence + 2,4-D post-emergence) during the first and second year respectively.

4.2.6 Soil nutrient status

The data on available nitrogen, phosphorus and potash content of the soil after the second crop season are presented in Table 52.

4.2.6.1 Available nitrogen content in soil

The weed control treatments had significant effect on available N-content of soil after the experiment. The available N-content of soil was maximum in T_2 (weedy check) and minimum in T_1 (weed free). Farmers' practice (T_3) recorded the next higher N-content which was on a par with T_5 (pretilachlor pre-emergence alone). All the herbicide treatments recorded less available nitrogen than farmers' practice.

The residual effect of treatments applied to the previous crop of rice was significant and the available N-content of the soil was high in Tr_3 (carry over effect of farmers practice of weeding applied to the first crop) which was on a par with Tr_4 (residual effect of pendimethalin pre-emergence) during the first year. In the second crop season of 1997-98, the available nitrogen content was higher in Tr_{12} and Tr_{11} (residual effects of oxyfluorfen pre-emergence + 2,4-D post-emergence and butachlor pre-emergence + 2,4-D post-emergence).

4.2.6.2 Available P_2O_5 content in soil

The data revealed that the weed control treatments applied during the second crop period had led to a significantly lower available phosphorus content compared to the residual effect of treatments applied

Table 52. Available N, P_2O_5 and K_2O content of the soil after second crop season 1996-97 and 1997-98 (kg ha^{-1})

Treatments	1996-97			1997-98		
	Available N	Available P_2O_5	Available K_2O	Available N	Available P_2O_5	Available K_2O
Treatment effect						
T_1	102.53	17.10	39.27	72.97	18.80	29.60
T_2	209.83	42.63	62.43	145.23	48.33	65.30
T_3	167.57	36.67	29.50	126.53	38.30	50.33
T_4	151.90	32.93	28.83	113.13	35.57	38.90
T_5	166.77	32.90	31.00	117.53	39.37	34.67
T_6	163.20	32.10	28.27	103.13	33.70	35.73
T_7	125.63	25.70	31.93	100.57	32.33	27.00
T_8	142.90	30.63	28.33	99.17	30.13	37.43
T_9	134.83	29.73	31.10	99.43	28.20	42.07
T_{10}	118.40	28.83	28.20	106.37	33.17	48.10
T_{11}	135.60	30.97	34.00	101.93	31.47	46.50
T_{12}	134.53	30.47	28.77	107.03	33.60	49.90
$F_{11,22}$	12.257**	8.409**	4.294**	6.966**	7.200**	1.572^{NS}
SE	4.37	1.01	1.88	3.49	1.38	4.98
CD (0.05)	12.82	2.97	5.51	10.22	4.05	NS
First crop residual effect						
Tr_1	157.70	36.23	26.23	114.20	38.60	47.70
Tr_2	165.53	35.53	21.83	118.73	38.87	53.00
Tr_3	172.69	34.43	23.67	120.97	39.37	46.43
Tr_4	168.68	35.73	30.03	118.47	38.67	49.23
Tr_5	154.13	34.03	26.60	120.07	38.27	49.46
Tr_6	160.55	35.60	31.33	120.56	38.37	52.40
Tr_7	162.93	35.23	31.67	117.70	37.03	53.60
Tr_8	159.42	35.73	29.67	118.70	36.67	58.20
Tr_9	156.14	35.77	29.93	121.40	38.07	61.50
Tr_{10}	160.87	34.23	29.40	121.16	36.20	60.80
Tr_{11}	166.17	35.97	29.87	123.67	36.93	56.43
Tr_{12}	155.83	35.47	31.00	123.67	35.07	55.97
$F_{1,24}$	29.081**	45.321**	19.639**	31.785**	35.734**	15.743**
SE	2.04	0.47	0.80	1.53	0.48	2.07
CD (0.05)	5.96	1.36	2.34	4.46	1.41	6.03

NS - Not significant ** - Significant at 1 % level

to the first crop of rice. Among the treatments, unweeded check (T_2) recorded higher available P_2O_5 content in soil after the experiment while T_1 (completely weed free) recorded the lowest content of the nutrient. Among the herbicide treatments, T_7 (pendimethalin pre-emergence + hand weeding) recorded the lowest available P_2O_5 content during the first year while thiobencarb pre-emergence + hand weeding (T_9) recorded the lowest available P_2O_5 content during the second year.

The residual effect of previous treatments showed significant variation in the available P_2O_5 content of the soil after the second crop. During the first year, Tr_1 (residual effect of completely weed free treatment) recorded the maximum available P_2O_5 content which was on a par with other residual effects except Tr_3 (carry over effect of farmers practice), Tr_{10} (residual effect of pendimethalin pre-emergence + 2,4-D post-emergence) and Tr_5 (residual effect of butachlor pre-emergence alone). During the second year, Tr_{12} (residual effect of oxyfluorfen pre-emergence + 2,4-D post-emergence) recorded the lowest P_2O_5 content in soil which was at par with Tr_{10} (residual effect of pendimethalin pre-emergence + 2,4-D post-emergence).

4.2.6.3 Available K_2O content in soil

The weed control treatments were significant only during the first year. Completely weed free treatment (T_1) recorded the lowest available K_2O content while weedy check (T_2) recorded the highest value. The effect of farmers' practice of weed control was on a par with the other herbicide treatments during the season.

The residual effect of previous treatments was significant. During the first year, Tr_7 (residual effect of pendimethalin pre-emergence + hand weeding) recorded the maximum nutrient content which was on a par with all other residual effects of herbicides studied in the experiment except that of Tr_5 (residual effect of butachlor pre-emergence alone). During the second year, Tr_9 (residual effect of oxyfluorfen pre-emergence + hand weeding) recorded the maximum available K_2O content which was on a par with other herbicide residual effects viz., Tr_8 to Tr_{12}.

4.2.7 Population dynamics of soil organisms

The data are presented in Tables 53 and 54.

4.2.7.1 Soil fungal population

There was no significant difference in the soil fungal population due to different treatments after the experiment during both the seasons.

4.2.7.2 Soil bacterial population

The different weed control treatments had no significant effect on soil bacterial population after the second crop of rice during both the years.

4.2.7.3 Soil actinomycetes population

Neither the treatments applied to the second crop nor the residual effect of treatments applied to the first crop had any significant effect on soil actinomycetes population during both the years.

Table 53. Effect of weed control treatments on soil microbial population after second crop rice (1996-97)

Treatment	Soil fungal population $1x10^4 g^{-1}$	Soil bacterial population $1x10^6 g^{-1}$	Soil actinomycetes population $1x10^5 g^{-1}$
Treatment effect			
T_1	11.31 (3.51)	15.32 (4.04)	1.08 (1.45)
T_2	10.26 (3.36)	15.65 (4.08)	1.04 (1.43)
T_3	10.39 (3.37)	15.28 (4.03)	1.16 (1.47)
T_4	12.59 (3.69)	16.88 (4.23)	1.08 (1.44)
T_5	11.95 (3.59)	16.59 (4.19)	1.07 (1.44)
T_6	12.30 (3.65)	15.99 (4.12)	1.09 (1.45)
T_7	10.61 (3.41)	18.33 (4.39)	1.30 (1.52)
T_8	11.31 (3.51)	18.65 (4.43)	1.13 (1.46)
T_9	11.31 (3.51)	16.61 (4.19)	1.14 (1.46)
T_{10}	11.63 (3.55)	16.58 (4.35)	1.09 (1.45)
T_{11}	11.95 (3.59)	17.96 (4.20)	0.77 (1.33)
T_{12}	9.98 (3.31)	16.66 (4.21)	1.16 (1.47)
$F_{11,22}$	0.327^{NS}	0.688^{NS}	0.256^{NS}
SE	0.13	0.09	0.04
CD (0.05)	NS	NS	NS

Contd...

Treatment	Soil fungal population $1x10^4g^{-1}$	Soil bacterial population $1x10^6g^{-1}$	Soil actinomycetes population $1x10^5g^{-1}$
First crop residual effect			
Tr_1	10.58 (3.40)	17.59 (4.31)	1.13 (1.46)
Tr_2	10.66 (3.41)	18.33 (4.39)	1.07 (1.44)
Tr_3	9.89 (3.30)	15.96 (4.12)	1.07 (1.44)
Tr_4	10.66 (3.41)	17.33 (4.28)	1.33 (1.53)
Tr_5	10.63 (3.41)	17.29 (4.28)	1.13 (1.46)
Tr_6	10.96 (3.46)	16.93 (4.23)	1.11 (1.45)
Tr_7	11.98 (3.60)	16.66 (4.20)	1.07 (1.44)
Tr_8	11.66 (3.56)	17.94 (4.35)	1.04 (1.43)
Tr_9	12.33 (3.65)	17.24 (4.27)	1.23 (1.49)
Tr_{10}	11.25 (3.49)	18.20 (4.38)	1.16 (1.47)
Tr_{11}	11.61 (3.55)	15.32 (4.04)	1.13 (1.46)
Tr_{12}	11.58 (3.55)	17.66 (4.32)	1.04 (1.43)
$F_{1,24}$	0.158^{NS}	0.866^{NS}	0.110^{NS}
SE	0.04	0.04	0.02
CD (0.05)	NS	NS	NS

NS - Not significant   Figures in parenthesis are transformed values

Table 54. Effect of weed control treatment on soil microbial population after second crop rice (1997-98)

Treatment	Soil fungal population $1x10^4 g^{-1}$	Soil bacterial population $1x10^6 g^{-1}$	Soil actinomycetes population $1x10^5 g^{-1}$
Treatment effect			
T_1	10.54 (3.39)	16.33 (4.16)	1.29 (1.52)
T_2	10.65 (3.41)	19.67 (4.58)	1.10 (1.45)
T_3	10.96 (3.46)	19.29 (4.50)	1.10 (1.45)
T_4	11.63 (3.55)	18.33 (4.40)	1.39 (1.55)
T_5	11.96 (3.60)	17.96 (4.35)	1.17 (1.47)
T_6	11.90 (3.59)	18.66 (4.43)	1.13 (1.46)
T_7	12.66 (3.69)	18.57 (4.42)	1.44 (1.56)
T_8	13.32 (3.78)	18.94 (4.46)	1.13 (1.46)
T_9	11.49 (3.53)	19.33 (4.51)	1.04 (1.43)
T_{10}	11.27 (3.50)	17.65 (4.32)	1.04 (1.43)
T_{11}	11.65 (3.56)	17.96 (4.35)	1.16 (1.47)
T_{12}	12.59 (3.69)	19.29 (4.51)	1.26 (1.51)
$F_{11,22}$	0.414^{NS}	0.594^{NS}	0.609^{NS}
SE	0.11	0.09	0.04
CD (0.05)	NS	NS	NS

Contd...

Treatment	Soil fungal population $1 \times 10^4 g^{-1}$	Soil bacterial population $1 \times 10^6 g^{-1}$	Soil actinomycetes population $1 \times 10^5 g^{-1}$
First crop residual effect			
Tr_1	12.33 (3.65)	17.73 (4.33)	1.53 (1.59)
Tr_2	10.91 (3.45)	16.97 (4.24)	1.19 (1.48)
Tr_3	12.33 (3.65)	18.29 (4.39)	1.16 (1.47)
Tr_4	12.28 (3.64)	15.96 (4.12)	1.31 (1.52)
Tr_5	11.99 (3.60)	17.31 (4.28)	1.07 (1.44)
Tr_6	10.55 (3.39)	18.26 (4.39)	1.24 (1.49)
Tr_7	11.99 (3.60)	19.29 (4.50)	1.13 (1.46)
Tr_8	11.31 (3.51)	17.99 (4.36)	1.44 (1.56)
Tr_9	11.61 (3.55)	17.64 (4.32)	1.28 (1.51)
Tr_{10}	10.94 (3.46)	19.99 (4.58)	1.41 (1.55)
Tr_{11}	11.19 (3.49)	17.99 (4.36)	1.23 (1.49)
Tr_{12}	11.63 (3.55)	17.57 (4.31)	1.16 (1.47)
$F_{1,24}$	0.059^{NS}	1.358^{NS}	1.002^{NS}
SE	0.05	0.04	0.02
CD (0.05)	NS	NS	NS

NS - Not significant

Figures in parenthesis are transformed values

4.2.8 Economics

4.2.8.1 Benefit cost ratio

The data on BCR are presented in Table 55.

The data revealed significant effect of weed control treatments on this aspect. Among the treatments, weed free (T_1) recorded the maximum BCR during both the seasons. Weedy check (T_2) recorded the lowest BCR. During the first year, T_9 (thiobencarb pre-emergence + hand weeding) recorded the next higher BCR which was equal to T_{11} (pretilachlor pre-emergence+ 2,4-D post-emergence) and on a par with T_{12} (thiobencarb pre-emergence + 2,4-D post emergence), T_{10} (pendimethalin pre-emergence + 2,4-D post-emergence) and T_5 (pretilachlor pre-emergence only).

Among the residual effects, Tr_7 (residual effect of pendimethalin pre-emergence + hand weeding) recorded the highest BCR of 1.07. Other residual effects were on a par except Tr_2 and Tr_4 (carry over effect from weedy check and pendimethalin pre-emergence alone) which were inferior. Residual effect of farmer's practice applied to first crop (Tr_3) and the carry-over effect of pendimethalin pre-emergence + 2,4-D post-emergence (Tr_{10}) recorded the maximum BCR during the second year. The residual effect of other herbicide treatments were on a par.

4.2.8.2 Net profit

The data on net profit recorded for weed control treatments of second crop are presented in Table 56.

Table 55. Economics of weed control treatments during the second crop rice (Benefit cost ratio)

Treatment	1996-97	1997-98
Treatment effect		
T_1	1.48	1.59
T_2	0.75	0.74
T_3	0.99	0.93
T_4	1.09	1.04
T_5	1.15	1.12
T_6	1.09	1.12
T_7	1.03	1.13
T_8	1.05	1.18
T_9	1.29	1.34
T_{10}	1.19	1.14
T_{11}	1.29	1.29
T_{12}	1.21	1.22
$F_{11,22}$	2.672*	11.544**
SE	0.06	0.03
CD (0.05)	0.17	0.09
First crop residual effect		
Tr_1	0.97	0.96
Tr_2	0.91	0.89
Tr_3	0.98	1.01
Tr_4	0.92	0.94
Tr_5	0.97	0.96
Tr_6	0.98	0.93
Tr_7	1.07	1.00
Tr_8	0.99	0.96
Tr_9	0.99	0.95
Tr_{10}	0.99	1.01
Tr_{11}	0.97	0.97
Tr_{12}	0.97	0.96
$F_{1,24}$	32.868**	94.684**
SE	0.02	0.01
CD (0.05)	0.06	0.04

* - Significant at 5 % level ** - Significant at 1 % level

Table 56. Economics of weed control treatments during the second crop rice (Net profit Rs. ha^{-1})

Treatments	1996-97	1997-98
Treatment effect		
T_1	7832.95	9559.45
T_2	-771.23	-3681.30
T_3	-16.85	-1117.67
T_4	1442.49	674.95
T_5	2258.71	1737.88
T_6	1420.23	1776.63
T_7	552.03	2251.82
T_8	929.77	2903.45
T_9	4998.09	5738.24
T_{10}	3146.00	2268.81
T_{11}	4373.42	4263.75
T_{12}	3370.48	3562.36
$F_{11,22}$	1.760^{NS}	11.812^{**}
SE	948.39	501.03
CD (0.05)	NS	1469.56
First crop residual effect		
Tr_1	-514.63	-596.85
Tr_2	-1336.97	-1556.27
Tr_3	-350.13	225.53
Tr_4	-1145.09	-871.64
Tr_5	-487.21	-679.08
Tr_6	-295.33	-1035.45
Tr_7	1184.94	33.66
Tr_8	-76.01	-624.26
Tr_9	-76.03	-679.09
Tr_{10}	-158.25	252.93
Tr_{11}	-487.18	-459.77
Tr_{12}	-432.38	-596.85
$F_{1,24}$	32.944^{**}	100.724^{**}
SE	346.08	214.46
CD (0.05)	1010.19	625.99

NS - Not significant ** - Significant at 1 % level

The data revealed significant difference between the treatments during the second year only.

During the second year, all the herbicide treatments were superior to weedy check and farmers' practice (T_3). Thiobencarb pre-emergence + hand weeding (T_9) recorded the highest net profit and was superior to other herbicide treatments.

The data on residual effect of first crop treatments indicated that Tr_7 (residual effect of pendimethalin pre-emergence + hand weeding) recorded the maximum net profit during the first year. Among the residual effect of first crop treatments, Tr_{10}, Tr_3 and Tr_7 (residual effect of pendimethalin pre-emergence + 2,4-D post-emergence, farmers practice and pendimethalin pre-emergence + hand weeding) recorded higher net profit and were on a par during the second year.

4.3 Third crop sesamum

4.3.1 Observation on weeds

4.3.1.1 Important weed species of the season

The different weed species found in the experimental field during the third crop season were collected, identified and classified into grasses, sedges and broad leaved weeds. The important species observed are presented in Table 57.

Table 57. Major weed flora in the experimental field during third crop season

Group	Name of weed	Family
Grasses	*Dactyloctenium aegyptium*	Gramineae
	Elusine indica	Gramineae
	Digitaria sp.	Gramineae
	Cynadon dactylon	Gramineae
	Brachiaria ramosa	Gramineae
Broad leaved weeds	*Cleome viscosa*	Capparaceae
	Amaranthus viridis	Amaranthaceae
	Leucas aspera	Labiatae
	Sida acuta	Malvaceae
	Emilia sonchifolia	Compositae
	Phyllanthus niruri	Euphorbiaceae
	Biophytum sensitivum	Oxalidaceae
	Gomphrenia decumbens	Amaranthaceae
	Spermacoce latifolia	Rubiaceae
Sedges	*Cyperus rotundus*	Cyperaceae

4.3.1.2 Monocot weed population m^{-2}

The data on monocot weed count m^{-2} at 30 and 60 DAS and at harvest are presented in Table 58.

4.3.1.2a. 30 days after sowing

There was significant difference on this aspect due to the residual effect of first and second crop treatments during both the years. The monocot weed population was significantly higher in the plots which received the no weeding treatment during the previous two seasons (FTr_2). Continuous application of pendimethalin pre-emergence to the first and second crop of rice (FTr_4) and oxyfluorfen pre-emergence to the first crop followed by thiobencarb pre-emergence to the second crop (FTr_6) had their carry over effect on the third crop equal to that of FTr_1 (weed free treatment applied to the first and second crop of rice) during the first and second year respectively. The residual effect of other herbicide treatments were at par during both the years.

During third crop season, among the carryover effect of first crop treatments, the residual effect of pendimethalin pre-emergence + hand weeding (STr_7) and oxyfluorfen pre-emergence + hand weeding (STr_9) recorded the lowest monocot weed count m^{-2} during the second year where as it was STr_3 (residual effect of farmers practice) which recorded the lowest monocot weed count m^{-2} in the first year.

4.3.1.2b. 60 Days after sowing

The data revealed that the monocot weed count during the first

Table 58. Residual effect of weed control treatments on moncot weed count m^{-2} during third crop season

Treatments	1997			1998		
	30 DAS	60 DAS	At harvest	30 DAS	60 DAS	At harvest
Residual effect from first and second crops						
F Tr_1	10.49	9.07	8.02	10.97	10.90	6.82
F Tr_2	11.90	11.51	9.95	12.58	12.69	8.50
F Tr_3	10.61	9.51	8.73	12.12	10.54	7.32
F Tr_4	10.81	9.54	8.34	11.90	11.70	6.94
F Tr_5	11.44	10.08	8.18	11.64	11.81	7.41
F Tr_6	11.21	9.61	8.38	11.47	11.84	7.13
F Tr_7	11.32	9.70	8.72	11.76	11.93	7.07
F Tr_8	11.53	9.89	8.73	11.73	11.87	7.23
F Tr_9	11.41	9.50	8.42	12.04	11.84	7.00
F Tr_{10}	11.49	9.53	8.49	12.14	11.72	7.59
F Tr_{11}	11.69	9.68	8.46	11.77	11.93	7.51
F Tr_{12}	11.50	9.54	8.88	11.64	12.01	7.24
$F_{11,22}$	63.599**	36.542**	30.639**	62.749**	98.484**	23.149**
SE	0.19	0.21	0.20	0.19	0.16	0.21
CD (0.05)	0.55	0.62	0.59	0.55	0.47	0.62
Residual effect from first crop						
S Tr_1	11.59	10.01	8.74	12.42	11.64	6.97
S Tr_2	11.40	9.94	8.58	11.79	11.70	7.40
S Tr_3	11.27	10.10	8.69	11.81	11.78	7.23
S Tr_4	11.62	9.84	8.51	11.67	11.56	7.54
S Tr_5	11.61	9.57	8.68	11.67	11.64	7.06
S Tr_6	11.41	9.70	8.66	11.84	11.78	7.59
S Tr_7	11.61	9.98	8.65	11.61	11.56	7.98
S Tr_8	11.43	9.47	8.86	11.90	11.76	7.37
S Tr_9	11.29	9.73	8.38	11.61	11.84	7.41
S Tr_{10}	11.50	9.70	8.65	11.92	11.82	7.45
S Tr_{11}	11.46	9.73	8.88	11.86	11.70	7.85
S Tr_{12}	11.69	9.78	8.81	11.84	11.62	7.75
$F_{1,24}$	123.394**	20.169**	22.570**	49.662**	83.737**	24.910**
SE	0.06	0.11	0.10	0.08	0.06	0.09
CD(0.05)	0.19	0.33	0.29	0.25	0.18	0.26

** Significant at 1% level

year of experimentation was the lowest in the plots which were maintained weed free during the first and second crop season (FTr_1). The residual effect of other herbicide treatments were at par and the carry over effect of weedy treatment recorded the maximum number of monocot weeds. In the second year of experimentation also, similar results were observed. However FTr_3 (carryover effect of farmers practice of weeding applied to the previous rice crops) was on a par with FTr_1.

The carryover effect of first crop treatments significantly influenced the number of monocot weeds. Maximum number of monocot weeds were noted in STr_3 (carry over effect of farmers practice applied to the first crop of rice) and STr_9 (carryover effect of oxyfluorfen pre-emergence + hand weeding applied to the first crop) during the first and second year respectively.

4.3.1.2c. At harvest

The monocot weed count at the stage of harvest of sesamum was the lowest in FTr_1 (residual effect of weed free treatment applied to the previous crops of rice) during both the years. During the first year, residual effect of herbicide treatments were on a par. During the second year, except FTr_4 (residual effect of pendimethalin pre-emergence applied to the first and second crop of rice) all other herbicide residual effect were at par. FTr_4 recorded lower monocot weed count.

The residual effect of first crop treatments on monocot weed count in sesamum crop was significant at this stage also. During the first year, all the herbicide residual effects except STr_4 (pendimethalin pre-emergence residual effect) and STr_9 (oxyfluorfen pre-emergence + hand weeding residual effect) were at par. During the second year, the lowest monocot weed count was observed in STr_1 (carryover effect of weed free treatment applied to the first crop of rice). Among the herbicide residual effect the lowest monocot weed population was observed in STr_5 (residual effect of butachlor pre-emergence alone) which was on a par with STr_3 (farmers practice of weeding applied to the first crop). Carryover effect of STr_5 was on a par with STr_1 (carryover effect of the weed free treatment).

4.3.1.3. Dicot weed population

The data are presented in Table 59.

4.3.1.3a. 30 days after sowing

The dicot weed count was the lowest in FTr_1 (residual effect of weed free treatment applied to the first and second crop of rice) during the first year which was at par with other residual effects. During the second year FTr_4 (residual effect of pendimethalin pre-emergence applied to the first and second crop of rice) and FTr_3 (carryover effect of farmers practice of weeding applied to the previous crops of rice) recorded significantly lower dicot weed count m^{-2} where as all other residual effects were at par.

Among the residual effect of first crop treatments on the third crop of sesamum, STr_4 (residual effect of pendimethalin pre-emergence)

Table 59. Residual effects of previous weed control treatments on dicot weed count m^{-2} during the third crop season

Treatments	1997			1998		
	30 DAS	60 DAS	At harvest	30 DAS	60 DAS	At harvest
Residual effect from first and second crop						
F Tr_1	4.93	4.78	5.63	4.16	4.10	4.62
F Tr_2	5.51	6.45	7.18	4.7	5.13	5.94
F Tr_3	5.15	4.92	6.24	3.69	4.28	4.96
F Tr_4	5.26	4.83	5.95	3.65	4.18	4.85
F Tr_5	5.03	5.11	5.79	4.25	4.19	4.56
F Tr_6	5.23	4.71	6.03	4.60	4.58	4.78
F Tr_7	5.48	4.92	6.20	4.71	4.79	5.17
F Tr_8	5.28	5.31	5.91	4.62	4.33	5.10
F Tr_9	5.31	4.82	5.55	4.72	4.11	4.77
F Tr_{10}	5.42	5.13	5.50	4.66	4.18	4.99
F Tr_{11}	5.48	5.22	6.13	4.99	4.47	4.58
F Tr_{12}	4.97	4.97	6.11	4.72	4.04	4.87
$F_{11,22}$	3.322^{**}	7.552^{**}	12.581^{**}	2.612^{**}	11.180^{**}	6.474^{**}
SE	0.35	0.23	0.21	0.36	0.17	0.20
CD (0.05)	1.03	0.69	0.62	1.05	0.49	0.58
Residual effect from first crop						
S Tr_1	5.43	5.19	6.01	4.65	4.11	5.49
S Tr_2	5.41	5.08	5.85	4.55	4.03	4.50
S Tr_3	5.67	5.09	5.96	5.50	4.03	4.32
S Tr_4	5.91	5.06	5.79	4.57	3.91	4.79
S Tr_5	5.30	5.49	6.13	4.73	4.04	5.29
S Tr_6	5.67	5.22	6.06	4.41	4.03	4.98
S Tr_7	5.58	4.93	5.62	4.48	4.58	4.93
S Tr_8	5.44	5.44	6.08	4.97	4.33	4.92
S Tr_9	5.43	5.22	6.05	4.85	4.42	4.69
S Tr_{10}	5.49	5.51	5.77	5.14	4.50	4.58
S Tr_{11}	5.41	5.05	5.56	4.82	4.79	4.82
S Tr_{12}	5.43	5.25	6.15	5.11	4.79	5.18
$F_{1,24}$	26.905^{**}	8.432^{**}	4.242^{NS}	15.213^{**}	2.186^{NS}	4.351^{*}
SE	0.08	0.10	0.21	0.12	0.10	0.08
CD(0.05)	0.23	0.37	NS	0.35	NS	0.24

NS - Not significant ** Significant at 1% level * Significant at 5% level

STr_3 (carryover effect of farmers practice) STr_6 (residual effect of pre-emergence application of oxyfluorfen) and STr_7 (residual effect of pendimethalin pre-emergence + hand weeding) recorded higher number of dicot weeds during the first year. All other residual effects were at par. During the second year of experimentation, STr_3 (carryover effect of farmers practice of weeding) recorded the highest number of dicot weeds whereas the residual effect of oxyfluorfen pre-emergence (STr_6) recorded the lowest dicot weed count.

