WEED MANAGEMENT IN SESAMUM

(Sesamum indicum L.)

By

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THESIS

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DECLARATION

I hereby declare that this thesis entitled "Weed management in sesamum (*Sesamum indicum.L*)" 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 any degree, diploma, associateship, fellowship or other similar title at any other university or society

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CERTIFICATE

Certified that this thesis entitled "Weed management in sesamum (Sesamum indicum L.)" is a record of research work done independently by Miss REENA.V.V. under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associate ship to her.

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LIST OF ABBREVIATIONS

mm	-	millimetre
cm	-	centimetre
m	-	metre
cm2	-	centimetre square
m2	-	metre square
h	-	hour
t	-	tonne
ha	-	hectare
Kg	-	Kilogram
N	-	Nitrogen
P	-	Phosphorus
K	-	Potassium
T	-	treatment
G	-	granule
EC	-	emulsifiable concentrate
%	-	per cent
oC	-	degree celsius
MSL	-	mean sea level
DAS	-	days after sowing
DAT	-	days after treatment
Kg ha-1	-	Kilogram per hectare
t ha-1	-	tonne per hectare
q ha-1	-	quintal per hectare
Kg ai ha-1	-	Kilogram active ingredient per hectare

INTRODUCTION

INTRODUCTION

Sesamum is a traditional oil seed crop of Kerala cultivated from time immemorial. Besides its use as an edible oil, sesamum is well appreciated as a source of protein and essential amino acid in human and livestock nutrition.

The total area under sesamum in Kerala is 7891 ha and the production is 2045 t. (Farm Information Bureau, 1996). The per hectare yield is however low in Kerala. The average productivity of the crop in the state is only 265 Kg ha-1, though its yield potential is estimated to be 600-1000 Kg ha-1 under dry land and 1000-1200 Kg ha^{-1} under irrigated conditions. The constraints for this low productivity are insufficient residual soil moisture and inadequate application of fertilizers, water and pesticides. Apart from these factors, weeds play a significant role in the reduction of yield of sesamum.

Sesamum is mainly grown in Kerala in the summer rice fallows of Onattukara tract spread over Kollam and Alappuzha districts. The soil in the area is typical sandy loam with low nutrient status. During the growing season of sesamum, the weed seeds germinate much earlier to the crop seeds and compete for water, nutrients, space and light. The initial slow growth of sesamum also enable the weeds to have an upper hand. It is estimated that 75 per cent increase in yield could be obtained by control of weeds. Of the weeds identified in this tract, Cleome viscosa requires special mention, as it contributes to the major share of dicot weed population.

Weeding is mainly carried out in the Onattukara tract with the local hand hoe, Kochuthoomba which does the purpose of intercultivation and weeding. Hoeing is however, found to be very expensive and often timely weed control is not done due to high cost and scarcity of labour. But at present, chemical control is rarely practised or recommended in this tract. Experiments conducted at various sesamum growing areas have shown promising control of weeds with different formulations of chemicals. But the indiscriminate use of chemicals have resulted in resurgance of weeds and environmental pollution. Also no single weed control practice is good enough for all cases. It has to be a combination of cultural and chemical practices that are effective at the farm level and that fit in the farmer's socio-economic resources. Therefore, to achieve the required level of oil seed production to meet the demand of oil for the ever increasing population, integrated approach of weed control is also gaining significance now-a-days.

The present investigation was, therefore, undertaken with the following objectives:

1) to find out the most effective method of weed control for sesamum in the summer rice fallows of Onattukara tract.

2) to study the effect of different pre-emergent weedicides in controlling the weeds of sesamum.

3) to find out the efficacy of weedicides on the germination, growth and uptake of nutrients by the weeds.

4) to find out the economics of mechanical as well as chemical methods of weed control.

REVIEW OF LITERATURE

REVIEW OF LITERATURE

Sesamum (Sesamum indicum L.) is a traditional oilseed crop of Kerala, cultivated mainly in the Onattukara tract. The average productivity of the crop in the state is very low. One of the major causes for reduction in yield of sesamum is the weeds. Weed problem is found to reduce the yield of sesamum upto 75 per cent.

Weed control is mainly done by hoeing. Hoeing is in fact, very expensive and time consuming. But experimental evidence on the use of chemicals for weed control is meagre. The continuous use of herbicides sooner or later results in resurgance of weeds and causes environmental hazards. An integrated weed management involving reduced dosage of herbicides and mechanical methods are increasingly adopted now a days. Hence the present study was undertaken to find out the most effective method of weed control in sesamum. A brief review of the work done in sesamum and other related crops on weed management is presented below.

2.1 Losses due to weeds.

The losses caused by weeds to crops are of generally two types. This include the loss resulting from direct reduction in crop yields through competition for nutrition, soil moisture and sunlight. Weeds also indirectly reduce the yield potential by reducing the quality of produce. Weeds increase the infestation of insect pests and diseases by acting as alternate hosts (Mukhopadhyay and Ghosh, 1981). Weeds interfere with cultivation operations, cause health hazards and enhance the cost of cultivation.

2.1.1. Losses in yield.

The magnitude of losses of crop yield due to weeds depend on time of infestation, composition and intensity of weed flora and agro-climatic conditions. In sesamum, the slow initial growth also finally result in substantial reduction in yield.

Losses caused by weeds were estimated to range between 50 and 70 per cent in sesamum. (Gaur and Tomar, 1978 and Ghosh and Mukhopadhyay., 1980.)

Kondap et al. (1983) recorded 24.60, 20.60 and 12.80 per cent yield reduction in sesamum due to the presence of both monocot and dicot, monocots alone and dicot weeds alone respectively. Shukla (1984) reported that unweeded sesamum crop recorded 54 per cent lesser seed yield. Rao and Rao (1991) observed an yield reduction of 76 per cent due to unchecked weed competition in sesamum.

Singh et al. (1993) reported 25 per cent reduction in grain yield of sesamum (308 Kg ha^{-1}) when it was kept unweeded upto maturity, over weed free control (540 Kg ha^{-1}).

The yield reduction due to weeds in other oilseed crops are also reviewed. In the case of groundnut, the loss caused by weeds had been estimated to be between 35 and 70 per cent. (Saini et al., 1974 and Sandhu and Walia, 1979). In rapeseed and mustard, the yield loss was estimated to be 24-70 per cent (Panchal et al., 1980).

Sawhney and Deepak (1980) found that the initial slow growth of sunflower favours the weed growth which reduces the seed yield to an extent of 40 per cent. In soybean, weeds reduced the grain yield by 37.4 per cent (Arya et al., 1994.)

2.2 Weed spectrum.

The kind of weed and degree of infestation in the fields of oilseed crops are determined by season, stand and establishment of crops, moisture regime, land preparation and cultural practices. The weed species identified in sesamum are reviewed.

The weed flora in sandy loam lateritic soil of West Bengal during the Kharif season in sesamum consisted mostly of Echinochloa colonum, Melochia corchorifolium, Dactyloctenium aegypticum, Brachiaria sp, Cynodon dactylon, Cyperus rotundus and Trianthema sp. Weed problem was mostly due to grasses (216 and 332 counts m^{-2} at 30 and 60 DAS respectively). Infestation of sedges (168 and 358 counts m^{-2}, at 30 and 60 DAS respectively) also damaged the crop to some extent, but the infestation of broad-leaved weeds (65 and 148 counts m^{-2} at 30 and 60 DAS respectively) were not so severe (Ghosh and Mukhopadhyay, 1980).

Ibrahim et al. (1988) observed Echinochloa colonum, Striga alba, Amaranthus viridis, Portulaca oleraceae and Enex spinosa as the major weeds in sesamum.

The weeds of major concern in sesamum fields were identified as Cyperus rotundus, Amaranthus viridis, Acanthospermum hispidum, Scoparia dulcis and Brachiaria mutica (Singh et al.,1992).

Singh et al. (1993) from Varanasi reported that the major weeds in pigeon-pea-sesamum intercropped fields were Eleusine indica, Digitaria ciliaris, Cyperus rotundus, C.iria, Amaranthus viridis, Commelina benghalensis and Eclipta alba.

Kannan and Wahab (1995) found that the predominant weed flora of sesamum of clay loam soil of Annamalai were Trianthema portulacastrum, Echinochloa spp. and Cyperus rotundus.

Patro and Kar (1995) identified the major weed species in sesamum fields in tribal belts of Orissa as follows Grasses- Echinochloa colonum, Panicum sp, Digitaria sp, Cynodon dactylon, sedges - Cyperus iria, Cyperus rotundus, Kyllingia berevifolia and broad leaved - Celosia argentia, Amaranthus sp Sida sp. Grasses were the predominant weeds, approximately 60 per cent of the total weed population. The sedges worked out to be 20-25 per cent. Weeds with broad leaves are very few and do not cause serious problem.

In the sandy clay loam soil of Tikamgarh, the important weed species identified with sesamum according to Sootrakar et al. (1995) were Echinochola spp, Commelina benghalensis, Euphorbia sp, Phyllanthus niruri, Cyperus rotundus, Digeria arvensis and Cynodon dactylon.

The weed flora identified in other oil seed crops are also reviewed.

Field investigations at Ludhiana (Brar et al., 1991) revealed that groundnut was infested with weeds like Cleome viscosa, Leucas aspera, Digeria arvensis and Celosia argentea. These weeds posed severe competition during the early growth period of groundnut and resulted in drastic reduction in yield.

Similarly, Ali and Rao (1990) identified the predominant weed flora in groundnut at 15 DAS as Echinochloa colonum, Panicum repens, Dactyloctenium aegyptium, Cynodon dactylon among grasses, Cyperus rotundus among sedges, Amaranthus viridis, Boerhaavia diffusa, Phyllanthus niruri, Tridax procumbens, Acanthospermum hispidum among broad leaved weeds.

Satish Kumar et al. (1994) observed that the predominant weeds in soybean fields were Cynodon dactylon, Dactyloctenium aegyptium, Cyperus rotundus, Euphorbia hirta, Amaranthus viridis, Phyllanthus niruri and Tridax procumbens.

Vaishya et al. (1990) reported that Chenopodium album, Euphorbia dracunculoides, Anagallis arvensis, Cyperus rotundus and Phyllanthus niruri were the important weeds of mustard field.

In sunflower, weeds like Cyperus rotundus, Echinochloa colonum, Phyllanthus niruri, Argemone mexicana and Acanthospermum hispidum reported to be the most common weeds (Singh et al., 1992).

2.3 Critical period of crop-weed competition.

As weeds often have a higher rate of growth initially, they compete very effectively with the crops in early stages of growth. The weeds if controlled at the most critical period, the crops will have more competitive ability to escape the weed menace. Several workers have identified the critical period of crop-weed competition in sesamum. Some of the works are reviewed as under.

Aiyer (1958) reported that weeding once or twice was sufficient to control weeds in sesamum grown under rainfed conditions.

Aslam et al. (1989) found that the critical period between weeds and oilseed crops was 10-30 days after emergence of the crop.

The critical period of weed competition with sesamum was noted to be from 2nd to 6th week after sowing (Rao and Rao, 1991).

Singh et al. (1993) found that sesamum grown in association with pigeon-pea showed maximum adverse effect of weed infestation on growth and yield in between 15 and 30 DAS. The weed free condition after 30 DAS did not prove beneficial in terms of height and drymatter accumulation of sesamum, also weed infestation upto 15 DAS did not interfere with the crop to significant level.

2.4 Weed management practices.

In sesamum, considerable yield reduction result from the occurence of weeds in the early stages of crop growth. These weeds can be effectively kept under check at the critical period itself by adopting proper weed management practices so as to enhance the yield potential.

Weed management involving the deployment of mechanical and chemical methods are reviewed.

2.4.1. Mechanical methods.

The mechanical methods of weed control are being employed eversince man began to grow crops. It involves the use of manpower and different implements to reduce the weed infestation. Handweeding, hoeing and intercultivation are the different mechancial methods. Mechanical methods continue to be the mainstay in weed control in field crops even today.

2.4.1.1 Hand weeding

It is probably the oldest method of eliminating weeds. This is very effective against annual and biennial weeds as they do not recover from the pieces of roots left behind in the ground.

Gaur and Tomar (1978) obtained highest grain yield in sesamum when two hand weedings were given.

Ghosh and Mukhopadhyay (1980) reported that hand weeding twice at 15 and 30 DAS recorded highest seed yield in sesamum (9.5 q ha^{-1}) and was superior to all other treatments. They attributed the reason for maximum seed yield as due to reduced crop-weed competition at critical stages. This also resulted in highest number of capsules per plant.

Sen <u>et</u> <u>al</u>. (1984) observed that weed competition in sesamum was substantially reduced by one hand weeding two weeks after crop emergence and yields increased by 75 per cent. Hand weedings given at two and five weeks after emergence gave optimum yields of sesamum.

Highest seed yield was obtained from hand weeded plots as compared to chemical weed control from sesamum fields (Shukla, 1984).

The results of experiments conducted at Kayamkulam showed minimum weed weight (3.5 g per 20 m^2 plot) from hand weeded plots of sesamum (KAU, 1987).

Hand weeding twice at 30 and 45 DAS resulted in highest seed yield of soybean (34 q ha^{-1}) as compared to unweeded check

(10 q ha^{-1}) and was superior to all other treatments. (Prakash et al., 1991).

Singh et al. (1993) found that in pigeon-pea-sesamum intercropped areas, hand weeding twice at 20 and 40 DAS was not effective in minimising weed growth.

Sharma and Chauhan (1995) recorded lowest weed dry weight (120 g m^{-2}) and highest seed yield (18.35 q ha^{-1}) over the weedy check (512 g m^{-2} and 12.12 q ha^{-1} respectively) when two handweedings at 30 and 45 DAS was done for mustard.

Sootrakar et al. (1995) found that in sesamum three hand weedings at 25, 40 and 55 DAS recorded minimum weed count (3.4 m^2), maximum vegetative growth and resulted in higher seed yield (7.66 q ha^{-1}).

2.4.1.2 Hoeing

Hoeing is still a very useful operation in controlling weeds effectively and cheaply. Hoeing is more effective with row crops and on annuals and biennials as weed growth can be completely destroyed.

Shanmugham (1981) opined that manual weeding by hand hoes on the 40th DAS is a must in groundnut as it removes weeds and loosens top soil.

Experiments conducted at Kayamkulam revealed that higher seed yield (253 Kg ha^{-1}) and lower weed dry weight (7.4 g m^{-2}) would be obtained with hoeing in sesamum (KAU, 1986). In another experiment with sesamum at Kayamkulam, maximum seed yield of 0.955 Kg per 20 m^2 plot was recorded when the crop was weeded with two hoeings (KAU, 1988).

Brar et al. (1991) recorded the highest yield of 16.2 q ha^{-1} in toria (Brassica campestris var. toria) with two hoeings (3 and 5 weeks after sowing) when compared to other weed control treatments.

Gogoi and Kalita (1995) found that wheel hoeing twice at 20 and 40 DAS registered highest weed control efficiency and seed yield of 9.07 q ha^{-1} by improving the yield components in mustard.

2.4.2 Chemical weed control

Manual weeding is often cumbersome and time consuming. At times soil and climatic conditions may not permit the use of implements. The necessity to decrease or replace the labour requirement for weeding, together with the difficulty of working with young crop has been a main incentive for the increased use of herbicide. (Weiss, 1971). Further, herbicides offer effective weed control during critical period of crop growth (Gupta *et al.*, 1978). Brar and Mehra (1989) opined that the chemical weeding is easier, time saving and economical as compared to hand weeding alone. Mukhopadhyay and Ghosh (1981) reported that pre-emergence application of herbicides offered very effective control of weeds from the early growth stages of the crop.

The effect of herbicides on weeds and growth and yield of sesamum and other oilseed crops are reviewed as under.

2.4.2.1 Alachlor. EC

Alachlor belongs to amides and acetamides group. This group of herbicides are known to inhibit germination, or seedling emergence, root elongation, mitosis in root tips, protein synthesis in roots, growth of shoot and finally resulting in necrosis and death. Alachlor is applied as pre-emergence or early post emergence for control of most of the annual grasses and certain broad-leaved weeds in rice, oilseed crop, cotton etc.

2.4.2.1.1. Effect on weeds.

Sancho and Garcia (1971) observed that alachlor at 3 Kg ha^{-1} controlled 95 to 98 per cent of weeds in sesamum.

Rangiah *et al*. (1976) showed that pre-emergence application of alachlor at 4 Kg ai ha^{-1} was as effective as hand-hoeing twice in controlling weeds and increasing yield of groundnut. The regeneration of weeds was reduced significantly when herbicides were supplemented with hand hoeing.

Negi and Saini (1994) reported that closer row spacing of 22.5 cm in soybean coupled with pre-emergence application of alachlor at 1.0 Kg ai ha^{-1} yielded maximum dry weed biomass (7.5 g m^{-2}).

2.4.2.1.2 Effect on crop growth and yield.

Moore (1974) reported good weed control for sesamum with slight damage and obtained yields of 0.62 t ha^{-1} with alachlor application at 3-4 Kg ha^{-1}.

In sesamum, alachlor recorded significantly higher seed yields of 613 Kg ha^{-1} during kharif when applied at the rates of 1.5 Kg ha^{-1} and 1.75 Kg ha^{-1} respectively (Subramanian and Sankaran, 1977).

Trials done at the Kayamkulam revealed that alachlor at 0.5 Kg ha^{-1} recorded maximum yield of 344 Kg ha^{-1} in sesamum (KAU, 1980).

Mehrotra *et al*. (1984) obtained effective control of weeds and average seed yield (1.63 t ha^{-1}) with pre-emergence application of 2 Kg ha^{-1} of alachlor to sunflower.

Experiments in sesamum conducted at Kayamkulam resulted in a maximum seed yield of 0.855 Kg per 20 m^2 plot with application of alachlor at 0.75 (KAU, 1987).

Singh and Patel (1991) obtained highest yield of groundnut (1.43 t ha^{-1}) and net returns per rupee with application of alachlor. Kannan and Wahab (1995) reported that in sesamum alachlor at 2 Kg ha^{-1} significantly increased the seed yield (760 Kg ha^{-1}) over other treatments. This was due to better weed control at initial stages.

Moorthy *et al*. (1995) also found that application of alachlor at 2 Kg ha^{-1} resulted in highest yields due to minimum weed competition in irrigated soybean.

2.4.2.2 Alachlor granules.

The granules ensure uniform and easy application in soil, there is no drift hazard and liquid carrier is not required. Herbicide movement from a granule in soil is affected by soil and environmental conditions. Erbach *et al*. (1976) reported that environmental conditions, weed-herbicide combination, depth of granule placement, depth of germinating weed seed and inter action of these factors affected the size of the area in which weeds were adequately controlled by an individual herbicide granule.

Trials at Tikamgarh centre gave best weed control in sesamum by pre-emergence application of alachlor granules at 20 Kg ha^{-1} coupled with one hand weeding at 40 DAS. The yields were also comparable with weed free situation. (AICORP, 1993)

Jain et al. (1995) reported that alachlor 10G at 1.5 Kg ha^{-1} with hand hoeing registered a weed control efficiency of 70.5 per cent in soybean.

In sunflower, good control of weeds could be obtained with application of alachlor granules 10G at 20 and 40 DAS (Coelho, 1971).

2.4.1.2.3 Metolachlor.

Metolachlor is another amide herbicide structurally similar to alachlor, applied as pre-emergence and is particularly effective against annual grasses. It inhibit seed germination by affecting cell division. It affects root growth by inhibiting protein synthesis. (Davis et al., 1979).

2.4.2.3.1 Effect on weeds.

Lagoke and Singh (1980) observed that application of metolachlor at 1.5 Kg ha^{-1} gave satisfactory weed control and higher pod yield in groundnut. Choudhary (1983) found that metolachlor at 1.5 Kg ai ha^{-1} applied pre-emergent followed by bentazone at 1.5 Kg ai ha^{-1} 3-4 DAS gave selective control of Cyperus esculentus, C. tuberosus and annual grasses and broad leaved weeds in groundnut at Nigeria.

Hong et al. (1983) reported the excellent grass weed control obtained on soybean with 1.7 Kg metolachlor per hectare as pre-emergence application but control of broad-leaved weeds was poor.

In an experiment it was proved that 900 g of metolachlor in 500 litre water per hectare applied pre-sowing or pre-emergence controlled weeds in sunflower and soybean (Pichon,1986).

Prusty et al. (1990) found that metolachlor at 0.75 Kg ha^{-1} gave best weed control and pod yields next to hand weeded and hoeing carried out plots in groundnut.

Dwivedi et al. (1991) indicated that in pigeon pea-sorghum intercropping system metolachlor was effective as cultural methods of weed control but proved better in situation where manual weeding is not possible.

Prakash et al. (1991) observed that application of metolachlor at 1.0 Kg ha^{-1} recorded a lowest weed dry weight values (156.6 Kg ha^{-1}) and weed control efficiency of 73.9 per cent in soybean.

About 65.7 per cent control of weeds could be obtained with pre-emergence application of metolachlor in soybean fields. (Bai and Najappa, 1994). Metolachlor when applied in groundnut at 1.0 Kg ha^{-1} recorded lower weed weight of 1871 Kg ha^{-1} (Guggari et al., 1995.)

2.4.2.3.2. Effect on crop growth and yield.

Ibrahim et al. (1988) reported 139 per cent increase in seed yield in rapeseed with the application of metolachlor at 2.4 Kg ha^{-1}. The highest yield of 21.5 q ha^{-1} was recorded by the application of metolachlor at 1.0 Kg ha^{-1} in soybean. This enhanced the yield due to decreased weed competition. (Prakash et al., 1991).

Increase in seed yield with application of metolachlor at 1.0 Kg ha^{-1} (pre-em) in soybean was 18.89 q ha^{-1}, in comparison to unweeded control (10.58 q ha^{-1}) (Negi and Saini, 1994).

2.4.2.4 Pendimethalin.

Pendimethalin is a dinitro-aniline herbicide with selective action. The chemical kills weeds by inhibiting the seedling emergence and elongation. Both root and shoot growth is inhibited by this chemical. The roots which do develop have swelling and thickening appearance and are devoid of or have only a limited number of secondary roots.

The predominant weeds controlled by pendimethalin were Brachiaria sp., Cenchrus ciliaris, Echinochloa colonum, E. Crusgalli, Phalaris minor etc among monocots and Angalis arvensis, Chenopodiuim album, Polygonum sp., Portulaca oleraceae, Tribulus tenetris etc among the dicots (Joshi, 1987).

2.4.2.4.1 Effect on weeds.

Pendimethalin at 1.0 Kg ha^{-1} was found effective in reducing the weed population in sesamum fields (Maiti et al., 1988).

Brar and Mehra (1989) observed that pre-emergent application of pendimethalin at 0.75 Kg ai ha^{-1} reduced the weed dry weight by four to five fold and increased the pod yield in groundnut. The dry weight of weeds with pendimethalin application at 1.0 Kg ha^{-1} was 145 to 149 Kg ha^{-1} as compared to 316-402 Kg ha^{-1} in weedy check. (Tomar and Namdeo, 1991).

Legha *et al*. (1992) found a reduction in dry weight of weeds (34.4 g m^{-2}) over unweeded control (579.6 g m^{-2}) when pendimethalin was applied at 1.0 Kg ha^{-1} along with one hand weeding at 40 DAS in soybean.

Maliwal and Rathore (1994) observed that application of pendimethalin at 0.5 Kg ha^{-1} with hand weeding once is the best method to control weeds and to get maximum economic returns from groundnut - sesamum intercropping.

The lowest weed dry weight (55.1 Kg ha^{-1}) was reported with application of pendimethalin at 1.0 Kg ha^{-1} at 4 DAS combined with an intercultivation at 40 DAS in sunflower, while the weed dry weight fron unweeded plots were recorded as 591.2 Kg ha^{-1} (Patel *et al*., 1994).

2.4.2.4.2 Effect on crop growth and yield.

Ghosh and Bera (1986) reported that pendimethalin at 1.0 Kg ha^{-1} (pre-em) resulted in good germination, highest plant population (35 plants m^{-1}), taller plants (94.0 cm), more number of branches per plant (7.5) and finally the highest grain yield (10 q ha^{-1}) of rapeseed and mustard by effectively suppressing the initial weed growth and these findings were comparable to hand weeded plots.

Girijesh and Patil (1989) concluded that pendimethalin at 0.75 Kg ha^{-1} with cultivation provided the highest oil yield of groundnut in groundnut-sunflower intercropping.

Experiments revealed that application of 1.5 Kg ha^{-1} of pre-emergence herbicides like metolachlor and pendimethalin with one hand weeding helped in effective weed control and higher groundnut pod yields (1470-1757 Kg ha^{-1}) than the use of herbicides alone (Ramakrishna et al., 1991).

Maliwal and Rathore (1994) found that application of pendimethalin at 0.5 Kg ha^{-1} with hand weeding once was the best method to control weeds and to get maximum seed yield (898 Kg ha^{-1}) of sesamum from groundnut - sesamum intercropping. The weed free control recorded a seed yield of 895 Kg ha^{-1}.

Reddy and Premlatha (1994) found that pod and haulm yields of groundnut were higher under pre-emergent application of pendimethalin at 1.0 Kg ha^{-1} than with unweeded control. Weeds could also be effectively controlled with this treatment.

2.5. Effect of weed management on weeds.

2.5.1. Weed density.

Sinha and Thakur (1965) reported the lowest weed population density of Cyperus rotundus in the acidic soil and the highest in the neutral soil. In alkaline soils, the population was in between the acidic and neutral soils.

Ghosh and Mukhopadhyay (1980) found that weed problem in sesamum field of sandy loam lateritic soil of Sriniketan was mostly due to grasses (216 and 232 weeds m^{-2} at 30 and 60 DAS respectively) of which Echinochloa colonum was the most prominent weed. Infestation of sedges (168 and 358 weeds m^{-2} at 30 and 60 DAS respectively) was not so severe in sesamum fields.

Experiments at Kayamkulam recorded lowest weed count in sesamum when hand weeded and maximum when the crop was kept unweeded (KAU, 1987).

The results of the experiment conducted with soybean at Pantnagar, revealed that maximum weed infestation (100 per cent) was observed in weedy check and the dominant weeds were Echinochloa colonum (35 per cent), Cyperus rotundus (40 per cent) Sorghum halopens (5 per cent), Trianthema portula castrum (10 per cent) and Solanum niqrum (5 per cent) (Chandel et al., 1995). Also, the lowest weed population at 30 DAS was recorded with alachlor at 2 Kg ha^{-1} (51 weeds m^{-2}) and at 60 DAS with the application of alachlor at 2 Kg ai ha^{-1} followed by hand weeding at 30 DAS (21 weeds m^{-2}).

Kannan and Wahab (1995) while experimenting with sesamum reported that pre-emergence application of alachlor at 1.0 Kg ha^{-1} combined with hand weeding at 40 DAS recorded a weed population of 29.2 m^{-2}, while two handweedings at 20 and 40 DAS and weedy check resulted in 50.7 and 202.2 weeds m^{-2} respectively at 60 DAS.