4.3.1.3b. 60 Days after sowing

At this stage, the residual effects of previous season treatments on dicot weed population were at par except that of FTr_2 (carryover effect from previous weedy treatments) during the first year and that of FTr_6 (residual effect of oxyfluorfen pre-emergence applied to the first crop followed by thiobencarb pre-emergence applied to the second crop of rice) and FTr_7 (residual effect of pendimethalin pre-emergence + hand weeding applied to the first and second crop of rice) which recorded higher weed count.

The residual effects of treatments applied to the first crop was significant only during the first year of experimentation. Among the residual effects, STr_{10} (residual effect of pendimethalin pre-emergence + 2,4-D post-emergence), STr_5 (residual effect of butachlor pre-emergence) and STr_8 (residual effect of butachlor pre-emergence + hand weeding) recorded higher dicot weed population. All other residual effects were at par.

4.3.1.3c. At harvest

The dicot weed count was the maximum in FTr_2 (carryover effect of weedy treatment applied to the first and second crop of rice). FTr_7 (residual effect of pendimethalin pre-emergence + hand weeding applied to the first and second crops of rice) recorded the highest dicot weed count among the residual effect of other herbicides studied.

The residual effect of weed control treatments applied to the first crop of rice was significant on the dicot weed population in sesamum crop only during the second year. Among the residual effect STr_1 (residual effect of weed free treatment applied to the first crop of rice) recorded higher weed count and the lowest by STr_3 (farmers practice residual effect).

4.3.1.4. Total weed population m^{-2}

The data are presented in Table 60.

4.3.1.4a. 30 days after sowing

The residual effects of previous season treatments on total weed count were significant at 30 DAS during both the years and FTr_2 carry over effect of weedy treatment recorded the highest number of weeds. FTr_1 (carry over effect of weed free treatment applied to the rice crops) recorded the lowest number of total weeds.

Table 60. Residual effects of previous weed control treatments on total weed count m^{-2} during the third crop season

Treatments	1997			1998		
	30 DAS	60 DAS	At harvest	30 DAS	60 DAS	At harvest
Residual effect from first and second crop						
F Tr_1	11.54	10.20	9.75	11.71	11.59	8.18
F Tr_2	13.07	13.07	12.23	13.25	13.65	10.33
F Tr_3	11.77	10.67	10.69	12.76	11.34	8.79
F Tr_4	11.98	10.66	10.21	12.44	12.39	8.42
F Tr_5	12.47	11.28	9.97	12.35	12.49	8.66
F Tr_6	12.36	10.65	10.30	12.33	12.66	8.53
F Tr_7	12.55	10.84	10.68	12.63	12.82	8.69
F Tr_8	12.66	11.20	10.49	12.58	12.61	8.81
F Tr_9	12.56	10.65	10.04	12.89	12.50	8.42
F Tr_{10}	12.68	10.81	10.08	12.99	12.42	9.03
F Tr_{11}	12.89	10.97	10.41	12.75	12.71	8.75
F Tr_{12}	12.50	10.72	10.75	12.53	12.66	8.72
$F_{11,22}$	56.906**	51.867**	57.039**	67.815**	145.249**	27.129**
SE	0.22	0.20	0.18	0.20	0.14	0.22
CD (0.05)	0.65	0.60	0.54	0.58	0.42	0.66
Residual effect from first crop						
S Tr_1	12.76	11.23	10.58	13.22	12.31	8.82
S Tr_2	12.59	11.14	10.34	12.63	12.34	8.61
S Tr_3	12.58	11.29	10.50	12.99	12.41	8.37
S Tr_4	12.99	11.02	10.31	12.53	12.18	8.88
S Tr_5	12.75	10.99	10.59	12.58	12.28	8.77
S Tr_6	12.73	10.99	10.52	12.65	12.42	9.03
S Tr_7	12.86	11.10	10.28	12.41	12.39	9.33
S Tr_8	12.63	10.87	10.71	12.91	12.50	8.81
S Tr_9	12.49	11.01	10.30	12.55	12.61	8.71
S Tr_{10}	12.71	11.14	10.38	12.96	12.61	8.69
S Tr_{11}	12.66	10.93	10.43	12.79	12.60	9.18
S Tr_{12}	12.84	11.07	10.72	12.87	12.53	9.28
$F_{1,24}$	153.226**	30.360**	22.484**	102.686**	99.009**	28.364**
SE	0.07	0.11	0.11	0.07	0.06	0.09
CD(0.05)	0.20	0.32	0.32	0.21	0.17	0.27

** Significant at 1% level

Among the carry over effect of previous season herbicide treatments, FTr_4 (residual effects of pendimethalin pre-emergence applied to the first and second crop of rice) and FTr_6 (residual effects of oxyfluorfen pre-emergence applied to the first crop of rice followed by thiobencarb pre-emergence applied to the second crop of rice) recorded the lowest weed count during the first and second year respectively.

The residual effects of first crop treatments were also significant. STr_9 (residual effect of oxyfluorfen pre-emergence + hand weeding applied to the first crop of rice) and STr_7 (residual effect of pendimethalin pre-emergence + hand weeding applied to the first crop of rice) recorded the lowest total weed count during the first and second year respectively.

4.3.1.4b. 60 days after sowing

At this stage also, the total weed count was the highest in FTr_2 (carry over effect of weedy treatments applied to the previous first and second crop of rice). The lowest weed count was recorded under FTr_1 (carry over effect of weed free treatment applied to the previous crop of rice) and FTr_3 (carry over effect of farmers practice of weeding applied to the previous rice crops during first and second seasons) recorded the lowest weed population m^{-2} during the first and second year of experimentation respectively. Among the residual effects of herbicide treatments, FTr_5 (residual effect of butachlor pre-emergence applied to the first crop followed by pretilachlor pre-emergence to the second crop) recorded the highest weed count during the first year and the lowest by FTr_9 (residual effect of oxyfluorfen pre-emergence + hand weeding applied to the first crop followed by thiobencarb pre-emergence + hand weeding applied to the second crop) and FTr_6 (residual effect of oxyfluorfen pre-emergence applied to the first crop of rice followed by thiobencarb pre-emergence applied to the second crop of rice). During the third crop season of 1997-98, FTr_4 (residual effect of pendimethalin pre-emergence applied to the first and second crop of rice) recorded the lowest weed count which was on a par with other residual effects except FTr_7 (residual effect of pendimethalin pre-emergence + hand weeding applied to the first and second crop of rice) which recorded higher weed count and was inferior.

Among the residual effects of weed control treatments applied to the first crop of rice, STr_8 (residual effect of butachlor pre-emergence + hand weeding) recorded the lowest weed count which was on a par with others except STr_1 and STr_3 (carryover effect of weed free treatment and farmers practice of weeding) which recorded higher weed count and were inferior. During the second year, STr_4 (residual effect of pendimethalin pre-emergence) recorded the lowest weed count which was on a par with other residual effects such as STr_5, STr_1 and STr_2.

4.3.1.4c. At harvest

The total weed count was the highest in FTr_2 (carry over effect of weedy treatment applied to the first and second crop of rice) and the lowest in FTr_1 (carry over effect of weedfree treatment applied to the first and second crop of rice) during both the years. Among the herbicide residual effects, during the first year FTr_5 (residual effect of butachlor pre-emergence applied to the first crop followed by pretilachlor pre-emergence applied to the second crop) recorded the lowest total weed count and during the second year, FTr_4 (residual effect of pendimethalin pre-emergence applied to the first and second crop of rice) recorded the lowest total weed count.

The residual effect of treatments applied to the first crop of rice was significant and STr_7 (residual effect of pendimethalin pre-emergence + hand weeding treatment applied to the first crop of rice) and STr_3 (carryover effect of farmers practice of weeding) recorded the lowest number of weeds during the first and second year of experimentation respectively.

4.3.1.5. Dry weight of weeds

The data on dry weight of weeds recorded at 30 and 60 DAS and at harvest are presented in Table 61.

4.3.1.5a. 30 days after sowing

The results indicated that the total weed dry weight was higher in FTr_2 (carryover effect of weedy treatment applied to the previous crops of rice). Among the residual effects of herbicide treatments, FTr_5 (residual effect of butachlor pre-emergence applied to the first crop of rice followed by pretilachlor pre-emergence applied to the second crop of rice) recorded the lowest weed dry weight which was on a par with other residual effects during the first year. FTr_{11} (residual effect of

Table 61. Residual effect of previous weed control treatments on weed dry weight (g m^{-2}) during third crop season

Treatments	1997			1998		
	30 DAS	60 DAS	At harvest	30 DAS	60 DAS	At harvest
Residual effect from first and second crop						
F Tr_1	39.90	71.98	77.10	39.00	70.00	76.80
F Tr_2	65.74	92.63	87.03	61.30	78.43	92.09
F Tr_3	39.63	74.16	84.20	37.81	78.15	80.73
F Tr_4	43.41	75.87	86.73	44.46	75.20	82.51
F Tr_5	37.91	76.50	88.20	41.53	73.27	84.27
F Tr_6	39.43	78.66	82.83	40.66	76.47	84.27
F Tr_7	43.30	72.71	82.17	40.33	76.00	81.80
F Tr_8	42.10	73.75	84.19	42.90	76.63	83.50
F Tr_9	43.73	79.00	80.23	43.13	76.20	85.00
F Tr_{10}	38.33	79.10	82.30	36.77	77.70	81.52
F Tr_{11}	42.87	80.27	82.87	35.00	75.80	83.09
F Tr_{12}	42.50	81.22	83.33	42.88	76.13	83.47
$F_{11,22}$	8.44^{**}	31.33^{**}	38.217^{**}	12.211^{**}	16.529^{**}	60.529^{**}
SE	2.43	2.09	1.98	2.04	2.75	1.51
CD (0.05)	7.11	6.14	5.81	5.99	8.06	4.44
Residual effect from first crop						
S Tr_1	43.73	80.53	82.07	41.70	75.83	84.90
S Tr_2	41.97	79.55	84.45	43.01	76.47	81.47
S Tr_3	40.27	82.90	80.40	39.98	75.07	81.92
S Tr_4	41.86	81.80	81.93	43.83	75.57	81.15
S Tr_5	43.50	80.52	81.71	37.93	77.23	82.52
S Tr_6	43.73	83.82	81.23	39.83	74.07	81.23
S Tr_7	40.93	80.53	81.56	38.21	77.43	82.33
S Tr_8	42.17	84.10	83.04	41.73	80.30	80.69
S Tr_9	40.70	82.16	82.09	43.40	75.63	83.19
S Tr_{10}	40.85	83.07	81.05	39.63	77.93	82.49
S Tr_{11}	43.40	80.30	84.26	42.15	77.70	82.81
S Tr_{12}	40.79	78.93	83.38	41.40	74.87	83.03
$F_{1,24}$	2.768^{NS}	33.954^{**}	21.992^{**}	3.857^{NS}	26.438^{**}	19.695^{**}
SE	0.88	1.16	0.78	0.78	0.89	0.87
CD(0.05)	NS	3.38	2.28	NS	2.61	2.54

** Significant at 1% level NS Not significant

butachlor pre-emergence + 2,4-D post-emergence applied to the first crop followed by pretilachlor pre-emergence + 2,4-D post-emergence) applied to the second crop of rice) recorded the lowest weed dry weight during the second year.

The residual effects of treatments applied to the first crop of rice was not significant on weed dry weight during third crop season.

4.3.1.5b. 60 days after sowing

The results revealed that the weed dry weights were high in FTr_2 (residual effect of weedy treatments applied to the first and second crop of rice) and the lowest in FTr_1 (carryover effect of weed free treatment applied to the first and second crop of rice). Among other herbicide residual effects, FTr_7 (residual effect of pendimethalin pre-emergence + hand weeding applied to the first and second crop of rice) recorded the lowest weed dry weight during the first year. In the second year, the residual effects of other herbicide treatments were on a par except FTr_2 and FTr_3 (residual effect of weedy treatment and farmers practice of weeding applied to the first and second crop of rice) which were inferior.

The data indicated significant residual effect from the first crop of rice in the cropping system. STr_{12} (Oxyfluorfen pre-emergence + 2,4-D post-emergence and STr_6 (residual effect of oxyfluorfen pre-emergence) recorded the lowest weed dry weight during the first and second year of experimentation respectively.

4.3.1.5c. At harvest

At this stage also, FTr_1 (carryover effect of weed free treatment applied to the first and second crop of rice) recorded the lowest weed dry weight. Among the herbicide treatments FTr_9 (residual effect of oxyfluorfen pre-emergence + hand weeding applied to the first crop and thiobencarb pre-emergence + hand weeding applied to the second crop of rice) recorded the lowest weed dry weight during the first year. In the third crop season of 1997-98, FTr_3 (residual effect of farmers practice) had recorded the lowest weed dry weight.

The treatments applied to the first crop of rice was significant. STr_3 (residual effect of farmers' practice) and STr_8 (residual effect of butachlor pre-emergence + hand weeding applied to the rice crop during the first crop season) recorded the lowest weed dry weight during the first and second year of experimentation respectively.

4.3.2 Observations on growth characters of sesamum

4.3.2.1 Plant height

The data are presented in Table 62.

The results revealed no significant difference in the height of plants due to residual effects of treatments applied to the previous first and second crops.

4.3.2.2. Number of branches

The data are presented in Table 63.

Table 62. Residual effect of weed control treatments on height of sesamum during third crop season (cm)

Treatments	1997			1998		
	30 DAS	60 DAS	At harvest	30 DAS	60 DAS	At harvest
Residual effect from first and second crop						
F Tr_1	38.93	83.33	96.47	28.67	66.70	92.53
F Tr_2	32.53	81.53	93.77	24.67	65.30	90.16
F Tr_3	36.10	82.47	96.50	24.97	64.00	89.40
F Tr_4	33.57	81.80	94.43	24.37	65.23	89.36
F Tr_5	33.90	84.67	95.00	23.33	64.37	89.83
F Tr_6	33.03	81.83	95.83	25.63	65.47	93.33
F Tr_7	34.83	82.16	94.67	25.77	64.83	88.66
F Tr_8	35.90	86.17	96.83	24.57	62.50	93.30
F Tr_9	33.57	83.00	95.30	26.10	63.77	94.13
F Tr_{10}	35.73	83.27	94.77	25.80	62.60	93.33
F Tr_{11}	33.80	81.17	95.67	24.13	63.40	91.27
F Tr_{12}	35.63	84.10	96.03	25.53	62.43	91.06
$F_{11,22}$	1.053^{NS}	0.430^{NS}	0.457^{NS}	0.514^{NS}	0.345^{NS}	0.676^{NS}
SE	0.98	1.21	1.31	1.06	1.11	1.53
CD (0.05)	NS	NS	NS	NS	NS	NS
Residual effect from first crop						
S Tr_1	33.73	81.73	95.10	24.10	63.10	94.40
S Tr_2	34.70	81.80	95.23	24.60	65.27	90.86
S Tr_3	33.63	85.07	95.43	24.03	64.17	90.56
S Tr_4	33.80	84.23	93.80	25.93	63.23	93.83
S Tr_5	34.23	82.53	94.60	24.07	63.53	94.36
S Tr_6	34.30	83.63	93.10	25.33	64.20	91.93
S Tr_7	34.13	85.26	93.90	25.90	65.47	89.90
S Tr_8	33.47	82.86	95.10	24.53	66.67	92.93
S Tr_9	32.33	83.20	90.63	23.67	63.00	90.53
S Tr_{10}	33.90	82.37	93.60	25.03	65.00	92.43
S Tr_{11}	33.63	82.77	93.30	23.97	65.80	92.03
S Tr_{12}	36.40	81.96	94.33	25.30	64.27	92.00
$F_{1,24}$	1.690^{NS}	0.045^{NS}	1.306^{NS}	1.149^{NS}	0.116^{NS}	0.906^{NS}
SE	0.42	0.55	0.89	0.39	0.57	0.54
CD(0.05)	NS	NS	NS	NS	NS	NS

NS Not significant

Table 63. Residual effect of weed control treatments on number of branches of sesamum during third crop season

Treatments	1997 30 DAS	1997 60 DAS	1997 At harvest	1998 30 DAS	1998 60 DAS	1998 At harvest
Residual effect from first and second crop						
F Tr_1	3.30	5.77	8.37	2.40	5.00	7.70
F Tr_2	3.23	5.53	8.16	2.37	4.90	7.90
F Tr_3	3.23	5.13	8.27	2.50	5.10	8.07
F Tr_4	3.17	5.73	8.76	2.20	5.23	7.80
F Tr_5	3.37	5.76	8.46	2.57	5.10	8.03
F Tr_6	3.13	5.56	8.43	2.43	5.00	7.73
F Tr_7	3.40	5.53	8.33	2.50	5.30	7.73
F Tr_8	3.17	5.37	8.10	2.47	5.00	7.63
F Tr_9	3.40	5.37	8.10	2.47	5.00	7.63
F Tr_{10}	3.43	5.47	8.33	2.40	5.33	7.80
F Tr_{11}	3.47	5.46	8.20	2.47	5.30	7.77
F Tr_{12}	3.40	5.43	8.43	2.23	5.17	7.23
$F_{11,22}$	0.439^{NS}	0.565^{NS}	0.520^{NS}	0.270^{NS}	0.758^{NS}	0.405^{NS}
SE	0.13	0.12	0.13	0.18	0.14	0.15
CD (0.05)	NS	NS	NS	NS	NS	NS
Residual effect from first crop						
S Tr_1	3.47	5.40	8.40	2.70	5.27	7.30
S Tr_2	3.40	5.47	8.56	2.77	5.33	7.20
S Tr_3	3.37	5.47	8.20	2.70	5.03	7.10
S Tr_4	3.07	5.47	8.47	2.70	5.37	7.40
S Tr_5	3.23	5.37	8.37	2.53	5.37	7.53
S Tr_6	3.30	5.30	8.30	2.40	5.30	7.26
S Tr_7	3.17	5.77	8.37	2.60	5.47	7.63
S Tr_8	3.47	5.56	8.37	2.67	4.83	7.30
S Tr_9	3.03	5.53	8.60	2.50	5.10	7.27
S Tr_{10}	3.43	5.43	8.33	2.60	5.40	7.40
S Tr_{11}	3.33	5.47	8.33	2.63	4.93	7.33
S Tr_{12}	3.23	5.57	8.43	2.33	5.00	7.73
$F_{1,24}$	0.032^{NS}	0.076^{NS}	0.221^{NS}	2.863^{NS}	0.572^{NS}	14.872^{**}
SE	0.07	0.07	0.06	0.07	0.05	0.07
CD(0.05)	NS	NS	NS	NS	NS	0.21

** Significant at 1% level NS Not significant

At 30 and 60 DAS, the residual effect of treatments were not significant. However at the stage of harvest of the crop, the residual effect of treatments applied to the first crop of rice significantly influenced the number of branches of sesamum during the second year of experimentation. Maximum number of branches was recorded in STr_{12} (residual effect of oxyfluorfen pre-emergence + 2,4-D post-emergence applied to the first crop of rice).

4.3.2.3 Leaf area index

The results are presented in Table 64.

The data indicated no significant response on LAI of the crop due to the residual effect of treatments applied to the previous rice crops.

4.3.2.4. Days to 50 per cent flowering

The data are presented in Table 65.

The residual effect of previous first and second crop treatments had no significant influence on this character during both the years. However the residual effect of treatments applied to the first crop alone had significantly influenced this character during the first year and the sesamum in the plots having the residual effect of pendimethalin pre-emergence + hand weeding from the first crop of rice (STr_7) flowered earlier than the other plots.

Table 64. Residual effects of weed control treatments on LAI of sesamum during third crop season

	1997			1998		
Treatments	30 DAS	60 DAS	At harvest	30 DAS	60 DAS	At harvest
Residual effect from first and second crop						
F Tr_1	0.39	0.95	1.60	0.32	0.91	1.61
F Tr_2	0.39	0.96	1.60	0.37	0.89	1.61
F Tr_3	0.40	0.97	1.60	0.34	0.90	1.63
F Tr_4	0.39	0.96	1.61	0.33	0.91	1.65
F Tr_5	0.39	0.95	1.61	0.34	0.91	1.61
F Tr_6	0.40	0.97	1.61	0.36	0.90	1.63
F Tr_7	0.40	0.96	1.62	0.34	0.91	1.63
F Tr_8	0.40	0.97	1.58	0.34	0.91	1.62
F Tr_9	0.39	0.98	1.59	0.35	0.90	1.62
F Tr_{10}	0.39	0.97	1.61	0.33	0.91	1.63
F Tr_{11}	0.39	0.96	1.59	0.33	0.90	1.61
F Tr_{12}	0.38	0.96	1.61	0.34	0.91	1.60
$F_{11,22}$	0.529^{NS}	0.376^{NS}	0.113^{NS}	0.444^{NS}	0.381^{NS}	0.931^{NS}
SE	0.006	0.009	0.016	0.010	0.009	0.011
CD (0.05)	NS	NS	NS	NS	NS	NS
Residual effect from first crop						
S Tr_1	0.38	0.96	1.60	0.33	0.91	1.61
S Tr_2	0.40	0.97	1.61	0.34	0.90	1.63
S Tr_3	0.39	0.97	1.60	0.36	0.91	1.61
S Tr_4	0.40	0.96	1.61	0.33	0.91	1.61
S Tr_5	0.40	0.98	1.61	0.34	0.90	1.60
S Tr_6	0.39	0.98	1.61	0.32	0.89	1.62
S Tr_7	0.39	0.97	1.61	0.35	0.91	1.63
S Tr_8	0.40	0.98	1.64	0.34	0.91	1.61
S Tr_9	0.39	0.97	1.64	0.33	0.91	1.66
S Tr_{10}	0.40	0.96	1.61	0.36	0.91	1.64
S Tr_{11}	0.39	0.90	1.62	0.33	0.91	1.65
S Tr_{12}	0.39	0.97	1.63	0.34	0.90	1.64
$F_{1,24}$	0.001^{NS}	3.330^{NS}	1.659^{NS}	0.055^{NS}	0.015^{NS}	0.544^{NS}
SE	0.002	0.003	0.007	0.003	0.004	0.006
CD(0.05)	NS	NS	NS	NS	NS	NS

NS Not significant

Table 65. Residual effects of weed control treatments on days to 50 per cent flowering and number of capsules plant^{-1} of sesamum during the third crop season

Treatments	Days to 50 % flowering 1997	Days to 50 % flowering 1998	No. of capsules plant^{-1} 1997	No. of capsules plant^{-1} 1998
Residual effect from first and second crop				
F Tr_1	44.33	41.3	47.7	48.7
F Tr_2	45.76	44.7	42.3	33.7
F Tr_3	45.00	43.7	40.0	34.7
F Tr_4	44.70	43.7	43.3	38.7
F Tr_5	45.00	44.3	42.7	40.3
F Tr_6	44.70	43.0	42.3	42.0
F Tr_7	44.70	43.3	41.7	43.7
F Tr_8	44.70	43.7	42.7	40.0
F Tr_9	45.00	43.7	38.0	41.3
F Tr_{10}	45.30	44.3	40.7	41.7
F Tr_{11}	44.70	43.3	42.0	43.3
F Tr_{12}	44.70	44.3	41.7	42.0
$F_{11,22}$	1.229^{NS}	1.889^{NS}	0.251^{NS}	1.316^{NS}
SE	0.34	0.34	2.43	2.21
CD (0.05)	NS	NS	NS	NS
Residual effect from first crop				
S Tr_1	45.7	43.3	34.0	42.7
S Tr_2	45.7	43.7	37.3	39.3
S Tr_3	44.7	43.3	41.7	38.7
S Tr_4	45.0	43.3	38.0	41.3
S Tr_5	45.3	43.3	36.3	41.3
S Tr_6	45.0	43.3	39.7	42.0
S Tr_7	44.3	43.0	40.7	41.0
S Tr_8	45.3	43.7	44.7	41.0
S Tr_9	45.3	43.0	40.0	40.7
S Tr_{10}	46.3	43.0	40.7	39.3
S Tr_{11}	45.0	43.0	39.0	43.0
S Tr_{12}	45.0	43.3	42.7	42.0
$F_{1,24}$	6.030*	3.597^{NS}	2.013^{NS}	0.026^{NS}
SE	0.10	0.12	1.26	0.86
CD(0.05)	0.30	NS	NS	NS

* Significant at 5 % level NS Not significant

4.3.3 Yield attributes and yield of sesamum

4.3.3.1 Number of capsules plant^{-1}

The data are presented in Table 65.

The results indicated no significant difference on this character during both the seasons.

4.3.3.2 Seed yield

The data on seed yield are presented in Table 66.

The residual effect of treatments applied to the first and second crop rice had no significant influence on the seed yield of sesamum during the third crop season.

4.3.3.3 Harvest index

The data are presented in Table 66.

The harvest index of the crop was not influenced by the residual effect of weed control treatments applied during the previous seasons in both the years of experimentation.

4.3.3.4 Dry matter production of crop

The results are presented in Table 67.

Table 66. Residual effect of weed control treatments on seed yield of sesamum and harvest index during third crop season

Treaments	Seed yield (kg ha^{-1})		Harvest index	
	1997	1998	1997	1998
Residual effect from first and second crop				
F Tr_1	375.00	451.39	0.26	0.29
F Tr_2	286.11	280.56	0.22	0.24
F Tr_3	330.56	352.78	0.24	0.26
F Tr_4	330.56	335.78	0.26	0.25
F Tr_5	345.84	370.84	0.24	0.27
F Tr_6	338.19	370.84	0.26	0.27
F Tr_7	347.23	350.00	0.24	0.26
F Tr_8	365.28	358.34	0.25	0.26
F Tr_9	362.50	356.95	0.26	0.27
F Tr_{10}	355.56	384.73	0.25	0.28
F Tr_{11}	340.28	356.95	0.23	0.26
F Tr_{12}	313.89	295.84	0.24	0.22
$F_{11,22}$	0.394^{NS}	0.643^{NS}	0.193^{NS}	0.388^{NS}
SE	20.15	26.44	0.01	0.015
CD (0.05)	NS	NS	NS	NS
Residual effect from first crop				
S Tr_1	327.78	340.28	0.23	0.25
S Tr_2	343.06	352.78	0.25	0.27
S Tr_3	308.34	333.33	0.21	0.25
S Tr_4	333.34	366.67	0.23	0.28
S Tr_5	336.11	337.50	0.23	0.26
S Tr_6	327.78	356.95	0.22	0.27
S Tr_7	329.17	347.22	0.23	0.26
S Tr_8	325.00	340.28	0.22	0.26
S Tr_9	354.17	352.78	0.23	0.27
S Tr_{10}	320.84	344.45	0.22	0.26
S Tr_{11}	355.56	356.95	0.24	0.27
S Tr_{12}	347.22	334.73	0.24	0.26
$F_{1,24}$	0.486^{NS}	0.283^{NS}	0.057^{NS}	0.031^{NS}
SE	6.98	11.17	0.004	0.007
CD(0.05)	NS	NS	NS	NS

NS Not significant

Table 67. Residual effect of weed control treatments on crop dry matter production at different growth stages during the third crop season (gm^{-2})

Treatments	1997			1998		
	30 DAS	60 DAS	At harvest	30 DAS	60 DAS	At harvest
Residual effect from first and second crop						
F Tr_1	543.30	903.70	1025.40	462.67	826.00	1087.03
F Tr_2	496.30	828.20	977.09	395.13	670.10	877.73
F Tr_3	529.07	851.80	1037.13	427.97	761.00	965.63
F Tr_4	505.43	854.30	962.47	411.80	758.20	985.63
F Tr_5	503.17	848.13	1057.47	423.63	754.40	968.70
F Tr_6	504.20	842.20	985.43	422.03	766.40	978.03
F Tr_7	504.73	837.97	1073.83	426.93	796.53	977.97
F Tr_8	514.83	840.27	1110.97	422.73	743.27	988.33
F Tr_9	518.17	841.13	1053.77	429.70	754.27	974.76
F Tr_{10}	520.00	839.93	1053.40	414.93	739.23	1008.18
F Tr_{11}	516.67	846.00	1133.73	427.13	733.27	1005.20
F Tr_{12}	518.53	838.63	997.00	416.53	764.13	994.03
$F_{11,22}$	2.846^{*}	4.175^{**}	1.251^{NS}	1.877^{NS}	1.402^{NS}	2.685^{*}
SE	4.97	5.29	32.02	5.67	18.86	15.76
CD (0.05)	14.58	15.51	NS	NS	NS	46.24
Residual effect from first crop						
S Tr_1	525.33	840.30	1064.77	419.87	777.76	987.80
S Tr_2	519.57	828.87	1019.77	427.37	750.47	981.47
S Tr_3	519.03	831.97	1138.50	423.67	724.50	998.97
S Tr_4	511.27	840.57	1109.87	416.07	734.63	922.47
S Tr_5	518.87	835.77	1103.67	420.00	725.63	944.87
S Tr_6	513.83	836.50	1136.90	418.37	730.30	957.77
S Tr_7	506.43	828.57	1120.37	418.50	750.83	955.80
S Tr_8	513.63	838.17	1111.97	415.90	747.03	978.43
S Tr_9	523.17	834.23	1161.67	410.63	731.27	951.00
S Tr_{10}	519.67	839.00	1129.80	411.73	725.90	957.03
S Tr_{11}	519.63	839.27	1097.07	424.10	739.30	970.47
S Tr_{12}	523.37	829.97	1100.37	427.40	732.50	963.37
$F_{1,24}$	0.526^{NS}	17.789^{**}	15.888^{NS}	0.888^{NS}	1.603^{NS}	3.412^{NS}
SE	3.18	2.08	12.23	2.97	9.15	7.71
CD(0.05)	NS	6.09	NS	NS	NS	NS

* Significant at 5% level   ** Significant at 1% level   NS Not significant

4.3.3.4a. 30 Days after sowing

The residual effect of treatments applied to the first and second crop of rice was significant only during the first year. Carryover effect of weed free treatment (FTr_1) recorded the maximum dry matter accumulation which was on a par with the carryover effect of farmers practice of weeding applied to the first and second crop of rice. Among the herbicide treatments residual effects FTr_{10} (residual effect of pendimethalin pre-emergence + 2,4-D post-emergence applied to the first and second crop of rice) recorded the maximum dry matter accumulation by sesamum. FTr_2 (carryover effect of weedy treatment from the previous first and second crop of rice) recorded the lowest dry matter accumulation by sesamum crop.

The residual effect of treatments applied to the first crop of rice alone was not significant during both the years.

4.3.3.4b. 60 days after sowing

The residual effect of previous treatment on crop dry matter production was significant only during the first year. The dry matter accumulation by the crop was found to be maximum in the plots having the residual effect of completely weed free treatment from the first and second crop of rice (FTr_1) followed by FTr_4 (residual effect of pendimethalin applied pre-emergence to the first and second crop of rice). FTr_4 was on a par with other residual effects except FTr_{12} (residual effect of oxyfluorfen pre-emergence + 2,4-D post-emergence applied to the first crop followed by thiobencarb pre-emergence + 2,4-D post-emergence to the second crop) and FTr_7 (residual effect of pendimethalin pre-emergence + hand weeding applied to the first and second crop of rice).

Among the residual effect of first crop treatment STr_4 (residual effect of pendimethalin pre-emergence) recorded the maximum dry matter accumulation by sesamum crop during the first year of experimentation.

4.3.3.4c. At harvest

The crop dry matter production as influenced by the residual effects of previous treatments was found to be significant only during the second year. FTr_1 (residual effect of weed free treatment applied to the first and second crop of rice) recorded the maximum crop dry matter accumulation followed by FTr_{10} (residual effects of pendimethalin pre-emergence + 2,4-D post-emergence applied to the first and second crop of rice). All the residual effects of treatments applied to the first crop of rice were not significant during both the years.

4.3.4 Uptake of nutrients by crop

The results are presented in Table 68.

4.3.4.1 Uptake of nitrogen

The data on nitrogen uptake by sesamum did not differ significantly during both the years.

4.3.4.2. Uptake of phosphorus

The results indicated that the uptake of phosphorus by sesamum

Table 68. Residual effect of weed control treatments on uptake of N, P and K by sesamum during third crop season (kg ha^{-1})

Treatments	1997 N uptake	1997 P uptake	1997 K uptake	1998 N uptake	1998 P uptake	1998 K uptake
Residual effect from first and second crop						
F Tr_1	27.03	5.47	24.24	28.24	6.08	25.38
F Tr_2	21.80	5.10	19.90	20.20	4.65	16.98
F Tr_3	25.29	5.49	22.73	22.57	5.31	20.92
F Tr_4	24.38	5.16	22.14	23.00	5.32	22.01
F Tr_5	26.04	5.82	22.58	23.59	5.23	21.90
F Tr_6	23.68	5.32	20.38	23.49	5.38	21.86
F Tr_7	25.42	5.94	22.92	22.19	5.31	20.82
F Tr_8	28.14	6.11	24.44	24.38	5.27	22.02
F Tr_9	25.66	5.79	22.85	23.03	5.33	20.79
F Tr_{10}	25.31	5.79	22.78	23.52	5.45	21.50
F Tr_{11}	27.18	6.24	24.58	24.39	5.46	20.79
F Tr_{12}	25.25	5.62	22.26	24.17	5.46	20.52
$F_{11,22}$	1.728^{NS}	2.225^{NS}	0.788^{NS}	1.823^{NS}	3.094^{*}	2.290^{*}
SE	0.94	0.17	1.03	0.72	0.11	0.59
CD (0.05)	NS	NS	NS	NS	0.31	1.73
Residual effect from first crop						
S Tr_1	25.90	5.71	23.42	22.39	5.50	20.43
S Tr_2	23.42	5.50	22.49	23.23	5.37	20.93
S Tr_3	26.48	6.33	25.54	23.98	5.59	21.33
S Tr_4	26.95	6.07	24.36	22.81	4.98	20.05
S Tr_5	26.89	6.21	23.58	22.70	5.23	19.86
S Tr_6	26.32	6.32	24.27	24.28	5.17	21.39
S Tr_7	26.53	6.16	24.66	21.34	5.13	21.01
S Tr_8	26.69	6.09	23.65	22.81	5.25	20.56
S Tr_9	28.38	6.37	25.56	22.20	5.20	21.54
S Tr_{10}	27.89	6.25	24.11	23.28	5.13	19.46
S Tr_{11}	25.95	5.93	24.15	23.29	5.27	20.95
S Tr_{12}	26.36	6.12	23.89	22.79	5.23	20.88
$F_{1,24}$	3.982^{NS}	18.592^{**}	11.419^{**}	2.093^{NS}	1.343^{NS}	2.619^{NS}
SE	0.37	0.07	0.31	0.31	0.06	0.26
CD(0.05)	NS	0.21	0.91	NS	NS	NS

* Significant at 5% level ** Significant at 1% level NS Not significant

crop was significantly influenced by the carry over effect of weed control treatments applied to the first and second crop of rice only during the second year of experimentation. FTr_1 (residual effect of weed free treatment applied to the first and second crop of rice) recorded the maximum uptake. The residual effects of other treatments were at par and significantly superior to FTr_2 (residual effect of weedy treatment from the first and second crop of rice).

The residual effect of treatments applied to the first crop of rice was significant only during the first year and STr_9 (residual effect of oxyfluorfen pre-emergence + hand weeding) recorded the maximum P uptake by the crop.

4.3.4.3. Uptake of potassium

The residual effect of treatments applied to the previous first and second crop were significant only in the second year. The results indicated that the residual effect of completely weed free treatment of the first and second crop seasons (FTr_1) recorded the maximum uptake of potassium by sesamum and minimum under the residual effect of weedy check of the first and second crop seasons (FTr_2). Other residual effects were at par.

Among the residual effect of treatments applied to the first crop of rice, STr_9 (oxyfluorfen pre-emergence + hand weeding residual effect) recorded the highest potassium uptake during the first year of experimentation. During the second year, the residual effects were at par.

4.3.5 Uptake of nutrients by weeds

The data are presented in Table 69.

4.3.5.1. Uptake of nitrogen

The residual effect of treatments applied to the first and second crop of rice was significant during both the years. During the first year, FTr_7 (residual effect of pendimethalin pre-emergence + hand weeding applied to the first and second crop of rice) recorded the lowest uptake which was at par with FTr_6 (residual effect of oxyfluorfen pre-emergence applied to the first crop and thiobencarb pre-emergence applied to the second crop of rice). During the second year, FTr_9 (residual effect of oxyfluorfen pre-emergence + hand weeding applied to the first crop followed by thiobencarb pre-emergence + hand weeding applied to the second crop) recorded the lowest N uptake by weeds which was at par with FTr_1 (carryover effect of weed free treatments applied to the rice crops).

The residual effect of treatments applied to the first crop of rice significantly influenced the nitrogen uptake by weeds during the first year and STr_5 (residual effect of butachlor pre-emergence) recorded the lowest uptake of nitrogen. However the carry over effects were not significant during the second year.

4.3.5.2. Uptake of phosphorus

The results revealed significant carryover effects of weed control treatments applied to the first and second crop of rice on weed uptake of

Table 69. Residual effect of weed control treatments on uptake of N, P and K by weeds during third crop season (kg ha^{-1})

Treatments	1997 N uptake	1997 P uptake	1997 K uptake	1998 N uptake	1998 P uptake	1998 K uptake
Residual effect from first and second crop						
F Tr_1	12.18	4.69	20.70	11.95	4.45	20.19
F Tr_2	14.49	5.66	21.77	14.71	5.57	21.80
F Tr_3	13.45	4.72	23.01	12.08	4.80	21.27
F Tr_4	13.67	4.82	23.78	12.37	5.27	22.55
F Tr_5	13.99	6.41	23.82	12.45	4.69	22.21
F Tr_6	11.33	5.82	22.63	13.49	4.42	21.91
F Tr_7	11.16	4.62	22.11	13.11	4.26	22.38
F Tr_8	14.87	3.57	22.72	13.40	4.54	21.97
F Tr_9	13.59	4.50	21.11	11.93	4.72	22.13
F Tr_{10}	13.39	5.14	22.51	13.82	4.86	21.49
F Tr_{11}	12.71	5.22	22.64	13.00	4.79	22.73
F Tr_{12}	13.33	5.57	21.89	12.80	5.42	21.98
$F_{11,22}$	11.395**	6.549**	27.857**	26.639**	6.099**	23.686**
SE	0.61	0.35	0.62	0.36	0.29	0.64
CD (0.05)	1.79	1.01	1.82	1.07	0.87	1.89
Residual effect from first crop						
S Tr_1	13.22	4.37	21.90	13.19	4.81	22.37
S Tr_2	13.18	4.42	22.52	11.41	4.21	21.99
S Tr_3	13.40	3.09	21.95	11.46	5.41	21.56
S Tr_4	14.49	3.80	21.85	11.57	4.22	21.61
S Tr_5	12.82	4.56	21.52	12.39	4.68	22.30
S Tr_6	13.33	4.33	21.69	12.43	4.58	20.87
S Tr_7	13.84	4.82	22.13	12.63	5.09	22.22
S Tr_8	14.11	4.71	21.87	11.61	4.74	21.01
S Tr_9	13.13	5.16	21.59	13.04	4.40	22.21
S Tr_{10}	14.33	4.83	22.13	13.46	4.79	21.71
S Tr_{11}	13.45	4.65	22.18	14.33	4.45	22.36
S Tr_{12}	13.63	4.95	22.81	13.52	5.33	22.69
$F_{1,24}$	15.654**	0.699^{NS}	10.284**	2.645^{NS}	3.754^{NS}	15.174**
SE	0.25	0.16	0.30	0.29	0.10	0.31
CD(0.05)	0.74	NS	0.87	NS	NS	0.90

** Significant at 1% level   NS Not significant

phosphorus during third crop season. Among the residual effects, FTr_8 (residual effect of butachlor pre-emergence + hand weeding applied to the first crop of rice followed by pretilachlor pre-emergence + hand weeding applied tot he second crop of rice) recorded the lowest uptake value which was on a par with FTr_9 (residual effect of oxyfluorfen pre-emergence + hand weeding applied to the first crop followed by thiobencarb pre-emergence + hand weeding applied to the second crop of rice). In the second year, the lowest P uptake was recorded by FTr_7 (residual effect of pendimethalin pre-emergence + hand weeding applied to the first and second crop of rice). Highest weed P uptake was noted in FTr_2 (residual effect of weedy treatment of the two seasons).

The data showed that the residual effect of treatments applied to the first crop was not significant during both the years.

4.3.5.3. Uptake of potassium

The results revealed significant difference in the uptake of potassium by weeds due to the residual effect of weed control treatments applied to the previous crops. During the first year, FTr_1 (residual effect of weed free treatment applied to the first and second crop) recorded the lowest K uptake. Among the residual effects, FTr_4 and FTr_5 (carryover effect of pendimethalin pre-emergence to the first and second crop and the residual effect of butachlor pre-emergence to the first crop followed by pretilachlor pre-emergence to the second crop) recorded the maximum K uptake by plants. In the second year also, FTr_1 recorded the lowest K uptake. FTr_3 (residual effect of hand weeding applied to the first and second crop) had a low K uptake value which was on a par with other residual effects.

The residual effects of treatments applied to the first crop of rice was significant. Among the residual effects, STr_5 and STr_6 (residual effects of butachlor pre-emergence and oxyfluorfen pre-emergence) recorded the lowest weed uptake of potassium during the first and second year of experimentation respectively.

4.3.6 Soil nutrient status

The data on available N, P_2O_5 and K_2O content of the soil after the experiment are presented in Table 70.

4.3.6.1. Available nitrogen content in soil

The residual effects of weed control treatments applied to the previous crops of rice were significant and FTr_1 (residual effect of weed free treatment applied to the first and second crop) recorded the lowest N content. Carry over effect of weedy treatment of the first and second crop (FTr_2) recorded the maximum available N content in the soil.

The carry over effect of weed control treatments applied to the first crop of rice was significant during the third crop season also. STr_{12} (residual effect of oxyfluorfen pre-emergence + 2,4-D post-emergence applied to the first crop of rice) recorded the maximum available N content which was on a par with other residual effects during the first year. In the second year, STr_8 (residual effect of butachlor pre-emergence

Table 70. Residual effect of weed control treatments on available N, P_2O_5 and K_2O content of the soil after third crop season (kg ha^{-1})

Treatments	1997 Available N	1997 Available P_2O_5	1997 Available K_2O	1998 Available N	1998 Available P_2O_5	1998 Available K_2O
Residual effect from first and second crop						
F Tr_1	112.33	26.57	35.13	94.73	22.09	44.83
F Tr_2	221.13	48.10	59.80	160.47	31.99	66.67
F Tr_3	177.43	46.33	25.17	143.67	30.83	56.07
F Tr_4	160.83	43.03	25.93	129.67	31.80	60.60
F Tr_5	177.27	43.07	27.10	136.67	35.03	55.30
F Tr_6	176.53	43.20	26.30	119.70	34.40	60.23
F Tr_7	136.27	35.77	28.27	118.93	35.97	60.87
F Tr_8	147.50	40.77	24.53	121.73	33.87	58.83
F Tr_9	145.80	39.40	27.47	120.23	35.03	56.53
F Tr_{10}	129.90	38.73	24.82	124.87	38.50	56.07
F Tr_{11}	144.77	40.73	29.37	118.80	30.93	56.46
F Tr_{12}	142.83	41.23	24.77	123.83	36.43	61.03
$F_{11,22}$	14.350**	4.224**	11.379**	4.364**	1.838^{NS}	0.727^{NS}
SE	3.79	1.22	1.45	4.21	1.35	2.69
CD (0.05)	11.11	3.56	4.26	12.36	NS	NS
Residual effect from first crop						
S Tr_1	176.43	45.30	24.23	132.57	36.40	62.77
S Tr_2	178.10	43.77	23.46	139.70	36.30	56.66
S Tr_3	177.70	42.70	24.10	138.47	32.73	58.70
S Tr_4	176.63	43.77	24.17	134.03	32.97	50.93
S Tr_5	175.13	44.37	24.03	139.73	32.93	63.70
S Tr_6	177.07	44.73	23.47	134.70	34.43	57.83
S Tr_7	179.00	44.03	23.70	135.63	33.50	59.70
S Tr_8	177.27	43.47	24.07	141.83	33.17	59.10
S Tr_9	177.30	43.60	24.00	138.67	32.90	59.20
S Tr_{10}	177.30	43.60	24.00	138.67	32.07	59.43
S Tr_{11}	177.20	43.27	23.00	138.67	32.90	59.20
S Tr_{12}	179.63	44.23	23.10	139.13	35.07	58.40
$F_{1,24}$	54.519**	23.941**	36.175**	21.885**	0.471^{NS}	0.638^{NS}
SE	2.04	0.47	0.72	1.78	0.75	0.89
CD(0.05)	5.95	1.36	2.11	5.21	NS	NS

** Significant at 1% level NS Not significant

+ hand weeding applied to the first crop) recorded the maximum available N content of the soil.

4.3.6.2. Available P_2O_5 content in soil

The data were significant during first year only. FTr_1 (carryover effect of weed free treatment from the first and second crop) recorded the lowest available P_2O_5 content followed by FTr_7 (residual effect of pendimethalin pre-emergence + hand weeding applied to the first and second crop of rice). Among the residual effects of treatments applied to the first crop of rice STr_1 (carryover effect of weed free treatment applied to the first crop) recorded the maximum available P_2O_5 content in soil.

4.3.6.3. Available K_2O content in soil

The available K_2O content in soil was the maximum in FTr_2 (carry over effect of weedy check of the previous two crops). FTr_8 (residual effect of butachlor pre-emergence + hand weeding applied to the first crop followed by pretilachlor pre-emergence + hand weeding to the second crop) had recorded the lowest available K_2O content in soil. FTr_8 was on a par with other residual effects except FTr_{11} (residual effect of butachlor pre-emergence + 2,4-D post-emergence to the first crop followed by pretilachlor pre-emergence + 2,4-D post-emergence to the second crop) during the first year of study. In the second year the residual effects were not significant.

Among the residual effect of first crop treatment, STr_1 (carryover effect of weed free treatment applied to the first crop) recorded the maximum available K_2O content in soil during the first year.

4.3.7 Population dynamics of soil organisms

The data are presented in Table 71.

4.3.7.1 Soil fungal population

There was no significant difference in the soil fungal population due to the residual effect of weed control treatments applied to the previous crops during both the years.

4.3.7.2. Soil bacterial population

The results indicated that all the residual effects had no significant influence on the soil bacterial population.

4.3.7.3 Soil actinomycetes population

Soil actinomycetes population was not significantly affected due to the residual effect of weed control treatments applied to the previous crops of rice during both the years.

4.3.7.4. Earthworm population

The data on population count of earthworms in the upper 50 cm soil layer after third crop of sesamum are presented in Table 72.

The results revealed that the residual effect of treatments applied

Table 71. Residual effect of weed control treatments on population of soil fungi, soil bacteria and soil actinomycetes after third crop season

Treatments	1997			1998		
	Soil fungi $1 \times 10^4 g^{-1}$	Soil bacteria $1 \times 10^6 g^{-1}$	Soil actinomycetes $1 \times 10^5 g^{-1}$	Soil fungi $1 \times 10^4 g^{-1}$	Soil bacteria $1 \times 10^6 g^{-1}$	Soil actinomycetes $1 \times 10^5 g^{-1}$
Residual effect from first and second crop						
F Tr_1	3.65	3.36	1.42	3.77	3.41	1.44
F Tr_2	3.51	3.31	1.47	3.59	3.26	1.41
F Tr_3	3.49	3.25	1.53	3.65	3.26	1.42
F Tr_4	3.74	3.26	1.57	3.53	3.41	1.54
F Tr_5	3.55	3.46	1.47	3.69	3.61	1.44
F Tr_6	3.69	3.16	1.47	3.51	3.55	1.35
F Tr_7	3.60	3.41	1.56	3.59	3.55	1.52
F Tr_8	3.65	3.26	1.48	3.60	3.51	1.44
F Tr_9	3.64	3.40	1.49	3.50	3.46	1.47
F Tr_{10}	3.73	3.36	1.52	3.63	3.64	1.59
F Tr_{11}	3.55	3.40	1.49	3.51	3.55	1.52
F Tr_{12}	3.69	3.46	1.52	3.74	3.44	1.56
$F_{11,22}$	0.102^{NS}	0.365^{NS}	1.020^{NS}	0.117^{NS}	1.101^{NS}	0.463^{NS}
SE	0.11	0.10	0.03	0.12	0.10	0.05
CD (0.05)	NS	NS	NS	NS	NS	NS
Residual effect from first crop						
S Tr_1	3.69	3.39	1.46	3.65	3.59	1.46
S Tr_2	3.77	3.46	1.44	3.60	3.26	1.59
S Tr_3	3.65	3.59	1.50	3.59	3.46	1.53
S Tr_4	3.55	3.60	1.47	3.78	3.37	1.45
S Tr_5	3.69	3.41	1.45	3.51	3.60	1.56
S Tr_6	3.69	3.60	1.50	3.64	3.51	1.49
S Tr_7	3.69	3.55	1.53	3.65	3.29	1.56
S Tr_8	3.50	3.74	1.50	3.59	3.45	1.56
S Tr_9	3.60	3.59	1.43	3.72	3.65	1.47
S Tr_{10}	3.74	3.49	1.46	3.64	3.49	1.49
S Tr_{11}	3.64	3.69	1.50	3.65	3.65	1.48
S Tr_{12}	3.64	3.69	1.50	3.65	3.65	1.48
$F_{1,24}$	0.303^{NS}	1.398^{NS}	1.304^{NS}	0.239^{NS}	0.070^{NS}	1.513^{NS}
SE	0.04	0.04	0.01	0.05	0.05	0.02
CD(0.05)	NS	NS	NS	NS	NS	NS

NS Not significant

Table 72. Residual effect of weed control treatments on the population of earth worms after third crop season (number m^{-2})

Treatments	1997	1998
Residual effect from first and second crop		
F Tr_1	2.15	2.16
F Tr_2	1.90	2.15
F Tr_3	2.08	1.72
F Tr_4	1.74	1.99
F Tr_5	1.71	1.89
F Tr_6	1.99	1.91
F Tr_7	1.82	1.96
F Tr_8	1.99	1.97
F Tr_9	1.71	2.21
F Tr_{10}	1.73	1.90
F Tr_{11}	1.72	1.88
F Tr_{12}	1.88	1.86
$F_{11,22}$	0.708^{NS}	0.300^{NS}
SE	0.18	0.14
CD (0.05)	NS	NS
Residual effect from first crop		
S Tr_1	1.91	2.04
S Tr_2	2.51	2.08
S Tr_3	1.88	2.10
S Tr_4	1.69	1.88
S Tr_5	1.99	1.90
S Tr_6	1.80	2.00
S Tr_7	1.88	2.14
S Tr_8	1.97	1.99
S Tr_9	1.71	1.97
S Tr_{10}	1.63	2.03
S Tr_{11}	2.08	2.15
S Tr_{12}	1.95	2.06
$F_{1,24}$	0.271^{NS}	0.358^{NS}
SE	0.07	0.07
CD(0.05)	NS	NS

NS Not significant

to the previous crops had no significant influence on the population of earthworm in soil after the third crop of sesamum.