Results from Tikamgarh (Soortrakar et al., 1995) showed that the lowest number of weeds (3.4 m^{-2}) were found in hand weeded plots of sesamum and the maximum weed count were observed in unweeded plots (306.5 m^{-2}) at maturity.

2.5.2. Dry matter production of weeds

Ghosh and Mukhopadhyay (1980) stated that the dry matter production of weeds in sesamum plots at 30 and 60 DAS with hand weeding twice were 17.9 g m^{-2} and 40.4 g m^{-2} respectively and corresponding weed weights for unweeded control were 87.6 g m^{-2} and 301.7 g m^{-2} respectively.

Subramanian and Sankaran (1981) reported that application of alachlor at 1.75 Kg ha^{-1} (pre-em) effectively controlled the dry matter production of Cyperus rotundus in sesamum fields. The trials conducted with sesamum at Kayamkulam indicated that application of alachlor at 0.75 Kg ha^{-1} with one hoeing at 20 DAS reduced the weed dry weight to 6.65 g per 20 m^2, but the best treatment was hand weeding at 20 DAS (3.25 g per 20 m^2 plot) (KAU, 1987).

The weed dry weight was lowest (592 Kg ha^{-1}) with application of alachlor at 1.5 Kg ha^{-1}) in sesamum (AICORP, 1993).

Weed biomass production at harvest in soybean was minimum (100. 2 q ha^{-1}) in plots treated with alachlor (pre-em) at 1.5 Kg ha^{-1} combined with a hand hoeing at 20 DAS. Hand weeding twice and unweeded plots recorded 125.5 and 715 q ha^{-1} of weed biomass respectively (Jain et al., 1995).

Kannan and Wahab (1995) reported that in sesamum, pre-emergence application of alachlor at 2 Kg ha^{-1} with hand weeding at 40 DAS resulted in the lowest weed dry matter production (607.9 Kg ha^{-1}) at harvest. The unweeded check recorded the highest dry matter production (25.07 Kg ha^{-1}).

2.5.3. Weed control efficiency.

Ghosh and Mukhopadhyay (1980) reported 83.86 per cent and 83.69 per cent weed control efficiency with handweeding twice (15 and 30 DAS) and with hoeing at 15 DAS along with hand weeding at 30 DAS, respectively in sesamum due to lowest weed biomass recorded with these treatments.

Weed control efficiency was maximum with the treatment involving hand weeding once at 20 DAS (86.09 per cent) followed by hoeing at 20 DAS in sesamum (71.53 per cent). Hoeing alone at 20 DAS resulted in a weed control efficiency of 65.11 per cent (KAU, 1988). In groundnut, continuous weeding recorded a weed control efficiency of 95 per cent and 83.7 per cent with two weedings (Gajendra Giri and Ganga saran, 1989).

Gogoi et al. (1991) reported that in soybean hand weedings at 20 and 40 DAS gave a weed control efficiency of 68.4 per cent and metolachlor application 3 DAS with handweeding at 30 DAS gave a weed control efficiency of 62.4 per cent.

Singh and Chandel (1995) found that in soybean cultural methods of hand weeding twice at 30 and 45 DAS and hoeings gave a higher weed control efficiency of 86.2 and 84.5 per cent respectively. The herbicidal treatment gave a weed control efficiency of 68.4 per cent only.

Highest weed control efficiency of 85.8 per cent due to pre-emergence application of pendimethalin at 1.0 Kg ai ha^{-1} combined with one hand weeding at 45 DAS was observed in mustard (Kanieria and Patel, 1994). Kannan and Wahab (1995) reported highest weed control efficiency of 75.8 per cent at harvest with alachlor at 2 Kg ha^{-1} coupled with hand weeding at 40 DAS in sesamum, two hand weedings at 20 and 40 DAS recorded a weed control efficiency of 51.2 per cent.

2.5.4 Integrated weed management

An integrated approach to use herbicides with cultural methods in being increasingly adopted. This approach is more acceptable to farmers as the local practices are also included. Tillage may be employed to make weeds more susceptible to herbicides or conversely herbicides may be used to make weeds more susceptible to tillage. In other words, this integrated weed management will not alter the existing agronomic practices but only allow more thorough and appreciable control of weeds (Ray, 1986).

2.5.5 Nutrient removal by weeds.

The loss of nutrients in groundnut due to weeds were reported to be 33.8 Kg N, 16.8 Kg P_2O_5 and 20.3 Kg K_2O ha^{-1} (Brar et al., 1973, Naidu et al., 1982). In soybean, Mani (1975) reported that nitrogen absorption by crop was 86 Kg ha^{-1} while it was 175 Kg ha^{-1} by weeds in control plots.

Ghosh and Mukhopadhyay (1980) reported that weed free situation in sesamum caused a depletion of nutrients in the order of 0.63 Kg N, 0.09 Kg P and o.83 Kg K ha^{-1} while the depletion from unweeded plots were 79.29, 11.52 and 104.84 Kg N, P and K ha^{-1} respectively at 60 DAS . Hand weeding twice at 15 and 30 DAS resulted in nutrient removal of 12.80, 1.86 and 16.92 Kg of N,P and K ha^{-1} respectively.

Jayakumar et al. (1985) found that weeds like Celosia argentia and Cleome viscosa have high nutrient status whereas Tridax procumbens have low nutrient contents, Oxalis corniculata have medium to high nutrient concentration.

Greatest decreases in N,P and K uptake by weeds were obtained by handweeding followed by the application of 1.5 Kg pendimethalin per hectare and this treatment recorded higher seed protein than unweeded control in groundnut (Kondap et al., 1985).

Ray (1986) estimated a loss of 30 Kg N to weeds from groundnut fields if they are not removed for the first 60 days after planting. Yadav et al. (1986) reported that in groundnut, the total N,P and K removal by weeds were 163,122 and 142 Kg ha^{-1} respectively and this can be saved by weeding within 45 DAS.

Weeds in sesamum fields removed 40 Kg N, 3 Kg P_2O_5 and 15 Kg K_2O ha^{-1} (Rao, 1989). Rao and Rao (1991) reported that the nutrient losses in groundnut was of the order of 58 Kg N,6 Kg P_2O_5 and 45 Kg K_2O ha^{-1} when weeds were allowed to grow in association with the crop.

N,P and K uptake by weeds in groundnut at harvest with hand weeding at 15 and 30 DAS and inter cultivation at 15, 30 and 45 DAS were 15.13, 4.2 and 4.2 Kg N,P and K ha^{-1} respectively while the unweeded control recorded a removal of 92.45 Kg N 29.64 Kg P and 46.04 Kg K ha^{-1} (Murthy et al., 1993).

2.6. Effect of Weed Management on Crop.

The effect of weed management on plant growth characters, yield attributes and also on nutrient uptake by crop are reviewed.

2.6.1. Plant height.

There is no consistent result or information on the influence of weed management practices on plant height. Brar et al. (1980) reported that weed control treatments failed to have significant effect on plant height in groundnut.

Ghosh and Mukhopadhyay (1980) observed that in the early growth stages of sesamum, tallest plants were observed in unweeded control plots (55 cm at 30 DAS) but at later stages these unweeded plots recorded shortest plants (104 cm at maturity) due to severe weed competition. Weed free condition resulted in a height of 143.5 cm at maturity.

According to Patterson et al. (1983) plant height was unaffected by the length of weed free period in soybean. Ghosh and Bera (1986) reported significant differences in plant height due to weed control treatments. Taller plants were obtained with pre-emergence application of pendimethalin at 1.0 Kg ai ha^{-1} (94.0 cm) closely followed by handweeding at 30 DAS (93.7 cm) in mustard.

Ali and Rao (1990) found that unweeded treatment resulted in greatest plant heights (42.8 cm) in groundnut. Maximum adverse effect of weed infestation on the growth of sesamum was observed between 15 and 30 DAS and the weed free condition upto maturity resulted in plant heights of 87 cm (Singh et al., 1993).

Sootrakar et al. (1995) observed that handweeding in sesamum at 25,40 and 55 DAS resulted in maximum plant height (110.4 cm) while hand weeding once recorded a height of 98.5 cm. The least height (97.8 cm) was recorded with unweeded control.

2.6.1.2 Dry matter accumulation.

Singh et al. (1993) reported that in sesamum, hand weeding at 30 DAS resulted in dry matter accumulation of 10.3 g per plant but weed free period upto 30 DAS resulted in dry matter production of 16 g per plant. Weeding beyond 30 DAS did not have any significant effect.

Chandel et al. (1995) found that in soybean at 60 DAS and at harvest, pre-emergence application of alachlor at 2 Kg ha^{-1} resulted in highest dry matter production of plants (23.6 g and 90.5 g per plant -1 respectively). This treatment with hand weeding at 30 DAS resulted in dry matter of 22.1 g plant -1 at 60 DAS and 85 g per $plant^{-1}$ at harvest.

Sootrakar et al. (1995) stated that highest dry matter accumulation in sesamum was caused by hand weeding at 25 DAS and unweeded control registered a dry matter accumulation of 18.3 g and 16.5 g per plant respectively.

2.6.1.3 Number of branches per plant.

The influence of weed control treatments on the number of branches per plant show variation.

Brar et al . (1980) did not find any significant difference in the number of branches per plant due to the different weed control treatments in groundnut.

Ali and Rao (1990) observed that in groundnut, pendimethalin at 1.0 Kg ai ha^{-1} with hand weeding at 35 DAS and hand weeding twice at 15 and 35 DAS resulted in more branches per plant (5.5 and 5.2 respectively) which were significantly superior to weedy check (4.6 branches per plant).

In soybean, higher number of branches per plant was noticed in weed free plots (5.06) followed by two hand weedings at 30 and 45 DAS (5.06) followed by two hand weedings at 30 and 45 DAS (5.03). The next best treatment was metolachlor (pre-em) at 1 Kg ha^{-1} (5.2) (Negi and Saini, 1994).

Sootrakar et al. (1995) found that the hand weedings at 25, 40 and 55 DAS resulted in plants with highest number of branches (5.5) but when only one handweeding was given (25 DAS) the number was reduced to 2.8 per plant in sesamum.

2.6.2 Yield and yield attributes.

2.6.2.1 Number of pods per plant.

Singh et al. (1993) observed that weed free condition in sesamum upto 45 DAS increased the number of pods to 27.0 and thereafter there was no significant effect. Weed removal upto 15 DAS increased the number to 27.2 as against the plots where no weeding was done upto 30 DAS.

Rao et al. (1995) found that weed free situation increased the pod number per plant 2.5 times. (44.6 pod number per plant) in soybean compared to weedy situation (17.4). This indicated the sensitivity of soybean to weed interference.

Singh and Chandel (1995) reported maximum number of pods per plant in soybean with two hand weedings at 30 and 45 DAS (90.5) as against the weedy check (51.8). Hoeing resulted in 74.2 pods per plant.

Sootrakar et al. (1995) obtained higher number of pods in sesamum with one hand weeding at 25 DAS (46.8) while three hand weedings at 25, 40 and 55 DAS gave 34.2 pods per plant.

2.6.2.2 Test weight.

Ghosh and Mukhopadhyay (1980) observed higher test weight of seed (3.67 g) in continuously weeded plots of sesamum followed by hand weeding twice at 15 and 30 DAS (3.6 g). The lowest test weight of 3.05 g was recorded under weedy check.

Singh et al. (1993) reported that weed management practices failed to have any influence on test weight of seeds in sesamum.

Patel et al. (1994) reported that test weight of sunflower recorded due to pendimethalin at 1 Kg ha^{-1} along with one intercultivation at 40 DAS was the highest (46.0 g) closely followed by weed free condition (45.97 g) as compared to unweeded treatment (39.90 g).

The findings of Singh and Chandel (1995) revealed that 1000 grain weight of soybean was higher with pre-emergence application of alachlor at 2 Kg ai ha^{-1} (129.0 g). The cultural methods of weed control viz., two hand weedings at 30 and 45 DAS and hoeing recorded test values of 127.3 g and 126.3 g respectively.

Test weight attained with three hand weedings at 25, 40 and 55 DAS (2.8g) was superior to hand weeding once at 25 DAS (2.3g) and weedy check (2.0 g) in sesamum (Sootrakar et al., 1995).

2.6.2.3 Seed yield.

Weed management practices adopted at critical stages resulted in reducing the crop-weed competition and enhanced seed yield.

Porwal et al. (1990) concluded that in soybean highest seed yield was with manual weeding twice at 20 and 40 DAS (1.41 t ha^{-1}) followed by alachlor at 2.5 Kg ha^{-1} (1.28 t ha^{-1} and the minimum was from unweeded plots (7.0 q ha^{-1}). Nimje (1992) reported maximum pod yield in groundnut with hand weeding twice at 20 and 40 DAS.

Weeding done at 15 DAS resulted in highest seed yeild (523 Kg ha^{-1}) in sesamum, but the weeding delayed upto 30 days reduced the seed yeild to 383 Kg ha^{-1} (Singh et al., 1993).

Experiments conducted at Bulgaria in sesamum showed that the application of alachlor at 4 Kg ha^{-1} controlled the weeds and resulted in higher seed yields and oil content (Lyubenov and Kostadinov, 1970).

Brar et al. (1980) obtained highest pod yield of groundnut with hoeing twice at 3 and 5 weeks after sowing (13.9 q ha^{-1}) and the lowest from weedy check (7.6 q ha^{-1}). Experiments done by Ghosh and Mukhopadhyay (1980) on sesamum indicated that maximum seed yield resulted from weed free situation (9.6 q ha^{-1}) and this was on par with hand weeding twice at 15 and 30 DAS (9.5 q ha^{-1}). The minimum yield was obtained from unweeded control (2.8 q ha^{-1}).

From trials conducted at Kayamkulam (KAU, 1980), it was found that alachlor at 0.5 Kg ha^{-1} gave higher yields of sesamum (3.44 Kg ha^{-1}).

Experiments done at Kayamkulam gave good yields (253 Kg ha^{-1}) with hoeing at 20 DAS in sesamum (KAU, 1984).

Naidu et al. (1985) reported that weed free maintenance in groundnut beyond 45 days was not beneficial in increasing the pod yield.

Kannan and Wahab (1995) reported that pre-emergence application of alachlor at 2 Kg ha^{-1} along with one hand weeding at 40 DAS resulted in higher seed yields of sesamum (760 Kg ha^{-1}) due to better weed control at initial stages.

Sootrakar et al. (1995) concluded that a seed yield of 7.66 q ha^{-1} was obtained with three hand weedings at 25,40 and 55 DAS as against unweeded control (4.53 q ha^{-1}).

2.6.2.4 Weed index.

Upadhyay and Kasbe (1977) estimated the weed index in groundnut as 12 per cent for the treatment involving alachlor at 2 l ai ha^{-1} as pre emergence spray along with one hoeing and one weeding at 3 and 6 weeks after sowing, while the herbicidal treatments alone resulted in weed index of 99.2 per cent and unweeded plots recorded 71.12 per cent as weed index.

Ghosh and Mukhopadhyay (1980) found that the weed index value was minimum with two hand weedings at 15 and 30 DAS (1.04 per cent) indicating the superiority of this treatment in sesamum while hoeing at 15 DAS with hand weeding at 30 DAS recorded 81.3 per cent and unweeded plots 70 - 83 per cent.

2.6.3. Harvest index

Bhadoria and Chauhan (1994) noticed higher harvest index (23.28 per cent) with one hand weeding at 45 DAS in mustard

Sootrakar et al. (1995) found that maximum value for harvest index (34.13 per cent) was obtained with three hand weedings at 25, 40 and 55 DAS in sesamum and the lowest in the unweeded plots (27.42 per cent).

2.6.4 Protein content

Porwal et al. (1990) observed that higher seed protein (509.7 Kg ha^{-1}) was obtained with manual weeding twice at 20 and 40 DAS. This treatment yielded 162.3 per cent higher protein than the unweeded control (194.1 Kg ha^{-1}) and 5.5 to 220.2 per cent higher than the herbicide treated plots (159.2 - 482.1 Kg ha^{-1}).

2.6.5 Oil content and yield

There is variation in the influence of weed management practices on oil yield also. Johnson (1971) observed that in sunflower oil content of seed increased in plots with the least amount of weed competition.

Girijesh and Patil (1989) found that treatment with pendimenthalin at 0.75 Kg ha^{-1} with cultivation resulted in highest oil yield of groundnut in groundnut - sunflower intercropping system.

Satish Kumar et al. (1994) concluded that the herbicidal treatments failed to have a significant influence on oil content of soybean. Likewise, Jain et al. (1995) opined that qualitative parameter like oil content of seed in soybean was unaffected by any of the weed management activities.

An oil content of 52.75 percent, 50.95 percent and 50.57 per cent were obtained with three hand weedings (25, 40 and 55 DAS), one hand weeding (25 DAS) and unweeded control respectively in sesamum (Sootrakar et al., 1995).

2.6.6. Nutrient uptake by crop

The depletion of nutrient by sesamum was estimated to be 40 Kg N, 3 Kg P_2O_5 and 15 Kg K_2O ha^{-1} (Rao, 1989). Weeding operations were found to have made the crop competitive with weeds. Hand weedings at 15 and 30 DAS supplemented with inter cultivation resulted in higher uptake of nutrients (82.46, 28.56 and 93.26 Kg N,P and K ha^{-1} respectively) by groundnut haulm (Murthy et al., 1994).

2.7 Microbial counts in soil

Sinha et al. (1980) reported that alachlor at 1.5 ppm did not produce any deterimental effect on soil fungi, actinomycetes or bacteria, instead stimualted soil respiration for first 20 days.

Nalayani and Sankaran (1992) concludeed that applicattion of pendimethalin in sunflower plots at 1 Kg ha^{-1} reduced the bacterial ($18x10^6$) and actinomycetes population significantly ($33.0x10^5$) over unweeded control ($31.3x10^6$ and $59.8x10^5$ respectively) at 5 days after treatment but at 25 days after treatment there was no significant difference.

The application of metolachlor at 0.5 Kg ha^{-1} in sesamum fields did not reduce the bacterial population but alachlor at 1 Kg ha^{-1} caused a reduction. Maximum fungal population was noticed with unweeded control followed by pendimethalin at 0.5 Kg ha^{-1}. Actinomycete population increased in unweeded and pendimethalin treated plots at 25 days after treatment (Nayak et al., 1994).

2.8 Economics and benefit - cost rattio

The crop yield can be enhanced considerably with appropriate weed management and this in turn result in increased net return from the plots receiving this treatment over unweeded plots.

Subramanian and Sankaran (1977) found that application of alachlor at 1.75 Kg ha^{-1} in combination with 30 Kg N ha^{-1} gave the maximum net income in sesamum, also the highest return per rupee invested. Similarly, Upadhyay and Kasbe (1977) realised that in groundnut alachlor at 2 kg ha^{-1}

(pre-em) with one hoeing and one weeding at 3 and 6 weeks after sowing caused a net profit of Rs 1351.30 over unweeded control.

The profit per hectare was found to be maximum when alachlor was used at 0.7 Kg ha^{-1} while it was minimum in hand weeded plots (KAU, 1984). In another trial at KAU (1991), it was found that weedicidal application followed by one hoeing at 20 DAS was more advantageous over cultural practices alone.

Weedy check recorded a net loss of Rs. 1271 ha^{-1} in soybean because of lowest grain yield and highest weed dry matter and weed population while the net return was highest with metolachlor at 1 Kg ha^{-1} with one hand weeding at 30 DAS (Rs. 10906). This was closely followed by alachlor at 2 Kg ha^{-1} with hand weeding at 30 DAS (Rs. 9587) (Chandel et al., 1995).

Kannan and Wahab (1995) obtained maximum net return of Rs 2.65 per rupee invested with alachlor at 2 Kg ha^{-1} integrated with hand weeding at 40 DAS while weedy check resulted in a net return of Rs 1.23 per rupee invested.

Sootrakar et al. (1995) concluded that in sesamum maximum benefit - cost ratio was obtained with herbicidal treatment alone (2.33) and when integrated method was adopted the monetary gain was reduced (2.01) due to uneconomical hand weeding .

MATERIALS AND METHODS

MATERIALS AND METHODS

The present investigation was carried out to evolve a suitable weed management technique for sesamum in the summer rice fallows of Onattukara. The field experiment was conducted during the summer from February 1995 to May 1995.

The details of materials used and methods adopted for the study are described below.

3.1. Experimental site.

The experiment was conducted in the summer rice fallows of Rice Research Station, Kayamkulam. The experimental field is located at 9° 30'N latitude and 76° 20'E longitude at an altitude of 3.05 m above MSL.

3.2. Cropping history of the field.

The experimental area was under bulk rice crop during the previous two seasons.

3.3. Weather conditions.

The weekly averages of temperature, relative humidity and rainfall during the cropping period were collected from the observatory attached to CPCRI, Kayamkulam and the data are presented in Appendix I and illustrated graphically in figure 1.

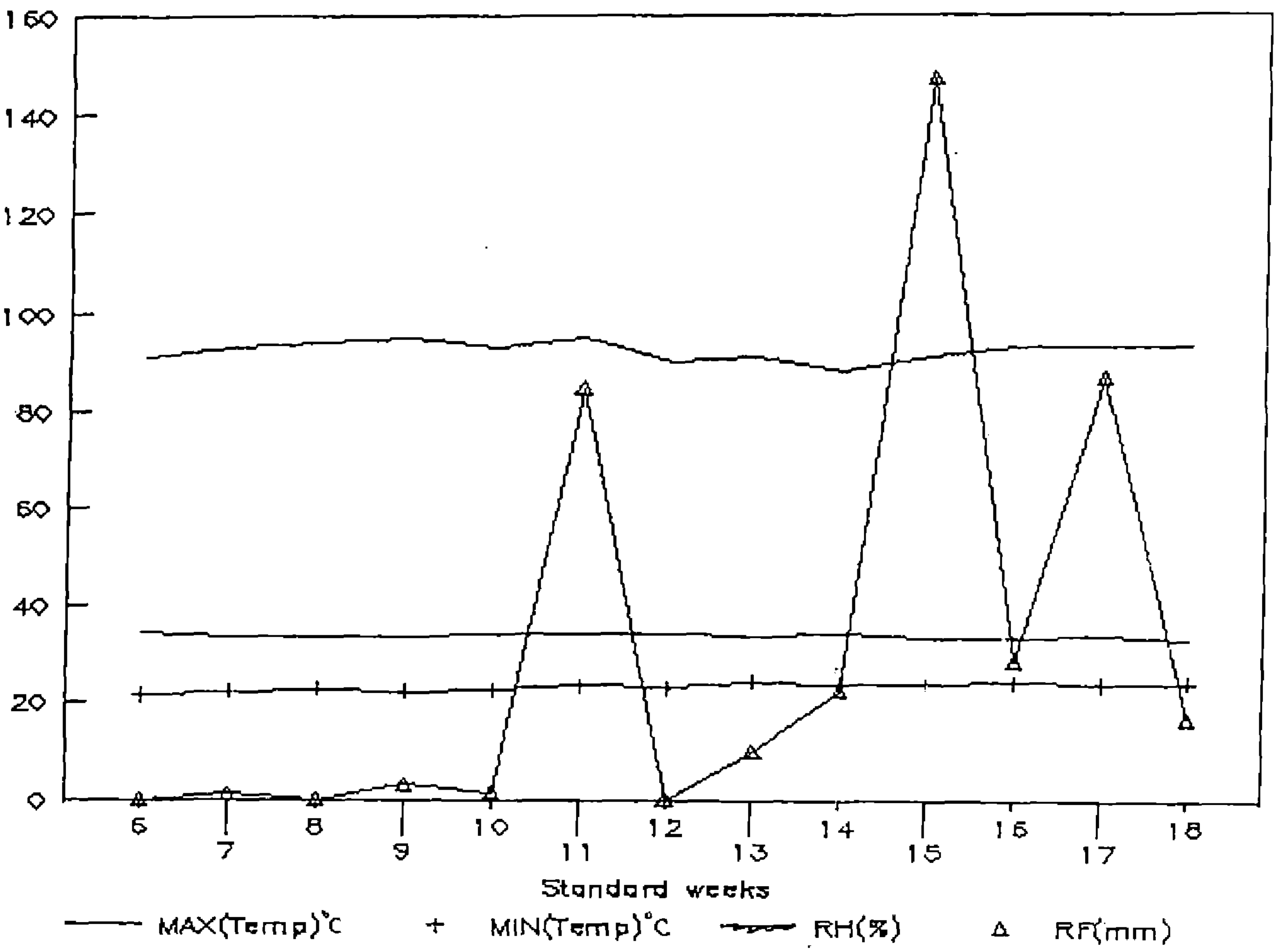


Fig 1.Weather condition during the cropping period

The weather condition during the period of study was favourable for the satisfactory growth of the crop.

3.4. Season.

The experiment was conducted during the summer season from February 1995 to May 1995 utilizing the residual soil moisture.

3.5. Soil.

The soil of the experimental site is loamy sand and acidic in nature. The soil belongs to the taxonomical order, Entisols. The physico-chemical properties of the soil are presented below.

(i) Mechanical analysis of the soil of the experimental site.

Sl.No.	Fractions	Content in Soil	Methods used
A. Mechanical composition			
1	Coarse sand (%)	56.50	International Pipette method (Piper, 1966).
2	Fine sand (%)	16.10	
3	Silt (%)	20.35	
4	Clay (%)	5.80	
5	Textural class	loamy sand	

Physical constants of the soil of the experimental site

Sl.No.	Particulars	Depth of soil layer (0-30 cm)	Methods
B.	Physical constants		
1	Field capacity (%)	16.05	
2	Permanent wilting point (%)	3.86	Pressure membrane apparatus (Richards, 1947)

Chemical properties of the soil of the experimental site.

Sl.No.	Parameter	Content	Rating	Method used
1	Available N (Kg ha^{-1})	188.16	low	Alkaline Permanganate Method (Subbiah and Asija, 1956).
2	Available P_2O_5 (Kg ha^{-1})	34.4	medium	Bray colorimetric Method (Jackson, 1973).
3	Exchangeable K_2O (Kg ha^{-1})	41.4	low	Ammonium acetate Method (Jackson, 1973).
4	Organic carbon (%)	0.45	low	Walkley and Black rapid titration method (Walkley and Black, 1934).
5	pH (dry soil)	5.1	acidic	1:2.5 soil solution ratio using pH meter with glass electrode (Jackson, 1973).

3.6 Materials

3.6.1 Crop variety

The variety used for the experiment was Thilak with a duration of 84 days. It is a pure line selection from a local variety of North Kerala released by KAU. Thilak is suited to the summer fallows of Onattukara.

Particulars of Sesamum variety - Thilak

Plant height	-	101 cm
Distinguishing morphological characters	-	Single poded, four loculed with highly branching.
Days to maturity	-	84 days
Reaction to major pests and diseases under field condition	-	No major pest or disease noticed
Average yield under normal condition	-	648 Kg ha^{-1}
Seed oil	-	51 per cent
Seed colour	-	Blackish brown
1000 seed weight	-	3.1 g.

3.6.2 Source of seed material

The seasmum seeds for the experiment were obtained from the Rice Research Station, Kayamkulam.