4.3.8 Economics

4.3.8.1 Benefit Cost Ratio

The data on BCR worked out during the third crop season are presented in Table 73.

The residual effect of weed control treatments, did not cause significant differences in benefit cost ratio of third crop of sesamum during both the years.

4.3.8.2 Net profit

The data are presented in Table 73.

There was no significant difference in the net profit during third crop of sesamum due to the residual effect of weed control treatments applied to the previous crop during both the years.

4.4 Herbicide residues in the soil

The persistance of the herbicide in the soil was studied by observing the germination and early growth response of a sensitive indicator plant cucumber (*Cucumis sativus* L.) grown in soil sample taken from the experimental plot after the experiment. The results are presented in Tables 74 and 75.

Table 73. Residual effect of weed control treatments on economics during the third crop season

Treatments	BCR		Net profit (Rs. ha^{-1})	
	1997	1998	1997	1998
Residual effect from first and second crop				
F Tr_1	1.29	1.56	2585.00	4876.67
F Tr_2	0.91	0.92	-748.33	-248.33
F Tr_3	1.14	1.22	1251.67	1918.33
F Tr_4	1.14	1.16	1251.67	1418.33
F Tr_5	1.19	1.28	1710.00	2460.00
F Tr_6	1.16	1.28	1480.67	2460.00
F Tr_7	1.20	1.21	1751.67	1835.00
F Tr_8	1.27	1.24	2293.33	2085.00
F Tr_9	1.25	1.24	2210.00	2043.33
F Tr_{10}	1.23	1.33	2001.67	2876.67
F Tr_{11}	1.18	1.28	1543.33	2043.33
F Tr_{12}	1.09	1.02	751.67	210.00
$F_{11,22}$	0.549^{NS}	0.746^{NS}	0.543^{NS}	0.643^{NS}
SE	0.07	0.09	598.51	793.37
CD (0.05)	NS	NS	NS	NS
Residual effect from first crop				
S Tr_1	1.14	1.18	1168.33	1543.33
S Tr_2	1.19	1.22	1626.67	1918.33
S Tr_3	1.07	1.56	585.00	1335.00
S Tr_4	1.15	1.27	1335.00	2335.00
S Tr_5	1.16	1.67	1418.33	1460.00
S Tr_6	1.13	1.24	1168.33	2043.33
S Tr_7	1.14	1.20	1210.00	1751.67
S Tr_8	1.13	1.18	1085.00	1543.33
S Tr_9	1.23	1.22	1960.00	1918.33
S Tr_{10}	1.11	1.19	960.00	1668.33
S Tr_{11}	1.23	1.24	2001.67	2043.33
S Tr_{12}	1.20	1.16	1751.67	1376.67
$F_{1,24}$	0.285^{NS}	0.216^{NS}	0.291^{NS}	0.286^{NS}
SE	0.02	0.04	197.84	384.98
CD(0.05)	NS	NS	NS	NS

NS Not significant

Table 74. Effect of weed control treatments on germination (%) and dry matter accumulation of indicator plant cucumber (g) after first crop season

Treatments	Germination (%)		Dry matter accumulation	
	1996-97	1997-98	1996-97	1997-98
T_1	94.5	94.5	2.53	2.33
T_2	97.2	97.2	2.53	2.46
T_3	91.7	97.2	2.50	2.47
T_4	94.4	91.7	2.50	2.33
T_5	91.7	97.2	2.53	2.47
T_6	94.4	88.9	2.53	2.70
T_7	88.9	91.7	2.47	2.50
T_8	88.9	88.9	2.53	2.27
T_9	97.2	94.5	2.53	2.53
T_{10}	90.5	88.9	2.37	2.57
T_{11}	94.5	94.5	2.50	2.37
T_{12}	94.5	94.5	2.53	2.50
$F_{11,22}$	0.517^{NS}	0.775^{NS}	0.239^{NS}	1.61^{NS}
SE	3.96	3.69	0.01	0.01
CD(0.05)	NS	NS	NS	NS

NS - Not significant

Table 75. Effect of weed control treatments on germination (%) and dry matter accumulation of indicator plant cucumber (g) after second crop season

Treaments	Germination (%)		Dry matter accumulation	
	1996-97	1997-98	1996-97	1997-98
Residual effect from first and second crop				
T_1	94.40	97.20	2.60	2.70
T_2	94.40	86.10	2.60	2.40
T_3	88.90	94.50	2.70	2.60
T_4	91.70	97.20	2.70	2.40
T_5	88.90	91.70	2.70	2.40
T_6	94.50	94.50	2.60	2.50
T_7	88.90	88.90	2.70	2.50
T_8	97.20	94.40	2.50	2.60
T_9	94.50	91.70	2.50	2.60
T_{10}	88.90	88.90	2.40	2.50
T_{11}	94.50	88.90	2.50	2.70
T_{12}	94.50	94.50	2.50	2.60
$F_{11,22}$	1.56^{NS}	0.52^{NS}	0.56^{NS}	0.63^{NS}
SE	2.15	3.38	0.08	0.07
CD(0.05)	NS	NS	NS	NS
Residual effect from first crop				
F Tr_1	88.90	94.50	2.50	2.50
F Tr_2	86.10	97.20	2.60	2.70
F Tr_3	94.50	88.90	2.70	2.50
F Tr_4	94.50	86.10	2.50	2.30
F Tr_5	91.70	94.50	2.60	2.50
F Tr_6	94.50	86.10	2.50	2.60
F Tr_7	86.10	91.70	2.50	2.50
F Tr_8	88.90	86.10	2.50	2.50
F Tr_9	97.20	97.20	2.50	2.50
F Tr_{10}	88.90	88.90	2.60	2.50
F Tr_{11}	94.50	86.10	2.60	2.40
F Tr_{12}	97.20	94.40	2.50	2.60
$F_{1,24}$	0.22^{NS}	1.38^{NS}	1.85^{NS}	0.15^{NS}
SE	1.04	0.84	0.02	0.02
CD(0.05)	NS	NS	NS	NS

NS Not significant

The data indicated that the germination and dry matter accumulation of the seedlings were not significantly influenced by the herbicide treatments.

4.9 Pooled analysis

4.9.1. Grain yield (pooled) of first crop rice

No interaction was observed between treatments and year. The average effect of treatments are presented in Table 76. Pooled data on grain yield of rice during first crop season in rice-rice-sesamum cropping system indicated that next to weed free treatment (T_1), maximum grain yield was recorded in T_7 (pendimethalin pre-emergence + hand weeding) which was on a par with T_3 (farmers practice) T_4 (pendimethalin pre-emergence) and T_{10} (pendimethalin pre-emergence + 2,4-D post emergence). All the herbicide treatments were found to have similar results as that of farmers practice.

4.9.2. Straw yield (pooled) of first crop rice

The results are presented in Table 76.

No interaction was observed between treatments and year. The results indicated that the straw yield was maximum in T_1 (completely weed free treatment) and minimum in T_2 (weedy check). Next to T_1, the straw yield was maximum in T_3 (farmers practice of weeding). Except T_5 and T_6 (butachlor and oxyfluorfen pre-emergence treatments) all other herbicide treatments found to give the same result as that of T_3.

Table 76. Pooled grain yield and straw yield of first crop rice

Treatments	Grain yield kg ha^{-1} (1996-97)	Grain yield kg ha^{-1} (1997-98)	Grain yield kg ha^{-1} (Pooled)	Straw yield kg ha^{-1} (1996-97)	Straw yield kg ha^{-1} (1997-98)	Straw yield kg ha^{-1} (Pooled)
T_1	3888.8	3474.7	3681.8	4232.3	3787.8	4010.1
T_2	1878.7	1570.7	1724.7	2383.8	2020.1	2202.0
T_3	2848.4	2818.1	2833.3	3686.8	3121.2	3404.0
T_4	2727.2	2777.7	2752.5	3121.2	2999.9	3060.6
T_5	2681.8	2363.6	2522.7	3020.2	2636.3	2828.3
T_6	2515.1	2373.7	2444.4	2676.7	2636.3	2656.6
T_7	3196.9	3171.7	3184.3	3282.8	3474.7	3378.8
T_8	3020.2	2387.2	2703.7	3202.0	2696.9	2949.5
T_9	2848.4	2303.0	2575.7	3550.5	2550.8	3050.6
T_{10}	3000.0	2636.3	2818.2	3323.2	2939.3	3131.3
T_{11}	2690.0	2707.0	2698.5	3202.0	3050.5	3126.3
T_{12}	2808.0	2505.0	2656.6	3141.4	2712.1	2926.8
F	4.881**	3.545**	8.633**	3.548**	2.178^{NS}	5.315**
SE	210.38	252.81	217.66	248.72	310.57	266.30
CD(0.05)	617.05	741.51	493.68	729.51	NS	537.93

** Significant at 1% level NS - Not significant

4.9.3. Grain yield (pooled) of second crop rice

The results are presented in Table 77.

No significant difference in the treatment x residual interaction was observed in the experiment. The grain yield of rice during the second crop season in rice-rice-sesamum cropping system revealed that the herbicide treatments applied to the second crop of rice had produced more grain yield compared to the residual effect of treatments applied to the first crop. Among the residual effect of first crop treatments, Tr_7 (pendimethalin pre-emergence + hand weeding residual effect) recorded the maximum grain yield of 2165 kg ha^{-1} which was on par with other residual effects except that of weedy check (Tr_2). Among the herbicide treatments applied to the second crop T_9 (thiobencarb pre-emergence + hand weeding) recorded the maximum grain yield.

4.9.4. Straw yield (pooled) of second crop rice

The data are presented in Table 78.

The pooled data indicated no significant interaction between the treatments and the year. The results showed significant effect of weed control treatments and the residual effect of previous season treatments on the straw yield or rice crop during the season. Among the residual effects the straw yield was the lowest in Tr_2 (residual effect of weedy check). All other residual effects were at par. Among the treatments applied to the second crop of rice, herbicide treatments integrated with

Table 77. Pooled grain yield (kg ha^{-1}) of second crop rice

Treatments	1996-97	1997-98	Pooled
Treatment effect			
T_1	3344.30	3591.01	3467.7
T_2	1425.44	1370.61	1398.0
T_3	2028.51	1891.45	1959.9
T_4	2357.46	2247.81	2302.6
T_5	2302.63	2220.39	2261.5
T_6	2357.46	2384.87	2371.2
T_7	2384.87	2631.60	2508.2
T_8	2247.81	2521.93	2384.9
T_9	2987.94	3097.59	3042.8
T_{10}	2631.58	2467.11	2549.3
T_{11}	2631.58	2604.16	2617.9
T_{12}	2658.99	2686.40	2672.7
F	3.493**	15.719**	17.32**
SE	135.97	72.74	129.91
CD (0.05)	398.82	213.36	259.82
First crop residual effect			
Tr_1	2001.10	1973.68	1987.4
Tr_2	1891.45	1836.62	1864.0
Tr_3	2028.51	2083.33	2055.9
Tr_4	1918.86	1946.27	1932.6
Tr_5	2001.10	1973.68	1987.4
Tr_6	2028.50	1918.86	1973.7
Tr_7	2275.22	2055.92	2165.6
Tr_8	2055.92	1973.68	2014.8
Tr_9	2055.92	1946.27	2001.1
Tr_{10}	2001.10	2138.16	2069.6
Tr_{11}	2001.10	1973.68	1987.4
Tr_{12}	2026.20	1973.68	1999.9
F	44.842**	119.938**	17.32**
SE	44.38	31.86	129.91
CD (0.05)	129.55	92.99	259.82

NS - Not significant ** - Significant at 1 % level

Table 78. Pooled straw yield (kg ha^{-1}) of second crop rice

Treatments	1996-97	1997-98	Pooled
Treatment effect			
T_1	4002.19	4248.90	4125.6
T_2	2110.75	2330.04	2220.4
T_3	2713.81	2768.64	2741.2
T_4	3042.76	2933.11	2987.9
T_5	2987.94	2960.53	2974.2
T_6	2960.53	3152.41	3056.5
T_7	2987.94	3207.24	3097.6
T_8	2987.94	3316.88	3152.4
T_9	3557.48	3837.72	3697.6
T_{10}	3426.53	3536.18	3481.4
T_{11}	3553.95	3508.77	3531.4
T_{12}	3426.93	3453.95	3440.4
F	5.851**	10.797**	20.47**
SE	113.43	85.14	121.32
CD (0.05)	332.71	249.72	242.64
First crop residual effect			
Tr_1	2713.81	2796.05	2754.9
Tr_2	2549.34	2658.99	2604.2
Tr_3	2713.81	2960.53	2837.2
Tr_4	2576.75	2686.40	2631.6
Tr_5	2741.23	2713.82	2727.5
Tr_6	2768.64	2686.40	2727.5
Tr_7	2768.64	2933.11	2850.9
Tr_8	2823.46	2768.64	2796.0
Tr_9	2823.46	2878.29	2850.9
Tr_{10}	2741.23	2987.94	2864.6
Tr_{11}	2741.23	2933.11	2837.2
Tr_{12}	2796.05	2796.05	2796.1
F	52.903**	105.319**	20.47**
SE	41.31	31.32	121.32
CD (0.05)	120.57	91.43	242.64

NS - Not significant ** - Significant at 1 % level

Table 79. Pooled seed yield (kg ha^{-1}) of third crop sesamum

Treatments	1996-97	1997-98	Pooled
Residual effect from first and second crop			
F Tr_1	375.00	451.39	413.2
F Tr_2	286.11	280.56	283.3
F Tr_3	330.56	352.78	341.7
F Tr_4	330.56	335.78	333.2
F Tr_5	345.84	370.84	358.3
F Tr_6	338.19	370.84	354.5
F Tr_7	347.23	350.00	348.6
F Tr_8	365.28	358.34	361.8
F Tr_9	362.50	356.95	359.7
F Tr_{10}	355.56	384.73	370.1
F Tr_{11}	340.28	356.95	348.6
F Tr_{12}	313.89	295.84	304.9
F	0.394^{NS}	0.643^{NS}	1.09^{NS}
SE	20.15	26.44	29.58
CD (0.05)	NS	NS	NS
Residual effect from first crop			
S Tr_1	327.78	340.28	334.0
S Tr_2	343.06	352.78	347.9
S Tr_3	308.34	333.33	320.8
S Tr_4	333.34	366.67	350.0
S Tr_5	336.11	337.50	336.8
S Tr_6	327.78	356.95	342.4
S Tr_7	329.17	347.22	338.2
S Tr_8	325.00	340.28	332.6
S Tr_9	354.17	352.78	353.5
S Tr_{10}	320.84	344.45	332.6
S Tr_{11}	355.56	356.95	356.3
S Tr_{12}	347.22	334.73	341.0
F	0.486^{NS}	0.283^{NS}	1.09^{NS}
SE	6.98	11.17	29.58
CD(0.05)	NS	NS	NS

* Significant at 5% level NS Not significant

hand weeding or post-emergence application of 2,4-D (T_7 to T_{12}) recorded higher straw yield.

4.9.5. Yield of sesamum (pooled)

The results are presented in Table 79.

No interaction was observed between the treatments and the year. The residual effects of treatments applied to the first and second crop of rice and first crop of rice alone were not significant on the yield of sesamum during third crop season.

DISCUSSION

5. DISCUSSION

Field experiments were conducted at Rice Research Station, Kayamkulam consecutively for two years from the first crop season of 1996-97 to third crop season of 1997-98 on weed management in relation to rice-rice-sesamum cropping system of Onattukara region. The results of the experiment presented in the previous chapter are discussed below.

5.1 First crop season

5.1.1 Observation on weeds

5.1.1.1 Weed Spectrum

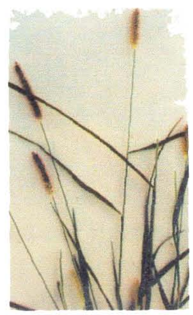
Observation on weed species revealed that grasses, broad leaved weeds and sedges competed with the rice crop. Among the grassy weeds *Echinochloa crusgalli* and *Brachiaria ramosa* were the predominant ones. Among the broad leaved weeds *Ammania baccifera, Ludwigia parviflora* and *Monochoria vaginalis* were the most serious. Species of *Cyperus*, *Scirpus* and *Fimbristylis* were the important sedges noted during the first crop season. Similar observations on weed spectrum infesting rice fields were reported earlier by Ravindran (1976) and Lakshmi (1983).

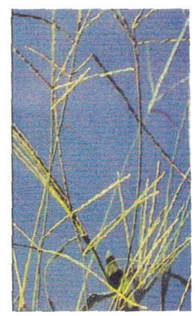

Echinochloa crus-galli


Echinochloa colonum

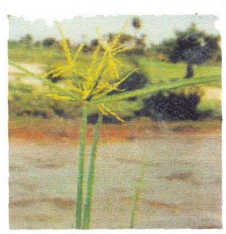

Panicum spp.


Dactyloctenium aegyptium


Setaria spp.


Digitaria spp.


Cyperus difformis


Cyperus iria


Fimbristylis miliacea

Plate 1. Major weed flora of the experimental field

Commelina benghalensis

Eclipta alba

Ludwigia parviflora

Monochoria vaginalis

Marsilea quadrifoliata

Sphenoclea zeylanica

Plate 2. Dicot weed flora of the experimental field

5.1.1.2 Effect of weed management practices on growth of weeds

In the present study, monocot, dicot and total weed count were recorded at 15, 30 and 45 DAS and at harvest. The weed index, weed control efficiency (WCE) and Herbicide efficiency index (HEI) were also worked out to study the effect of weed management practices on the growth of weed flora.

The data on weed count indicated that the different weed control treatments had significant effect on the monocot, dicot and total weed population. The unweeded check (T_2) recorded higher number of weed population compared to other weed control treatments. In general, all the herbicide treatments either pre-emergence application only or a combination of pre-emergence application and hand weeding/post-emergence application of 2,4-D had reduced the weed population significantly than the control. Among the herbicide treatments, pendimethalin treatments were found to show spectacular inhibitory effect on the emergence of broad leaved weeds. From the results, it was evident that the pre-emergence application of herbicides such as pendimethalin and butachlor suppressed the total weed count upto 15 DAS, the herbicide and hand weeding combination suppressed the total weed count at 30 DAS, and integration of pre and post-emergence herbicide treatments suppressed total weed count at 45 DAS and at the stage of harvest of the crop. Efficiency of pre-emergence herbicides, butachlor and pendimethalin has been earlier reported by De Datta (1980). Lubigan and Moody (1980) also suggested combination of herbicides for better weed control in rice. These results are also in line with the report of Mohamed Ali and Sankaran (1975), Mohamed Ali *et al.* (1986), Angiras and Rana (1998) and Ramamurthy *et al.* (1998).

The weed control efficiency of all the herbicide treatments were superior to farmers' practice (T_3) and no weeding (T_2). The weed control efficiency of the farmer's practice (T_3) was 60.05 and 55 per cent during the first and second year of experimentation respectively. This indicate that it was not sufficient to suppress the weed population till the harvest of the crop. Also the soil disturbance caused by the manual weeding operation might have favoured the growth of the dormant weed seeds which were below the soil surface. This is in agreement with the findings of Gupta *et al* (1975). Among the herbicide treatments, higher WCE was noted when pre-emergence application of pendimethalin, butachlor and oxyfluorfen were combined with hand weeding or post-emergence application of 2,4-D than the pre-emergence application alone. Thus it is evident that chemical control of weeds is more efficient. This is in agreement with the findings of Rangiah *et al.* (1976), Ramiah and Muthukrishnan (1992) and Rao and Singh (1997).

An appraisal of the data on herbicide efficiency index revealed that pendimethalin pre-emergence + hand weeding (T_7) was superior over the other treatments. Among the herbicides oxyfluorfen pre-emergence + hand weeding (T_9) recorded the lowest herbicide efficiency index indicating that it was ineffectual in suppressing the weed growth upto the harvest stage of the crop. Similar results were reported earlier by Joseph and Bridjit (1993) and Kathiresan *et al.* (1997).

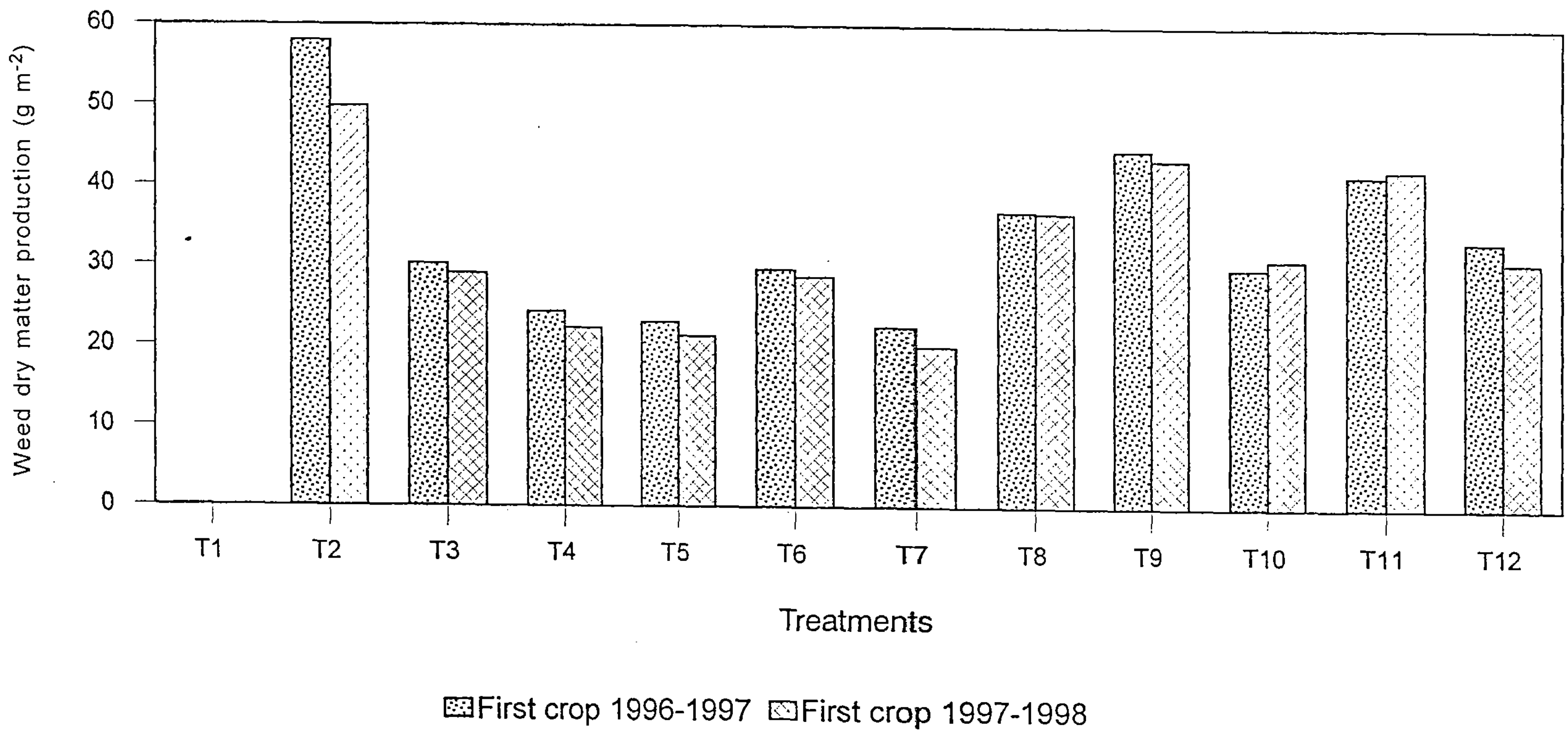


Fig. 3. Effect of weed management practices on weed dry matter production at harvest during first crop season

5.1.1.3 Weed dry matter production and nutrient uptake

Results of the experiment revealed significant effect of weed control treatments on the dry weight of weeds at various growth stages of the crop. At 15 DAS, the effect of different weed control treatments was inconsistent. This might be due to the effect of climatic conditions that prevailed during the first fortnight of the semi-dry rice crop of the first crop season. De Datta (1980) has opined that results with herbicides in dry-seeded rice have been inconsistent from site to site and from year to year at the same site. Various weed species, their intensities and soil, moisture and climatic conditions may account for this. Total weed dry weight at 30 and 45 DAS and at harvest were maximum under weedy check (T_2). Unchecked weed growth exploited the available nutrients in greater amounts resulting in better growth and dry matter production. Similar observations have been made by Ravindran (1976), Balu and Sankaran (1977) who reported that maximum dry weight of weeds was found in the weedy check. The results of the experiment have clearly indicated that the dry matter accumulation by weeds could be substantially reduced by herbicide treatments. Among the herbicide treatments, pendimethalin pre-emergence application @ 1.5 kg ai ha^{-1} in combination with hand weeding (T_7) is more beneficial in reducing the dry matter accumulation by weeds. Eventhough farmers' practice (T_3) was on a par with pendimethalin pre-emergence + hand weeding (T_7) at 30 DAS, it was inferior to all the herbicide treatments at 45 DAS and at harvest. In similar lines, Balu and Sankaran (1977), Joseph and Bridgit (1993) and Kathiresan *et al.* (1997) reported reduction in dry weight of weeds by the use of herbicides such as pendimethalin in rice.