3.6.3 Manures and fertilizers

Farm yard manure (0.4 per cent, 0.3 per cent, 0.2 per cent N, P_2O_5 and K_2O respectively) was used for the experiment. Urea (46 per cent N), Mussoriephos (20 per cent P_2O_5) and muriate of potash (60 per cent K_2O) were used as source of nitrogen (N), phosphorus (P) and potassium (K) respectively.

3.6.4 Herbicides

The herbicides alachlor, metolachlor and pendimethalin were applied in spray form and alachlor was applied in granular form also according to the treatments.

Alachlor (Lasso)

Lasso is an amide (acetanilide) herbicide formulation containing 50 per cent active ingredient - alachlor [2-chloro-2,6-diethyl-N-(methoxymethyl) acetanilide]. It is a product of Monsanto Ltd. Alachlor is a pre-emergence herbicide with good efficiency for controlling annual grasses and broad leaved weeds. It is available in EC and granular formulations.

Metolachlor (Dual)

Dual is another amide herbicide formulation containing 50 per cent active ingredient - metolachlor [2-chloro-N-(2-ethyl-6-methyl phenyl)-N-(2-methoxy-1-methyl

ethyl) acetamide]. It is a product of Monsanto Ltd. Metolachlor controls annual and perennial grasses. It is used as pre-emergence herbicide.

Pendimethalin (Stomp)

Stomp is a dinitroaniline herbicide formulation with 30 per cent active ingredient - pendimethalin [N-(1-ethyl propyl)-2, 6 dinitro 3, 4-xylidine] which is the present name of penoxalin. Stomp is a proprietory product of Cynamid India Ltd. It is available in the form of EC and granules. This is a pre-emergence herbicide used for selective weed control of a wide spectrum of grasses and broad leaved weeds.

3.6.5 Sand

Clean dry river sand of 2 mm size were used for preparing alachlor granules.

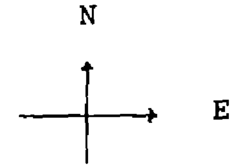
3.7 Methods

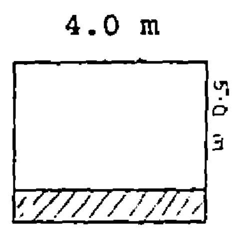
3.7.1 Design and layout

The experiment was laid out in simple radomised block design as suggested by Snedecor and Cochran (1967). The experiment consisted of 12 treatments with 3 replications. The layout plan of the experiment is given in figure 2.

Fig.2 Layout plan - Randomised Block Design

Rep I	Rep II	Rep III
T6	T9	T9
T7	T1	T10
T3	T8	T7
T5	T6	T1
T2	T7	T2
T10	T2	T3
T12	T5	T8
T11	T3	T11
T1	T12	T6
T9	T4	T5
T8	T10	T4
T4	T11	T12





Treatments - 12
Replication - 3
Gross plot size - 5.0 x 4.0 m
Net plot size - 3.2 x 3.6 m

▨ Observational area

T1-Hoeing twice (15&25DAS)
T2-Unweeded control
T3-Weed free check
T4-Hand weeding twice (20&30 DAS)
T5-Alachlor at 1.5 Kg ai ha^{-1}
T6-Pendimethalin at 1.0Kg ai ha^{-1}
T7-Metolachlor at 1.25 Kgaiha^{-1}
T8-Alachlor G at 20 Kg ha^{-1}
T9-Alachlor at 1.5 Kgai ha^{-1} + I hand weeding at 30 DAS
T10-Pendimethalin at 1.0 Kgaiha^{-1} + I hand weeding at 30 DAS
T11-Metolachlor at 1.25 Kg ai ha^{-1} +1hand weeding at 30 DAS
T12-Alachlor G at 20 Kg ha^{-1} +1 hand weeding at 30 DAS

The details of the layout are given below.

Number of treatments	=	12
Number of replications	=	3
Gross plot size	=	5x4 m
Weed observation area in each plot	=	1x1 m
Net plot size	=	3.2x3.6 m
Spacing	=	20x10 cm
Total number of plots	=	36

An area of 1x4 m was left as observation area on the same side of all the plots for taking periodical observations on weeds. Two rows of plants were left as border on all the side of the remaining plots.

3.7.2 Treatments

T1 - Local practice of two hoeings at 15 and 25 DAS

T2 - Unweeded control

T3 - Weed free check

T4 - Hand weeding at 20 and 30 DAS

T5 - Alachlor (pre-emergence) 1.5 Kg ai ha^{-1}

T6 - Pendimethalin (pre-emergence) 1.0 Kg ai ha^{-1}

T7 - Metolachlor (pre-emergence) 1.25 Kg ai ha^{-1}

T8 - Alachlor granules 20 Kg ha^{-1}

T9 - Alachlor 1.5 Kg ai ha^{-1} + 1 hand weeding at 30 DAS

T10 - Pendimethalin at 1.0 Kg ai ha^{-1} + 1 hand weeding at 30 DAS

T11 - Metolachlor 1.25 Kg ai ha^{-1} + 1 hand weeding at 30 DAS

T12 - Alachlor granules 20 Kg ha^{-1} + 1 hand weeding at 30 DAS.

Field culture

3.7.3 Land preparation

The experimental area was ploughed with a power tiller, clods broken and weeds and stubbles of previous crop were removed. The plots were laid out according to the design of the experiment. The experimental area was levelled and cow dung was applied at the rate of 5 t ha^{-1} and incorporated with the soil. The plots were separated by a spacing of 40 cm and blocks by 60 cm spacing.

3.7.4 Fertilizer application

Urea, Mussoriephos and Muriate of potash were applied as basal dose to each plot so as to supply nutrients at the rate of 30 Kg N, 15 Kg P_2O_5 and 30 Kg K_2O per hactare respectively as per the package of Practices Recommendations of Kerala Agricultural University.

3.7.5 Weed management

Pre-emergence application of herbicides

The liquid formulations of alachlor, metolachlor and pendimethalin were made into emulsions with water at the required dose. The herbicide formulations were sprayed uniformly at the rate of 500 l ha^{-1}, the day after sowing in the respective treatment plots.

The 5 per cent granular formulation of alachlor was made in the laboratory by mixing in the ratio of 10 litres of product with 95 Kg dry sieved river sand. After mixing, the granules were spread in a tray and kept overnight for the granules to dry. These granules were broadcasted uniformly in the respective treatment plots the day after the sowing of sesamum seeds.

3.7.6 Seeds and sowing

Dry sowing of seeds by line sowing was done on 7th February, 1995. The seeds at the rate of 5 Kg ha^{-1} were mixed with four times its quantity of sand before sowing. After sowing, the seeds were covered with soil and planking done.

3.7.7 Thinning

The seedlings were thinned to a spacing of 20x10 cm one week after sowing.

3.7.8 Hoeing

Two hoeings were done, on the 15th day after sowing and on the 25th day after sowing in the respective treatment plots.

3.7.9 Hand weeding

Hand weeding was done on the 20th day after sowing and on the 30th day after sowing in the hand weeding plots. Hand weeding was done only on the 30th day after sowing in plots where herbicide and hand weeding are combined. In weed free plots, complete weed free condition was maintained by repeated hand weedings.

3.7.10 Irrigation

The crop was irrigated twice its growth period on 20th February and 21st March for proper vegetative growth and better flowering.

3.7.11 Plant protection

There was no incidence of pests or diseases during the crop period and hence no plant protection operations were carried out.

3.7.12 Harvesting

The crop was harvested on 4th May 1995 when the leaves and lower pods started turning yellow. Harvesting was done by pulling out the plants, cutting out the root portion and stacking the plants in shade in bundles for 3-4 days. Later, the bundles were spread in the sun and beaten with sticks to break the capsules and seeds collected. Drying and threshing were repeated for four more days. In all the treatments, the crop in the observation area was harvested separately. The crop was harvested from the net plot after leaving the border rows. The dry weight of seeds and stalk of individual plots were recorded.

3.8. Observations

Observation on weeds and crops were recorded from the area set apart for the purpose.

3.8.1 Observations on weeds

3.8.1.1 Weed species

The weeds collected from experimental site before the start and after the conduct of experiment were identified and grouped into grasses, sedges and broad-leaved weeds.

3.8.1.2 Weed count

Weed samples were, collected from an area of 1.0 m^2 in the weed observation area on 30th and 60th day after sowing and at the time of harvest. The weeds were classified as monocots and dicots and their counts were taken separately. The weed population is expressed as the number of monocots, dicots and total weeds per m^2.

3.8.1.3 Weed dry weight

The weed sample collected on 30th and 60th day after sowing and at harvest for taking the observation on weed count were pulled out carefully along with roots, washed and dried under shade and later they were oven dried to a constant weight. The dry weight of weeds was recorded in whole units and expressed as g per m^2.

3.8.1.4 Weed control efficiency

Weed control efficiency was worked out on the basis of total weed dry weight. The formula used for the calculation of weed control efficiency was as follows.

$$WCE = \frac{(WDC - WDT) X100}{WDC} \quad \text{where}$$

WCE - Weed control efficiency

WDC - Weed dry weight in the control plot

WDT - Weed dry weight in the treated plot

3.8.2 Observations on crop

Ten plants were selected at random from each plot. The following observations were recorded and the mean values worked out.

3.8.2.1 Height of the plant

The height of the plant was measured from the ground level to the tip of the longest leaf on 30th and 60th days after sowing and at harvest and the values expressed in cm.

3.8.2.2 Number of branches per plant

The total number of branches per plant were counted at 30th and 60th days after sowing and at harvest.

3.8.2.3 Leaf area index (LAI)

The leaf area of observational plants were found out by length - width method using the formula, $A = K\ (LXW)$ [Padalia and Patel, 1980] where L is the length, W the maximum width and K is the leaf area constant which is estimated as 0.618 (Chandramony and Nayar, 1989).

Leaf area index was then worked out using the following formula.

$$\text{Leaf area index} = \frac{\text{Leaf area per plant (cm}^2\text{)}}{\text{Land area occupied by the plant (cm}^2\text{)}}$$

3.8.2.4 Dry matter production (DMP)

Dry matter production was recorded during 30 and 60 days after sowing and at harvest. Five plants were uprooted at each stage from each plot carefully without damaging the roots. At the time of harvest, the observation plants were used for recording dry matter production. The plants were dried under shade and then oven dried at 80±5°C till consecutive weights agreed. The dry weight of the plants were found out and expressed as Kg ha^{-1}.

3.8.3 Yield and yield attributing characters

3.8.3.1 Days to 50 per cent flowering

Number of days taken by 50 per cent of plants for the emergence of flowers in each treatment were noted and recorded.

3.8.3.2 Number of pods per plant

The number of pods obtained from the observational plants were taken at 60th day after sowing and at harvest.

3.8.3.3 1000 seed weight

From the produce obtained from the observational plants 1000 seeds were counted and their weights recorded after oven drying and expressed in grams.

3.8.3.4 Seed yield

The seed harvested from each net plot was dried, weighed and expressed as Kg ha^{-1}.

3.8.4 Haulm yield

The haulm harvested from each net plot was dried, weighed and the weight expressed in Kg ha^{-1}.

3.8.5 Harvest index (HI)

Harvest index was calculated by dividing the weight of seeds with the total weight of seed and stalk of each plot. (Singh and Stoskopf, 1971).

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

3.8.6 Weed index

Weed index was computed by using the formula suggested by Gill and Viajayakumar, 1969.

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

WI = weed index

x = yield from weed free plot or the treatment which recorded minimum weeds.

y = yield from the treatment for which weed index is to be worked out.

3.9 Chemical analysis

3.9.1 Plant analysis

The whole plants of sesamum and composite sample of weeds collected at 30 and 60 days after sowing and at harvest were analysed for nitrogen, phosphorus and potassium. The samples were dried to constant weight in an electric hot air oven at 80 ± 5°C, ground into fine powder using a Wiley mill and used for chemical analysis.

3.9.1.1 Total nitrogen

Total nitrogen content was estimated by modified microkjeldhal method (Jackson, 1973).

3.9.1.2 Total phosphorus

Total phosphorus content was estimated by using Vanado-molybdo phosphoric yellow colour method after extraction with triple acid. The yellow colour was read in a Klett Summerson Photoelectric Colorimeter at 470 nm (Jackson, 1973).

3.9.1.3 Total potassium

The extract used for phosphorus estimation was used for estimation of total potassium using flame photometer method (Jackson, 1973).

3.9.1.4 Uptake of nutrients

The total uptake of nitrogen, phosphorus and potassium by crop and weed at 30 and 60 days after sowing and at harvest were calculated by multiplying the content of their nutrients in the plant sample and the respective dry weight expressed as Kg ha^{-1}.

3.9.1.5 Crude protein content of seeds

The crude protein content of sesamum was calculated by multiplying the percentage of nitrogen in the seeds by the factor 6.25 (Simpson et al., 1965).

3.9.1.6 Oil content of seeds

Samples of seeds were drawn from the bulk of seed of each plot and oil content estimated by cold percolation method (Kartha and Sethi, 1957).

3.9.2 Soil analysis

Soil analysis was done before and after the experiment. A representative soil sample of the field obtained by mixing the soil samples collected from different parts of the field was used for the initial determination of available nitrogen, available phosphorus and available potassium. After the harvest of the crop, soil samples were taken from each plot separately and analysed for available N, available P_2O_5 and avialable K_2O.

3.9.3 Microflora count

Fresh soil samples were taken from each plot before the experiment and also on the 5th and 30th day after herbicidal treatment for taking microflora counts after incubating them in suitable media by serial dilution technique (Timonin, 1940). The media used were beef extract agar (Allen, 1957), Kenknight's and Munaier's medium and Martin's Rose bengal agar (Martin, 1950) for taking counts on bacteria, actinomycetes and fungi respectively.

3.10 Economics of cultivation

The economics of cultivation was worked out based on the various input costs.

$$\text{Benefit - cost ratio} = \frac{\text{Gross income}}{\text{Cost of cultivation}}$$

Net returns per rupee invested

$$= \frac{\text{Gross income - cost of cultivation}}{\text{Cost of cultivation}}$$

Net income = Gross income - Cost of cultivation

3.11 Statistical analysis

The data generated from the experiment was subjected to analysis of variance (ANOVA) technique as applied to randomised block design described by Cochran and Cox (1965). The data were analysed in a computer.

RESULTS

RESULTS

The data recorded in this study were statistically analysed and the mean values corresponding to various characters are given in Tables 1 to 18.

4.1.Observations on weeds

4.1.1. Weed species

The different weed species noted in the experimental area before and during the crop period were collected and iadentified. These weeds were categorised into grasses, sedges and broad leaved weeds. The predominant weeds identified in the experimental area were Brachiaria ramosa, Cynodon dactylon; Panicum repens, Cyperus spp., Cleome viscosa, Leucas aspera, Commelina spp., Sida acuta, Emilia sonchifolia. Cleome viscosa constitute 90 per cent of the total weight of dicot weeds from the experimental field.

The weeds identified in the experimental area are enlisted

List of weeds present in the experimental field

Scientific name	Family
I Grasses	
Brachiaria ramosa (Griseb) Stapf	Graminae
Cynodon dactylon Pers.	Graminae
Panicum repens L.	Graminae
II Sedges	
Cyperus iria L.	Cyperaceae
Cyperus rotundus L.	Cyperaceae
Fimbrystylis miliaceae Vahl	Cyperaceae
III Broad - leaved weeds	
Cleome viscosa L.	Capparidaceae
Sida acuta L.	Malvaceae
Leucas aspera Spreng.	Labiatae
Cassia occidentale L.	Leguminosae
Phyllanthus niruri L.	Euphorbiaceae
Amaranthus viridis L.	Amaranthaceae
Emilia sonchifolia L.	Compositae
Commelina spp. L.	Commelinaceae

4.1.2 Weed count

The counts of monocot and dicot weeds and also total weed count in the experimental area were taken before the experiment and also at 30 and 60 days after sowing and at harvest.

Weed count before the experiment was taken from an area of 1.0 m^2 each at three different locations in the experimental field and the mean values expressed as weed counts per square metre were monocots - 648, dicots - 198 and total - 846.

4.1.2.1 Monocot weed population

The data on monocot weed population at 30 and 60 DAS and at harvest were analysed statistically after square root transformation and the mean values presented in Table 1 (a).

4.1.2.1.a 30 DAS

The maximum monocot weed population was recorded with unweeded control (408.3 weeds m^{-2}) and minimum with weed free check at 30 DAS. Hand weeding twice at 20 and 30 DAS was efficient in recording lower counts of monocot weeds (134.0 weeds $^{-2}$), next to weed free check, although not on par with weed free situation. The other superior treatments were application of pendimethalin at 1.0 Kg ai ha^{-1} either alone or

Table 1(a). Effect of treatments on monocot weed population per metre square at different days after sowing.

(after $\sqrt{x+1}$ transformation).

Treatments	Days after sowing		Harvest
	30	60	
T1	15.3 (233.6)	11.7 (136.9)	7.4 (54.3)
T2	20.2 (408.3)	24.2 (585.2)	25.2 (632.1)
T3	1.0 (0)	1.0 (0)	1.0 (0)
T4	11.6 (134.0)	11.1 (122.8)	7.1 (49.4)
T5	15.0 (225.0)	12.3 (149.0)	7.5 (55.0)
T6	13.4 (179.5)	15.4 (237.0)	9.1 (81.6)
T7	15.7 (247.0)	16.0 (256.0)	9.7 (92.7)
T8	16.0 (255.0)	16.8 (281.1)	10.4 (107.2)
T9	14.4 (207.7)	10.2 (103.4)	6.8 (45.5)
T10	13.7 (187.6)	10.9 (117.5)	6.1 (36.7)
T11	15.5 (240.7)	11.5 (130.0)	7.4 (53.0)
T12	16.4 (268.5)	16.3 (263.8)	9.9 (98.6)
CD (0.05)	*0.38	*1.06	*0.95
SE	0.18	0.51	0.46

Note:- The figures in paranthesis are the original values.

* Significant at 0.05 level.

combined with hand weeding at 30 DAS (179.5 and 187.6 weeds m^{-2} respectively) and these two treatments were on par with each other. The application of granular form of alachlor at 20 Kg ha^{-1} followed by hand weeding at 30 DAS was inferior to rest of treatments, except unweeded control with higher monocot weed counts at 30 DAS (268.5 weeds m^{-2}). The treatments T8 and T7 also recorded higher weed counts at this stage.

4.1.2.1.b 60 DAS

The monocot weed population at 60 DAS also showed significant difference with different weed control treatments. The unweeded control undoubtedly, recorded the maximum population of monocot weeds (585.2 weeds m^{-2}) at 60 DAS also, while the minimum population was recorded by weed free check. These treatments were not comparable with any other treatment. The treatments found superior by recording lower monocot weed population, next to weed free check, were application of alachlor at 1.5 Kg ai ha^{-1} or pendimethalin at 1.0 Kg ai ha^{-1}, each integrated with hand weeding at 30 DAS (103.4 and 117.5 weeds m^{-2} respectively) and hand weeding twice at 20 and 30 DAS (122.8 weeds m^{-2}) and these treatments were on par with each other. The application of metolachlor at 1.25 Kg ai ha^{-1} combined with hand weeding at 30 DAS and hoeing with Kochuthoomba twice at 15 and 25 DAS also stood on par with two hand weedings. The treatments which closely followed the unweeded control in recording higher monocot weed population were application of granules of alachlor at 20 Kg ha^{-1} alone (281.1 weeds m^{-2}) and also alachlor granule application combined with hand weeding at 30 DAS (263.8 weeds m^{-2}). The treatments T7 and T6 also were on par with T12.

4.1.2.1.c Harvest

At harvest stage also, the unweeded control and weed free check continued to record the maximum (632.1 weeds m^{-2}) and minimum monocot weed population respectively. The weed free check and unweeded control were not on par with any other treatment. The application of pendimethalin at 1.0 Kg ai ha^{-1} followed by a hand weeding at 30 DAS (36.7 weeds m^{-2}) and alachlor at 1.5 Kg ai ha^{-1} combined with hand weeding at 30 DAS (45.5 weeds m^{-2}) were the treatments which recorded minimum weed count next to weed free situation indicating the superiority of these treatments. The treatment T9 inturn was on par with T4, T11, T1 and T5. The application of alachlor in granular form at 20 Kg ha^{-1} alone (107.2 weeds m^{-2}) and also the application of alachlor granules integrated with hand weeding at 30 DAS (98.6 weeds m^{-2}) on the other hand, recorded higher weed counts although not on par with unweeded control. The treatment T12 was on par with T7 and T6 and these treatments were inferior to other treatments.

4.1.2.2 Dicot weed population

The data on dicot weed population were also analysed statistically after square root transformation and the mean values presented in Table 1 (b).

4.1.2.2.a 30 DAS

At 30 DAS, the dicot weed population was significantly influenced by different treatments adopted for weed control. The highest number of weeds per square metre was recorded with the unweeded control (39.5 weeds m^{-2}) and the lowest with continuous weeding treatment. The treatment T2 was inferior to all other treatments so also, T3 was superior to rest of treatments. The cultural practice of giving two hand weedings at 20 and 30 DAS reduced the dicot weed population at 30 DAS (7.4 weeds m^{-2}). The application of pendimethalin at 1.0 Kg ai ha^{-1} was also found to be effective in reducing the weed count (8.4 weeds m^{-2}) at this stage and these two treatments were on par with each other. Application of pendimethalin alone was comparable to this chemical application integrated with hand weeding at 30 DAS (10.6 weeds m^{-2}). The treatment T10 in turn was on par with T9. The treatments which recorded higher dicot weed population next to unweeded control were application of alachlor granules at 20 Kg ha^{-1} combined with hand weeding at 30

Table 1(b) Effect of treatments on dicot weed population per metre square at different days after sowing.

(after $\sqrt{x+1}$ transformation).

Treatments	Days after sowing 30	60	Harvest
T1	4.2 (16.8)	6.4 (39.3)	6.8 (45.5)
T2	6.4 (39.5)	7.6 (56.5)	8.4 (68.8)
T3	1.0 (0)	1.0 (0)	1.0 (0)
T4	2.9 (7.4)	5.7 (31.7)	6.4 (39.3)
T5	3.9 (14.0)	6.4 (40.3)	7.0 (48.2)
T6	3.1 (8.4)	6.7 (43.7)	7.3 (51.5)
T7	4.9 (22.6)	7.0 (48.1)	7.6 (56.6)
T8	5.0 (23.9)	7.4 (54.2)	8.0 (63.2)
T9	3.5 (11.1)	5.2 (25.5)	5.6 (30.8)
T10	3.4 (10.6)	5.6 (29.9)	5.1 (24.7)
T11	4.6 (20.0)	6.1 (31.7)	6.7 (43.8)
T12	5.2 (25.9)	7.2 (50.1)	7.8 (59.0)
CD (0.05)	*0.38	*0.45	*0.60
SE	0.18	0.22	0.29

Note:- The figures in paranthesis are the original values.

* Significant at 0.05 level.

DAS (25.9 weeds m^{-2}) and also this treatment applied without adopting a hand weeding at 30 DAS and metolachlor application at 1.25 Kg ai ha^{-1} alone. The treatment T7 was on par with T11. Hoeing with Kochuthoomba recorded higher dicot weed count (16.8 weeds m^{-2}).

4.1.2.2.b 60 DAS

At later stages also dicot weed population was maximum with unweeded control (56.5 weeds m^{-2}) and minimum with weed free check. Application of alachlor at 1.5 Kg ai ha^{-1} or pendimethalin at 1.0 Kg ai ha^{-1}, each supplemented with hand weeding at 30 DAS also recorded lower dicot weed count (25.5 and 29.9 weeds m^{-2} respectively) next to weed free check. The treatment T4 in turn was on par with T11. The granular application of alachlor at 20 Kg ha^{-1} either alone (54.2 weeds m^{-2}) or combined with hand weeding at 30 DAS (50.1 weeds m^{-2}) and metolachlor at 1.25 Kg ai ha^{-1} (48.1 weeds m^{-2}) registered higher count of dicot weeds next to unweeded control. The treatment T7 was on par with T6.

4.1.2.2.c Harvest

The unweeded control and weed free check continued to record the highest (68.8 weeds m^{-2}) and lowest dicot weed counts respectively at harvest stage also. The treatments found superior next to weed free check, in recording lower weed counts were application of alachlor at 1.5 Kg ai ha^{-1} along with hand weeding at 30 DAS (24.7 weeds m^{-2}) and pendimethalin spray at 1.0 Kg ai ha^{-1} followed by a hand weeding at 30 DAS (30.8 weeds m^{-2}). The treatments T9 and T10 were superior to all other treatments except weed free check. At this stage, the granular application of alachlor at 20 Kg ha^{-1} either alone or combined with hand weeding at 30 DAS (63.2 and 59 weeds m^{-2} respectively) were comparable with unweeded control. The treatment T12 in turn was on par with T7 and T6.

4.1.2.3 Total weed population

The total weed population at different growth stages of crop were analysed statistically after square root transformation and the mean values presented in Table 1 (c).

4.1.2.3.a 30 DAS

The total weed count at 30 DAS also recorded significant difference with different weed control treatments. The total weed population was maximum with unweeded control (447.8 weeds m^{-2}) and minimum with weed free check at 30 DAS. The practice of giving two hand weedings at 20 and 30 DAS recorded the least weed count (141.4 weeds m^{-2}), next to weed free check and was significantly superior to other treatments except the weed free

Table 1(c). Effect of treatments on total weed population per metre square at different days after sowing.

(after $\sqrt{x+1}$ transformation)

Treatments	Days after sowing		Harvest
	30	60	
T1	15.9 (250.4)	13.3 (176.2)	10.0 (99.7)
T2	21.2 (447.8)	25.4 (641.7)	26.4 (700.9)
T3	1.0 (0)	1.0 (0)	1.0 (0)
T4	11.9 (141.4)	12.5 (154.5)	9.5 (88.7)
T5	15.5 (239.0)	13.8 (189.3)	10.2 (103.2)
T6	13.7 (187.9)	16.8 (280.7)	11.6 (133.1)
T7	16.4 (269.6)	17.5 (304.1)	12.3 (149.3)
T8	16.7 (278.9)	18.3 (335.3)	13.1 (170.4)
T9	14.8 (218.8)	11.4 (128.9)	8.8 (76.3)
T10	14.1 (198.2)	12.2 (147.4)	7.9 (61.4)
T11	16.2 (260.7)	12.9 (166.0)	9.9 (96.8)
T12	17.2 (294.4)	17.7 (313.9)	12.6 (157.6)
CD (0.05)	*0.40	*1.04	*1.06
SE	0.20	0.50	0.51

Note:- The figures in paranthesis are the original values.

* Significant at 0.05 level.

check. Application of pendimethalin at 1.0 Kg ai ha^{-1} either alone (187.9 weeds m^{-2}) or combined with hand weeding at 30 DAS (198.2 weeds m^{-2}) also recorded lower weed counts and were comparable with each other. The treatment T9 also recorded lower weed count. The application of alachlor granules at 20 Kg ha^{-1} combined with hand weeding at 30 DAS recorded higher weed counts (294.4 weeds m^{-2}), next to unweeded control and was inferior to all other treatments except unweeded control. The treatments T8 and T7 also continued to record higher total weed population.