The uptake of nutrient by weeds is the product of dry matter production and nutrient content of weeds. Results of the study revealed that the uptake of N, P and K was maximum under unweeded check. Herbicide treatments registered lower uptake values. The uptake was minimum under pendimethalin pre-emergence + hand weeding (T_7). The uptake of nutrients by weeds was considerable under oxyfluorfen pre-emergence + hand weeding (T_9) which implied that this treatment allowed considerable weed growth especially towards the later stages of crop growth. This might be due to the non-persistent nature of the herbicide. Difference in the uptake of nutrients due to weed control treatments were reported earlier by Lakshmi (1983) and Soman (1988).

5.1.2 Observation on crop

5.1.2.1 Effect of weed management practices on crop growth characters

The results revealed that the growth characters of rice were significantly influenced by the weed management practices studied.

Plant height was maximum in completely weed free treatment (T_1) and minimum in the no weeding treatment (T_2) during both the years. In general, at 30 and 45 DAS, all the herbicide treatments registered higher values for plant height than the no weeding treatment. During both years, the treatment pendimethalin pre-emergence + hand weeding (T_7) recorded higher plant height which were on a par with weed free check. Similar increase in plant height due to weed control treatments have been reported by Gill and Kolar (1980). Similarly weed removal had some positive influence on the number of tillers m^{-2}. At 30 DAS, pendimethalin pre-emergence + hand weeding (T_7) was on a par with weed free treatment. At 45 DAS and at harvest, pendimethalin pre-emergence + 2,4-D post-emergence (T_{10}) was superior and recorded higher number of tillers m^{-2}. No weeding treatment (T_2) recorded the lowest tiller number at all stages of crop growth. From the data it was obvious that in weedy check, the weeds competed for nutrients and space with the rice crop which inhibited the rice from putting forth higher number of tillers. Among the chemical treatments, pendimethalin pre-emergence + hand weeding (T_7) recorded higher number of tillers at 30 DAS, pendimethalin pre-emergence + 2,4-D post-emergence (T_{10}) recorded higher values at 45 DAS and at harvest. Better weed control and enhanced tillering of plants through sequential application of pendimethalin followed by 2,4-D Na salt was earlier reported by Ramiah and Muthukrishnan (1992) and Behera and Jena (1998).

The LAI of the crop was also influenced significantly by the weed management practices. At 15 and 30 DAS, eventhough the effect of the treatments on LAI was significant, the analysis of the data did not reveal any consistent results. This might be due to the fact that in the very early stages of development, when the resources are not limited, a vigorously growing crop can produce a temporary competitive advantage over the infesting weeds. At later stages of development, such advantage is lost as revealed from the data at 45 DAS during both the years. At 45

DAS, completely weed free treatment recorded the highest LAI during both years and minimum by the weedy check which may be attributed to the severe competition between the crop and weeds in the no weeding treatment. Sreedevi (1979) also reported such decrease in LAI due to weed competition.

Results of the present study also revealed that the RGR and CGR of the crop were not significantly influenced by the weed management techniques. The CGR which indicates the crop production potential per unit land area basis was at par at a particular period of growth of rice crop.

Among the treatments, pendimethalin pre-emergence + hand weeding (T_7) combination recorded lower weed index during both the seasons. The weedy check (T_2) recorded the highest weed index values of 58.11 and 58.53 per cent during the first and second year respectively. This might be due to the significantly higher weed population and weed biomass found in unweeded plots as weeds were not disturbed during the whole season of crop growth. The reduced weed indices noted with herbicide treatments indicate the degree of suppression on weed growth by the application of herbicides. Similar results were earlier reported by Behera and Jena (1998) and Gogoi (1998).

The overall indication from the result was that the growth characters of rice were significantly influenced by the weed management practices studied.

5.1.2.2 Effect of weed management practices on the yield attributing characters and yield of rice

From the data on yield attributing characters, it was evident that effective weed management did have a positive role in determining the yield of rice. The rice plant recorded maximum number of productive tillers, total spikelets panicle^{-1}, percentage of filled grains and grain yields in weed free treatment (T_1). This was closely followed by pendimethalin pre-emergence + hand weeding (T_7). From the data on number of productive tillers m^{-2} the no weeding treatment (T_2) recorded the lowest number of productive tillers which was only 63.7 and 61.8 per cent of the completely weed free plots during the first year and second year respectively which reflected the intensity of weed competition. Comparing the different weed control treatments pendimethalin either alone or in combination with hand weeding/post-emergence application of 2,4-D produced higher number of productive tillers. In similar lines Mohamed Ali and Sankaran (1975) and Kathiresan *et al.* (1997) reported increased number of productive tillers in pendimethalin treated plots. The herbicidal treatments registered higher number of spikelets than the unweeded control plots. The number of filled grains panicle^{-1} was also influenced by the weed control treatments. Completely weed free plot had recorded the highest number of filled grains during the second year while it was on a par with pendimethalin + hand weeding treatment during the first year. The competition of lesser intensity by weeds for nutrients and light due to herbicide treatments might have enabled the crop to produce more photosynthates thereby resulting in the maximum number

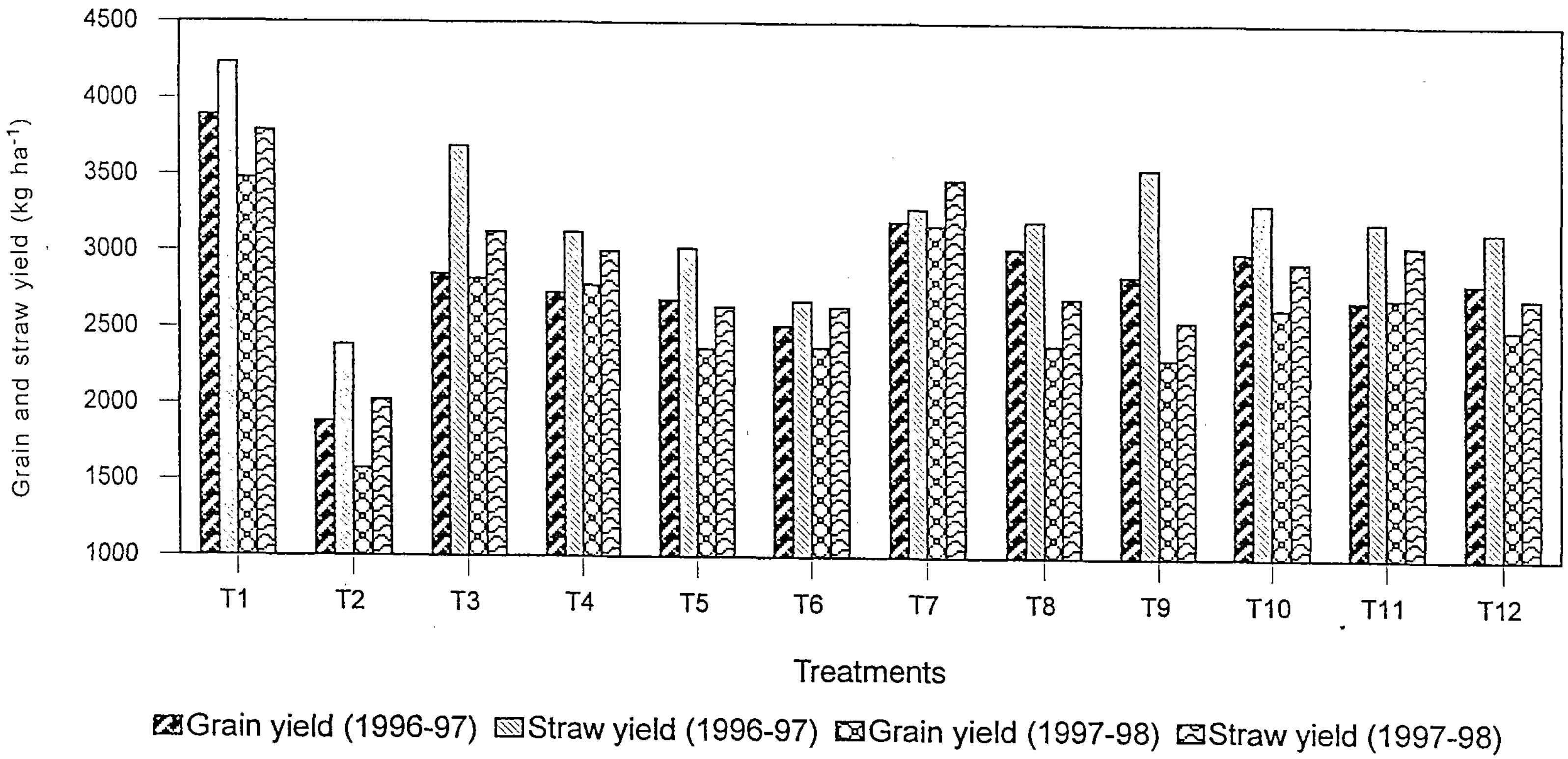


Fig. 4. Effect of weed control treatments on grain yield and straw yield of rice during first crop season

of filled grains. Sukumari (1982) and Lakshmi (1983) have reported significant influence of weed growth on the number of filled grains panicle^{-1}. In contrast, Rethinam and Sankaran (1974) observed that different weed control treatments had no significant effect on the number of grains per earhead. However the weight of panicle was not affected by the weed control practices studied.

A critical analysis of the yield data clearly showed that crop yield was higher in treatments which were effective in controlling weeds. When the field was kept completely weed free during the entire season significantly higher yield was obtained. The enhanced yield was consistent with the growth characters discussed earlier. In rice, grain yield is a function of number of productive tillers, number of spikeletes panicle^{-1} and number of filled grains. Higher values of these characters recorded under the treatments T_1 and T_7 (weed free and pendimethalin pre-emergence + hand weeding) might have resulted in higher grain yield. The direct influence of weed competition on yield characters and yield of rice has been reported by several workers like Pillai *et al.* (1983), Ramamoorthy and Mohamed Ali (1992), Joseph and Bridjit (1993) and Behera *et al.* (1997).

The harvest index values ranged from 0.44 (no weeding treatment) to 0.52 (pendimethalin pre-emergence + hand weeding) during the first season and from 0.44 (no weeding treatment) to 0.48 (pendimethalin pre-emergence + hand weeding, weed free and farmer's practice) during the second year. In general all the herbicide treatments recorded higher harvest index than weedy check. But Hussain and Khan (1976) and Maheswari (1987) reported no significant difference in the grain-straw ratio of rice among the different weed control treatments.

5.1.2.3 Effect of weed management on dry matter production and nutrient removal by crop

Results indicated that the rice crop under herbicide treatments registered higher dry matter accumulation than the hand weeding (T_3) and unweeded check (T_2). At harvest stage the dry matter accumulation by crop in the unweeded plots was found to be only 47 to 50.3 per cent of that under completely weed free treatment. This indicated the severe competition between the crop and weeds in the unweeded plots and also the antagonistic effect of crop and weed on the drymatter production. Similar trend was observed in various herbicide treatment plots where the drymatter accumulation by crop was high.

Maximum uptake of N, P, K was recorded by the completely weed free treatments whereas the weedy check registered the minimum uptake values for the major nutrients. Results showed that the uptake of N, P, K in unweeded plot is about 38, 37 and 33 per cent of the uptake of the nutrient in completely weed free plots-which clearly indicated the antagonistic influence of the weeds on nutrient uptake by crop. Similar observations were made earlier by Ravindran (1976), Nanjappa and Krishnamurthy (1980), Lakshmi (1983), Ramamoorthy (1991), Choubey

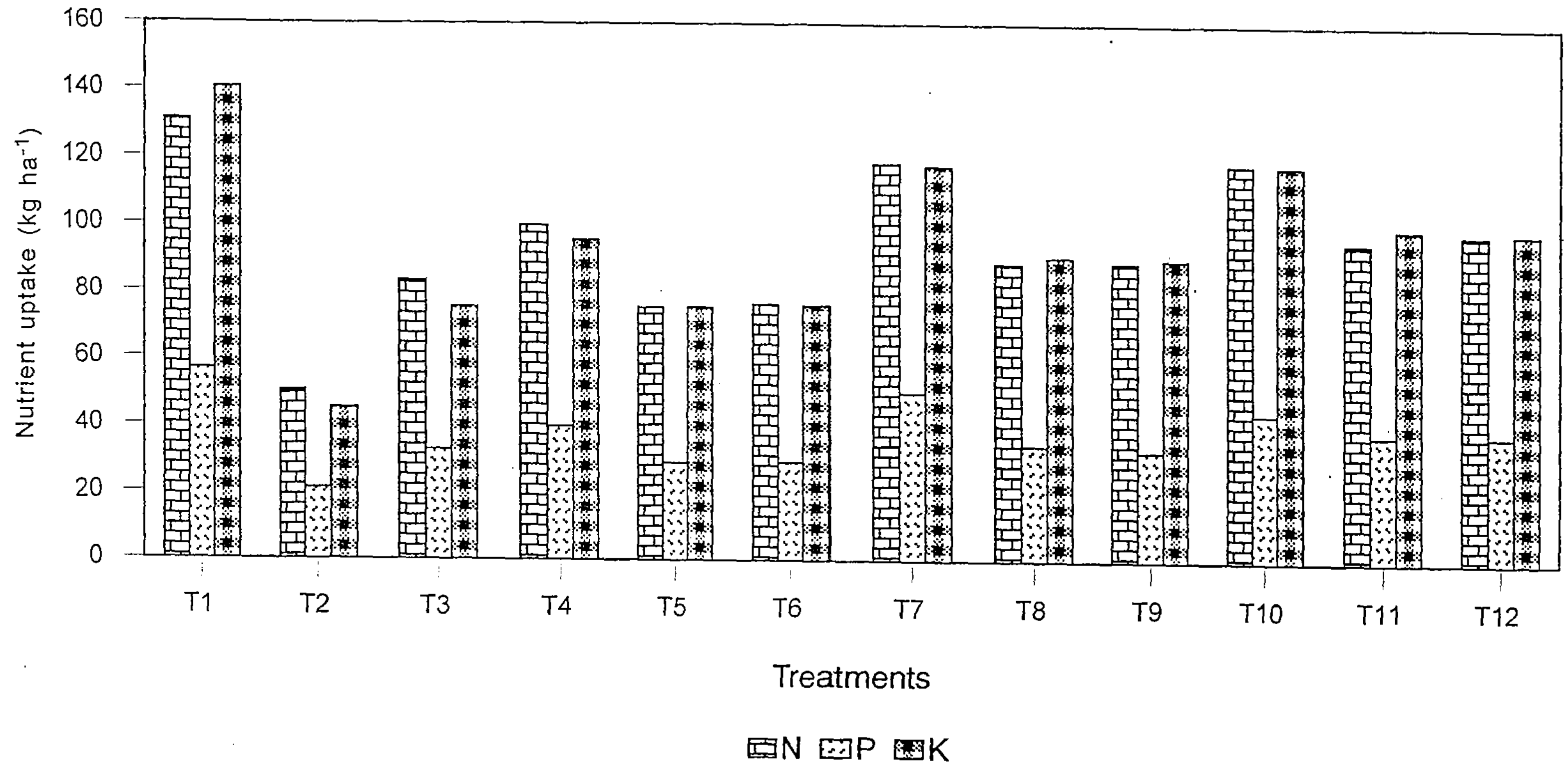


Fig. 5a. Effect of weed management practices on nutrient uptake by rice during first crop season (1996-1997)

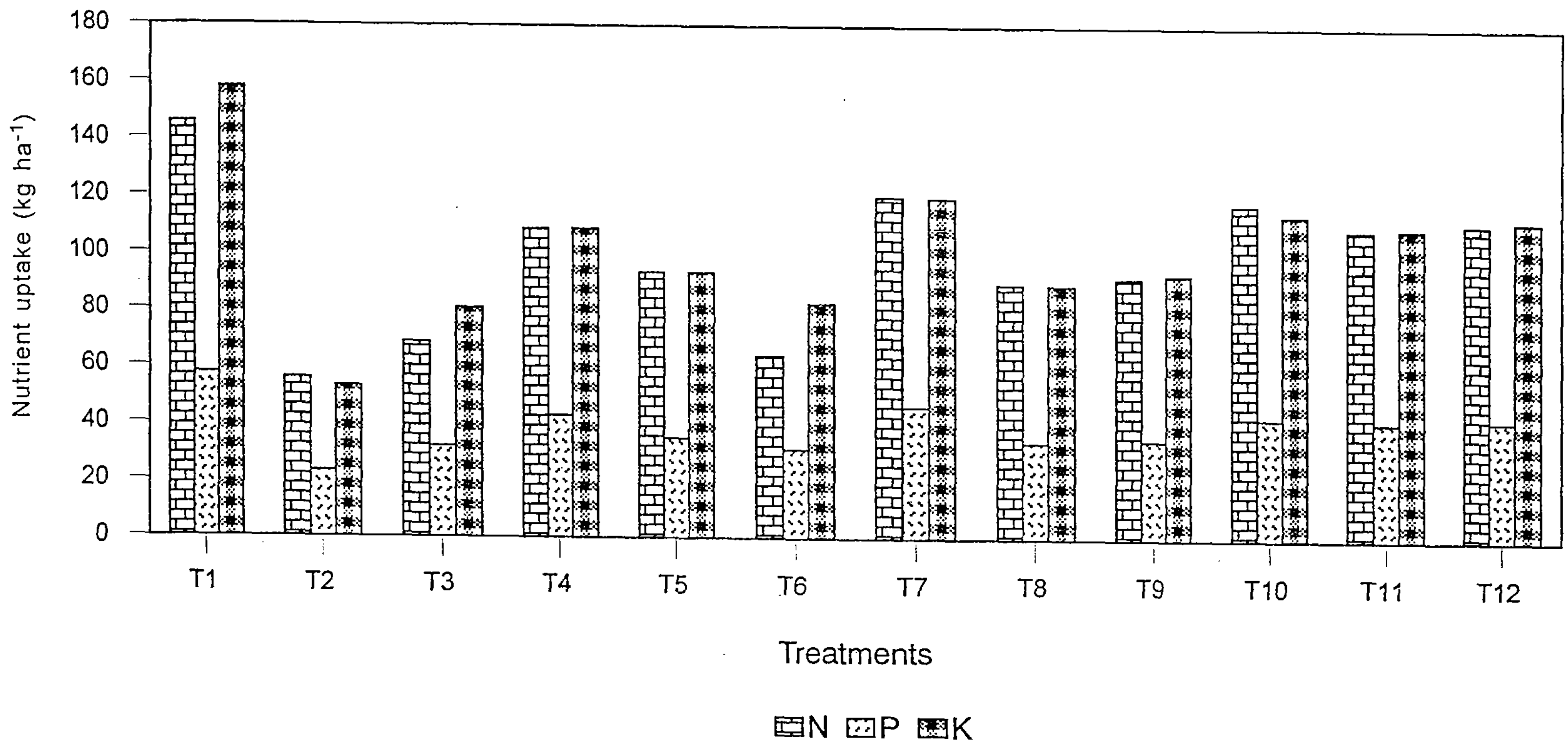


Fig. 5b. Effect of weed management practices on nutrient uptake by rice during first crop season (1997-1998)

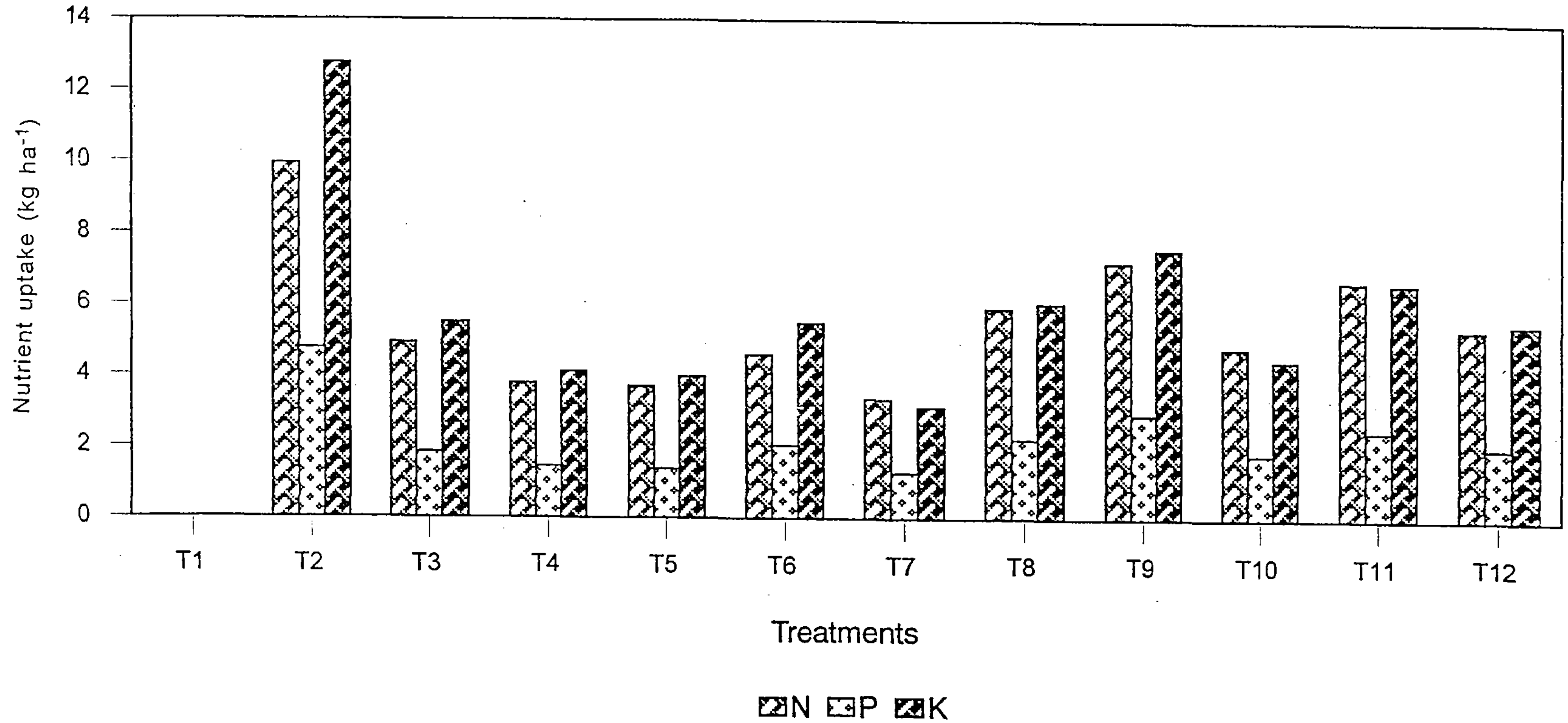


Fig. 6a. Effect of weed management practices on nutrient uptake by weeds during first crop season (1996-1997)

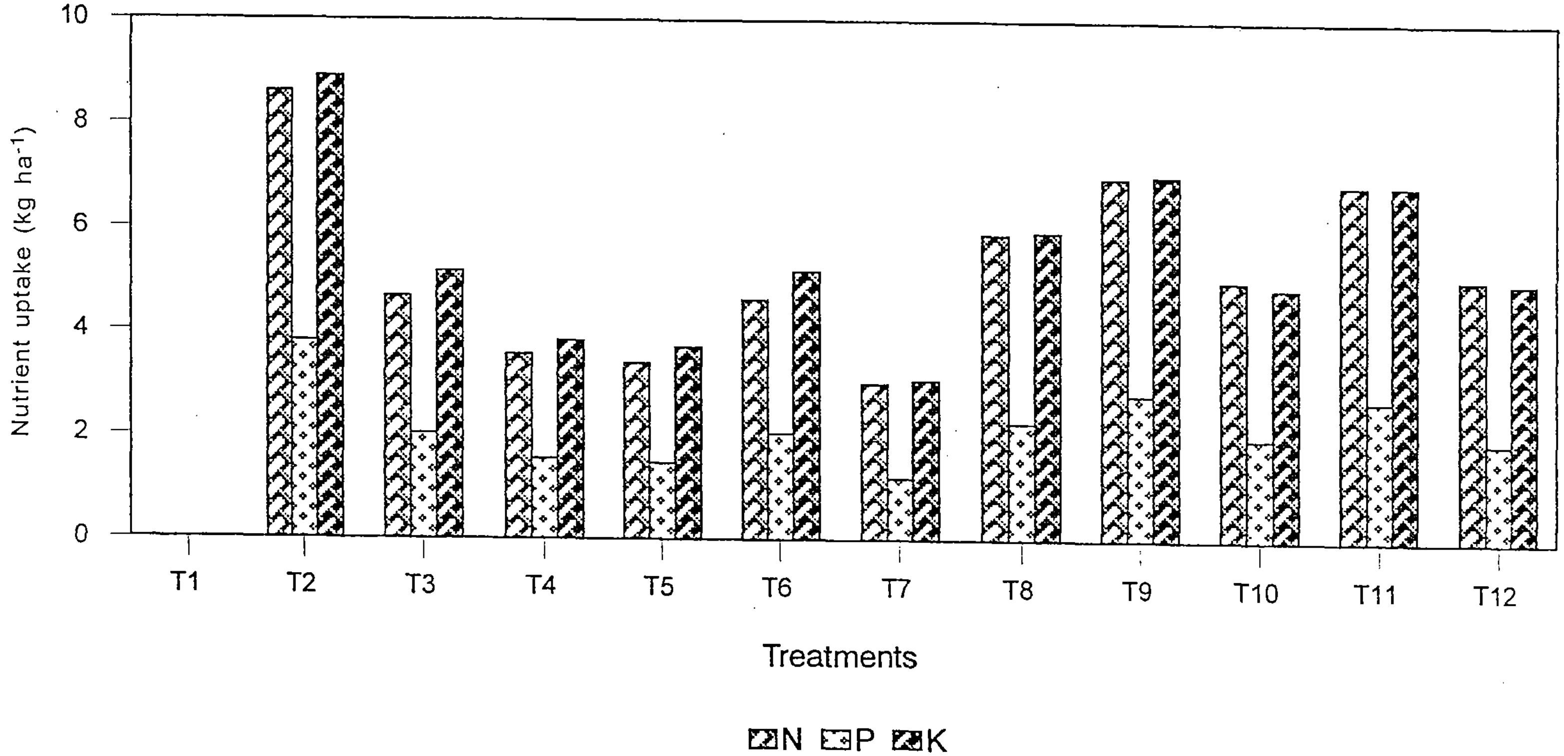


Fig. 6b. Effect of weed management practices on nutrient uptake by weeds during first crop season (1997-1998)

et al. (1999). It is apparent from the results of the study that where the nutrient removal by weeds was more the corresponding uptake of the nutrient by the crop was less and vice versa. Hence for efficient use of applied nutrients for better crop production, the weeds should be kept under control.

5.1.2.4 Nutrient status of the soil after the experiment

The nutrient status of the soil after the experiment showed a marginal decrease in the N, P, K content over the initial status. Among the treatments, the status of N and P was the lowest in completely weed free treatments and the highest in weedy check. Eventhough the K status after the experiment was found to be influenced significantly by the weed control treatments, the result was not conclusive. The unweeded check recorded the highest content of K in the soil. In general the results indicated that effective weed control could have a positive effect on the soil nutrients.

5.1.2.5 Effect of weed control treatments on population dynamics of soil organisms

Results of the study revealed that weed control treatments did not produce significant difference in the microbial population of the soil after the first crop of rice. The result was in supporting with the findings of Mukhopadhyay (1980) who reported adverse effect of herbicides on soil microflora immediately after application but after 15 days, all kinds of soil micro organisms regained their lost population. Similar was the observation of Singh (1990), Kumar and Kandaswamy (1994), Gopalaswamy *et al.* (1994).

5.1.2.6 Economics of weed management

Economic analysis revealed significant difference in the BCR and net profit during the first year only. All the herbicide treatments and farmer's practice recorded higher BCR than unweeded check. From the data it is revealed that integrated method of control *viz.* butachlor pre-emergence followed by one hand weeding or pendimethalin pre-emergence followed by one hand weeding are more remunerative than the farmer's pratice of hand weeding alone. This is in confirmity with the findings of Nanjareddy and Ramanna (1978), Joseph and Bridjit (1993) and Behera *et al.* (1997).

5.2 Second Crop Season

5.2.1 Observations on weeds

5.2.1 Weed spectrum

Weeds belonging to the category grasses, sedges and broad-leaved weeds competed with the rice crop. The prominent weed species observed were *Echinochloa* spp., *Cyperus* spp., *Monochoria vaginalis*, *Fimbristylis miliaceae* and *Marsilea quadrifoliata*.

5.2.1.2 Effect of weed management practices on growth of weeds

The monocot, dicot and total weed counts were studied at four intervals *viz.* 15, 30, 45 DAT and at harvest. The effect of weed mangament practices on weed flora was studied by working out weed index, weed control efficiency and herbicidal efficiency index. The residual effect of treatments applied to the first crop was also studied.

The data revealed significant difference on the monocot, dicot and total weed count at the various growth stages studied. Invariably, the unweeded check (T_2) recorded higher number of weed population. All the herbicide treatments reduced the weed population m^{-2} than the weedy check. Among the herbicide treatments, application of thiobencarb in the early stages and integration of thiobencarb pre-emergence with hand weeding (T_9) exhibited good result. Completely weed free treatment (T_1) was superior as it was kept weed free season long. It may be noted that the dicot weed population was significantly reduced at 30 and 45 DAT and at harvest when the pre-emergent herbicide was combined with 2,4-D post-emergence application. Better weed control through sequential application of pre-emergent herbicide followed by 2,4-D Na salt were reported by Ramiah and Muthukrishnan (1992), Behera and Jena (1998). Similarly significant control of monocot weed population by thiobencarb was reported earlier by Gill and Kolar (1980), Lakshmi (1983) and Soman (1988).

The residual effects of treatments applied to the first crop of rice were significant on weed population counts. Eventhough the data were not conclusive, some of the residual effects of the first crop treatments could markedly reduce the weed counts owing to a better reduction in the weed seed inoculum in the soil. The monocot and dicot weed counts during second crop season were significantly lowered by the carryover effect of pendimethalin pre-emergence alone or in combination with 2,4-D post-emergence treatment applied to the first crop of rice.

The weed index values indicated higher weed growth in the weedy check compared to the herbicide treatments. Among the herbicide treatments integrated method employing pre-emergence application of thiobencarb followed by hand weeding was the best. The data revealed that farmer's practice of hand weeding had a WCE of 52.13 and 50.96 per cent during the first and second year respectively whereas the WCE of herbicide treatments ranged from 60-70 per cent. The lowest weed index, weed number and weed drymatter accumulation in these treatments might have increased the WCE also. Among the herbicides studied, thiobencarb pre-emergence followed by hand weeding (T_9) was the best. Thiobencarb is a non-hormonal herbicide having growth regulating properties similar to hormones which act primarily on the lipid and protein bio-synthesis of affected weeds (Rao, 1983). Higher weed control efficiency of thiobencarb was earlier reported by Balyan (1982), Lakshmi (1983) and that of thiobencarb + hand weeding by Maheswari (1987). Similarly T_9 has recorded the highest herbicide efficiency index during both the years. The results also revealed significant effect of residual treatments on weed control efficiency and herbicide efficiency index during the second crop season. The data were significantly superior in

Tr_4 and Tr_{10} (residual effect of pendimethalin pre-emergence and pendimethalin pre-emergence + 2,4-D post-emergence applied to the first crop of rice).

5.2.1.3 Weed dry matter production and nutrient uptake

Results indicated the significant effect of weed control treatments on the dry weight of weeds at the various stages of the crop. The season long weed free situation as in the case of completely weed free treatment was superior. The unchecked weed growth in the weedy treatment had resulted in higher drymatter accumulation by weeds. The results emphasised the need for herbicide treatments for the weed control in second crop rice. Among the herbicide treatments studied thiobencarb alone or in combination with hand weeding could lower the weed drymatter production significantly at various growth stages. The farmer's practice of hand weeding alone was not sufficient to control the weed drymatter production as it was inferior to the herbicide treatments. Similar observations were made earlier by Lakshmi (1983) and Mohamed Ali and Sankaran (1985). The residual effect of previous crop treatments were significant but the data were not conclusive. In general, the weed dry matter accumulation was significantly lowered due to the carryover effect of previous herbicide treatments.

As discussed earlier uptake of nutrient by weed is the product of dry matter production and nutrient content of weeds. All the herbicide treatments registered lower uptake values compared to weedy check. Next to weed free treatment the N, P, K uptake by weeds was minimum under

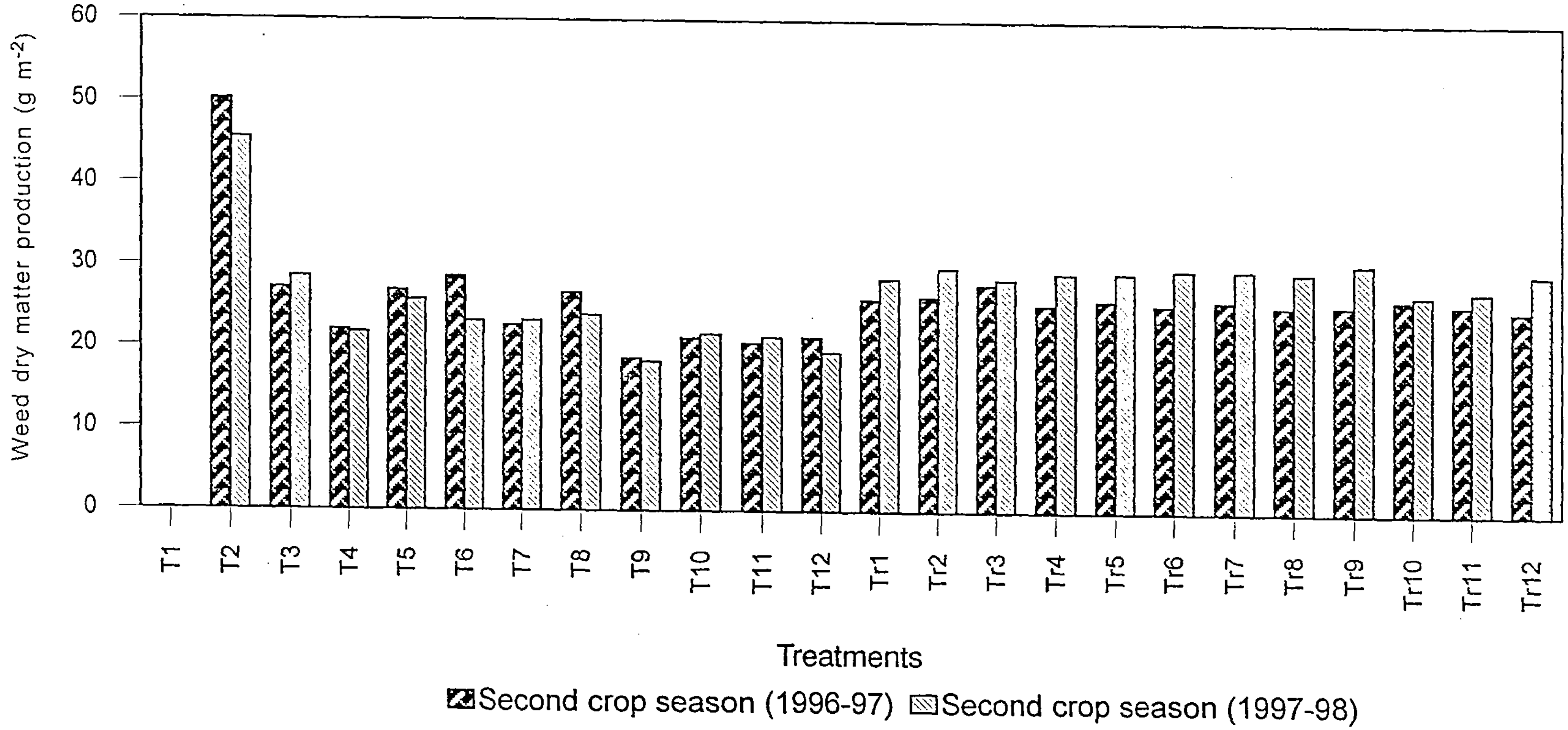


Fig. 7. Effect of weed management practices on weed dry matter production at harvest during second crop season (1996-1997 and 1997-1998)

thiobencarb pre-emergence + hand weeding (T_9). The reduced weed growth and lesser drymatter accumulation by weeds might be the reason for reduced nutrient uptake by weeds in this plots. Significant residual effect on N, P, K uptake by weeds was noted owing to reduced weed dry matter production in such plots. Ramamoorthy *et al.* (1974), Lakshmi (1983) and Soman (1988) have reported lesser nutrient uptake by weeds in herbicide treated plots than the weedy check.

5.2.2 Observation on crop

5.2.2.1 Effect of weed management practices on crop growth characters

The results indicated that the growth characters of rice were significantly influenced by the weed management practices and residual effect of weed control treatments studied.

The completely weed free treatment was superior. The superiority of weed free treatment may be due to the zero competition from weeds. In the weedy check the growth characters were affected adversely. Severe competition from weeds might have led to poor crop growth characters in unweeded check. The herbicide treatments were superior to weedy check and farmer's practice with regard to the growth characters studied. Among the herbicide treatments, T_9 (thiobencarb pre-emergence + hand weeding) was found to be superior as evidenced by better weed control efficiency, lower weed count and weed dry weight which ultimately improved the growth characters of rice crop. On similar lines beneficial effect of weed control treatments on height of rice plant was reported by Gill and Kolar (1980). Ravindran *et al.* (1978) and Sukumari (1982) have reported adverse effect on tiller production due to weed competition in rice. Iruthayaraj and Morachan (1980) reported a decrease in LAI due to weed competition. Lakshmi (1983) and Maheswari (1987) reported an increase in LAI of rice by the application of thiobencarb. The residual effect of previous treatments on growth characters of second crop of rice were significant but the results were not conclusive. Pre-emergence application of oxyfluorfen and pendimethalin integrated with hand weeding or 2,4-D post-emergence application significantly influenced the growth characters at various growth stages of the rice crop.

The results of the present study indicated that the growth indices like CGR and RGR of rice crop were significantly influenced by the weed control treatments. Thiobencarb pre-emergence + hand weeding treatment (T_9) and pretilachlor pre-emergence + hand weeding had significant influence at 15-30 DAT interval. Among the residual effect of previous crop treatments Tr_{12} (oxyfluorfen pre-emergence + 2,4-D post-emergence applied to the first crop) recorded higher CGR values and Tr_7 and Tr_6 (residual effect of pendimethalin pre-emergence + hand weeding and oxyfluorfen pre-emergence alone applied to the first crop of rice) recorded higher RGR values indicating their superiority over other carryover effects.

5.2.2.2 Effect of weed management practices on the yield attributing characters and yield of rice during second crop season

It is obvious from the results that the weed control treatments did have a prominent role in determining the yield of rice. Under

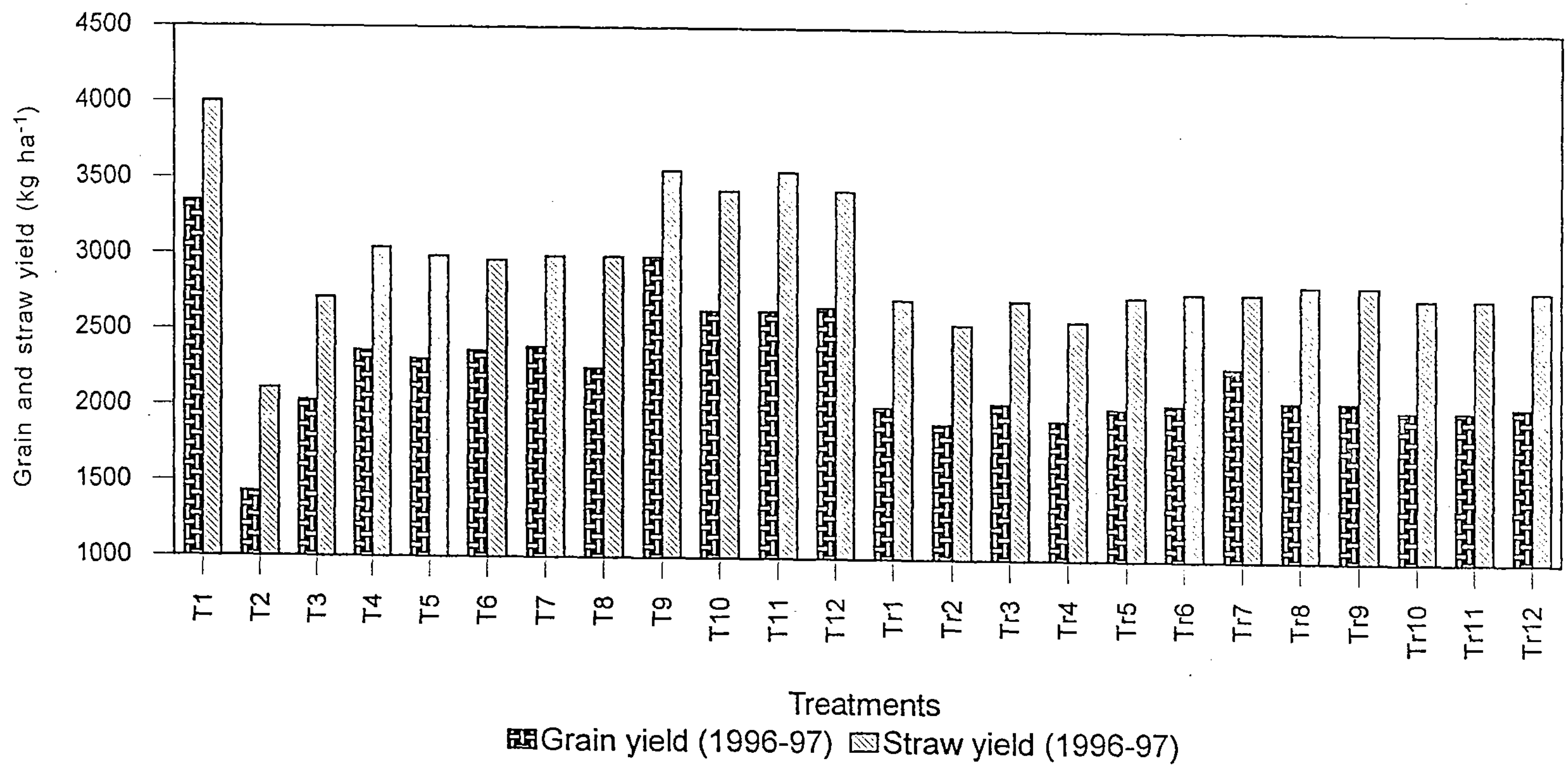


Fig. 8a. Effect of weed control treatments on grain yield and straw yield of rice during second crop season (1996-1997)

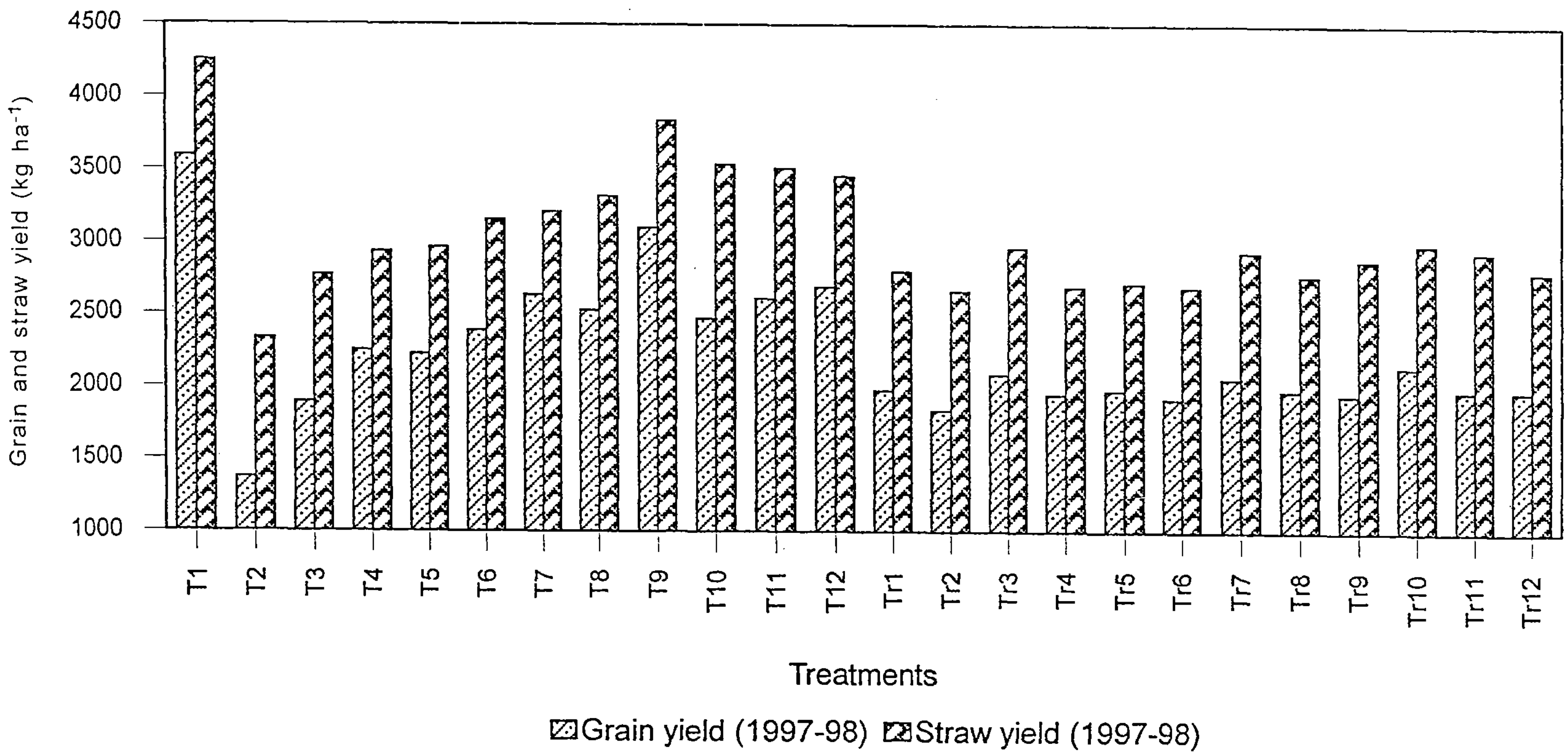


Fig. 8b. Effect of weed control treatments on grain yield and straw yield of rice during second crop season (1997-1998)

completely weed free situation the rice plant produced maximum number of productive tillers, total spikelets panicle^{-1}, percentage of filled grains, grain yield and straw yield. The season long weed free situation in T_1 enabled the crop to absorb more nutrients and better accumulation of photosynthates which might have increased the yield attributing characters and yield of rice. As discussed earlier, severe competition from weeds might be the reason for reduced yield attributes and yield in weedy check and farmer's practice of weeding. All the herbicide treatments were superior over farmer's practice and weedy check, which could largely be attributed to reduced weed index, weed dry weight and better weed control efficiency which ultimately allowed better crop growth interms of plant height, tiller number, yield attributes and yield. Among the herbicide treatments thiobencarb pre-emergence + hand weeding was superior. Reduction in grain yield of rice due to weed competition was reported by several earlier workers such as Ravindran (1976), Sukumari (1982), Rao and Singh (1997). Superiority of thiobencarb in increasing the number of productive tillers was reported earlier by Gill and Kolar (1980). Similarly increased panicle weight due to weed control treatments including herbicide treatments were reported by Sukumari (1982) and Shasidhar (1983). The results of the present study are also in conformity with the findings of Ramamoorthy (1991) and Ramamoorthy *et al.* (1998). The residual effects were not conclusive on the yield and yield attributing characters of rice. Among the significant residual effects Tr_7 (pendimethalin pre-emergence + hand weeding residual effect), Tr_{10} (pendimethalin pre-emergence + 2,4-D post-emergence residual effect) and Tr_9 (oxyfluorfen pre-emergence + hand weeding residual effect) invariably produced increased yield attributing characters and yield.

5.2.2.3 Effect of weed management on drymatter production and nutrient removal by crop

The drymatter accumulation registered under weedy check and hand weeding treatments were higher than the herbicide treatments. The weed control treatments had a significant influence on crop drymatter production on all stages of crop growth. The weed free environment in the completely weed free treatment had enabled the crop to utilise the available nutrients, water and sunlight for maximum production of photosynthates leading to higher drymatter accumulation. The antagonistic effect of weeds on crop dry matter production was earlier reported by workers like Ravindran (1976) and Lakshmi (1983).

The weed free treatment recorded the maximum uptake of N, P and K by the crop and the minimum in the weedy check. The enhanced growth characters in weed free situation contributed to high drymatter production and nutrient uptake being a product of drymatter production and nutrient content, was enhanced under such situations. The results revealed that the uptake of nutrients by second crop rice was increased due to the carryover effect of herbicide treatments applied to the first crop of rice. Carryover effect of pendimethalin pre-emergence integrated with hand weeding or 2,4-D post-emergence and oxyfluorfen pre-emergence + 2,4-D post-emergence exhibited significant carryover effects which increased the nutrient uptake by the crop. It was also evident that with minimum weeds to compete with, and share resources, the uptake of nutrients by the crop was facilitated, resulting in more vigorous growth of crop and better yield.