4.1.2.3.b 60 DAS

On the 60th day after sowing also, the weed free check recorded the lowest and unweeded control the highest total weed count (641.7 weeds m^{-2}). Application of alachlor at 1.5 Kg ai ha^{-1} integrated with hand weeding at 30 DAS (128.9 weeds m^{-2}) and also application of pendimethalin at 1.0 Kg ai ha^{-1} combined with hand weeding at 30 DAS (147.4 weeds m^{-2}) were effective in recording lower weed counts, next to weed free check and these treatments were on par with each other, but not on par with weed free check. Hand weeding twice at 20 and 30 DAS and application of metolachlor at 1.25 Kg ai ha^{-1} followed by hand weeding at 30 DAS (154.5 and 166.0 weeds m^{-2} respectively) were in turn on par with T10. The treatment T11 stood on par with T1 and T5. The application of alachlor granules at 20 Kg ha^{-1} either alone or integrated with hand weeding at 30 DAS (335.3 and 313.9 weeds m^{-2} respectively) registered higher weed counts, next to unweeded control. The treatment T12 was on par with T7 and T6.

4.1.2.3.c Harvest

The total weed count at harvest stage was significantly reduced by different treatments. Of the various treatments the weed free check continued to be the most superior treatment with lowest weed count and the unweeded control, the inferior of all the treatments with highest weed count (700.9 weeds m^{-2}). At this stage, the application of pendimethalin at 1.0 Kg ai ha^{-1} with hand weeding at 30 DAS recorded lower weed counts (61.4 weeds m^{-2}) than the application of alachlor at 1.5 Kg ai ha^{-1} along with hand weeding at 30 DAS (76.3 weeds m^{-2}), but were on par with each other. Hand weeding twice at 20 and 30 DAS also recorded total weed counts (88.7 weeds m^{-2}) comparable with application of alachlor along with hand weeding at 30 DAS. The treatment T4 in turn was on par with T11, T1 and T5. Although not on par with unweeded control, the higher weed counts were recorded with alachlor granules at 20 Kg ha^{-1} alone (170.4 weeds m^{-2}) and also alachlor granules combined with hand weeding at 30 DAS (157.6 weeds m^{-2}) and these two treatments were on par with each other.

4.1.3. Weed dry matter production

The data on the weed dry matter at 30 and 60 days after sowing and at harvest were analysed statistically after square root transformation and the mean values are presented in Table 2 (a). The effect of treatments on dry weight of weeds recorded at harvest is illustrated in Figure 3.

4.1.3.a. 30 DAS

The weed control treatments significantly influenced the dry weight of weeds at 30 DAS. The minimum dry matter production was observed in treatments which received two handweedings at 20 and 30 DAS (10.8 g m^{-2}), Pendimethalin at 1.0 kg ai ha^{-1} combined with hand weeding at 30 DAS (14.2 g m^{-2}) and also alachlor at 1.5 Kg ai ha^{-1} followed by hand weeding at 30 DAS (20.7 g m^{-2}) and this chemical used alone (21.4 g m^{-2}). However the least dry matter production was recorded by the weed free situation which was significantly superior to all other treatments. The unweeded control recorded the highest dry matter of weeds (84.5 g m^{-2}) and it was significantly inferior to all other treatments.

4.1.3.b. 60 DAS

The weed control treatments considerably influenced the weed dry matter production at 60 DAS also. Here again the lowest dry

Table 2(a). Effect of treatments on dry matter production of weeds (g m^{-2}) at different days after sowing.

(after $\sqrt{x+1}$ transformation)

Treatments	Days after sowing		Harvest
	30	60	
T1	6.19 (37.36)	7.88 (61.15)	8.16 (65.61)
T2	9.25 (84.49)	17.23 (298.86)	17.37 (300.83)
T3	1.00 (0)	1.00 (0)	1.00 (0)
T4	3.44 (10.87)	6.98 (48.60)	7.07 (49.84)
T5	4.73 (21.40)	8.87 (77.33)	9.02 (80.29)
T6	3.68 (12.53)	9.87 (96.33)	10.02 (99.46)
T7	6.33 (40.39)	10.36 (106.36)	10.63 (112.02)
T8	6.70 (43.89)	10.88 (117.48)	10.92 (118.35)
T9	4.66 (20.70)	6.50 (41.29)	6.51 (41.38)
T10	3.89 (14.16)	6.09 (36.12)	6.22 (37.75)
T11	6.12 (36.50)	7.02 (40.28)	7.36 (53.18)
T12	7.02 (48.35)	10.79 (115.41)	10.83 (116.34)
CD (0.05)	* 0.25	* 1.25	* 1.26
SE	0.008	0.43	0.43

Note:- The figures in paranthesis are the original values.

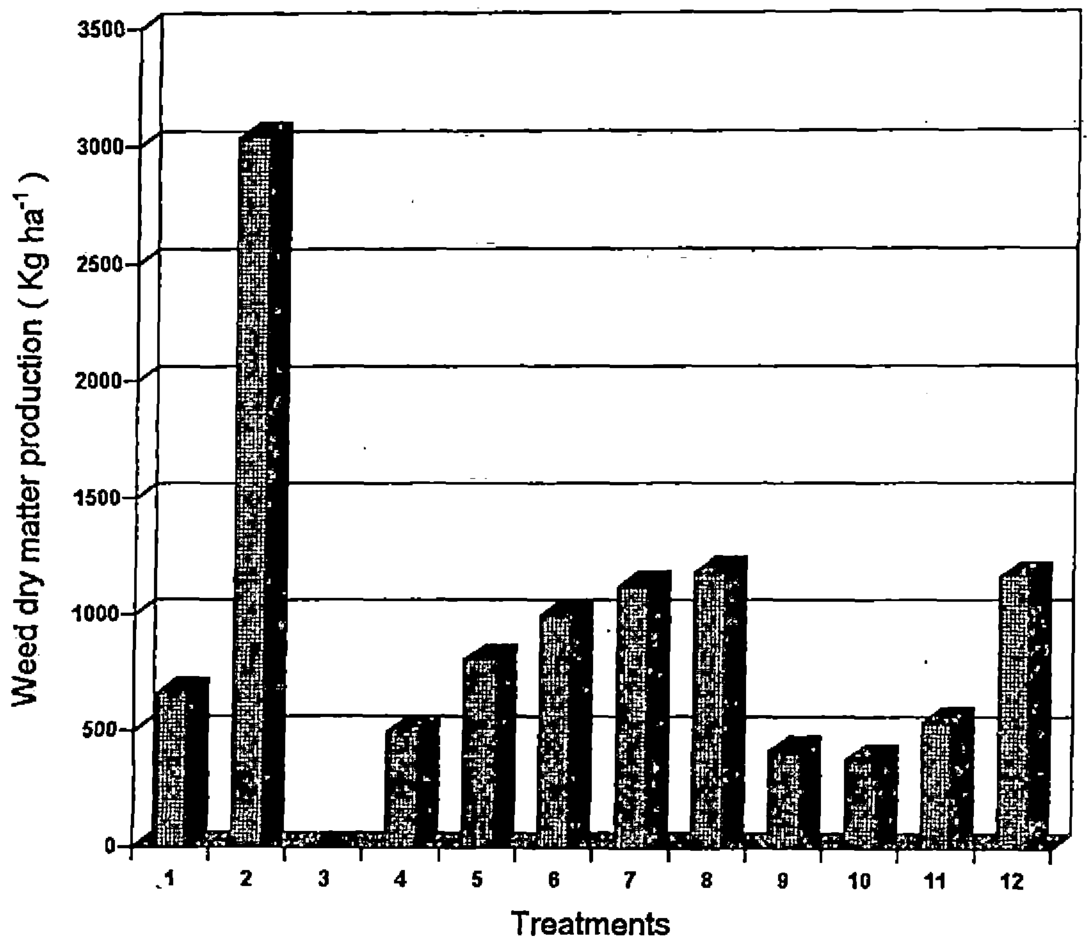
* Significant at 0.05 level.

matter production was recorded by weed free check which was significantly superior to all other treatments. Application of pendimethalin, alachlor and metolachlor when combined with one hand weeding at 30 DAS and also twice hand weeding at 20 and 30 DAS (36.1, 41.3,40.3 and 48.60 g m^{-2} respectively) recorded significantly lower weed dry matter production when compared to the treatments which received these chemicals alone. The local practice of two hoeings with Kochuthoomba at 15 and 25 DAS (61.5 g m^{-2}) is comparable with the application of metolachlor accompanied with one hand weeding at 30 DAS. The highest dry matter production was noticed with unweeded control (298.9 g m^{-2}) and was significantly inferior to all other treatments.

4.1.3.c.At harvest

As in the case of other two stages, the weed free check recorded the least and the unweeded control the highest (303.6 g m^{-2}) dry matter production of weeds at harvest stage. Next to weed free check, pendimethalin at 1.0 kg ai ha-1 combined with hand weeding at 30 DAS (37.8 g m^{-2}) recorded lowest weed dry matter production. This treatment in turn, was on par with integration of application of alachlor at 1.5 Kg ai ha^{-1} with one hand weeding at 30 DAS (41.4 g m^{-2}), two hand weedings at 20 and 30 DAS (49.8 g m^{-2}) and also metolachlor application accompanied with hand weeding at 30 DAS

Fig 3. Effect of treatments on dry weight of weeds at harvest (Kg ha $^{-1}$)



(53.2 g m^{-2}). All the weed control treatments were found significantly superior to unweeded control. The chemicals like alachlor, pendimethalin and metolachlor when applied alone recorded significantly more weed dry weight than when these chemical applications were followed by one hand weeding at 30 DAS.

4.1.4. Weed control efficiency

The data on weed control efficiency at harvest were analysed statistically after angular transformation and the mean values presented in Table 2(b).

The weed free check no doubt, recorded 100 per cent efficiency in controlling weed and this was significantly more efficient than all other treatments. Among the herbicidal treatments, pendimethalin at 1.0 Kg ai ha^{-1} followed by one hand weeding at 30 DAS recorded the maximum weed control efficiency (87.3 per cent) and was on par with alachlor at 1.5 Kg ai ha^{-1} followed by one hand weeding at 30 DAS (86.2 per cent) and two hand weedings at 20 and 30 DAS (83.8 per cent). So also, the treatment T4 was on par with T11 and T1. Alachlor granules when applied either alone or when supplemented with one hand weeding at 30 DAS (59.6 and 60.3 per cent respectively) were not efficient enough in controlling the weeds. This was

Table 2(b). Effect of treatments on weed control efficiency (per cent) (after angular transformation).

Treatments	Weed control efficiency
T1	61.92 (78.88)
T2	0 (0)
T3	90 (100.00)
T4	66.23 (83.78)
T5	58.43 (72.62)
T6	54.26 (65.92)
T7	51.86 (61.89)
T8	50.54 (59.64)
T9	68.14 (86.17)
T10	69.13 (87.34)
T11	65.20 (82.44)
T12	50.94 (60.32)
CD (0.05)	* 5.37
SE	1.83

Note:- The figures in paranthesis are the original values.

* Significant at 0.05 level.

significantly inferior to alachlor, pendimethalin and metolachlor applied as spray.

4.2. Observations on crop.

4.2.1. Plant height

The height of plants recorded on 30th and 60th day after sowing and at harvest were analysed statistically. The mean values are presented in Table 3.

4.2.1.a. 30 DAS

The different weed management practices did not significantly influence the height of the plants at 30 DAS. At this stage, the plants were taller in the unweeded control (37.4 cm) and the shorter plants were observed with application of metolachlor at 1.25 kg ai ha^{-1} alone. (28.7 cm).

4.2.1.b. 60 DAS

At 60 DAS, significant influence could be observed with weed control practices on the height of plants. The height was maximum with plots receiving continuous weeding (98.6 cm) and was comparable with two hand weedings at 20 and 30 DAS (91.5 cm). The other treatments found superior for this character were application of alachlor and pendimethalin

Table 3. Effect of treatments on height of plants (cm) at different days after sowing.

Treatments	Days after sowing		Harvest
	30	60	
T1	33.07	79.90	99.73
T2	37.40	68.37	69.23
T3	32.00	98.67	125.97
T4	31.53	91.47	115.60
T5	33.87	76.47	97.00
T6	28.93	78.77	93.33
T7	28.73	72.07	82.93
T8	28.93	82.00	79.23
T9	29.93	87.87	114.57
T10	33.80	84.10	117.73
T11	32.80	83.50	108.70
T12	31.33	80.73	106.47
CD (0.05)	NS	* 7.78	*13.52
SE		2.65	4.61

NS Not significant
* Significant at 0.05 level.

integrated with hand weeding at 30 DAS. The lowest value for height was recorded with unweeded control (68.4 cm) and was on par with the application of metolachlor at 1.25 Kg ai ha^{-1}. The treatments T5 and T6 also recorded lower values for height.

4.2.1.c.At harvest

At harvest also, weed control treatments exerted significant influence on height of plants. The maximum height was recorded with weed free check (126.0 cm) and the minimum with unweeded control (69.2 cm). Pendimethalin spray at 1.0 Kg ai ha^{-1} combined with hand weeding at 30 DAS and the application of alachlor at 1.5 kg ai ha^{-1} along with hand weeding at 30 DAS also recorded plant heights that were comparable to that recorded by weed free check. The treatments T11 and T12 could also result in greater heights. The inferior treatments next to unweeded control were application of granular form of alachlor at 20 Kg ha^{-1} (79.2 cm) and metolachlor applied at 1.25 Kg ai ha^{-1} (82.9 cm).

4.2.2. Number of branches per plant

The number of branches were recorded at 30 and 60 days after sowing and at harvest. The data were analysed statistically and the mean values presented in Table 4.

Table 4. Effect of treatments on number of branches per plant at different days after sowing.

Treatments	Days after sowing		Harvest
	30	60	
T1	3.8	3.8	3.8
T2	1.4	3.1	3.1
T3	5.2	5.2	5.2
T4	5.0	5.0	5.0
T5	3.5	3.5	3.5
T6	3.2	3.3	3.3
T7	2.2	3.1	3.1
T8	1.7	3.1	3.1
T9	4.4	4.4	4.4
T10	4.4	4.4	4.4
T11	3.2	3.4	3.4
T12	3.8	3.9	3.9
CD (0.05)	*0.82	NS	NS
SE	0.39		

NS Not significant
* Significant at 0.05 level.

The different weed control treatments were found to be effective in influencing the number of branches per plant significantly at early stage.

4.2.2.a.30 DAS

On the 30th day after sowing, weed free check registered the maximum number of branches per plant (5.2) and the unweeded control the minimum (1.4). The treatments receiving two hand weedings at 20 and 30 DAS and application of alachlor or pendimenthalin, each supplemented with a hand weeding at 30 DAS recorded more number of branches. The treatments on par with unweeded control were application of alachlor as granules (1.7) and metolachlor as spray (2.2). The treatments T7, T8 and T2 were found to be significantly inferior to all other treatments.

4.2.2.b. 60 DAS

There was no significant increase in the number of branches after 60 DAS. At this stage, weed free treatment (5.2) and hand weeding twice at 20 and 30 DAS (5.0) recorded the maximum number of branches per plant and this being on par with each other was significantly superior to all other treatments. The treatments, T9 and T10 were also superior to other treatments except T3 and T4. The lowest branch number per plant was observed with unweeded control (3.1). The application of spray formulation of alachlor, pendimethalin and metolachlor and application of alachlor granules recorded lower number of branches when compared to the treatments where the above chemical sprays were combined with one hand weeding.

4.2.3. Leaf area index

The data on leaf area index recorded on 30 and 60 days after sowing and at harvest were analysed statistically and the mean values presented in Table 5.

The leaf area index was found to be unaffected by the different weed control treatments. The highest value of leaf area index was obtained at 60 DAS and thereafter there was a gradual decrease. Though there was no significant difference between the different weed management treatments, the maximum value was registered by the weed free treatment (1.25, 2.40 and 2.10 at 30 and 60 DAS and at harvest respectively).

4.2.4 Dry matter production of crop.

The dry matter production of crop was recorded at 30 and 60 days after sowing and at harvest. The mean values of the data are presented in Table 6. The effect of treatments on crop dry matter production at harvest is illustrated in Figure 4.

Table 5. Effect of treatments on leaf area index at different days after sowing

Treatments	Days after sowing		Harvest
	30	60	
T1	1.22	2.37	2.09
T2	1.21	2.34	2.07
T3	1.25	2.40	2.10
T4	1.25	2.39	2.10
T5	1.18	2.34	2.06
T6	1.20	2.35	2.08
T7	1.18	2.33	2.05
T8	1.18	2.33	2.06
T9	1.23	2.38	2.09
T10	1.21	2.37	2.09
T11	1.19	2.37	2.07
T12	1.19	2.35	2.06
CD (0.05)	NS	NS	NS

NS Not significant

Table 6. Effect of treatments on dry matter production of crop (Kg ha^{-1}) at different days after sowing.

Treatments	Days after sowing		Harvest
	30	60	
T1	572.10	2179.70	2039.93
T2	623.10	1326.97	1160.80
T3	570.50	2664.07	2611.77
T4	562.10	2449.23	2275.53
T5	594.10	1903.27	1798.37
T6	618.40	1934.77	1689.60
T7	550.50	1683.20	1583.73
T8	426.40	1617.27	1472.80
T9	556.30	2014.10	2122.90
T10	606.20	2333.4	2214.63
T11	586.20	1963.27	1841.50
T12	548.60	1961.20	1689.60
CD (0.05)	*24.59	*431.73	*230.10
SE	8.38	147.19	78.45

* Significant at 0.05 level.

The plant dry matter production was considerably influenced by the weed management practices at 30 and 60 DAS as well as at harvest. There was a steady increase in the dry matter production of plants from 30 DAS to harvest stage.

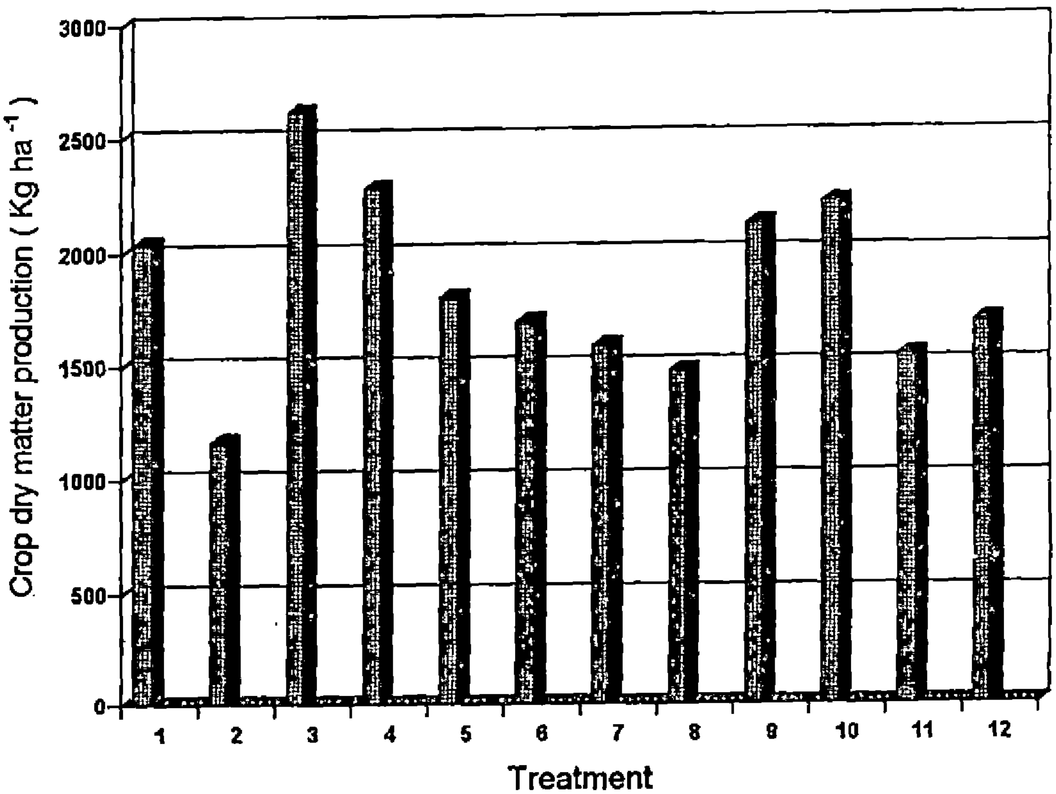
4.2.4.a. 30 DAS

At 30 DAS, unweeded control recorded the highest plant dry matter production of 623.1 Kg ha^{-1} and this was on par with pendimethalin application at 1.0 Kg ai ha^{-1} (618.4 Kg ha^{-1}). Application of pendimethalin at 1.0 Kg ai ha^{-1} and its combination with one hand weeding at 30 DAS (606.2 Kg ha^{-1}) and also application of alachlor at 1.5 Kg ai ha^{-1} (594.1 Kg ha^{-1}) were equally good in producing higher plant dry matter at this stage. The minimum dry weight of plant was registered with application of alachlor in granular form (426.4 Kg ha^{-1}). This treatment was inferior to rest of treatments.

4.2.4.b 60 DAS

At 60 DAS, hand weeding twice at 20 and 30 DAS (2664.1 Kg ha^{-1}) and application of pendimethalin at 1.0 Kg ai ha^{-1} along with one hand weeding at 30 DAS (2333.4 Kg ha^{-1}) were on par with weedfree check which recorded the highest plant dry matter production (2664.1 Kg ha^{-1}). The lowest plant dry matter

Fig 4. Effect of treatments on dry matter production of crop at harvest
(Kg ha $^{-1}$)



recorded by unweeded control (1327.0 Kg ha^{-1}) and was on par with application of alachlor as granules at 20 Kg ha^{-1} and metolachlor spray at 1.25 Kg ai ha^{-1}.

4.2.4.c. At harvest.

The continuously weed free condition was significantly superior to all other treatments in recording higher plant dry matter production (2611.8 Kg ha^{-1}) at harvest. This was closely followed by hand weeding twice at 20 and 30 DAS, pendimethalin at 1.0 Kg ai ha^{-1} combined with one hand weeding at 30 DAS, alachlor at 1.5 Kg ai ha^{-1} combined with one hand weeding at 30 DAS and the two hoeings at 15 and 25 DAS which were on par with each other. At this stage also, unweeded plots recorded the least plant dry matter production (1160.8 Kg ha^{-1}) and was significantly inferior to all other t"eatments. The treatments T5, T6, T7 and T8 consisting of the herbicidal application alone were not very effective in increasing the dry matter production at this stage.

Yield attributing characters

4.2.5. 50 per cent flowering

The data on 50 per cent flowering were analysed statistically and the mean values are presented in Table-7.

Table 7. Effect of treatments on yield attributing characters.

Treatments	Days to 50% flowering	Number of pods per plant		1000 seed weight
		60 DAS	Harvest	
T1	43.00	42.73	86.43	2.70
T2	47.00	20.03	40.63	2.10
T3	40.70	61.00	116.80	2.95
T4	41.30	50.50	104.23	2.80
T5	44.00	37.67	69.77	2.62
T6	44.00	36.67	67.47	2.50
T7	45.00	24.17	47.57	2.20
T8	46.30	31.33	50.80	2.40
T9	43.30	47.27	95.33	2.70
T10	42.00	54.20	99.20	2.80
T11	42.30	45.53	80.37	2.30
T12	44.30	34.27	54.43	2.50
CD (0.05)	*0.80	*7.97	*16.45	*0.11
SE	0.39	2.72	5.61	0.05

* Significant at 0.05 level.

The control of weeds by different treatments could significantly reduce the days taken for completing 50 per cent flowering. The completely weed free situation was efficient in completing 50 per cent of flowering earlier to all other treatments (40.7 days). Two hand weedings at 20 and 30 DAS (41.3 days) was on par with application of pendimethalin at 1.0 Kg ai ha^{-1} along with one hand weeding at 30 DAS (42 days). This in turn was closely followed by T11, T1 and T9. The maximum number of days taken for completing 50 per cent flowering was noticed with unweeded control (47 days) and this was on par with granular application of alachlor at 20 Kg ha^{-1}. These treatments were inferior to all other treatments.

4.2.6. Number of pods per plant

The mean values of the data recorded on 60th day after sowing and at harvest after statistical analysis are presented in Table 7.

4.2.6.a 60 DAS

The results reported on the effect of various weed control treatments generally indicate a kind of positive response. At 60 DAS treatments receiving continuous weeding recorded the highest number of pods per plant (61.0). The application of pendimethalin at 1.0 Kg ai ha^{-1} supplemented with hand weeding at 30 DAS (54.2) was found to be as effective as weed free check in registering maximum number of pods per plants. Hand weeding twice at 20 and 30 DAS and alachlor at 1.5 Kg ai ha^{-1} or metolachlor at 1.25 Kg ai ha^{-1} when applied as spray combined with one hand weeding at 30 DAS were the other best treatments for this character. The application of herbicides alone were inferior to the other treatments. The lowest pod number per plant was registered with unweeded control (20.0) and application of metolachlor at 1.25 Kg ai ha^{-1} alone (24.2) which were on par with each other.

4.2.6.b. At harvest

At harvest also, there was an increase in pod number per plant with weed control treatments. The weed free situation recorded the highest number of pods per plant (116.8) and was statistically on par with two hand weedings at 20 and 30 DAS (104.2). Herbicidal applications of pendimethalin at 1.0 Kg ai ha^{-1} or alachlor at 1.5 Kg ai ha^{-1}, each supplemented with hand weeding at 30 DAS could produce pods equal to two hand weeding treatment. This is closely followed by T1 and T11. The unweeded control recorded minimum number of pods per plant (40.6) and did not show significant difference from application of metolachlor, alachlor granules or alachlor granules combined with hand weeding at 30 DAS.

4.2.7. 1000 seed weight

The data on 1000 seed weight were analysed statistically. The mean values are presented in Table 7.

The different treatments adopted to control the weeds resulted in significant positive effect on 1000 seed weight. The weed free check was significantly superior to all other treatments in recording higher 1000 grain weight (2.95 g). Next to weed free situation, higher 1000 grain weight was obtained with hand weeding twice at 20 and 30 DAS (2.8 g) and the local practice of hoeing twice at 15 and 25 DAS (2.7 g). Application of alachlor at 1.5 Kg ai ha^{-1} integrated with hand weeding at 30 DAS registered higher 1000 seed weight than the herbicide application alone. The lowest 1000 seed weight was found to be with unweeded control (2.1 g) and was on par with metolachlor application at 1.25 Kg ai ha^{-1} (2.2 g)

4.2.8. Seed yield

The data on seed yield were statistically analysed and the mean values are presented in Table 8 and illustrated in Figure5.