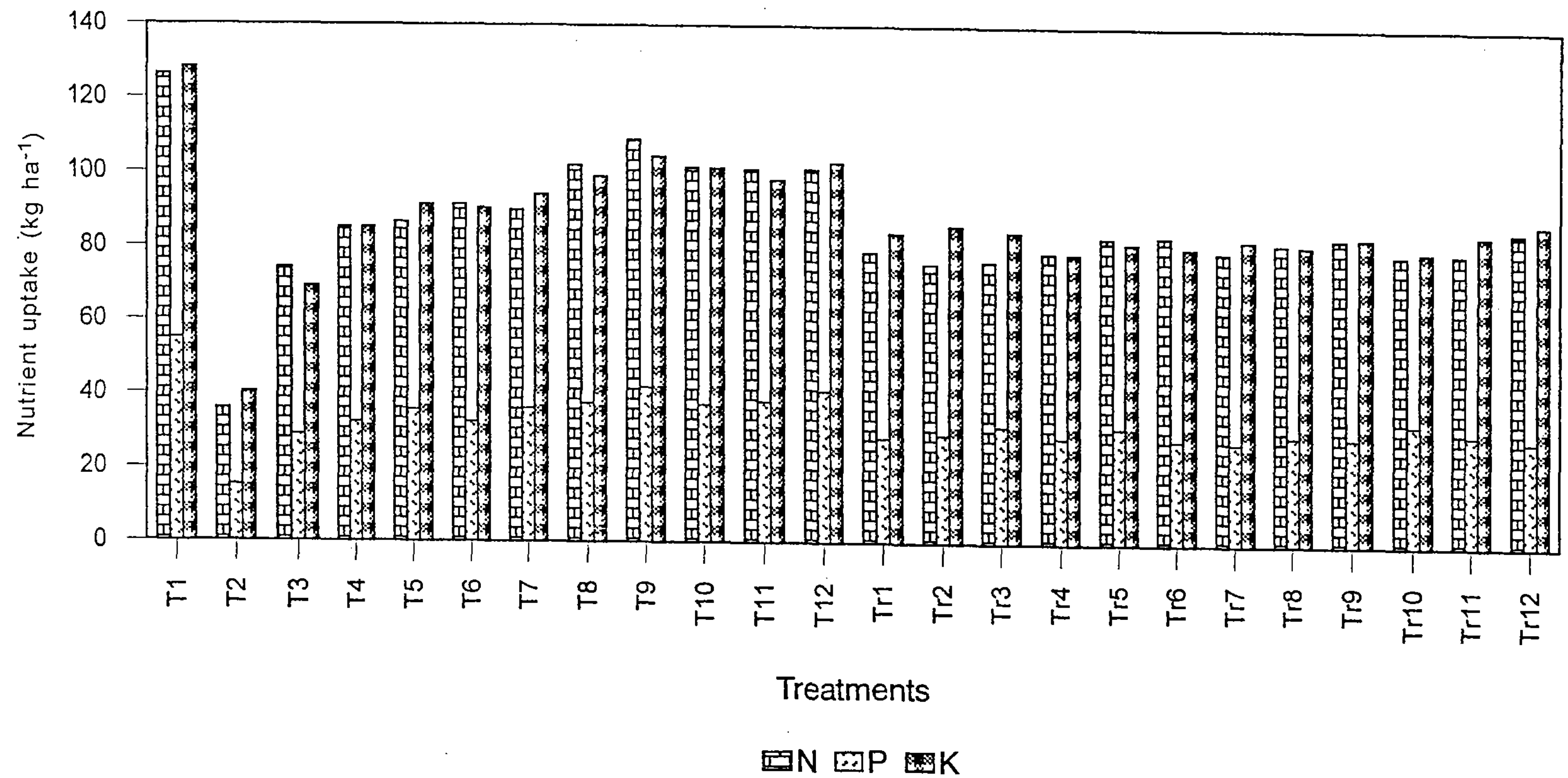


Fig. 9a. Effect of weed management practices on nutrient uptake by rice during second crop season (1996-1997)

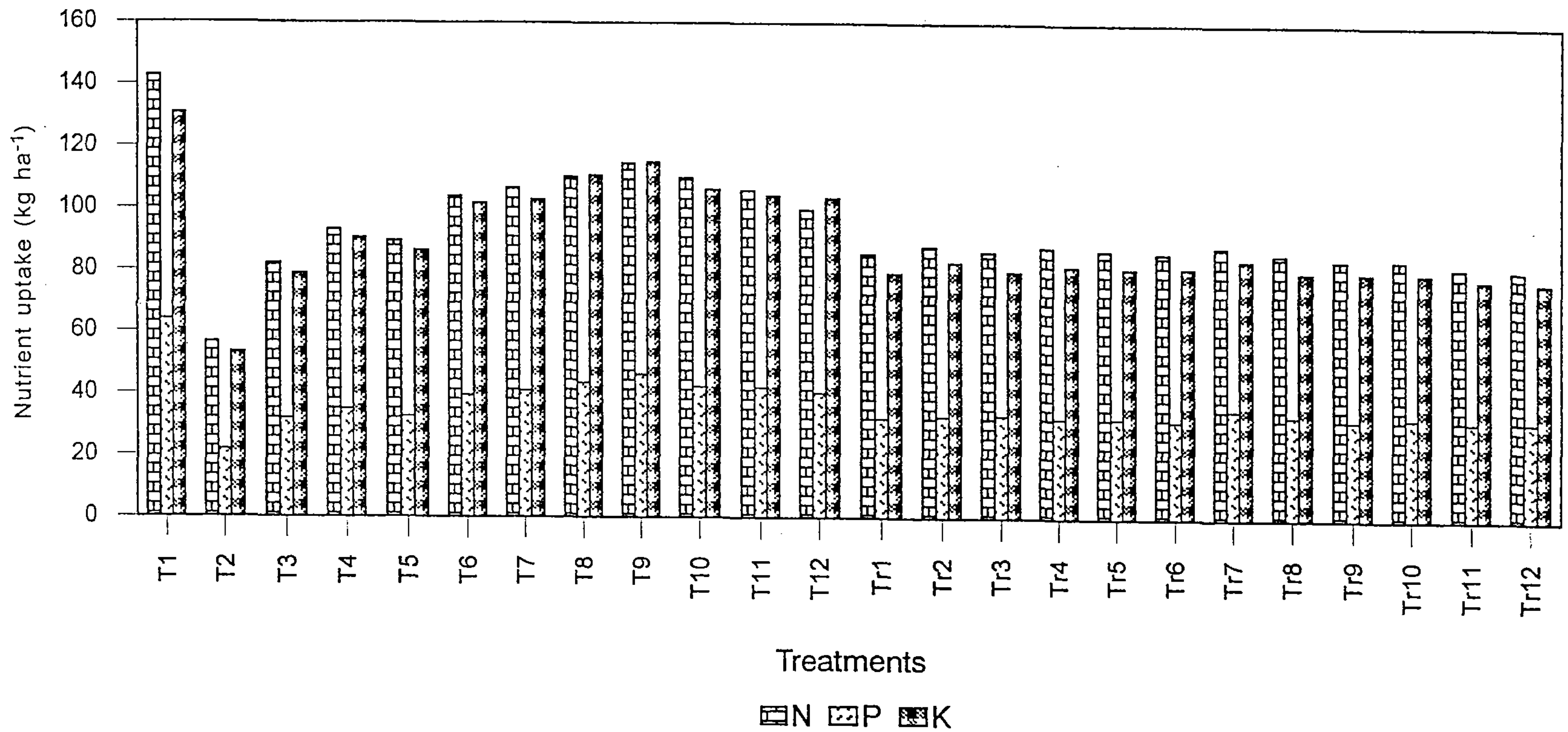


Fig. 9b. Effect of weed management practices on nutrient uptake by rice during second crop season (1997-1998)

5.2.2.4 Nutrient status of the soil after the experiment

The soil nutrient status after the second crop rice indicated maximum contents of available N, P, K under weedy check and minimum under weed free treatment. Higher uptake of the nutrients in the weed free treatment might be the reason for lesser content of the nutrients in soil after the experiment. The results in general indicated that effective weed control could have favourable effect on soil nutrient status. The residual effect of previous crop treatments also highlighted this fact. In general, better weed control reduced the uptake by weed, and thus more nutrients were left in the soil for the crop plants.

5.2.2.5 Effect of weed control treatments on population dynamics of soil organisms

The present study revealed that neither the weed control treatments nor the residual effect of weed control treatments applied to the previous crop had any significant effect on the population dynamics of soil organisms. This was in conformity with the findings of Mukhopadhyay (1980), Kumar and Kandaswamy (1994) who observed that 15-30 days after application of the herbicides, the soil organisms regained their lost population.

5.2.2.6 Economics of weed management

The data indicated that the farmer's practice of weeding and all the herbicides treatments recorded higher BCR than unweeded check. The results of the study revealed that integrated method of weed control viz. thiobencarb pre-emergence + hand weeding and pretilachlor pre-emergence + 2,4-D post emergence were more remunerative than the farmer's practice of weed control. The carry over effect of weed control treatments applied to the first crop of rice were significant. Among the carry over effects that of farmer's practice applied to the first crop recorded higher BCR values which explained why the practice still remains prevalent among the rice farmers. The results also emphasised the need for successful weed control in profitable rice production. Economical benefits of herbicide application over manual weed control have been reported earlier by workers like Rangiah *et al.* (1976), Versteeg and Maldonado (1978) and Lakshmi (1983).

5.3 Third crop season

5.3.1 Observation on weeds

5.3.1.1 Weed spectrum

Observation on weed species revealed that grasses, sedges and broad-leaved weeds competed with the crop. Important grassy weeds observed were *Dactyloctenium aegyptium*, *Elusine indica* and *Digitaria sanguinalis*. The broad-leaved weeds of predominent occurrance were *Cleome viscosa*, *Amaranthus viridis*, *Phyllanthus niruri*, *Biophytum sensitivum* and *Spermacoce latifolia*. *Cyperus rotundus* was the predominent sedge weed. The weeds infesting sesamum crop during third crop season was also reported by Reena (1997).

5.3.1.2 Effect of weed management practices on growth of weeds

In the study, monocot, dicot and total weed count were studied at 30 and 60 DAS and at harvest. The residual effect of weed control treatments applied during the first and second crop seasons on the weed flora during third crop season was studied.

The monocot weed count data recorded at 30 and 60 DAS and at harvest revealed significant variation due to the residual effect of herbicides. The monocot weed population differed significantly in the cumulative residual effect of first and second crop treatments compared to the residual effect of first crop treatments alone. Among the residual effects of treatments, carryover effect of completely weedfree treatment applied to the previous crops were significant and recorded the lowest monocot weed count. The carryover effect of weedy check resulted in higher number of monocot weeds. The carryover effect of other herbicide treatments were significant but the result was inconsistent. Similarly the data revealed that the residual effect of first crop treatments were statistically at par at different growth stages of the crop. In general the monocot weed population was highest in plots having the residual effect of first crop treatments compared to the plots having first and second crop treatment residual effect. The dicot and total weed population was also significantly influenced by the residual effect of previous treatments. The herbicides proved effcient as evidenced by the carryover effects during third crop seasons. Application of pendimethalin, oxyfluorfen and 2,4-D during first crop season had resulted in low weed growth during third crop season. Among the residual effects carryover effects of weedy checks of the two seasons recorded highest number of weeds during both years. From the results it is seen that the weed growth during third crop season is controlled to some extent by the weed control methods practiced in the previous first and second crop of rice. Previous weed control treatments registered substantial control over weed population which might be primarily due to the destruction of immense weed seed inoculam that was present in the soil, thereby allowing reduced weed growth in subsequent crop. In similar lines Klingman *et al.* (1982) reported that crop rotation with related herbicide rotation could effectively hold back hard to control weeds. Lowest count and drymatter of weed species in greengram and other succeeding crops in rice based cropping system was earlier reported by Pawan and Gill (1981), Srinivasan and Pothiraj (1990).

5.3.1.3 Weed drymatter production and nutrient uptake

Results of the study indicated that the dry matter accumulation by weeds was significant at various growth stages of the crop studied. The carryover effect of weedy check of the previous crops (FTr_2) had recorded maximum dry matter accumulation by weeds and the minimum under carry over effect of weed free treatment (FTr_1) applied to the previous rice crops. The herbicide treatments applied to the previous crops of rice had resulted in reduced weed drymatter production at 60 DAS and at harvest. Eventhough the residual effects of previous crop treatments were found to be significant the data were inconsistent. This might be due to the uniform weed management practiced in sesamum during third crop season. The uptake of nutrients N, P, K by weeds was significantly influenced by the residual effect of weed control

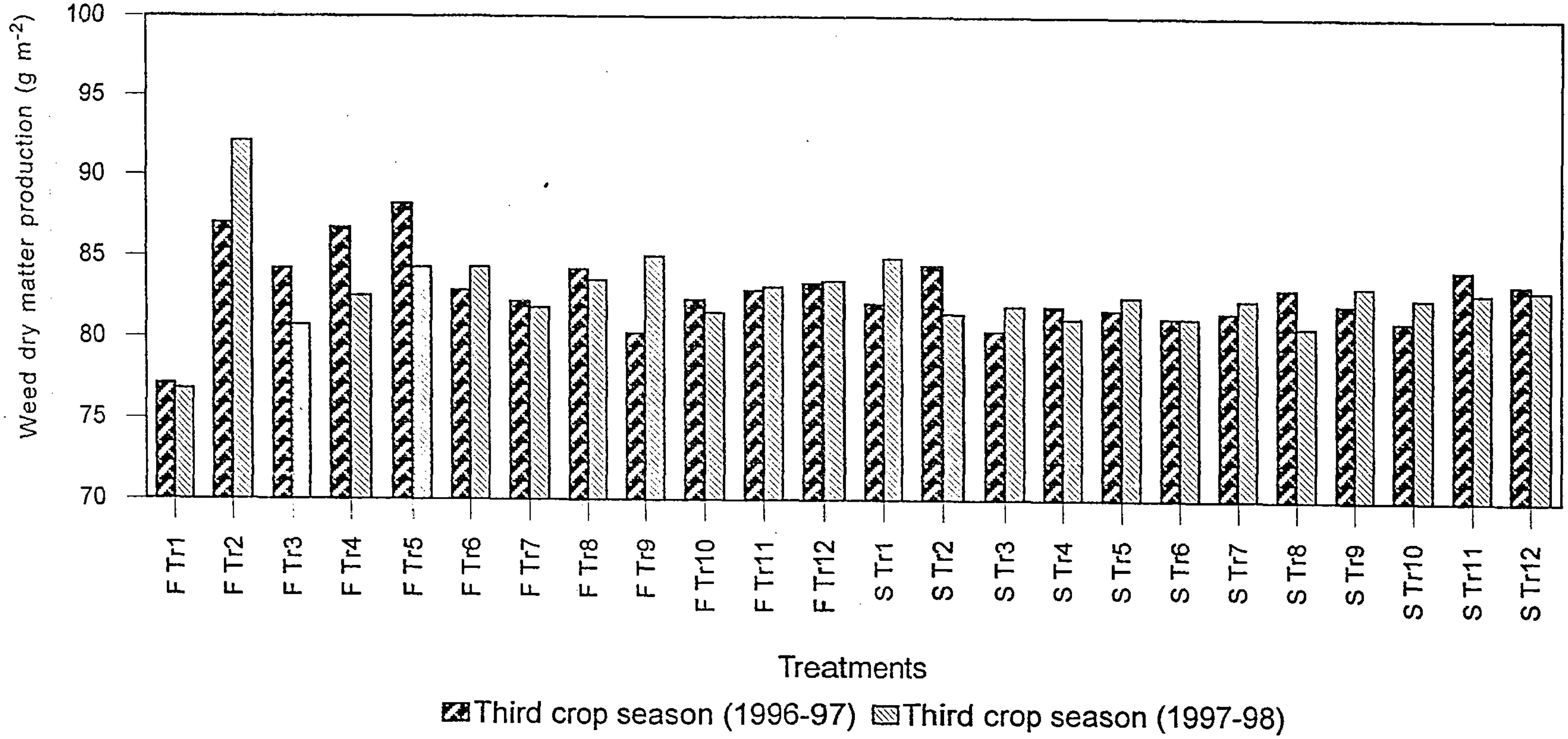


Fig. 10. Residual effect of weed management practices on weed dry matter production at harvest during third crop season (1996-1997 and 1997-1998)

treatments continuously applied to the previous crops of rice. Herbicide treatments applied to the first and second crop of rice had significant carryover effect on uptake of nutrients by weeds during third crop season. With regard to N uptake, pendimethalin + hand weeding applied to the first and second crop of rice and oxyfluorfen integrated with hand weeding applied to the first crop of rice and thiobencarb integrated with hand weeding during second crop of rice had significantly reduced the N uptake by weeds. The carryover effect from sequential application of butachlor pre-emergence + hand weeding to the first crop of rice and pretilachlor pre-emergence + hand weeding to the second crop of rice and pendimethalin pre-emergence + hand weeding applied to the first and second crop of rice significantly reduced the P uptake by weeds. K uptake was significantly low in plots which were kept weed free during the previous crops.

5.3.2 Observation on crop

5.3.2.1 Effect of weed management practices on crop growth characters

The results of the present study revealed that the growth characters of sesamum was not influenced significantly by the residual effect of weed control treatments applied to the previous crops of rice. However observation on number of branches plant^{-1} at the stage of harvest of the crop, residual effect of the first crop treatment were found to be superior but the data did not give any conclusive result on this aspect. This may be due to the fact that number of branches is a varietal character and the different weed control measures adopted in the cropping system might

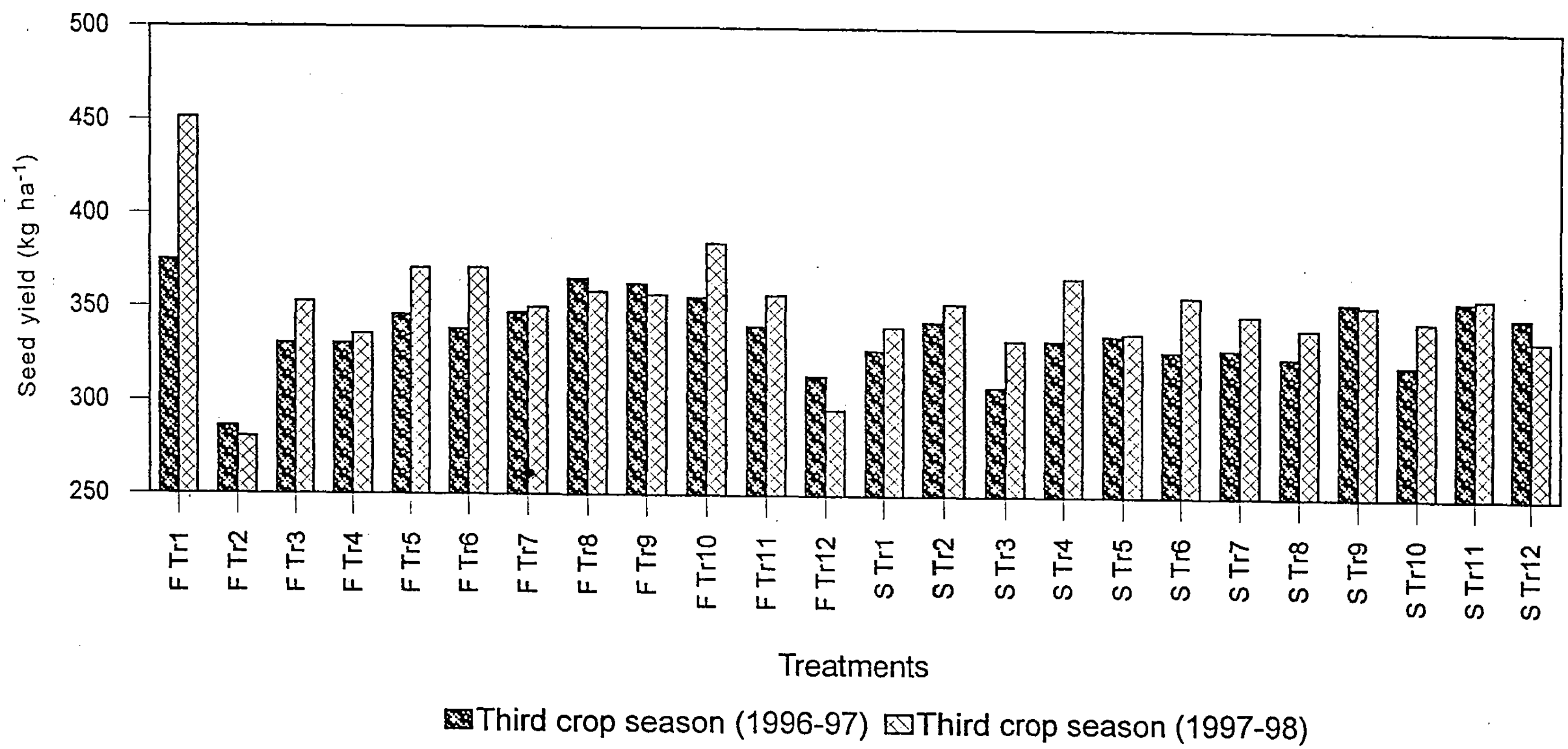


Fig. 11. Residual effect of weed management practices on seed yield of sesamum during third crop season (1996-1997 and 1997-1998)

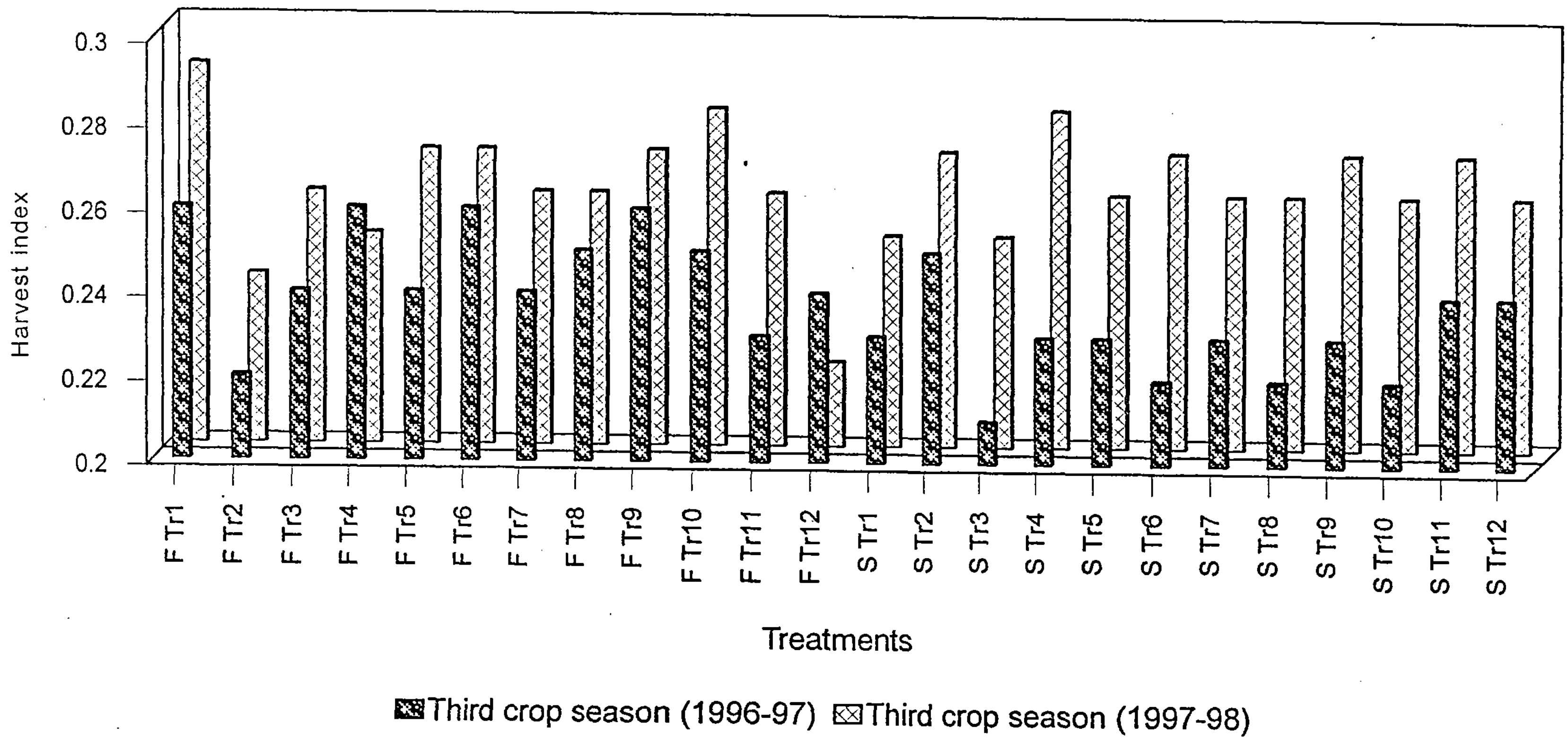


Fig. 12. Residual effect of weed management practices on harvest index of sesamum during third crop season (1996-1997 and 1997-1998)

have added to that effect. The overall inference from the result is that the weed control treatments practiced during the first and second crop season had not influenced the growth characters and yield of crop. The data indicated significant influence of residual effect of previous treatments on the number of days to 50 per cent flowering. However the data were inconsistent. Flowering is an important physiological stage of a crop and serves as an index of maturity. The carryover effect of first and second crop weed control treatments during the third crop season might have helped the plants to absorb more nutrients and complete the vegetative phase at faster rate. The carryover effect of rice treatments on succeeding ground nut crop was earlier reported by Pannu *et al* (1989) and Rajendran and Kempuchetty (1999).

5.3.2.2. Effect of weed management practices on the yield attributing characters and yield of sesamum

The results revealed that residual effect of weed control treatments applied to the first and second crop of rice had no significant influence on the yield attributing characters and yield of sesamum during the third crop season. Similarly the harvest index was also not influenced by the residual effect of previous weed control treatments.

5.3.2.3 Effect of weed management on drymatter production and nutrient removal by crop

From the results it is seen that the dry matter accumulation by crop was not significantly influenced by the residual effect of weed control treatments from the first crop at 30 DAS. The drymatter accumulation was significant at 60 DAS during the first year of experimentation. The drymatter accumulation was found to be maximum in plots having the residual effect of completely weed free treatment from the first and second crop season. The season long weed free treatment maintained during first and second crop season had supported the crop growth during the summer season also. The continuous weeding operation done in the first and second crop of rice in the cropping system might have considerably reduced the weed inoculum in the soil. This might have favoured better nutrient uptake and photosynthate accumulation by the crop during the third crop season. Such increase in drymatter production due to previous weed control treatments were reported earlier by Pannu *et al* (1989).

Appraisal of the data on nutrient uptake by crop revealed no significant variation in the case of N. The results on uptake of P and K by the crop were inconsistant. In general uptake of P by the crop was higher in treatments where there was significantly higher crop drymatter production. The carryover effect of herbicides applied to the previous crop might have caused appreciable decrease in the nutrient depletion by weeds as a consequence of which considerable improvement in the nutrient uptake of the crop occured. Similar increase in nutrient uptake by crop because of reduced weed competition was earlier reported by Maurya *et al.* (1990) and Chhokar *et al.* (1997).

5.3.2.4 Nutrient status of the soil after the experiment

The results showed that the N, P and K content of the soil after the experiment were influenced by residual effect of weed control

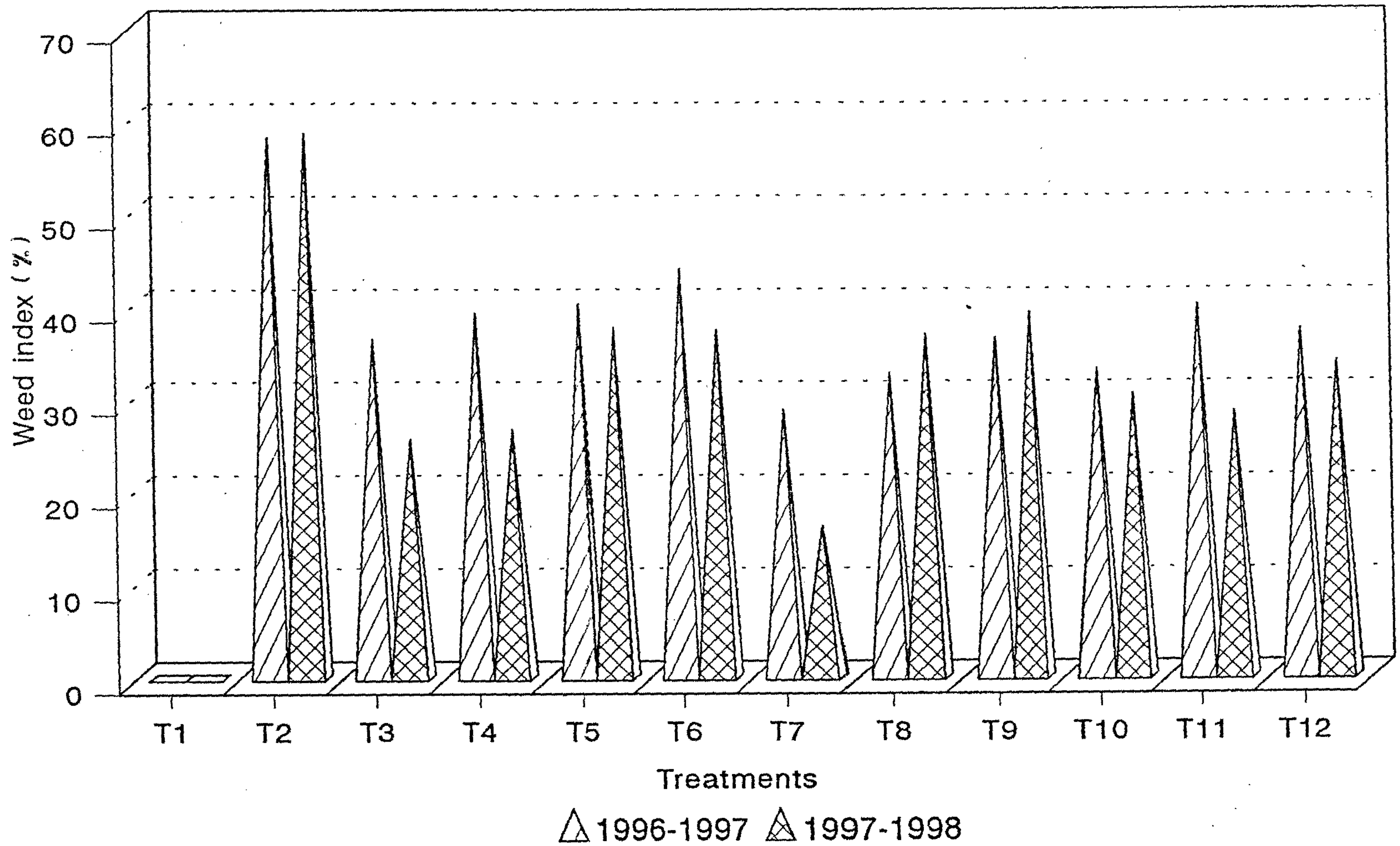


Fig. 13. Effect of weed control treatments on weed index during first crop season

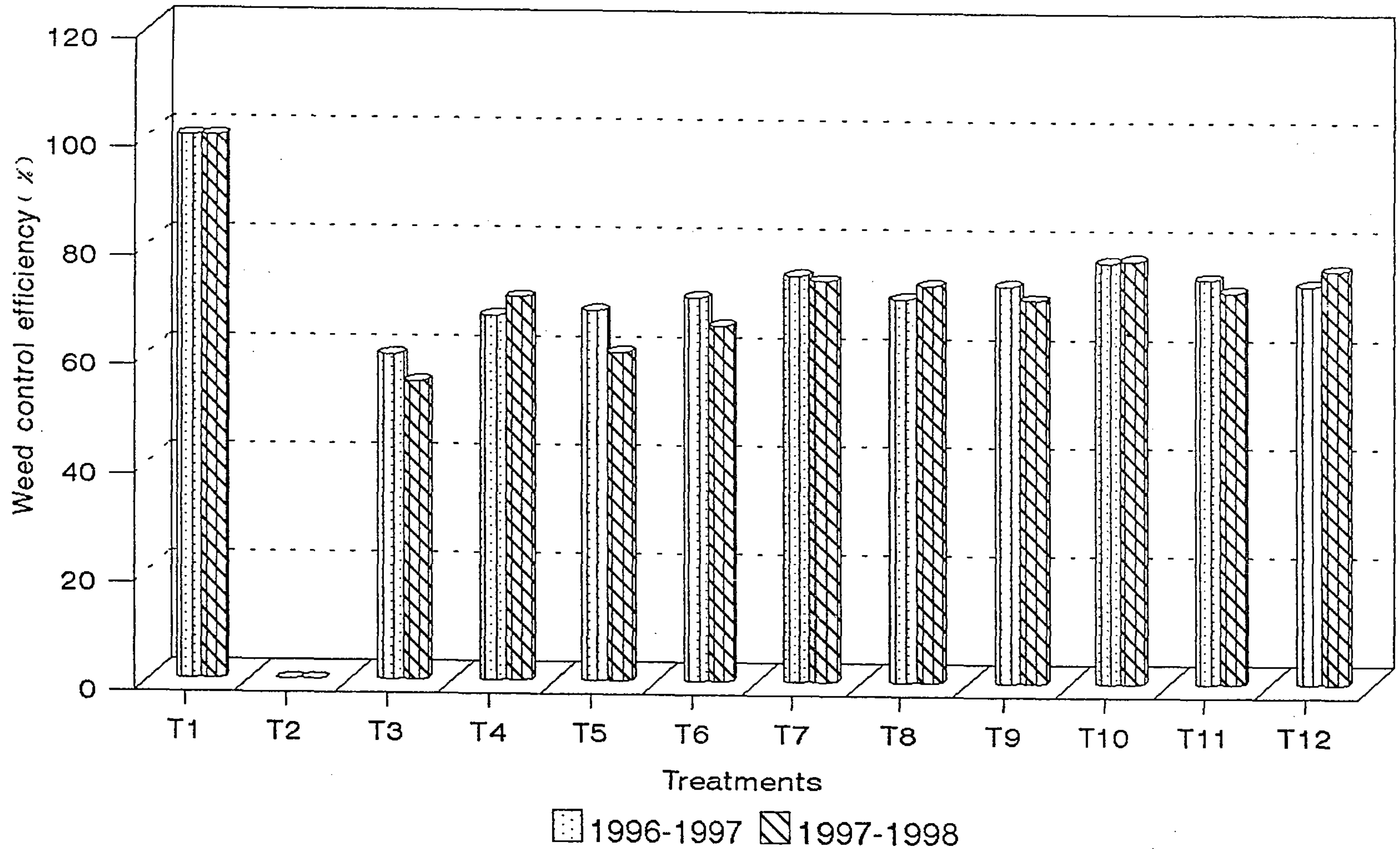


Fig. 14. Effect of weed control treatments on weed control efficiency during first crop season

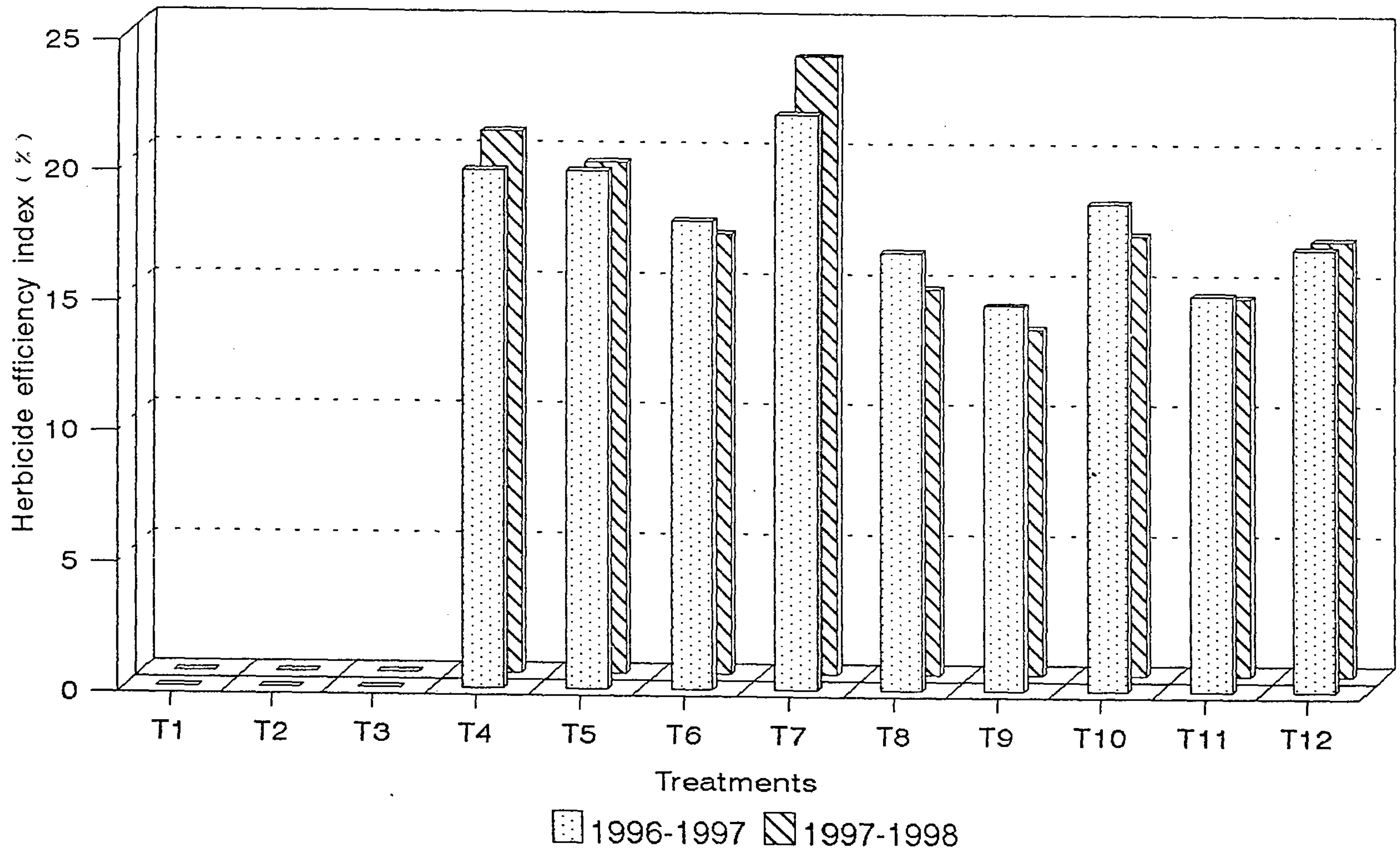


Fig. 15. Effect of weed control treatments on herbicide efficiency index during first crop season

treatments. The lowest nutrient contents after the experiment were noted with the carryover effects of weed free treatments of first and second crop of rice and higher content of the nutrients under residual effect of weedy check. Eventhough phosphorous content was significantly influenced by the residual effect of previous weed control treatments, the results were inconsistent. The available potassium content was also the lowest under the treatment having the residual effect of weed free treatment. Better weed management due to the carryover effect of weed control treatments might have reduced the weed uptake of the nutrient, thus more nutrients were left in the soil for crop plants.

5.3.2.5 Effect of weed control treatments on population dynamics of soil organism

The results revealed that the population of soil micro organisms was not influenced significantly by the residual effect of weed control treatments applied to the previous crop. The results are in conformity with the findings of Singh (1990), Kumar and Kandaswamy (1994).

5.3.2.6 Economics of weed management

The results revealed no significant difference in the BCR and net profit analysis due to the residual effect of weed control treatments applied to the first and second crop of rice.

5.4 Herbicide residues in the soil

In the present study, the persistance of the herbicides pendimethalin, butachlor, oxyfluorfen, thiobencarb, pretilachlor and

2,4-D in soil was studied by observing the germination and early growth of an indicator plant cucumber in soil samples collected from the plots after the experiment. The results were found comparable with that of untreated control. Presumably all the herbicides had degraded bearing little toxic residues in the soil. The result indicated that the herbicides such as pendimethalin, butachlor, pretilachlor, thiobencarb, oxyfluorfen and 2,4-D applied to rice crop can have no adverse effect on the succeeding crops in the cropping system. This is in conformity with the reports of Balyan *et al.* (1981) and Soman (1988).

SUMMARY

6. SUMMARY

A field experiment entitled "Integrated weed management for rice based cropping system of Onattukara tract" was undertaken at the Rice Research Station, Kayamkulam starting from the first crop season of 1996 for a period of two years. The objectives of the study were to find out an effective integrated weed management technology for rice-rice-sesamum cropping sequence of Onattukara tract, to study the effect of different weed control methods on the growth and presistance of weed flora infesting rice and sesamum, to assess the effect of weed control treatments on the growth and yield of crops in the cropping system, to study the persistance and residual effect of herbicides and to workout the economics of different weed management practices.

The salient results of the experiment are summerised below.

The predominant weeds that infested the experimental field were *Echinochloa crusgalli, Echinochloa colonum, Brachiaria ramosa* among the grasses, *Ammania baccifera, Ludwigia parviflora* and *Marsilea quadrifoliata* among the broad leaved weeds and *Cyperus rotundus, Cyperus iria, Cyperus difformis* and *Fimbristylis miliacea* among the sedges during the first crop season. The predominent species during the second season were *Echinochloa colonum, Echinochloa crusgalli* among grasses, *Monochoria vaginalis, Marsilea quadrifoliata* among broad leaves weeds and *Cyperus* spp. among sedges.

Major weed flora infested the experimental field during third crop season were *Dactyloctenium aegyptium, Elusine indica* and *Digitaria sanguinalis* among grasses, broad leaved weeds such as *Cleome viscosa, Amaranthus viridis, Phyllanthus niruri, Biophytum sensitivum* and sedges like *Cyperus rotundus.*

Unweeded control registered maximum weed growth throughout the growth period of rice and sesamum in rice-rice-sesamum cropping system.

Monocot weeds constituted the major portion of the weed population throughout the rice-rice-sesamum cropping system. The use of herbicides was effective than the farmer's practice of hand weeding.

Pendimethalin pre-emergence + hand weeding or pendimethalin pre-emergence + 2,4-D post emergence controlled monocot weed better than other treatments during first crop season. In the second crop of rice thiobencarb + handweeding was better than the other herbicide treatments in suppressing the monocot weed population.

The carryover effect of pendimethalin pre-emergence applied to the first and second crop of rice and oxyfluorfen pre-emergence to the first crop and thiobencarb pre-emergence to the second crop of rice controlled monocot weeds in sesamum during the third crop season.

Herbicide application was better than the cultural method in suppressing the dicot weed population. Pre-emergence application of herbicides pendimethalin and oxyfluorfen integrated with 2,4-D post emergence application suppressed dicot weeds during first crop season in rice whereas thiobencarb pre-emergence integrated with hand weeding controlled dicot weeds better than other herbicides during second crop season. The carry over effect of oxyfluorfen pre-emergence + 2,4-D post emergence from first crop rice controlled dicot weeds during second crop season. Pendimethalin treatments applied to the first and second crop of rice had significantly reduced the dicot weed population in third crop season.

The total weed population was suppressed by pendimethalin pre-emergence + 2,4-D post emergence during first crop season whereas thiobencarb pre-emergence + hand weeding was better during second crop season. The total weed count was reduced during second crop season due to the interaction of integrated weed control measures and their residual effects from previous crop.

The total weed count in sesamum was the lowest due to the carryover effect of weed free treatment of the first and second crop of rice. Sequential application of pendimethalin pre-emergence to the first and second crop of rice, butachlor pre-emergence to the first crop and pretilachlor pre-emergence to the second crop reduced the total weed count during third crop season. The hand weeding treatments integrated with herbicides exhibited significant carryover effects and suppressed the total weed count during third crop season.

Pendimethalin pre-emergence + hand weeding (T_7) supressed the dry matter accumulation of weeds in the first crop of rice. Thiobencarb + hand weeding, pretilachlor pre-emergence + 2,4-D post emergence or thiobencarb pre-emergence + 2,4-D post emergence controlled total weed population in the second crop of rice. The herbicide treatments applied to the previous first and second crops of rice had reduced the weed dry matter production in sesamum during third crop season.

The weed control efficiency of pendimethalin pre-emergence + 2,4-D post emergence and thiobencarb pre-emergence + hand weeding was higher than that of other integrated method during first and second crops respectively.

The herbicide efficiency index of pendimethalin and thiobencarb was enhanced when integrated with hand weeding during first and second crop seasons respectively.

The plant height, number of tillers and leaf area index of rice during first crop season were higher in plots treated with pendimethalin pre-emergence + hand weeding or its integration with 2,4-D post emergence. The integrated weed management method showed significant difference in the growth characters of rice during second crop season and thiobencarb pre-emergence + hand weeding recorded maximum growth characters.

The residual effect of weed control treatments applied to the first and second crop of rice had no carry over effect on the growth characters of sesamum during third crop season.

The pendimethalin treatments helped in increasing the dry matter accumulation of rice during first crop season and thiobencarb pre-emergence + hand weeding treatment increased the dry matter accumulation by rice crop during second crop season. The carryover effect of weed free treatment applied to the first and second crop of rice and pendimethalin pre-emergence + 2,4-D post emergence applied to the first and second crop of rice recorded maximum dry matter accumulation in sesamum during third crop season. The residual effect of treatments applied to the first crop alone was not significant on the dry matter accummulation in sesamum crop.

The yield attributing characters of rice were significantly influenced by the weed management practices. Pendimethalin pre-emergence + hand weeding had recorded the maximum number of productive tillers, total spikelets, percentage of filled grains and grain yield during first crop season. In the second crop of rice thiobencarb pre-emergence + hand weeding recorded maximum number of productive tillers, weight of panicle, number of filled grains, percentage of filled grains and grain yield. The first crop residual effects were at par.

The carry over effect of weed control treatments applied to the first and second crop of rice had no significant influence on the number of capsules, seed yield and harvest index of sesamum during third crop season.

The yield loss due to weeds indicated by the weed indices was maximum under weedy check. Next to weed free, the yield loss was minimum under pendimethalin pre-emergence + hand weeding and thiobencarb pre-emergence + hand weeding applied to first and second crop of rice in the rice-rice-sesamum cropping system.

Maximum uptake of N, P and K by the crop was recorded with weed free treatments while weedy check had the lowest uptake during first and second crop seasons respectively. The N uptake by sesamum was not influenced by the carry-over effect of weed control treatments applied to the first and second crop of rice.

The carryover effect of weed free treatment applied to the previous first and second crop of rice (FTr_1) recorded maximum P uptake by sesamum during third crop season. Among the residual effect of first crop treatments oxyfluorfen pre-emergence + hand weeding (STr_9) recorded higher P uptake during third crop season.

The carry over effect of completely weed free treatment of the first and second crop season recorded maximum uptake of K by sesamum and among the residual effect of first crop treatments oxyfluorfen pre-emergence + hand weeding recorded higher K uptake by sesamum during third crop season.

Unchecked weed growth exploited the available nutrients and water resulting in better growth and dry matter production throughout the cropping system.

Application of pendimethalin pre-emergence + hand weeding to the first crop of rice and thiobencarb pre-emergence + hand weeding to the second crop of rice had significantly reduced the N, P, K uptake by weeds during the first and second crop season respectively. The N, P, K uptake by weeds during third crop season was significantly reduced due to the carryover effect of pendimethalin pre-emergence + hand weeding applied to the first and second crop of rice.

There was no significant influence on the population dynamics of soil organisms due to the weed management practices included in the study.

Bioassay studies indicated that there was no significant residual effect of the herbicides on the germination and dry matter accumulation of indicator plant cucumber.

The results revealed higher BCR and net profit for herbicide treatments and farmer's practice of hand weeding compared to unweeded check. Integrated weed management practices are more remunerative than the farmer's practice of hand weeding alone in rice crop.

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* Original not seen.

APPENDIX

Appendix - 1

Weather parameters during the cropping period
(April 1996 – May 1998)

Month	Rainfall (mm)	Temperature (°C) Maximum	Temperature (°C) Minimum	Relative Humidity (%)
Apr.'96	86.4	33.4	24.4	73.8
May'96	252.3	32.5	24.1	76.7
Jun.'96	568.3	25.8	23.1	83.6
Jul.'96	452.6	30.3	22.8	83.8
Aug.'96	235.3	31.2	22.8	82.5
Sep.'96	432.2	32.1	22.5	78.9
Oct.'96	265.6	31.3	22.6	79.2
Nov.'96	135.8	31.2	21.9	78.6
Dec.'96	258.5	33.8	21.4	73.4
Jan.'97	11.2	31.6	21.1	70.5
Feb.'97	12.1	32.5	22.2	71.2
Mar.'97	24.6	31.0	23.6	72.2
Apr.'97	85.7	33.2	24.6	72.9
May'97	264.5	32.6	24.3	75.9
Jun.'97	572.4	26.9	23.6	83.4
Jul.'97	448.5	30.5	23.4	83.4
Aug.'97	232.1	31.3	22.9	82.8
Sep.'97	438.2	31.6	22.8	78.3
Oct.'97	268.4	31.3	22.8	79.6
Nov.'97	132.7	31.4	21.6	79.2
Dec.'97	33.1	33.6	21.6	73.1
Jan.'98	8.4	31.5	21.3	71.2
Feb.'98	9.2	32.8	22.4	70.5
Mar.'98	16.1	31.3	23.7	72.4
Apr.'98	68.4	33.1	24.0	73.6
May.'98	258.2	32.4	24.2	76.8

Appendix - II

Mean monthly weather data for the past 10 years (1986 to 1995)

Month	Rainfall (mm)	Temperature (^{o}C)		Relative Humidity (%)
		Maximum	Minimum	
January	10.9	31.7	20.1	70.80
February	13.4	32.5	22.2	70.50
March	34.8	31.1	23.4	72.15
April	103.5	33.1	24.4	73.96
May	292.4	32.6	24.3	76.82
June	565.3	26.9	23.1	83.50
July	447.3	30.2	22.9	83.62
August	230.4	29.7	22.6	82.50
September	435.2	30.9	22.3	78.80
October	272.4	31.1	22.3	79.52
November	130.4	31.0	21.5	78.40
December	33.8	29.1	21.3	72.30

INTEGRATED WEED MANAGEMENT FOR RICE BASED CROPPING SYSTEM OF ONATTUKARA TRACT

BY

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ABSTRACT OF THE THESIS
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VELLAYANI, THIRUVANANTHAPURAM

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ABSTRACT

Field experiments were conducted at Rice Research Station, Kayamkulam from April 1996 to May 1998 to study the effect of integrated weed management practices for rice-rice-sesamum cropping system of Onattukara tract. The experiment was laid out in randomised block design with twelve treatments during the first crop season and in split plot randomised block design with twelve treatments and twelve residual effects during second crop season and with twenty four residual effects during the third crop season. Rice varieties Bhagya and Dhanya and sesamum variety Thilak were used for the study during the first, second and third crop seasons respectively.

Results of the study revealed that grasses, broad leaved weeds and sedges competed with the crop plants in the rice-rice-sesamum cropping system. The herbicide treatments significantly reduced the monocot, dicot and total weed population in the cropping system. Pendimethalin pre-emergence application alone or integrated with hand weeding/2,4-D post emergence significantly reduced the weed growth during the first crop season whereas thiobencarb pre-emergence + hand weeding reduced the weed growth in the second crop of rice. The weed count and dry matter accumulation by weeds in the sesamum crop during the third crop season was significantly reduced by the carry over effect of herbicide

treatments applied both to first and second crop rice compared to the carry over effect of herbicide treatments applied to first crop rice alone.

The herbicide treatments significantly influenced the growth and yield attributing characters of the first and second crop of rice. The residual effects of previous weed control treatments on the growth and yield of sesamum was not significant. Pendimethalin pre-emergence + hand weeding or its integration with 2,4-D post emergence influenced the growth characters of first crop of rice, thiobencarb pre-emergence + hand weeding found to exert considerable influence on the growth and yield of second crop of rice. Weedy check recorded the lowest yield and under weed free situation the crop plants had registered maximum growth and yield. The yield loss due to weed indicated by the weed indices was maximum under weedy check and minimum for pendimethalin pre-emergence + hand weeding and thiobencarb pre-emergence + hand weeding applied to first and second crop of rice in rice-rice-sesamum cropping system.

The weed management practices and their carry over effects had significant influence on the uptake of nutrients by the crop and weeds during the first, second and third crop seasons. Unweeded check exploited the available nutrients and water resulting in better weed growth and dry matter accumulation through out the cropping system.

The soil nutrient status was also affected by the weed management practices studied. The N, P, K status of soil was high for weedy check compared to herbicide treatments and weed free treatments owing to poor crop utilization of the nutrients.

The herbicide treatments applied both to the first and second crop of rice and their carry over effects on third crop of sesamum had no significant effect on the population of soil organisms.

Economic analysis revealed that herbicide treatments were remunerative compared to weedy check and farmers practice in the first and second crop seasons. The residual effects of weed management practices had not influenced the economics of sesamum crop during third crop season.

Bioassay studies revealed no phytotoxic concentration of herbicide residues in the soil after the rice-rice-sesamum cropping sequence.