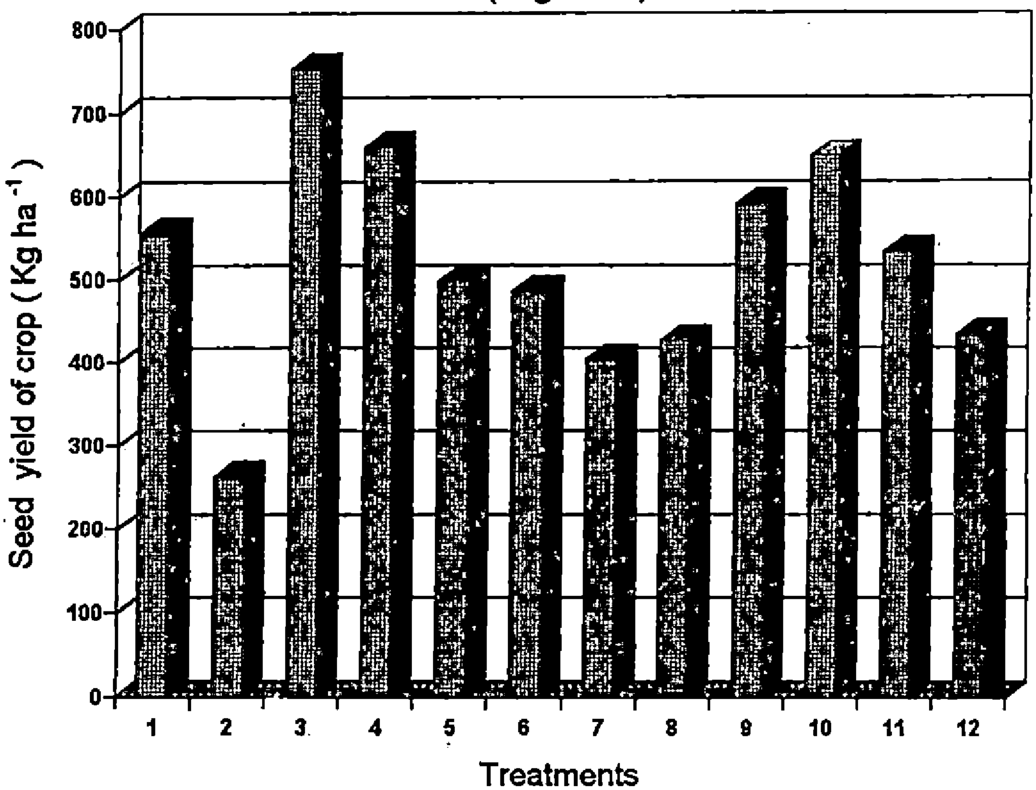
The seed yield was found to be significantly influenced by the different weed control treatments. The maximum seed yield of 752.17 Kg ha^{-1} was recorded with weed free situation and was

Table 8. Effect of treatments on seed and haulm yield (Kg ha-1) and harvest index.

Treatments	Seed yield	Haulm yield	Harvest index
T1	556.83	1483.1	0.27
T2	262.50	898.3	0.23
T3	752.17	1859.6	0.29
T4	659.33	1616.2	0.29
T5	498.17	1300.2	0.28
T6	486.50	1203.1	0.29
T7	404.17	1191.3	0.26
T8	426.50	1046.3	0.29
T9	591.50	1531.4	0.28
T10	648.33	1566.3	0.29
T11	534.00	1307.5	0.29
T12	433.50	1256.1	0.26
CD (0.05)	*80.61	*284.74	NS
SE	27.48	97.08	0.04

NS Not significant
* Significant at 0.05 level.

Fig 5 . Effect of treatments on seed yield of crop at harvest(Kg ha $^{-1}$)



significantly superior to all other treatments. The hand weeding twice at 20 and 30 DAS (659.3 Kg ha^{-1}), application of pendimethalin at 1.0 Kg ai ha^{-1} or alachlor at 1.5 Kg ai ha^{-1}, each integrated with one hand weeding at 30 DAS (648.3 and 591.5 Kg ha^{-1} respectively) recorded higher seed yields and were on par. This was comparable to the seed yield obtained with two hoeings at 15 and 25 DAS (556.8 Kg ha^{-1}). The lowest seed yield was recorded with unweeded control (262.5 Kg ha^{-1}) and was significantly inferior to all other treatments. Application of metolachlor at 1.25 Kg ai ha^{-1}, alachlor granules at 20 Kg ha^{-1} and granular application of alachlor combined with hand weeding at 30 DAS were not effective in recording higher seed yields.

4.2.9. Harvest index.

The mean values of the data on harvest index are presented in Table 8.

There was no significant difference in harvest index between the different treatments. However, the lowest harvest index of 0.23 was recorded by the unweeded control and the highest harvest index of 0.29 was recorded by the treatments T10, T11, T4, T8, T3 and T6.

4.2.10. Weed index.

The weed index values at harvest were analysed statistically after angular transformation and the mean values are presented in Table 9.

The different weed control treatments exerted significant influence on weed index. The lower value of weed index for a treatment indicate its superiority over other treatments. The lowest weed index values were recorded with hand weeding twice at 20 and 30 DAS (11.26 per cent) and pendimethalin application at 1.0 Kg ai ha^{-1} combined with a hand weeding at 30 DAS (12.54 per cent) and were on par with each other. The weed free situation was significantly superior to all the treatments. T_{10} was in turn on par with T_9. The most inferior treatment was unweeded control which recorded the highest value for weed index (65.12 per cent). The other treatments found inferior were application of metolachlor at 1.25 Kg ai ha^{-1}, alachlor granules at 20 Kg ha^{-1}, alachlor granules combined with hand weeding at 30 DAS and pendimethalin spray at 1.0 Kg ai ha^{-1}.

Quality attributes

4.2.11. Protein content

The mean values of the data are presented in Table 10.

Table 9. Effect of treatments on weed index (per cent) (after angular transformation).

Treatments	Weed index (per cent)	
T1	30.41	(25.63)
T2	53.78	(65.12)
T3	0	(0)
T4	19.60	(11.26)
T5	35.42	(33.78)
T6	35.52	(33.78)
T7	42.54	(45.74)
T8	40.77	(42.67)
T9	27.10	(20.77)
T10	20.73	(12.54)
T11	32.45	(28.82)
T12	40.28	(41.83)
CD (0.05)	*7.15	
SE	2.44	

Note :- The figures in paranthesis are the original values.

* Significant at 0.05 level.

Table 10. Effect of treatments on protein content of seed (per cent).

Treatments	Protein content (per cent)
T1	22.17
T2	19.83
T3	22.67
T4	22.17
T5	21.58
T6	21.58
T7	21.00
T8	20.42
T9	21.58
T10	22.17
T11	21.00
T12	21.00
CD (0.05)	NS

NS Not significant

The different weed control treatments did not affect the protein content of seeds significantly. However, it showed an increasing trend with weed free check (22.7 per cent) over the unweeded control (19.83 per cent).

4.2.12. Oil content

The mean values of the data analysed statistically are presented in Table 11.

There was a significant increase in oil content with weed control treatments. The highest oil content of 51.7 per cent was obtained by weeding the plots continuously upto harvest. This weed free check was significantly superior to all other treatments. Hand weeding twice at 20 and 30 DAS, application of pendimethalin at 1.0 Kg ai ha^{-1} along with hand weeding at 30 DAS, hoeing twice at 15 and 25 DAS and alachlor application combined with hand weeding at 30 DAS were also superior in recording higher oil content. The herbicidal treatments alone did not have any significant effect on increasing the oil content. The lowest oil content in seeds was registered with unweeded control (43.4 per cent) and was significantly inferior to all other treatments. Herbicidal application of alachlor granules at 20 Kg ha^{-1} alone or its combination with hand weeding were also poor recorders of seed oil content.

Table 11. Effect of treatments on oil content of seed (per cent)

Treatments	Oil content (per cent)
T1	49.7
T2	43.4
T3	51.7
T4	50.6
T5	48.8
T6	47.9
T7	46.8
T8	45.7
T9	49.4
T10	50.1
T11	49.0
T12	46.3
CD (0.05)	*0.71
SE	0.34

* Significant at 0.05 level.

4.3. Chemical analysis.

4.3.1. Uptake of nutrients by weeds

The nutrient uptake of weeds were determined on the 30th and 60th day after sowing and also at harvest. The data were analysed statistically and the mean values are presented in Tables 12 (a),12(b) and 12 (c). The effect of treatments on the uptake of nitrogen, phosphorus and potassium by weeds at harvest is illustrated in Figure 6.

4.3.1.1 Nitrogen

The mean values of the data are presented in Table 12(a).

The weed control practices significantly affected the nitrogen uptake by weeds at 30 and 60 DAS and at harvest. The plots which received no weeding resulted in maximum uptake of nitrogen by weeds at all stages of growth of sesamum (21.30, 60.33 and 60.09 Kg nitrogen ha^{-1} at 30 and 60 DAS and at harvest respectively) and the minimum uptake was with weedfree condition.

4.3.1.1.a. 30 DAS

At 30 DAS, application of alachlor as granules at 20 Kg ha^{-1} combined with hand weeding at 30 DAS (12.16 Kg ha^{-1}, recorded the highest uptake of nitrogen next to unweeded control. This

Table 12(a). Effect of treatments on nitrogen uptake of weeds (Kg ha^{-1}) at different days after sowing.

(after $\sqrt{x+1}$ transformation)

Treatments	Days after sowing		Harvest
	30	60	
T1	3.22 (9.37)	3.66 (12.36)	3.74 (13.01)
T2	4.72 (21.27)	7.83 (60.33)	7.82 (60.09)
T3	1.00 (0)	1.00 (0)	1.00 (0)
T4	1.92 (2.70)	3.33 (10.12)	3.28 (9.73)
T5	2.52 (5.35)	4.09 (15.73)	4.12 (15.95)
T6	2.03 (3.12)	4.53 (19.53)	4.56 (19.77)
T7	3.34 (10.14)	4.75 (21.57)	4.83 (22.29)
T8	3.47 (11.03)	4.99 (23.92)	4.96 (23.62)
T9	2.48 (5.17)	3.05 (8.33)	3.03 (8.18)
T10	2.13 (3.53)	3.25 (9.54)	2.91 (7.46)
T11	3.18 (9.14)	3.28 (9.75)	3.40 (10.54)
T12	3.63 (12.15)	4.95 (23.49)	4.92 (23.17)
CD (0.05)	*0.12	*0.58	*0.55
SE	0.04	0.20	0.19

Note :- The figures in paranthesis are the original values.

* Significant at 0.05 level.

treatment was also significantly inferior to all other treatments. Hand weeding twice at 20 and 30 DAS (2.69 Kg ha^{-1}) and application of pendimethalin at 1.0 Kg ai ha^{-1} alone (3.11 Kg ha^{-1}) and also pendimethalin combined with one hand weeding at 30 DAS (3.50 Kg ha^{-1}) recorded the least uptake of N by weeds.

4.3.1.1.b. 60 DAS and at harvest.

At 60 DAS and at harvest, the weed nitrogen uptake was maximum with application of alachlor granules at 20 Kg ha^{-1} either alone (23.90 and 23.60 Kg ha^{-1} respectively) or in combination with hand weeding at 30 DAS (23.50 and 23.19 Kg ha^{-1} respectively), metolachlor at 1.25 Kg ai ha^{-1} (21.60 and 22.30 Kg ha^{-1} respectively) and pendimethalin at 1.0 Kg ai ha^{-1} (19.50 and 19.80 Kg ha^{-1} respectively) next to unweeded control. The lowest uptake of nitrogen at these stages was recorded by weed free check. The other treatments found superior in reducing the weed nitrogen uptake were application of pendimethalin at 1.0 Kg ai ha^{-1} or alachlor at 1.5 Kg ai ha^{-1}, each integrated with hand weeding at 30 DAS, two hand weedings at 20 and 30 DAS and also application of metolachlor at 1.25 Kg ai ha^{-1} along with a hand weeding at 30 DAS.

4.3.1.2. Phosphorus

The data were analysed statistically and the mean values of the data are presented in Table 12 (b).

The phosphorus uptake by weeds also exhibited significant difference with different weed control treatments at all stages of growth of sesamum. In the case of phosphorus also, uptake was maximum with unweeded control (3.70, 10.84 and 8.95 Kg ha^{-1} at 30 and 60 DAS and at harvest respectively) and minimum with weedfree check.

4.3.1.2.a. 30 DAS

On the 30th day after sowing, granular form of alachlor applied at 20 Kg ha^{-1} followed by one hand weeding at 30 DAS (2.12 Kg ha^{-1}) resulted in higher uptake of phosphorus by weeds and this was found inferior to all other treatments except unweeded control. This was closely followed by T8, T7, T1 and T11. The lowest uptake next to weedfree check resulted with hand weeding twice at 20 and 30 DAS (0.46 Kg ha^{-1}), application of pendimethalin at 1.0 Kg ai ha^{-1} alone (0.53 Kg ha^{-1}) and also supplemented with hand weeding at 30 DAS (0.60 Kg ha^{-1}). These treatments were superior to other weed control treatments.

Table 12(b). Effect of treatments on phosphorus uptake of weeds (Kg ha $^{-1}$) at different days after sowing.

(after $\sqrt{x+1}$ transformation)

Treatments	Days after sowing 30	Days after sowing 60	Harvest
T1	1.61 (1.61)	1.78 (2.16)	1.68 (1.84)
T2	2.17 (3.70)	3.44 (10.84)	3.15 (8.95)
T3	1.00 (0)	1.00 (0)	1.00 (0)
T4	1.21 (0.46)	1.63 (1.66)	1.54 (1.36)
T5	1.38 (0.91)	1.94 (2.76)	1.82 (2.30)
T6	1.24 (0.53)	2.11 (3.44)	1.97 (2.89)
T7	1.66 (1.75)	2.20 (3.84)	2.07 (3.28)
T8	1.71 (1.91)	2.30 (4.30)	2.12 (3.50)
T9	1.37 (0.88)	1.56 (1.44)	1.47 (1.17)
T10	1.26 (0.60)	1.50 (1.24)	1.43 (1.04)
T11	1.60 (1.56)	1.64 (1.70)	1.59 (1.52)
T12	1.76 (2.12)	2.28 (4.19)	2.10 (3.42)
CD (0.05)	*0.04	*0.21	*0.19
SE	0.02	0.07	0.06

Note :- The figures in paranthesis are the original values.

* Significant at 0.05 level.

4.3.1.2.b. 60 DAS and at harvest

Almost the same trend in checking the weed phosphorus uptake was recorded at 60 DAS and at harvest by weed control treatments. Alachlor applied in granular form without hand weeding (4.30 and 3.50 Kg ha^{-1} at 60 DAS and at harvest respectively) and with hand weeding at 30 DAS (4.19 and 3.42 Kg ha^{-1} at 60 DAS and at harvest respectively), metolachlor at 1.25 Kg ai ha^{-1} and pendimethalin at 1.0 Kg ai ha^{-1} resulted in higher uptake of phosphorus by weeds at later stages. The treatments T5 and T1 were on par with each other. On the other hand, the lowest P uptake was with application of either pendimethalin at 1.0 Kg ai ha^{-1} or alachlor at 1.5 Kg ai ha^{-1}, each supplemented with hand weeding at 30 DAS, hand weeding twice at 20 and 30 DAS and integration of metolachor spray at 1.25 Kg ai ha^{-1} with hand weeding at 30 DAS.

4.3.1.3. Potassium

The statistical analysis of data on potassium uptake by weeds were done and the mean values of the data are presented in Table 12 (c).

A trend similar to nitrogen and phosphorus uptake by weeds was observed with potassium also. An increased uptake of potassium by weeds was recorded with unweeded control (8.0,

Table 12(c). Effect of treatments on potassium uptake of weeds ($Kg\ ha^{-1}$) at different days after sowing.

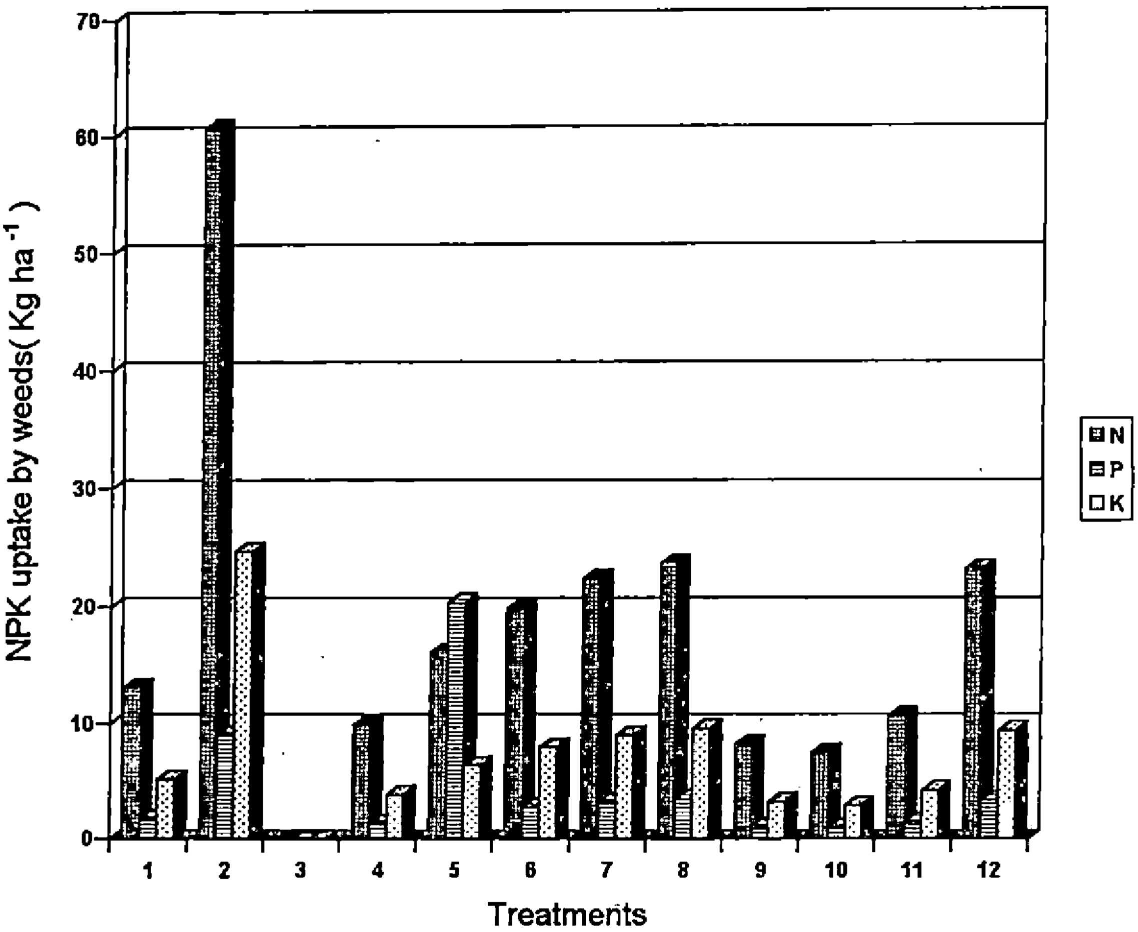
(after $\sqrt{x+1}$ transformation).

Treatments	Days after sowing		Harvest
	30	60	
T1	2.12 (3.50)	2.51 (5.32)	2.49 (5.20)
T2	3.00 (8. 0)	5.19 (25.98)	5.04 (24.38)
T3	1.00 (0)	1.00 (0)	1.00 (0)
T4	1.41 (1.00)	2.27 (4.14)	2.20 (3.86)
T5	1.73 (2.00)	2.79 (6.77)	2.72 (6.38)
T6	1.47 (1.16)	3.07 (8.41)	2.98 (7.90)
T7	2.19 (3.80)	3.21 (9.30)	3.16 (8.98)
T8	2.27 (4.14)	3.36 (10.29)	3.25 (9.55)
T9	1.71 (1.92)	2.14 (3.57)	2.06 (3.25)
T10	1.52 (1.31)	2.03 (3.11)	1.99 (2.95)
T11	2.10 (3.42)	2.28 (4.20)	2.28 (4.22)
T12	2.36 (4.56)	3.33 (10.12)	3.22 (9.37)
CD (0.05)	*0.07	*0.36	*0.34
SE	0.02	0.12	0.12

Note :- The figures in paranthesis are the original values.

* Significant at 0.05 level.

Fig 6. Effect of treatments on Nitrogen , Phosphorus and Potassium uptake by weeds at harvest (Kg ha $^{-1}$)



25.98 and 24.40 Kg ha^{-1} at 30 and 60 DAS and at harvest respectively), while the least uptake was noted with weedfree check.

4.3.1.3.a. 30 DAS

Application of alachlor granules either alone or when accompanied with one hand weeding at 30 DAS recorded the maximum uptake of potassium by weeds (4.14 Kg ha^{-1} and 4.56 Kg ha^{-1} respectively). The treatments T7, T1 and T11 were on par with each other. At this stage, lower uptake of potassium next to completely weed free situation was recorded with hand weeding twice at 20 and 30 DAS (1.0 Kg ha^{-1}) and application of pendimethalin at 1.0 Kg ai ha^{-1} (1.16 Kg ha^{-1}). Application of pendimethalin at 1.0 Kg ai ha^{-1} without hand weeding was equally good in recording lower uptake of potassium by weeds.

4.3.1.3.b. 60 DAS and at harvest

The effect of treatments on K uptake at 60 DAS and at harvest was almost similar. At both these stages, next to the unweeded control, the maximum uptake of potassium by weeds recorded with the application of alachlor granules alone at 20 Kg ha^{-1} (10.30 and 9.55 Kg ha^{-1} at 60 DAS and harvest respectively) and alachlor granules combined with hand weeding at 30 DAS (10.12 and 9.37 Kg ha^{-1} at 60 DAS and at harvest respectively). This was closely followed by metolachlor at 1.25 Kg ai ha^{-1} and pendimethalin at 1.0 Kg ai ha^{-1}. Likewise among the weed management treatments, the minimum uptake of potassium by weeds was recorded with application of either pendimethalin at 1.0 Kg ai ha^{-1} or alachlor at 1.5 Kg ai ha^{-1}, each combined with hand weeding at 30 DAS, hand weeding twice at 20 and 30 DAS and also metolachlor applied at 1.25 Kg ai ha^{-1} followed by hand weeding at 30 DAS.

4.3.2. Uptake of nutrients by the crop

The nutrient uptake of crop were calculated on the 30th and 60th day after sowing and at harvest. The data were analysed statistically and the mean values presented in Tables 13 (a), 13 (b) and 13 (c). The effect of treatments on nitrogen, phosphorus and potassium uptake by the crop at harvest is illustrated in Figure 7.

The nutrient uptake by the crop was also affected significantly by the various treatments adopted for controlling weeds.

4.3.2.1. Nitrogen

The mean values of the data are presented in Table 13(a).

Table 13(a). Effect of treatments on nitrogen uptake of crop ($Kg\ ha^{-1}$) at different days after sowing.

Treatments	Days after sowing 30	Days after sowing 60	Harvest
T1	15.52	56.40	50.48
T2	16.91	34.77	25.07
T3	15.48	70.71	64.92
T4	15.25	65.16	56.60
T5	16.12	49.48	47.43
T6	16.78	50.77	44.17
T7	14.93	44.15	40.37
T8	11.56	42.53	37.34
T9	15.09	58.20	52.03
T10	16.45	62.09	54.83
T11	15.90	52.11	47.49
T12	14.88	51.27	42.99
CD (0.05)	*0.67	*9.81	*4.66
SE	0.23	3.34	1.59

* Significant at 0.05 level.

4.3.2.1.a. 30 DAS

The uptake of nitrogen by the crop at 30 DAS was highest when the crop was kept unweeded (16.91 Kg ha^{-1}). Some of the weed control treatments such as application of pendimethalin at 1.0 Kg ai ha^{-1} (16.78 Kg ha^{-1}) and pendimethalin followed by one hand weeding at 30 DAS (16.45 Kg ha^{-1}) were also effective in recording higher nitrogen uptake by the crop at this stage. The treatments, T5, T11 and T1 were on par with each other with respect to N uptake. But the least uptake of nitrogen was estimated with application of granular form of alachlor at 20 Kg ha^{-1} (11.56 Kg ha^{-1}). This treatment was significantly inferior to rest of the treatments.

4.3.2.1.b. 60 DAS

However, when the uptake of nitrogen by crop at 60 DAS was analysed it was found that the weedfree situation, (70.71 Kg ha^{-1}) was comparable to hand weeding twice at 20 and 30 DAS and pendimethalin application at 1.0 Kg ai ha^{-1} along with hand weeding at 30 DAS in recording a substantial increase in the uptake of nitrogen. The unweeded control resulted in the lowest nitrogen uptake by the crop (34.77 Kg ha^{-1}). Application of alachlor granules at 20 Kg ha^{-1} and metolachlor at 1.25 Kg ai ha^{-1} were also on par with unweeded control.

4.3.2.1.c. At harvest

The weed free treatment continued to record maximum nitrogen uptake by the crop at harvest stage (64.92 Kg ha^{-1}) and the treatment was significantly superior to all others. Next to weedfree condition, hand weeding twice at 20 and 30 DAS and application of pendimethalin at 1.0 Kg ai ha^{-1} or alachlor at 1.5 Kg ai ha^{-1}, each supplemented with hand weeding at 30 DAS recorded higher nitrogen uptake. The treatment, T9 in turn was on par with T1 and T11. The unweeded control was significantly inferior to all other treatments with the minimum uptake of nitrogen by crop at harvest (25.07 Kg ha^{-1}). Similarly, T8 and T7 also resulted in poor uptake.

4.3.2.2.. Phosphorus

The statistical analysis on the data were done and the mean values presented in Tables 13 (b).

The uptake of phosphorus by the crop was found to be considerably increased with the weed control treatments at all growth stages.

4.3.2.2.a. 30 DAS

On the 30th day after sowing, the highest uptake of phosphorus was with unweeded control (4.22 Kg ha^{-1}) and this was on par with the application of pendimethalin at 1.0 Kg ai ha^{-1}

Table 13(b). Effect of treatments on phosphorus uptake of crop (Kg ha^{-1}) at different days after sowing.

Treatments	Days after sowing		Harvest
	30	60	
T1	3.72	9.30	7.33
T2	4.22	5.36	3.98
T3	3.70	11.70	9.55
T4	3.63	10.80	8.32
T5	3.87	7.84	6.48
T6	4.18	8.04	6.12
T7	3.53	6.87	5.62
T8	2.68	6.62	5.34
T9	3.58	9.46	7.67
T10	4.02	10.23	8.11
T11	3.84	8.35	6.71
T12	3.49	8.07	5.96
CD (0.05)	*0.16	*1.35	*0.55
SE	0.05	0.46	0.19

* Significant at 0.05 level.

(4.18 Kg ha $^{-1}$). Similarly, T10, T5 and T11 also resulted in higher uptake of phosphorus by the crop. The application of granules of alachlor at 20 Kg ha^{-1} was inferior to all the weed control treatments (2.68 Kg ha^{-1}) at this stage.

4.3.2.2.b. 60 DAS

At 60 DAS, the highest uptake was with continuous weeding (11.70 Kg ha^{-1}) and was comparable with two hand weedings at 20 and 30 DAS (10.8 Kg ha^{-1}). Application of pendimethalin at 1.0 Kg ai ha^{-1} or alachlor at 1.5 Kg ai ha^{-1}, each supplemented with a hand weeding at 30 DAS were as efficient as two hand weedings at 20 and 30 DAS regarding the uptake of phosphorus. The lowest uptake was with unweeded check (5.36 Kg ha^{-1}) and this was on par with application of alachlor granules at 20 Kg ha^{-1} (6.62 Kg ha^{-1}). So also, T5 and T7 recorded low phosphorus uptake by the crop.

4.3.2.2.c. At harvest

At harvest stage also, continuous weeding resulted in maximum phosphorus uptake by the crop (9.55 Kg ha^{-1}) and was significantly superior to the other treatments. Two hand weedings at 20 and 30 DAS (8.32 Kg ha^{-1}), application of pendimethalin at 1.0 Kg ai ha^{-1} followed by hand weeding at 30 DAS (8.11 Kg ha^{-1}) were the treatments next to weed free situation in recording higher uptake of phosphorus. The treatments T9 and T1 were on par with each other. The unweeded control resulted in the lowest uptake (3.98 Kg ha^{-1}) of phosphorus by the crop. Application of alachlor granules and metolachlor also resulted in poor phosphorus uptake by the crop.

4.3.2.3. Potassium

The statistical analysis on the data were done and the mean values are presented in Table 13 (c).

There was significant influence of the various weed control treatments on potassium uptake by crop at all stages of growth.

4.3.2.3.a. 30 DAS

There was higher uptake of potassium with unweeded control at 30 DAS (6.77 Kg ha $^{-1}$). This treatment was statistically on par with all other treatments except application of pendimethalin at 1.0 Kg ai ha^{-1} and alachlor granules at 20 Kg ha^{-1}. The application of granules of alachlor resulted in the least uptake (4.61 Kg ha^{-1}) and was inferior to all other treatments.

4.3.2.3.b. 60 DAS and at harvest

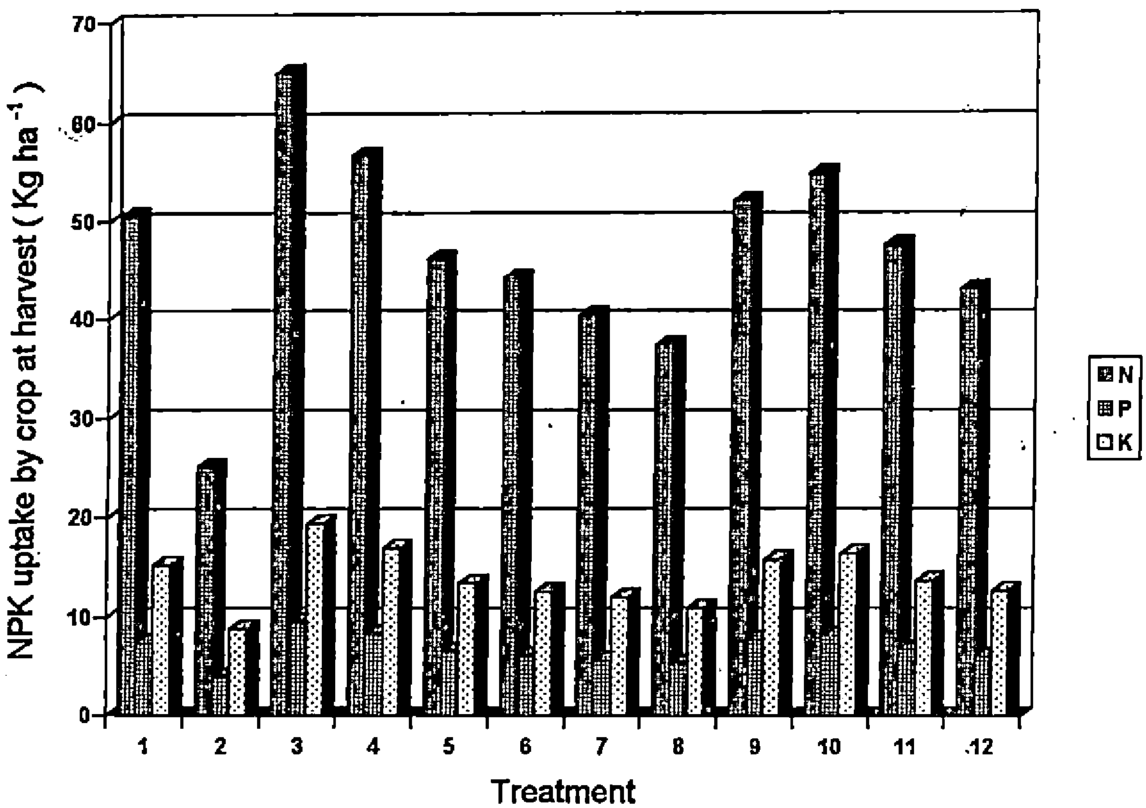
However, on the 60th day after sowing and at harvest, the uptake of potassium by the crop showed almost a similar trend.

Table 13(c). Effect of treatments on potassium uptake of crop ($Kg\ ha^{-1}$) at different days after sowing.

Treatments	Days after sowing		Harvest
	30	60	
T1	6.20	18.90	15.20
T2	6.77	11.60	8.78
T3	6.18	22.91	19.39
T4	6.09	20.95	16.87
T5	6.45	16.12	13.38
T6	5.79	16.92	12.51
T7	5.96	14.70	11.96
T8	4.61	14.05	10.89
T9	6.02	18.84	15.78
T10	6.58	19.92	16.40
T11	6.35	16.79	13.64
T12	5.94	17.28	12.66
CD (0.05)	*0.87	*3.69	*2.03
SE	0.30	1.26	0.69

* Significant at 0.05 level.

Fig 7 . Effect of treatments on Nitrogen , Phosphorus and Potassium uptake by crop at harvest (Kg ha $^{-1}$)



At both these stages, maximum uptake was observed with weedfree check (22.91 and 19.39 Kg ha^{-1} at 60 DAS and at harvest respectively). At 60 DAS, hand weeding twice at 20 and 30 DAS and application of pendimethalin at 1.0 Kg ai ha^{-1} supplemented with hand weeding at 30 DAS were as good as weed free check. But at harvest no other treatment could be compared with the weed free check. At harvest stage, the treatments other than weed free situation which resulted in higher potassium uptake were two hand weedings at 20 and 30 DAS, application of pendimethalin or alachlor, each along with a hand weeding at 30 DAS and hoeing done twice at 15 and 25 DAS. The treatments T1, and T11 were comparable with each other. At 60 DAS, application of alachlor granules at 20 Kg ai ha^{-1} (14.05 Kg ha^{-1}) and metolachlor at 1.25 Kg ai ha^{-1} (14.70 Kg ha^{-1}) were comparable with unweeded control and resulted in lower uptake of potassium. At harvest also, T8, T7, T6 and T2 recorded very low potassium uptake by the crop when compared to the other treatments.

4.3.3. Soil analysis after experiment

The soil samples collected from the individual plots after the experiment were analysed for available nitrogen, available phosphorus and exchangeable potassium. The mean values of the data are given in Table 14.

Table 14. Effect of treatments on Nitrogen, Phosphorus and Potassium content (Kg ha^{-1}) of soil after experiment

Treatments	Nitrogen	Phosphorus	Potassium
T1	210.47	39.92	48.30
T2	195.18	37.01	43.42
T3	201.69	45.12	46.22
T4	212.95	42.56	47.34
T5	186.33	35.82	43.38
T6	196.81	39.21	44.60
T7	173.60	38.16	45.13
T8	200.14	38.54	43.14
T9	191.57	38.28	43.95
T10	206.70	37.52	45.50
T11	204.91	36.92	43.28
T12	194.23	39.13	43.60
CD (0.05)	*7.65	* 1.51	NS
SE	2.61	0.52	

NS Not significant
* Significant at 0.05 level.

The nutrient content of soil after experiment was found to be influenced by the weed control treatments.

4.3.3.1. Nitrogen

The hand weeded plots recorded a higher content of nitrogen in soil (212.95 Kg ha^{-1}) and was on par with hoeing twice at 15 and 25 DAS (210.47 Kg ha^{-1}) and application of pendimethalin at 1.0 Kg ai ha^{-1} along with a hand weeding at 30 DAS (206.7 Kg ha^{-1}). The treatments T9, and T12 resulted in comparatively lower nitrogen content in soil and the lowest was recorded with the application of metolachlor at 1.25 Kg ai ha^{-1} (173.6 Kg ha^{-1}), this being significantly inferior to all other treatments. The treatment T5 was comparable with T9 in recording lower nitrogen content in soil after the experiment.

4.3.3.2. Phosphorus

In the case of phosphorus content of soil, the weed control treatments exhibited a significant influence. The weed free check was superior to all other treatments in recording higher content of phosphours (45.62 Kg ha^{-1}) in soil, closely followed by hand weeding twice at 20 and 30 DAS (42.56 Kg ha^{-1}), hoeing twice at 15 and 25 DAS (39.42 Kg ha^{-1}) and application of pendimethalin at 1.0 Kg ai ha^{-1} alone (39.21 Kg ha^{-1}). The lowest content of phosphorus was recorded with the application of alachlor at 1.5 Kg ai ha^{-1} (35.82 Kg ai ha^{-1}) followed by metolachlor at 1.25 Kg ai ha^{-1} along with a hand weeding at 30 DAS (36.92 Kg ha^{-1}) and the unweeded control 37.01 Kg ha^{-1}).

4.3.3.3. Potassium

The potassium content of soil after the experiment revealed that all the treatments were comparable with each other. The highest content in soil was recorded with hoeing twice at 15 and 25 DAS (48.3 Kg ha^{-1}) and was comparable with hand weeding twice at 20 and 30 DAS (47.34 Kg ha^{-1}), weed free check (46.22 Kg ha^{-1}), application of pendimethalin at 1.0 Kg ai ha^{-1} combined with hand weeding at 30 DAS (45.5 Kg ha^{-1}) and metolachlor at 1.25 Kg ai ha^{-1} (45.13 Kg ha^{-1}). T3 inturn was on par with other treatments. The lowest content of potassium recorded with alachlor application in granular form at 20 Kg ha^{-1} (43.14 Kg ha^{-1}).

4.3.4. Soil microflora count

4.3.4.1. Bacterial count

The fresh soil taken from the respective treatment plots were used for determining bacterial count at 5 and 30 days after herbicidal treatment. The data were analysed statistically and the mean values are presented in Tables 15 (a) & 15 (b) and illustrated in Figures 8 and 9.

4.3.4.1.a. 5 Days after herbicidal treatment

At this stage, significant difference could be noted with different weed control treatments for bacterial count. The bacterial counts were lower for herbicidal treatments over cultural methods. The highest count of bacteria was noted in continuously weed free situation (27.0×10^6) The other treatments like unweeded control (26.3×10^6) and hand weeding twice at 20 and 30 DAS (25.7×10^6) were also as good as weed free check. The treatment T2 inturn was on par with T1 also. The treatments involving the application of pendimethalin or alachlor, each followed by a hand weeding at 30 DAS and also application of pendimethalin alone did not show significant difference in bacterial count. The lowest count was recorded with metolachlor spray at 1.25 Kg ai ha^{-1} alone (9.3×10^6) and metolachlor at 1.25 Kg ai ha^{-1} combined with hand weeding at 30 DAS (9.3×10^6). The other treatments found inferior with respect to bacterial count were T12, T8, T5 and T6.

4.3.4.1.b. 30 Days after herbicidal treatment

At this stage also significant difference could be observed with different weed control treatments. Among the different treatments, the highest number of bacteria was recorded with weed free check (29.3×10^6). But this treatment did not differ significantly from unweeded control, hand weeding twice at 20

Table 15(a). Effect of treatments on bacterial, fungal and actinomycete population of soil at 5 days after herbicidal treatment.

Treatments	Microbial population		
	Bacteria ($x10^6$)	Fungi ($x10^4$)	Actinomycete ($x10^5$)
T1	24.7	14.7	51.3
T2	26.3	15.0	52.0
T3	27.0	15.3	54.7
T4	25.7	15.3	52.0
T5	11.0	9.3	24.0
T6	11.3	9.3	24.3
T7	9.3	8.0	21.7
T8	10.6	9.0	22.3
T9	11.7	10.0	23.7
T10	12.0	9.7	24.7
T11	9.3	8.3	21.3
T12	10.3	9.0	22.3
CD (0.05)	*1.85	*1.35	*1.28
SE	0.63	0.50	0.44

Fig 8. Effect of treatments on bacterial, fungal and actinomycete population at 5 days after herbicidal treatment

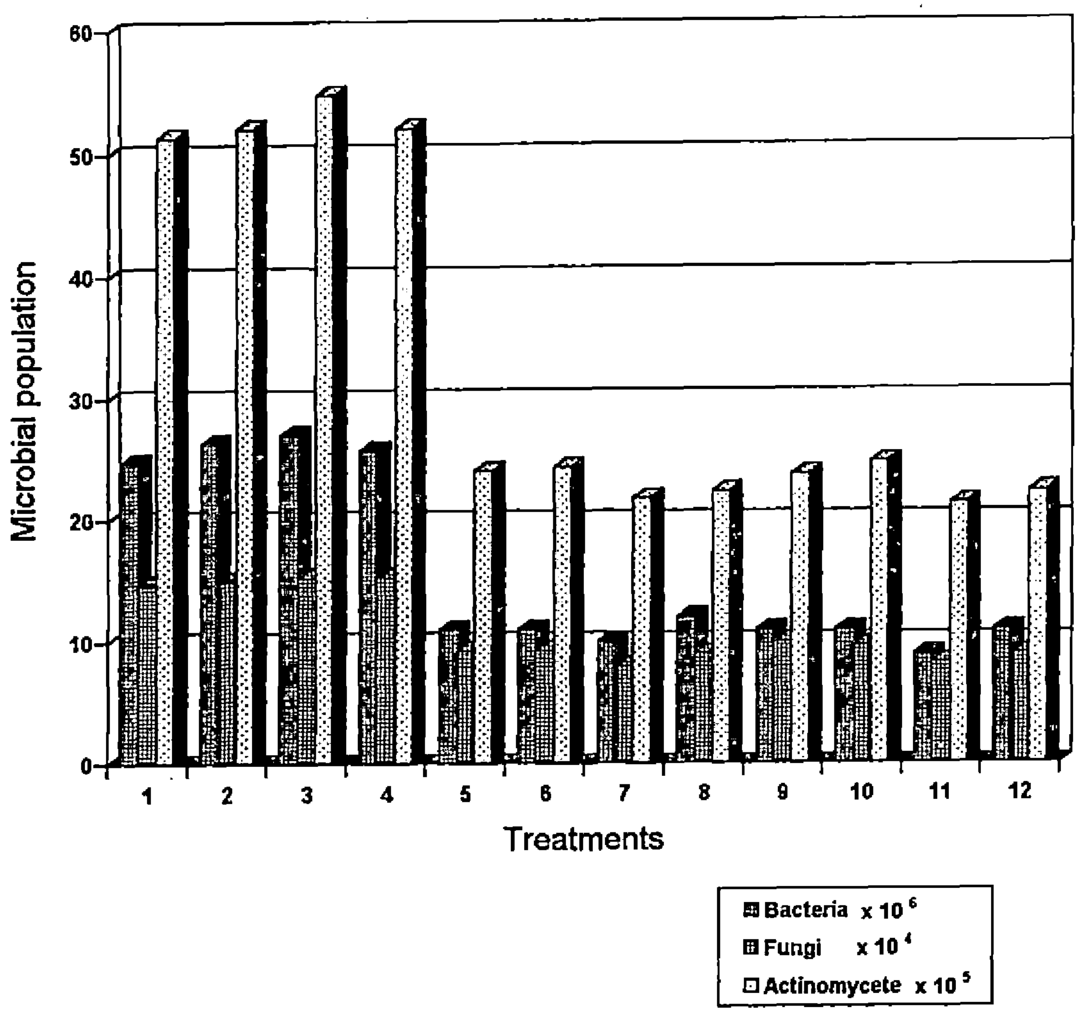
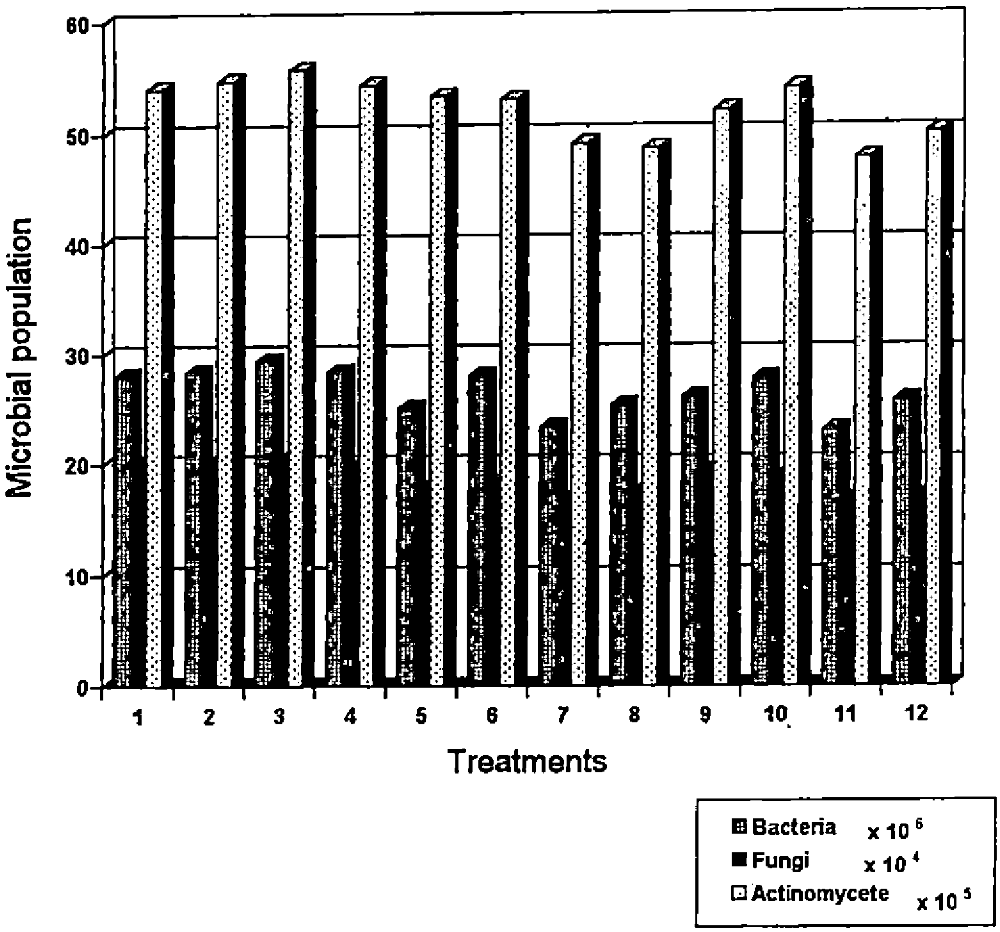


Table 15(b) Effect of treatments on bacterial, fungal and actinomycete population of soil at 30 days after herbicidal treatment.

Treatments	Microbial population		
	Bacteria ($\times 10^6$)	Fungi ($\times 10^4$)	Actinomycete ($\times 10^5$)
T1	28.0	19.7	54.0
T2	28.3	19.7	54.7
T3	29.3	20.3	55.7
T4	28.3	19.6	54.3
T5	25.0	17.7	53.3
T6	28.0	18.3	53.0
T7	23.3	16.7	49.0
T8	25.3	17.3	48.6
T9	26.0	19.3	52.0
T10	27.7	18.7	54.0
T11	23.0	16.7	47.7
T12	25.7	17.0	50.0
CD (0.05)	*2.22	*1.81	*1.69
SE	0.76	0.62	0.58

* Significant at 0.05 level.

Fig 9. Effect of treatments on bacterial, fungal and actinomycete population at 30 days after herbicidal treatment



and 30 DAS, hoeing twice at 15 and 25 DAS, application of pendimethalin at 1.0 Kg ai ha^{-1} alone or its combination with hand weeding at 30 DAS. The lowest count was noted with metolachlor application at 1.25 Kg ai ha^{-1} followed by one hand weeding at 30 DAS (23.0) and was on par with the treatment involving the application of metolachlor at 1.25 Kg ai ha^{-1} alone.

4.3.4.2. Fungal count

The fresh soil samples were used for estimating the fungal count at 5 and 30 days after herbicidal application. The data were analysed statistically and the mean values of the data are presented in the Tables 15(a) & 15 (b).

4.3.4.2.a. 5 days after herbicidal treatment.

The fungal count was found to be less at 5 days after herbicide application than at 30 days after application. The highest number of fungi were recorded with continuous weeding and hand weeding twice at 20 and 30 DAS (15.3×10^4), but this did not differ statistically from unweeded control or hoeing twice at 15 and 25 DAS. However, these treatments were statistically superior to all other treatments. The treatments T9, T10, T5, T6 and T8 were on par for this aspect. The lowest number of fungi were noted with the application of metolachlor at 1.25 Kg ai ha^{-1} (8.0×10^4).

4.3.4.2.b. 30 days after herbicidal treatment

There was a gradual increase in the fungal count at this stage when compared to the count taken at 5 days after treatment, the trend being the same. Here the weed free check recorded the maximum count ($20.3x10^4$) and the application of metolachlor at 1.25 Kg ai ha^{-1} alone and its combination with hand weeding at 30 DAS, the minimum ($16.7x10^4$). Though the effect of weed control treatments had a statistically significant influence on the fungal count at 30 days after treatment, the treatments T3,T2,T1,T4,T9 and T10 were on par.

4.3.4.3. Actinomycete count

The fresh soil samples were used for determining the actinomycete count. The data were stastically analysed and the mean values of data are presented in Tables 15 (a) & 15 (b).

4.3.4.3.a. 5 days after herbicidal treatment

The different herbicidal treatments showed significant difference on actinomycete population. At this stage, weed free check recorded the highest population of actinmycete ($54.7x10^5$) and this treatment was found superior to all others. This was closely followed by the unweeded control, hand weeding twice at 20 and 30 DAS and hoeing twice at 15 and 25 DAS. The lowest population was noted with the application of metolachlor at 1.25 Kg ai ha^{-1} along with hand weeding ($21.3x10^5$). The treatments T7,T12 and T8 were also on par with T11.

4.3.4.3.b. 30 days after herbicidal treatment.

The herbicidal treatments showed a significant influence on the count of actinomycetes at this stage. Though the continuous weed free situation recorded the highest actinomycete population ($55.7x10^5$), this was on par with unweeded control, hand weeding twice at 20 and 30 DAS, hoeing twice at 15 and 25 DAS and application of pendimethalin at 1.0 Kg ai ha^{-1} combined with one hand weeding at 30 DAS. The minimum count was recorded by application of metolachlor at 1.25 kg ai ha^{-1} along with a hand weeding at 30 DAS ($47.7x10^5$) and T7 and T8 also resulted in a significant reduction in the actinomycete count.

4.4. Economics of cost of cultivation

The economics of cost of cultivation worked out for the different treatments are presented in Table 18.

4.4.1 Net income

The net income was substantially influenced by different weed management practices. The highest net income was obtained

Table 16. Economics of crop production

Treatments	Normal expenditure (Rs.ha^{-1})	Additional expenditure (Rs ha^{-1})	Total expenditure (Rs ha^{-1})	Gross income (Rs ha^{-1})	Net income	Net return per rupee invested	Benefit- co ratio
T1	17773.00	2949.00	20722.00	22272.00	1550.00	0.07	1.07
T2	17773.00	-	17773.00	10500.00	-7273.00	-	0.59
T3	17773.00	11374.00	29147.00	30087.00	940.00	0.03	1.03
T4	17773.00	5055.00	22828.00	26372.00	3544.00	0.16	1.16
T5	17773.00	871.00	18644.00	19928.00	1284.00	0.07	1.07
T6	17773.00	1636.00	19409.00	19460.00	51.00	0.003	1.00
T7	17773.00	1171.00	18944.00	16168.00	-2776.00	-	0.85
T8	17773.00	971.00	18744.00	17060.00	-1684.00	-	0.91
T9	17773.00	1714.00	19487.00	23660.00	4173.00	0.21	1.21
T10	17773.00	2479.00	20252.00	25932.00	5680.00	0.28	1.28
T11	17773.00	2014.00	19787.00	21360.00	1573.00	0.08	1.08
T12	17773.00	1814.00	19587.00	17340.00	-2247.00	-	0.89

Cost of seed - Rs.40 per Kg
Cost of alachlor - Rs.150 per litre
Cost of Metolachlor - Rs.300 per litre
Cost of pedimethalin - Rs.368 per litre

Cost of sand - Rs.100.00
Wages for men - Rs.84.25 per man day
Wages for women - Rs.84.25 per man day
Charge for sprayer - Rs.2.00 per hour

from application of pendimethalin at 1.0 Kg ai ha^{-1} integrated with hand weeding at 30 DAS (Rs. 5680.00). This treatment was closely followed by application of alachlor at 1.5 Kg ai ha^{-1} coupled with hand weeding at 30 DAS (Rs. 4173.00). The cultural practices like hand weeding twice at 20 and 30 DAS and hoeing twice at 15 and 25 DAS recorded higher net income (Rs. 3544.00 and Rs. 1550.00 respectively), when compared to the application of herbicides alone. The unweeded control recorded a net loss of Rs.7273.00. The other treatments not economically viable were application of metolachlor at 1.25 Kg ai ha^{-1} alone (-Rs.2766.00) and application of alachlor granules at 20 Kg ha^{-1} either alone or combined with hand weeding at 30 DAS (-Rs. 1684.00 and -Rs. 2247.00 respectively).

4.4.2 Net returns per rupee invested

The net returns per rupee invested was maximum with application of pendimethalin at 1.0 Kg ai ha^{-1} along with hand weeding at 30 DAS (28 paise) and was closely followed by application of alachlor at 1.5 Kg ai ha^{-1} integrated with hand weeding at 30 DAS (21 paise). Hand weeding twice at 20 and 30 DAS gave a net return of 16 paise per rupee invested. The treatments involving unweeded control, metolachlor application at 1.25 Kg ai ha^{-1} alone and application of alachlor granules at 20 Kg ha^{-1} alone or combined with hand weeding at 30 DAS, on the other hand resulted in a loss.

The benefit - cost ratio was found to be the highest with application of pendimethalin at 1.0 Kg ai ha^{-1} or alachlor at 1.5 Kg ai ha^{-1}, each followed by hand weeding at 30 DAS (1.28 and 1.21 respectively). The next higher benefit - cost ratio of 1.16 was recorded by hand weeding twice at 20 and 30 DAS. The unweeded control, undoubtedly, recorded the lowest benefit - cost ratio (0.59). The other inferior treatments were application of metolachlor at 1.25 Kg ai ha^{-1} alone (0.85) and application of alachlor granules at 20 Kg ha^{-1} either alone or combined with hand weeding at 30 DAS (0.91 and 0.89 respectively).

DISCUSSION

DISCUSSION

An experiment was conducted in the rice fallows of Rice Research Station, Kayamkulam during the summer season of 1994-1995 to evolve a suitable method of weed control in sesamum. The results of the experiment are discussed here.

5.1. Observations on weeds

5.1.1. Weed species

The weed species present in the experimental area before and during the conduct of experiment were identified and classified as grasses, sedges and broadleaved weeds. The most predominant grasses were Brachiaria ramosa and Cynodon dactylon. Cyperus spp. was the important sedge identified in the experimental field. The broad-leaved weeds included Cleome viscosa, Leucas aspera, Emilia sonchifolia, Commelina spp and Sida acuta.

5.1.2. Weed count.

5.1.2.1. Monocot weed population

The monocot weeds dominated the experimental field with more grasses like Cynodon dactylon and Brachiaria ramosa. At all growth stages of the crop, the monocot weed population in the experimental field was least with weed free check and was significantly lesser than all other treatments, whereas the highest counts were with unweeded control (408.3, 585.2 and 632.1 weeds m^{-2} at 30 and 60 DAS and at harvest respectively) which was significantly higher than rest of the treatments. The continuous weeding as and when the weeds appeared in weed free check resulted in lowest weed count in these plots, while the non-removal of weeds resulted in highest weed count in unweeded control. It was found that the weed control treatments involving herbicides and cultural practices were superior to unweeded control at all stages.

At 30 DAS, hand weeding twice at 20 and 30 DAS was the best treatment in recording lower counts of monocot weeds (134.0 weeds m^{-2}), next to weed free check. Hand weeding reduced the monocot weed population to the extent of 67 per cent as compared to unweeded control. The monocot weeds could be controlled with pre-emergence application of pendimethalin at 1.0 Kg ai ha^{-1} alone (179.5 weeds m^{-2}). The application of pendimethalin when supplemented with hand weeding at 30 DAS (187.6 weeds m^{-2}) was also comparable with the application of this chemical alone. The weeds which escaped herbicides were removed by hand weeding at 30 DAS. The application of alachlor in granular form combined with hand weeding at 30 DAS recorded the highest count of monocot weeds. The granular form of herbicides resulted in poor stand of the crop, as the moisture status of soil was already low and the application of granular form of herbicide aggravated the deficiency of moisture in soil. This enabled the luxurious growth of monocot weeds and the weed population was also highest with application of alachlor in granular form. The additional hand weeding given have disturbed the soil and enabled the weed seeds in the lower layers of soil to be exposed to light and germinate which in turn, contributed to highest monocot weed population. The application of alachlor granules alone and metolachlor application at 1.25 Kg ai ha^{-1} alone were on par with each other in recording higher counts of monocot weeds.

At later stages of crop growth the lowest weed count was observed with application of herbicides like alachlor at 1.5 Kg ai ha^{-1} along with hand weeding at 30 DAS or pendimethalin at 1.0 Kg ai ha^{-1}, each integrated with hand weeding at 30 DAS (103.4 and 117.5 weeds m^{-2} at 60 DAS respectively and 45.5 and 36.7 weeds m^{-2} at harvest respectively) and also with two hand weedings at 20 and 30 DAS (122.8 weeds m^{-2} at 60 DAS and 49.4 weeds m^{-2} at harvest respetively) as compared to the best treatment involving application of alachlor along with hand weeding. Excellent weed control during initial stage of the crop by alachlor and pendimethalin and suppression of late emerging weeds by hand weeding resulted in the least weed count. The application of granules of alachlor either alone or combined with hand weeding at 30 DAS continued to record higher weed population per square metre at 60 DAS and also at harvest.

In general, upto the harvest stage the monocot weed population was kept to the minimum by application of pendimethalin at 1.0 Kg ai ha^{-1} along with hand weeding at 30 DAS and was comparable with alachlor application at 1.5 Kg ai ha^{-1} integrated with hand weeding at 30 DAS.

5.1.2.2. Dicot weed population

The maximum dicot weed population was observed in weedy check (39.5,56.5 and 68.8 weeds m^{-2} at 30 and 60 DAS and at harvest respectively) and the minimum in continuously weed free condition at all growth stages.

On the 30th day after sowing, two hand weedings at 20 and 30 DAS resulted in least dicot weed count (7.4 m^{-2}), but was comparable to the application of pendimethalin at 1.0 Kg ai ha^{-1} alone which in turn was on par with application of pendimethalin at 1.0 Kg ai ha^{-1} combined with hand weeding at 30 DAS. The treatment T10 was closely followed by T9. This indicates that at 30 DAS, hand weeding twice and application of herbicides like pendimethalin and alachlor were equally effective in reducing the dicot weed population. The dicot weed population was more with application of alachlor granules at 20 kg ha^{-1} along with hand weeding at 30 DAS and was significantly inferior to other treatments except unweeded control.

At later stages of crop growth, the integration of chemicals like alachlor at 1.5 kg ai ha^{-1} with hand weeding at 30 DAS and pendimethalin spray at 1.0 Kg ai ha^{-1} with hand weeding at 30 DAS reduced the dicot weed population to the minimum (by 55 and 47 per cent at 60 DAS respectively and by 64 and 55 per cent at harvest respectively). At 60 DAS, hand weeding twice at 20 and 30 DAS closely followed the application of pendimethalin followed by hand weeding, while at harvest, these integrated treatments were significantly superior to rest of the treatments. The application of herbicides alone were not effective in reducing the dicot weed count at maturity. At later stages, the application of alachlor granules at 20 Kg ha^{-1} either alone or combined with hand weeding at 30 DAS was comparable with unweeded control indicating their inferiority over other treatments. The dicot weed population was more with application of granular form of herbicides mainly due to the poor crop stand.

5.1.2.3. Total weed population

Considering both monocot and dicot weeds together, the total weed population also was maximum with unweeded control (447.8, 641.7 and 700.9 weeds m^{-2} at 30 and 60 DAS and harvest respectively) and minimum with weed free check at all stages of crop growth. In the early stages, hand weeding twice at 20 and 30 DAS (141.4 weeds m^{-2} at 30 DAS) was significantly superior over other treatments, except the weed free check in recording lower weed counts. Among the herbicides the application of pendimethalin either alone (187.9 weeds m^{-2}) or combined with hand weeding at 30 DAS (198.2 weeds m^{-2}) and alachlor application at 1.5 Kg ai ha^{-1} with hand weeding at 30 DAS (218.8 weeds m^{-2}) were also good enough in reducing the total weed population per square metre. The application of alachlor granules supplemented with hand weeding at 30 DAS recorded the maximum count of weeds and was significantly inferior to other treatments except unweeded control. The treatment T12 was followed by T8 and this in turn was on par with T7.

The total weed population per square metre at later stages were least with application of alachlor at 1.5 Kg ai ha^{-1} supplemented with hand weeding at 30 DAS (128.9 and 76.3 weeds m^{-2} at 60 DAS and at harvest respectively), application of pendimethalin at 1.0 Kg ai ha^{-1} combined with hand weeding at 30

DAS (147.4 and 61.4 weeds m^{-2} at 60 DAS and at harvest) and was comparable with twice hand weeding at 20 and 30 DAS (154.5 and 88.7 weeds m^{-2} at 60 DAS and at harvest respectively). Hoeing with Kochuthoomba reduced the total weed count next to application of metolachlor at 1.25 Kg ai ha^{-1} combined with hand weeding at 30 DAS. The efficiency of alachlor in reducing the total weed count in sesamum at 60 DAS and at harvest was also reported by Kannan and Wahab (1995). Reduced weed counts with three hand weedings in sesamum was reported by Sootrakar et al.(1995). The findings of the present experiment also confirm to the above results. The application of herbicides alone did not have much influence in reducing weed count. This is because though the weeds were controlled in the early stages, new flushes appeared at later stages and it was necessary to control it. Similar findings were also reported by Chandel et al. in soybean (1995). The application of granular form of alachlor at 20 Kg ha^{-1} either alone or combined with hand weeding continued to result in more weed population per square metre at later stages also. The predominance of weeds in the plots treated with granular form of alachlor resulted from the poor stand of the crop indicating its inefficiency in controlling the weeds in sesamum crop.

5.1.3. Dry matter production of weeds

The weed free check recorded the minimum dry matter production of weeds at all growth stages of crop. The unweeded control on the other hand, recorded the maximum dry matter production of weeds. The weed count was minimum with weed free check and thus there was little absorption of nutrients. This resulted in lowest dry matter production of weeds also. The weed population and thereby absorption of nutrients was maximum with unweeded control and hence the dry matter production of weeds was also maximum with this treatment. The weed free situation was superior to all other treatments. Also the unweeded condition was inferior to rest of the treatments.

On the 30th day after sowing hand weeding twice at 20 and 30 DAS could suppress the weed dry matter to the minimum (10.8 g m^{-2}) and was comparable with application of pendimethalin at 1.0 kg ai ha^{-1} alone (12.5 g) and pendimethalin along with hand weeding at 30 DAS (14.2 g m^2) On the 60th day after sowing and at harvest, application of pendimethalin at 1.0 Kg ai ha^{-1} combined with hand weeding at 30 DAS kept the weed dry matter production to the minimum, next to weed free check.

In general, in the early stages of growth, hand weeding twice was comparable with application of pendimethalin at 1.0 Kg ai ha^{-1} alone and also this treatment combined with hand weeding at 30 DAS in reducing the weed dry matter production. But at later stages, the effective treatments were application of pendimethalin along with hand weeding and alachlor at 1.5 Kg ai ha^{-1} with hand weeding. The alachlor application followed by hand weeding was comparable with hand weeding twice at 20 and 30 DAS, metolachlor application at 1.25 Kg ai ha^{-1} combined with hand weeding at 30 DAS and the local practice of two hoeings at 15 and 25 DAS.

The application of granular form of herbicide either alone or combined with one hand weeding was not found to be effective in reducing the dry matter production of weeds.

In the later stages of crop growth, herbicidal application involving pendimethalin at 1.0 Kg ai ha^{-1} or alachlor at 1.5 Kg ai ha^{-1}, each combined with a hand weeding at 30 DAS reduced the weed dry matter production more than the mechanical methods. The reduction in dry matter production of weeds by integration of herbicide with mechanical methods may be the consequence of their weed control potential due to prolonged persistence in soil and also the weeds that germinated later when removed with hand weeding, promoted the crop growth and thereby enabled it to suppress the weed growth more effectively. Patel et al. (1994) and De et al. (1995) reported the efficency of chemicals in reducing the weed biomass in other oilseed crops. Trials conducted at different centres of AICRP also revealed that pre-emergence application of pendimethalin at 1.0 Kg ai ha^{-1} with one hand weeding at 35 DAS was effective in decreasing the weed dry matter accumulation in sesamum fields at all stages of crop growth.

5.1.4. Weed control efficiency.

The integration of herbicides with hand weeding was found to enhance the weed control efficiency over the use of herbicides alone. The efficiency of integrated methods ranged from 61.7 to 87.5 per cent, while the application of herbicides was found to vary from 61 to 73.5 per cent. Similar results were obtained by Gogoi et al. (1991) with soybean.

Next to completely weed free situation, application of pendimethalin at 1.0 Kg ai ha^{-1} followed by one hand weeding on the 30th day after sowing was found to have the highest weed control efficiency (87.5 per cent), while the application of pendimethalin alone at 1.0 kg ai ha^{-1} resulted in a weed control efficiency of 65.92 per cent. Thus one additional hand weeding given was sufficient to control the regeneration of weeds. The application of alachlor along with one hand weeding and two hand weedings at 20 and 30 DAS were also effective in recording higher weed control efficiency of 86.2 and 83.6 per cent respectively.

Among the weed control treatments, the lowest weed control efficiency was recorded by the application of granular form of alachlor at 20 Kg ha^{-1} alone (60 per cent) followed by alachlor granules combined with one hand weeding (60.3 per cent) and application of metolachlor at 1.25 Kg ai ha^{-1} alone (61.89 per cent).

The application of granules did not improve the stand of the crop as the moisture status of the soil was already low and the application of granules also did not provide moisture and the weeds germinated earlier to crop seeds in plots receiving this treatment. Similar observations were made by Jain et al.(1995) in soybean.

The results of the present experiment show that the efficiency of chemicals were further increased by giving hand weeding at 30 DAS as this operation helped to remove the later emerging weeds. The results of this experiment are in confirmity with the findings of Kaneira and Patel (1994) in soybean. They obtained a higher weed control efficiency of 85.8 per cent due to pre-emergence application of pendimethalin at 1.0 Kg ai ha^{-1} combined with hand weeding at 45 DAS in comparison to weed free plot.

Kannan and Wahab (1995) reported a weed control efficiency of 75.8 per cent at harvest in sesamum with the application of alachlor at 2 Kg ha^{-1} followed by hand weeding at 40 DAS.

5.2. Observations on crops

Crop growth characters

5.2.1. Plant height

The height of the plants measured on the 30th day after sowing did not show any significant difference between treatments. But on the 60th day after sowing and at harvest, significant difference was noticed in plant height with various treatments. At 30 DAS, although there was no significant difference, the height of the plants was more in unweeded plots (37.4 cm). Ghosh and Mukhopadhyay (1980) also observed tallest plants in the unweeded control plots in the early growth stages of sesamum. This might probably be due to severe competition with weeds which resulted in thin and tall sesamum plants. The lowest height at this stage was recorded with application of metolachlor at 1.25 Kg ai ha^{-1} (28.7 cm).

At advanced stages of crop growth in general, the weed free situation recorded the maximum plant height. The competition of weeds with crop plants was reduced enabling the crops to utilise the nutrients and space to the maximum. The unweeded control, on the contrary recorded the minimum plant height due to severe competition with weeds. The luxurious weed growth in this situation almost suppressed the crop growth.

Hand weedings at 20 and 30 DAS increased the plant heights to the maximum (91.5 cm) at 60 DAS. This treatment was closely followed by application of alachlor at 1.0 Kg ai ha^{-1} combined with a hand weeding at 30 DAS. At harvest, the plant height was higher in plots treated with pendimethalin at 1.0 Kg ai ha^{-1} with a hand weeding at 30 DAS (117.7 cm). These treatments were as good as weed free situation both at 60 DAS and at harvest. In confirmity to the present finding, Ghosh and Bera (1986) reported that height of mustard increased with pre-emergence application of pendimethalin at 1.0 Kg ai ha^{-1}.

The lowest height was noted with metolachlor application at 1.25 Kg ai ha^{-1} (72.1 cm) at 60 DAS and it was on par with unweeded control. At harvest, alachlor granules at 20 Kg ha^{-1} decreased the plant heights as in the unweeded control. Brar et al. (1980) and Patterson et al. (1983) also found that herbicidal treatments did not influence the height of groundnut and soybean.

5.2.2. Number of branches per plant.

The number of branches per plant recorded at all stages of crop growth showed significant difference between the various weed management practices. The plot receiving continuous weeding recorded the maximum number of branches per plant at all stages (5.2 at 30 DAS and 60 DAS and at harvest). The unweeded control resulted in minimum number of branches per plant at all stages (1.4 at 30 DAS and 3.1 at 60 DAS. and at harvest) as there was severe competition for nutrients and space between crops and weeds. The treatment involving application of alachlor granules at 20 Kg ha^{-1} alone and metolachlor at 1.25 kg ai ha^{-1} recorded the least number of branches per plant and was on par with unweeded control at 60 DAS and at harvest stage.

At later stages, there was no significant difference between hand weeding twice and weed free situation. Among the herbicidal treatments, pendimethalin at 1.0 Kg ai-ha^{-1} combined with hand weeding registered highest number of branches per plant (4.4). Negi and Saini (1994) also obtained similar results in soybean. The higher number of branches indicates a more translocation of photosynthates in these plants. The effectiveness of hand weeding in increasing the branch number per plant in sesamum was reported by Sootrakar et al. (1995).

5.2.3. Leaf area index.

The leaf area index recorded at different stages of the crop did not show significant difference between the treatments.

There was a steady increase in leaf area index from 30 DAS to 60 DAS and thereafter a steady decline noticed. The weed free treatment recorded the highest leaf area index at 30 DAS (1.25) and 60 DAS (2.40) and at harvest (2.10) which may be attributed to the least competition between the crop and the weeds. The unweeded control and the application of chemicals alone recorded the lower values of leaf area index indicating that these treatments were not efficient in controlling the weeds compared to the application of herbicide treatment combined with one hand weeding, two hand weedings at 20 and 30 DAS and the local practice of hoeings with Kochuthoomba.

5.2.4. Dry matter production of crop

There was significant difference between the treatments for dry matter production at the different growth stages. The highest dry matter production on 30th day after sowing was recorded with unweeded control (623.1 Kg ha^{-1}). This is due to the greater plant heights recorded by this treatment at the stage. But on the 60th day after sowing and at harvest, weed free treatment recorded the highest dry matter production (2664.1 and 2611.8 Kg ha^{-1} respectively). The lowest dry matter accumulation was obtained with application of granular form of alachlor at 20 Kg ha^{-1} (426.4 Kg ha^{-1}) on the 30th day after sowing and with unweeded control on the 60th day after sowing and at harvest (1327.0 and 1160.8 Kg ha^{-1} respectively).

Among the herbicidal treatments, at 30 DAS, the highest dry weight was recorded by pendimethalin application at 1.0 Kg ai ha^{-1} alone (618.4 Kg ha^{-1}) and was on par with unweeded situation. This treatment was closely followed by the integration of pendimethalin with one hand weeding (606.2 Kg ha $^{-1}$). At 60 DAS, hand weeding twice resulted in higher production of crop biomass (2449.2 Kg ha^{-1}) followed by pendimethalin spray combined with hand weeding at 30 DAS(2333.4 Kg ha $^{-1}$) and was on par with weed free situation. At harvest, although not on par with weed free condition, the highest dry matter production was obtained with hand weeding twice (2275.5 Kg ha^{-1}) and application of pendimethalin along with hand weeding (2214.6 Kg ha^{-1}). Hand weeding resulted in maximum height, number of leaves and branches per plant which in turn contributed to higher dry matter production at later stages by this treatment.

The lowest accumulation of dry matter at 30 DAS, next to alachlor application in granular form was recorded with the granular application of alachlor combined with hand weeding (548.6 kg ha^{-1}) and metolachlor at 1.25 Kg ai ha^{-1} (550.5 Kg

ha^{-1}). The higher weed growth in the plots receiving these treatments suppressed the crop growth and resulted in lower dry weights. At 60 DAS and at harvest, minimum dry matter production was registered with application of alachlor granules at 20 Kg ha^{-1} (1617.3 and 1472.8 Kg ha^{-1} respectively) and metolachlor application at 1.25 Kg ai ha^{-1} (1683.2 and 1583.7 Kg ha^{-1} respectively). At 60 DAS, these inferior treatments were on par with unweeded control. Alachlor application in the form of granules followed by hand weeding and pendimethalin application as spray was also found inferior to other treatments.

In general, the herbicidal application of pendimethalin at 1.0 Kg ha^{-1} alone and also its combination with hand weeding at 30 DAS increased the plant dry matter production more than the hand weeding treatment in the early growth stage. But as growth advanced, hand weeding twice at 20 and 30 DAS was as good as application of pendimethalin at 1.0 Kg ai ha^{-1} along with hand weeding at 30 DAS. Reddy and Premalatha (1994) also found similar results and found that higher haulm yield of groundnut obtained with pre-emergence application of pendimethalin at 1.0 Kg ha^{-1}. Singh et al. (1993) reported the efficiency of hand weeding in increasing the dry matter accumulation of sesamum.

The dry matter accumulation under unweeded control was lower at later stages of crop growth due to decreased growth of plants as the competition with weeds was severe with no weeding. The dry matter accumulation during earlier growth stages was higher under weedy check due to more vegetative growth by the crop plants to compete with weeds. Under unweeded control, the dry matter production of crops was 49.8 per cent and 44.7 per cent of the total dry matter production of crop in completely weed free condition at 60 DAS and at harvest respectively (Table 17). The severity of weed competition under weedy check resulted in decreased dry matter production of crop as more nutrients was absorbed by the weeds from the soil as compared to the crop.

Yield attributing characters.

5.2.5. Days to 50 per cent flowering.

There was significant influence of the different herbicide treatments on the number of days taken by 50 per cent of the plants in the treated plots to complete flowering. The maximum number of days to complete 50 per cent flowering was observed with unweeded control (47 days) while the minimum number of days was with treatment receiving continuous weeding (40.7 days). The non-removal of weeds resulted in severe crop-weed competition with unweeded treatment. The crop as a result put forth prolonged vegetative growth in these treatments at an early

Table.17. Effect of treatments on dry matter production of crop in the weedy check and completely weed free plot compared (Kg ha^{-1}).

Days after sowing	Weedy check			Weed Free Plot			
	Weed	Crop	Total	Weed	Crop	Total	Percent increase in DMP
30	846.0	623.1	1469.1	-	570.7	570.7	
60	2987.0	1327.0	4314.0	-	2664.1	2664.1	49.8
Harvest	336.0	1160.8	4196.8	-	2611.8	2611.8	44.7

stage. On the other hand, in continuously weed free situation the crop was able to translocate more phtosynthates to flowering branches. This caused an earlier flowering in treatments receiving continuous weeding.

Hand weeding twice at 20 and 30 DAS (41.3 days) was comparable with weed free condition in recording minimum days to complete 50 per cent flowering. This treatment in turn was on par with application of pendimethalin at 1.0 Kg ai ha^{-1} along with one hand weeding at 30 DAS (42 days). The granular form of alachlor application at 20 Kg ha^{-1} did not prove beneficial in this aspect.

5.2.6. Number of pods per plant

The number of pods per plant was significantly influenced by the different herbicide treatments. Completely weed free treatment recorded the maximum number of pods per plant (61.0 and 116.8 at 60 DAS and at harvest respectively) while the weedy check, the minimum number (20.0 and 40.6 at 60 DAS and at harvest respectively). On the 60th day after sowing and at harvest, the best treatments next to weed free condition were hand weeding twice at 20 and 30 DAS (50.5 and 104.2 respectively) and application of pendimethalin at 1.0 Kg ai ha^{-1} integrated with hand weeding at 30 DAS (54.2 and 99.2 respectively).

The other herbicidal treatments found good in recording higher number of pods were application of alachlor at 1.5 Kg ai ha^{-1} along with hand weeding at 30 DAS (47.3 at 60 DAS and 95.3 at harvest), hoeing twice at 15 and 25 DAS (42.7 at 60 DAS and 86.4 at harvest) and application of alachlor at 1.5 Kg ai ha^{-1} alone (37.6 at 60 DAS and 69.8 at harvest).

The weed competition reduced with weed free situation and herbicidal treatments proved to be good in enhancing the pod number per plant by absorbing more of nutrients and producing more number of flowering branches. In these treatments, there was greater translocation of nutrients to these branches.

The granular application of herbicides did not provide good stand for the crop and this enabled the weeds to compete with crops. The flowering branches were also reduced with these treatments.

Sootrakar et al. (1995) found that maximum pod number per plant could be obtained with hand weeding once at 25 DAS. The present study also obtained good results with hand weeding treatment.

5.2.7. 1000 seed weight

The completely weed free situation recorded the maximum test weight (2.95 g) and this treatment was superior to all other treatments. The minimum test weight value was obtained with unweeded control (2.1 g) and was on par with application of metolachlor at 1.25 Kg ai ha^{-1} (2.2 g).

Hand weeding twice at 20 and 30 DAS and application of pendimethalin followed by hand weeding at 30 DAS recorded higher test weight (2.8 g) next to weed free check. The hoeings given at 15 and 25 DAS and application of alachlor along with hand weeding (2.7 g) were also equally good. All the weed control treatments were found to be on par with each other, except the weed free situation.

Ghosh and Mukhopadhyay (1980) have reported that higher test weight of seeds were obtained with chemical weeding in sesamum followed by hand weeding twice at 15 and 30 DAS. Similar results were obtained from this experiment also. But Singh et al. (1993) could not get significant difference between weed control treatments for test weight of seeds in sesamum.

5.2.8. Seed yield.

The different weed management practices exerted significant influence on the seed yield. The highest grain yield (752.17 Kg ha^{-1}) was recorded by the plots receiving continuous weeding. No other treatment is comparable with weed free situation. This was followed by hand weeding twice at 20 and 30 DAS (659.3 Kg ha^{-1}), application of pendimethalin at 1.0 Kg ai ha^{-1} along with hand weeding at 30 DAS (648.3 Kg ha^{-1}) and alachlor at 1.5 Kg ai ha^{-1} with hand weeding at 30 DAS (591.5 Kg ha^{-1}) which did not differ from each other. Two hoeings at 15 and 25 DAS with Kochuthoomba also recorded higher seed yields (556.8 Kg ha^{-1}) and was comparable with alachlor application along with hand weeding.

Hand weeding twice and application of pendimethalin followed by one hand weeding were found to have resulted in more number of branches, pods per plant and maximum test weight values. This in turn resulted in higher seed yield with these treatments. The reduced weed competition with these treatments ultimately enabled the plants to put forth more yield attributing characters.

The lowest seed yield was obtained with weedy check (262.5 Kg ha^{-1}) and this treatment was inferior to rest of the treatments. The other treatments not found to be effective in enhancing seed yield were application of metolachlor at 1.25 Kg ai ha^{-1} (404.2 Kg ha^{-1}) and granular application of alachlor integrated with hand weeding (433.5 Kg ha^{-1}). The higher weed intensity in these plots reduced the seed yield. Ghosh and Mukhopadhyay (1980), KAU (1980), Kannan and Wahab (1995) and

Sootrakar et al. (1995) also reported higher seed yield in sesamum with weed control.

5.2.9. Harvest index

The weed control treatments were found to have influenced the grain and haulm yield of sesamum, but the harvest index was not affected by these treatments. The highest value being recorded was 0.29 with application of pendimethalin at 1.0 Kg ai ha^{-1} or metolachlor at 1.25 Kg ai ha^{-1} and both integrated with hand weeding at 30 DAS, hand weeding twice at 20 and 30 DAS, alachlor granules at 20 Kg ai ha^{-1}, weed free check and pendimethalin spray at 1.0 Kg ai ha $^{-1}$ alone. The lowest value was 0.23 with unweeded control.

The findings of Sootrakar et al. (1995) showed significant difference for harvest index with weed control treatments in sesamum. This was contrary to the result of the present experiment.

5.2.10. Weed index.

Weed index indicates the extent of yield loss due to weeds over the weed free treatment. The weed control treatments had significant effect on weed index.

The lesser weed competition enabled to enhance the yield from the plots receiving two hand weedings at 20 and 30 DAS and pendimethalin spray at 1.0 Kg ai ha^{-1} followed by one hand weeding at 30 DAS. This was indicated by lower weed indices for these two treatments (11.26 per cent and 12.54 per cent respectively). The next lowest value was recorded by the application of alachlor at 1.5 Kg ai ha^{-1} followed by one hand weeding at 30 DAS (20.77 per cent) which in turn was on par with two hoeings at 15 and 25 DAS (25.63 per cent) and application of metolachlor at 1.25 Kg ai ha^{-1} with one hand weeding at 30 DAS (29.01 per cent). The greatest yield reduction was registered with weedy check and this recorded the highest weed index value (65.1 per cent). All the herbicides were superior to weedy check. The higher weed index values next to weedy check were recorded with metolachlor spray at 1.25 Kg ai ha^{-1} (45.74 per cent), application of alachlor granules alone (41.83 per cent) and also integrated with hand weeding once at 30 DAS (42.37 per cent). The higher yield reduction suffered by these treatments was due to severe weed competition.

Similar results in confirmity with the present findings, that lower weed index values could be obtained by weed control treatments were reported by Upadhyay and Kasbe (1977), Ghosh and Mukhopadhyay (1980) in sesamum and other oil seed crops.

5.2.11. Protein content

The protein content of seeds were unaffected by any of the tried treatments which gave an indication that application of herbicides had no marked adverse influence on this qualitative parameter. Similar results were reported by Jain et al. (1995) in soybean. The unweeded control recorded the lowest protein content in seeds (19.83 per cent) indicating a lower uptake of N by the crop under this treatment. The weed free condition recorded the higher value of 22.7 per cent.

5.2.12. Oil content.

This qualitative parameter however showed significant difference with weed control treatments. The highest oil content was recorded from the completely weed free plot (51.7 per cent) and this treatment was however superior to all other treatments. The next best treatments were hand weeding twice at 20 and 30 DAS (50.6 per cent) and pendimethalin spray at 1.0 Kg ai ha^{-1} integrated with hand weeding at 30 DAS (50.1 per cent). These treatments were also comparable with cultural practice of two hoeings at 15 and 25 DAS (49.7 per cent) and application of alachlor at 1.5 Kg ai ha^{-1} with a hand weeding at 30 DAS (49.4 per cent). The weedy check recorded the lowest oil content (43.4 per cent). No other treatment was comparable with the weedy check, but the application of alachlor granules alone (45.7 per cent) and this in combination with hand weeding (46.3 per cent) were inferior treatments. Sootrakar et al. (1995) reported an oil content of 50.95 per cent with three hand weedings in sesamum.

The increase in oil content with various treatments may be attributed to the least weed competition and thereby highest nutrient uptake and oil yield. Girijesh and Patil (1989) also reported higher oil content with herbicidal treatment in groundnut.

5.3. Chemical analysis

5.3.1. Uptake of nutrients by the weeds

5.3.1.1. Nitrogen

There was significant influence of weed control treatments on the uptake of nitrogen by weeds at all stages of crop growth. The highest uptake of nitrogen was observed in weedy check (21.30, 60.33 and 60.09 Kg nitrogen ha^{-1} at 30 DAS, 60 DAS and at harvest respectively) and lowest with completely weed free situation at all growth stages of crop.

On the 30th day after sowing, weed uptake of nitrogen was maximum with application of alachlor in granular form at 20 Kg ha^{-1} along with one hand weeding at 30 DAS (12.16 Kg ha^{-1}). This plot recorded highest weed dry weight also at this stage and was inferior to all treatments, except the unweeded control. The minimum uptake of nitrogen by weeds was recorded with hand weeding twice at 20 and 30 DAS (2.70 Kg ha^{-1}), application of pendimethalin at 1.0 Kg ai ha^{-1} alone (3.11 Kg ha $^{-1}$) and also pendimethalin in combination with hand weeding at 30 DAS (3.53 Kg ha $^{-1}$). These treatments were not comparable with other treatments.

On the 60th day after sowing and at harvest, application of alachlor granules at 20 Kg ha $^{-1}$ alone and also integrated with hand weeding, application of metolachlor at 1.25 Kg ai ha $^{-1}$ and application of pendimethalin at 1.0 Kg ai ha $^{-1}$ alone recorded higher uptake of nitrogen by weeds. At these stages also, pendimethalin or alachlor application, each supplemented with hand weeding, hand weeding twice and application of metolachlor with hand weeding recorded lower uptake of nitrogen by weeds. The weed population and weed dry matter production were less in these treatments. The herbicide treatments when supplemented with hand weeding prevented the regrowth of weeds and this indicates the superiority of these treatments in reducing the uptake of nitrogen by the weeds.

Mani (1975) reported that there is two fold depletion of nitrogen by unweeded plots compared to weed free situation in soybean. Nimje (1992) also observed a greater removal of nitrogen by unweeded plots in groundnut.

5.3.1.2. Phosphorus

The effect of herbicidal treatments on the uptake of phosphorus by weeds is significant at all stages. The highest uptake was recorded by weedy check at all stages of growth (3.70, 10.84 and 8.95 Kg ha^{-1} at 30 and 60 DAS and at harvest respectively) and was significantly inferior to all other treatments. The lowest uptake of phosphorus by weeds was observed with weed free condition from 30 DAS upto harvest.

Application of granular form of alachlor at 20 Kg ha^{-1} resulted in maximum uptake of phosphorus by weeds at 30 DAS (1.91 Kg ha^{-1}). This was found inferior to all other treatments. Application of alachlor alone and metolachlor spray also did not prove beneficial for the crop as they recorded higher uptake of phosphorus by weeds. Next to weed free condition, the lowest uptake of phosphorus by weeds were estimated with two hand weedings at 20 and 30 DAS and application of pendimethalin at 1.0 Kg ai ha^{-1}. These two treatments were found equally good in reducing the weed uptake of phosphorus. Application of pendimethalin at 1.0 Kg ai ha^{-1} integrated with hand weeding at 30 DAS also stood on par with application of herbicide alone.

The highest uptake of phosphorus by weeds at 60 DAS and at harvest were recorded with the treatments involving application of alachlor granules at 20 Kg ha^{-1} alone (4.30 and 3.50 Kg ha^{-1} respectively), alachlor granules combined with hand weeding at 30 DAS (4.19 and 3.42 Kg ha^{-1} respectively), metolachlor spray at 1.25 Kg ai ha^{-1} and pendimethalin at 1.0 Kg ai ha^{-1}. The best treatment with lower uptake of phosphorus by weeds at 60 DAS and at harvest was recorded with pendimethalin application at 1.0 Kg ai ha^{-1} supplemented with hand weeding at 30 DAS and was on par with weed free condition. The other treatments such as application of alachlor at 1.5 Kg ai ha^{-1} along with hand weeding at 30 DAS, hand weeding twice at 20 and 30 DAS, application of metolachlor at 1.25 Kg ai ha^{-1} with hand weeding at 30 DAS, hoeings at 15 and 25 DAS were also found superior with a lower uptake of phosphorus by the weeds at both 60 DAS and at harvest. The production of more dry matter of weeds resulted in a higher uptake of nutrients by the weeds.

5.3.1.3. Potassium

The different weed control treatments significantly influenced the uptake of potassium by weeds. Weedy check continued to have higher uptake of potassium by weeds at all stages (8.0, 25.98 and 24.38 Kg ha^{-1} at 30 and 60 DAS and at harvest respectively). All other herbicidal treatments were superior to weedy check. Likewise, completely weed free plots recorded the lowest uptake of potassium throughout the crop period.

At 30 DAS, granular application of alachlor at 20 Kg ha^{-1} followed by hand weeding at 30 DAS (4.56 Kg ha^{-1}) was inferior to rest of weed control treatments except weedy check. The next inferior treatment with higher uptake of potassium was with the same herbicide applied without any hand weeding (4.14 Kg ha^{-1}). The lowest weed uptake of potassium next to weed free condition was by hand weedings given at 20 and 30 DAS, application of pendimethalin alone and also supplemented with hand weeding at 30 DAS.

At 60 DAS and at harvest next to unweeded condition, the maximum potassium uptake by weeds was with application of granules of alachlor at 20 Kg ha^{-1} alone (10.30 and 9.55 Kg ha^{-1} respectively). The other treatments found on par with this treatment were alachlor granules in combination with hand weeding at 30 DAS, application of pendimethalin at 1.0 Kg ha^{-1} and metolachlor at 1.25 Kg ai ha^{-1}. Application of pendimethalin at 1.0 Kg ai ha $^{-1}$ with a hand weeding at 30 DAS, alachlor at 1.5 Kg ai ha^{-1} with hand weeding at 30 DAS, hand weeding twice at 20 and 30 DAS recorded lower uptake of potassium at later stages.

5.3.2. Uptake of nutrients by the crop

5.3.2.1 **Nitrogen**

The highest uptake of nitrogen by the crop at 30 days after sowing was recorded by the weedy check (16.91 Kg ha^{-1}). At this stage, dry matter production of crop was also highest with the unweeded treatment. Due to severe weed intensity in the unweeded plots, the crop put forth good vegetative growth to compete with the weeds. This was followed by application of pendimethalin at 1.0 Kg ai ha^{-1} alone (16.78 Kg ha^{-1}) or this treatment integrated with hand weeding at 30 DAS (16.45 Kg ha^{-1}), and alachlor application at 1.5 Kg ai ha^{-1} alone (16.12 Kg ha $^{-1}$). The application of alachlor granules at 20 Kg ha^{-1} recorded the lowest uptake of nitrogen at 30 DAS (11.56 Kg ha^{-1}).

At later stages of crop growth, the highest nitrogen uptake (70.71 and 64.92 Kg ha^{-1} at 60 DAS and at harvest respectively) was registered by the completely weed free condition and the lowest uptake by the unweeded control (34.77 and 25.07 Kg ha^{-1} at 60 DAS and at harvest respectively).

Hand weeding twice at 20 and 30 DAS recorded higher uptake of nitrogen (65.16 Kg ha^{-1}) and was on par with the application of pendimethalin at 1.0 Kg ai ha^{-1} along with hand weeding at 30 DAS (62.09 Kg ha^{-1}) and the weed free condition at 60 DAS. At this stage, the lowest uptake was by weedy check (34.77 Kg ha^{-1}) The other treatments that recorded lower uptakes were application of alachlor granules at 20 Kg ha^{-1} (42.53 Kg ha^{-1}) and metolachlor at 1.25 Kg ai ha^{-1} (44.15 Kg ha^{-1}) which were on par with weedy check.

The hand weeded plots recorded higher nitrogen uptake at harvest also (56.60 Kg ha^{-1}). The application of pendimethalin at 1.0 Kg ai ha^{-1} and alachlor at 1.5 Kg ai ha^{-1} ha^{-1} along with hand weeding at 30 DAS (54.83 and 52.03 Kg ha^{-1} respectively) were as effective as two hand weedings. The lowest nitrogen uptake by crop at this stage was by the application of alachlor granules at 20 Kg ha^{-1} (40.37 Kg ha^{-1})

In general, the nitrogen uptake by the crop was found to decrease from 60 DAS upto harvest. This may be due to decrease in crop dry matter production with the senescence of leaves with maturity. The increase in nitrogen uptake by crop with weed control treatments was observed by Nimje (1992) and Murthy *et al*. (1993) in groundnut.

5.3.2.2 **Phosphorus**

The phosphorus uptake of crop at different growth stages revealed significant effect of weed control treatments. As in the case of nitrogen uptake by crop at 30 DAS, unweeded control recorded the highest uptake of phosphours (4.22 Kg ha^{-1}). At this stage, pendimethalin spray at 1.0 Kg ai ha^{-1} (4.19 Kg ha^{-1}) was equally effective as unweeded control. The lowest uptake of phosphorus was by granular application of alachlor at 20 Kg ai ha^{-1}. (2.68 Kg ha^{-1}). This treatment was inferior to all other treatments.

On the 60th day after sowing, weed free condition (11.70 Kg ha^{-1}) recorded the highest uptake of phosphorus which was on par with two hand weedings at 20 and 30 DAS (10.8 Kg ha^{-1}) and this in turn was comparable with application of pendimethalin at 1.0 Kg ai ha^{-1} integrated with hand weeding at 30 DAS (10.23 Kg ha^{-1} and alachlor application at 1.5 Kg ai ha $^{-1}$). The lowest uptake of phosphorus was recorded with weedy check (5.36 Kg ha^{-1}) which was comparable with alachlor granule application at 20 Kg ha^{-1} (6.62 Kg ha^{-1}). Other treatments recording lower uptake were application of metolachlor at 1.25 Kg ai ha^{-1} (6.87 Kg ha^{-1}) and pre emergent application o f alachlor at 1.5 Kg ai ha^{-1} (7.84 Kg ha^{-1}). The lower dry matter production of crop resulted in lesser uptake of nutrients by these inferior treatments.

At harvest also, phosphorus uptake was maximum with weed free situation (9.55 Kg ha^{-1}). This treatment was superior to all other treatments. The next higher uptakes were by hand weeding twice at 20 and 30 DAS (8.32 Kg ha^{-1}), application of pendimethalin at 1.0 Kg ai ha^{-1} or alachlor at 1.5 Kg ai ha^{-1}, each combined with a hand weeding at 30 DAS (8.11 and 7.67 Kg ha^{-1} respectively) and hoeings at 15 and 25 DAS (7.33 Kg ha^{-1}). The lowest uptake was by weedy check (3.98 Kg ha^{-1}). This treatment was inferior to all other treatments.

Hand weedings although did not prove beneficial in enhancing phosphorus uptake at early stages, it resulted in higher uptake at later stages. This was due to an increase in dry matter production of the crop at later stages due to removal of weeds by hand weedings. Among the herbicidal treatments, application of pendimethalin at 1.0 Kg ha^{-1} spray along with a hand weeding at 30 DAS was found to be effective in improving phosphorus uptake by crop. The uptake of phosphorus was also found to decrease after 60 DAS towards maturity for all the treatments.

Murthy et al. (1993) have reported decreased uptake of phosphorus by crop in weedy check as compared to weed free situation in groundnut. The results of the present study are in agreement with the findings of Murthy et al.

5.3.2.3. Potassium

The uptake of potassium by the crop was found to increase from 30 DAS upto 60 DAS and thereafter there was a steady decline upto harvest. This is due to an increase in dry matter production of crop at 30 DAS and 60 DAS and decrease in dry matter production thereafter. The highest uptake was recorded by unweeded control at 30 DAS (6.77 Kg ha^{-1}) and weed free check at 60 DAS (22.91 Kg ha^{-1}) and at harvest (19.39 Kg ha^{-1}), while the lowest uptake was with granular application of alachlor at 20 Kg ha^{-1} (4.61 Kg ha^{-1} at 30 DAS and with unweeded control both at 60 DAS (11.6Kg ha^{-1}) and at harvest (8.78 Kg ha^{-1})

On the 30th day after sowing, higher uptake of potassium was recorded by the application of pendimethalin spray at 1.0 Kg ai ha^{-1} with one hand weeding at 30 DAS (6.58 Kg ha^{-1}) and was on par with other treatments except the application of granular form of alachlor at 20 Kg ha^{-1} (4.61 Kg ha^{-1}) which registered the lowest uptake of potassium.

On the 60th day after sowing, a higher uptake of potassium on par with weed free check was recorded by two hand weedings at 20 and 30 DAS (20.95 Kg ha^{-1}), pendimethalin at 1.0 Kg ai ha^{-1} in the spray form with hand weeding at 30 DAS (19.92 Kg ha^{-1}). The integration of herbicides with hand weeding helped to control the re-emergence of weeds and reduce the competition. This resulted in a higher uptake by the crop plants. Hoeings at 15 and 25 DAS, application of alachlor as spray or granules with one hand weeding at 30 DAS did not differ significantly from the treatment involving hand weeding twice in recording higher uptake of potassium at 60 DAS. Application of alachlor granules at 1.5 Kg ai ha^{-1} or metolachlor spray at 1.25 Kg ai ha^{-1} did not result in higher uptake by the crop. It may be noted that the dry matter production of crop was also low with these treatments.

At harvest, no significant difference was noted in the uptake of potassium among the treatments that were hand weeded twice at 20 and 30 DAS (16.87 Kg ha^{-1}) or with application of pendimethalin at 1.0 Kg ai ha^{-1} or alachlor at 1.5 Kg ai ha^{-1}, each followed by one hand weeding (16.40 and 15.78 Kg ha^{-1} respectively) or hoeing twice at 15 and 25 DAS (15.20 Kg ha^{-1}). But these treatments were not on par with weed free situation. All these treatments were superior to weedy check also. The next lowest uptake was with application of alachlor granules at 20 Kg ha^{-1}, metolachlor at 1.25 Kg ai ha^{-1}, pendimethalin at 1.0 Kg ai ha^{-1} and alachlor granules at 20 Kg ha^{-1} with one hand weeding at 30 DAS.

The uptake of potassium was thus maximum with completely weed free situation at branching and flowering stages and this was reflected on yield of crop also. The herbicidal application of pendimethalin at 1.0 Kg ai ha^{-1} with one hand weeding at 30 DAS was as effective as hand weeding twice in recording higher uptake of potassium at all stages.

When all the three major nutrients were considered it was seen that herbicidal application could suppress the weed growth and enhance crop growth and nutrient uptake comparable with hand weeding.

A comparison of nutrient uptake in weedy check and completely weed free situation reveals the significance of weed control in sesamum. The data on the percentage of uptake of nitrogen, phosphorus and potassium in weedy check compared to complete weed free condition is presented in Table18.

The uptake of nitrogen by the crop on the 30th day after sowing in the unweeded control treatment was higher than under weed free situation. This was because in the early stage, under weedy check the crop put forth good vegetative growth to compete with weeds resulting in higher dry matter production. At 60 DAS and at harvest as the crop failed to with stand the competition from weeds, the uptake at 60 DAS, under weedy check

Table 18. Effect of treatments on Nitrogen, Phosphorus and Potassium uptake (Kg ha $^{-1}$) in the weedy check and completely weed free plot

Days after sowing	Weedy Check			Weed Free Plot			Percent uptake by crop
	Weed	Crop	Total	Weed	Crop	Total	
<u>N uptake</u>							
30	21.30	16.91	38.21	-	15.48	15.48	+9.24
60	60.90	34.77	95.67	-	70.71	70.71	-49.17
Harvest	60.63	25.07	85.70	-	64.92	64.92	-38.62
<u>P uptake</u>							
30	3.71	4.22	7.93	-	3.70	3.70	+14.05
60	10.93	5.36	16.29	-	11.70	11.70	-45.81
Harvest	9.02	3.98	13.00	-	9.55	9.55	-41.68
<u>K uptake</u>							
30	8.00	6.77	14.77	-	6.19	6.19	+9.37
60	26.23	11.60	37.83	-	22.91	22.91	-50.63
Harvest	24.59	8.78	33.37	-	19.39	19.39	-45.28

was only 49.17 per cent of the uptake at 60 DAS under complete weed free treatment. At harvest a reduction of 38.62 per cent in the uptake of nitrogen noticed with weedy check.

Considering the uptake of phosphorus at 30 DAS, 14.05 per cent more of phosphorus was absorbed by weedy check as against the weed free treatment. Later at 60 DAS and at harvest, weedy check recorded 45.81 per cent and 41.68 per cent lower uptake of phosphorus over weed free treatment.

In the case of potassium also, at 30 DAS a higher uptake was observed with weedy check (9.37 per cent) as compared to unweeded control. But at later stages, 45.28 to 50.63 per cent reduction in uptake of potassium was recorded with weedy check.

In general, occurence of weeds were found to reduce the uptake of nutrients by 45 per cent in sesamum. The initial increase in uptake was due to more vegetative growth of plants to compete with weeds. But the seed yield was substantially reduced by weed infestation. Therefore, at later stages the total dry matter accumulation of crop was reduced substantially under weedy check, consequently a reduction in uptake of nutrients was also noticed at later stages.

5.3.3. N, P and K content of soil after the experiment.

The content of nitrogen and phosphorus after the experiment was significantly influenced by various weed control treatments. The potassium content of the soil however did not vary significantly with the different treatments. The highest nitrogen content (212.95 Kg ha^{-1}) in soil after the experiment was estimated with hand weeding twice at 20 and 30 DAS and the weed free check recorded the highest phosphorus content (45.12 Kg ha^{-1}) in soil after the experiment. The better control of weeds by these treatments resulted in a higher content of nutrients left in the soil even after the experiment as the uptake of nutrients by the weeds was reduced considerably by these treatments.

5.3.4. Microflora count in the soil

5.3.4.1. Bacterial count

5.3.4.1.a. 5 Days after herbicidal treatment

The bacterial population was found to decrease with herbicidal application at this stage. In the weed free check, unweeded control and in twice hand weeded plots (27×10^6, 26.3×10^6 and 25.7×10^6 respectively) a higher count of bacteria at this stage was recorded over the herbicide treated plots. The maximum decline in bacterial population was noticed in plots treated with metolachlor at 1.25 Kg ai ha^{-1} alone and also metolachlor along with hand weeding at 30 'DAS ($9.3x10^6$). The adverse effect of herbicides on the bacterial population was due to the lethal action. Degradation in soil was nullified in herbicide treated plots.

5.3.4.1.b 30 Days after herbicidal treatment

The bacterial population gradually increased with time. But significant difference was noted with different weed control treatments at 30 DAT also. At this stage, weed free check was superior in recording the maximum bacterial count ($29.3x10^6$) but was on par with unweeded control, hand weeding twice at 20 and 30 DAS, hoeing twice at 15 and 25 DAS, application of pendimethalin at 1.0 Kg ai ha^{-1} alone and pendimethalin integrated with hand weeding at 30 DAS.

The bacterial count in pendimethalin treated plots, being on par with the weed free check indicates that this chemical degraded in soil over a period of time and was not found harmful to bacteria. Among the herbicides used, metolachlor application along with hand weeding at 30 DAS was the least effective ($23.0x10^6$) in enhancing the bacterial population in soil after its application indicating a longer persistence of this chemical in the soil. But the increase in bacterial population in weed free check as compared to metolachlor application was only 21.5 per cent. The decrease in bacterial population with herbicide application over unweeded control was noted by Nayak et al. (1994) in sesamum.

5.3.4.2. Fungal count

5.3.4.2.a. 5 Days after herbicidal treatment

The fungal population was also found to decrease with herbicide application and was lower at this stage than at a later stage. The continuously weed free condition and hand weeding twice at 20 and 30 DAS recorded the same count at 5 DAT (15.3×10^4) and were comparable with unweeded treatment and also two hoeings at 15 and 25 DAS. The cultural practices did not cause any harmful effect on fungal count but the application of herbicides resulted in a lower count and the least value was recorded with the application of metolachlor at 1.25 Kg ai ha^{-1} (8.0×10^4). The herbicides were toxic to soil fungi soon after their treatment.

5.3.4.2.b. 30 Days after herbicidal treatment

As in the case of bacteria, the fungal population also showed an increasing trend at a later stage of herbicide application. The highest count was recorded with weed free check (20.3×10^4) and other cultural practices and the lowest with metolachlor application (16.7×10^4). The fungal population did not increase to such an extent as in the case of bacteria with time for herbicide treated plots. From this, it is evident that herbicides were more toxic to fungi than for bacteria. Nayak et al. (1994) also reported a decrease in fungal population with the application of different herbicides in sesamum.

5.3.4.3. Actinomycete count.

5.3.4.3.a. 5 Days after herbicidal treatment

Actinomycete population also declined with the application of herbicides. In this case also, weed free check was superior to other treatments in recording higher count of actinomycete (54.7×10^5). This treatment however was superior to all other treatments. Application of metolachlor at 1.25 Kg ai ha^{-1} combined with hand weeding (21.3×10^5) showed a toxic effect on actinomycete population also. The adverse effect of herbicides on soil microflora was the maximum with actinomycete.

5.3.4.3.b. 30 Days after herbicidal treatment

The weed free check continued to record the highest actinomycete count (55.7×10^5) at this stage also and the lowest value (47.7×10^5) was with metolachlor application integrated with hand weeding. The different herbicides applied to control weeds degraded in soil and their toxic effect on actinomycete decreased at a later stage and the decrease in percentage of actinomycete population with the application of metolachlor combined with hand weeding over the weed free check was 14.36 per cent. Similar decrease in actinomycete population with application of herbicides was reported by Nayak et al. (1994) in sesamum fields.

5.4. Economics of cost of cultivation

5.4.1. Net income.

The net income from different weed control treatments showed marked differences. The integrated method of weed control involving, application of chemicals along with hand weeding were superior in recording higher income when compared to application of chemicals alone. The best treatments in recording maximum net income were application of either pendimethalin at 1.0 Kg ai ha^{-1} or alchlor at 1.5 Kg ai ha^{-1} , each supplemented with hand weeding at 30 DAS (Rs.5680.00 and Rs.4173.00 respectively) Hand weeding twice at 20 and 30 DAS recorded higher net income (Rs.3544.00) than hoeing twice at 15 and 25 DAS (Rs.1550.00). The hand weeding treatment although recorded the maximum yield, the net income was not the highest, due to the high cost of labour. The application of chemicals alone did not prove beneficial in recording higher net income. The application of pendimethalin alone recorded lower net income (Rs.51.00) than when pendimethalin was supplemented with hand weeding at 30 DAS (Rs.5680.00), which stresses the need for a supplementary hand weeding after herbicide application. A similar trend was seen in the case of alachlor where the net income was at RS.1284.00 when alachlor was applied alone and it was increased to Rs.4173.00 when alachlor was supplemented with a hand weeding at 30 DAS. The unweeded control recorded the maximum loss of RS.7273.00 which indicates the significance of weeding in sesamum cultivation. The granular application of alachlor and also spray application of metolachlor did not improve the yield of sesamum and these treatments thus recorded the lowest net income.

The superiority of integrated methods of weed control in sesamum in recording higher net income was established by the experiments conducted at KAU (1991). The application of alachlor was economically superior in maximising the profit in sesamum (KAU, 1984).

5.4.2. Net returns per rupee invested

The net returns per rupee invested for different treatments showed a trend similar to that of net income. The highest net returns was from application of pendimethalin at 1.0 Kg ai ha^{-1} integrated with hand weeding at 30 DAS (28 paise). This was mainly due to higher seed yield obtained by this treatment. The other treatments found superior for this aspect were application of alachlor at 1.5 Kg ai ha^{-1} along with hand weeding at 30 DAS (21 paise) and hand weeding twice at 20 and 30 DAS (16 paise). The unweeded control, application of metolachlor at 1.25 Kg ai ha^{-1} alone and application of alachlor granules at 20 Kg ai ha^{-1} either alone or combined with hand weeding at 30 DAS had negative returns.

Kannan and Wahab (1995) also obtained higher net return per rupee invested for sesamum with application of alachlor integrated with hand weeding.

The monetary gains from the superior treatments can thus be attributed to the higher seed yield obtained with these treatments by effective control of weeds. The integrated treatments were more superior as the later emerged weeds were substantially reduced by hand weeding when the crop was at flowering and pod formation stages.

5.4.3. Benefit - cost ratio

The highest ratio was recorded with application of pendimethalin at 1.0 Kg ai ha^{-1} followed by hand weeding at 30 DAS (1.28) and this treatment was closely followed by application of alachlor at 1.5 Kg ha^{-1} along with hand weeding at 30 DAS (1.21). The application of chemical alone recorded ratios ranging from 0.91 to 1.07. The unweeded control was inferior to other treatments with lower ratio of 0.59 as the yield from the treatment was the lowest. Weed free check, although recorded higher yield, the cost of cultivation was also high and recorded a ratio of 1.03. The lowest benefit-cost ratio, next to unweeded control, was obtained with application of metolachlor at 1.25 Kg ai ha^{-1} alone (0.85) and application of alachlor granules at 20 Kg ha^{-1} either alone (0.91) or combined with hand weeding (0.89).

SUMMARY

An experiment was undertaken in the rice fallows of Rice Research Station, Kayamkulam to develop an appropriate method of weed control for sesamum during the summer season of 1994-1995. The results of the study are summarised below.

1 Grasses like *Cynodon dactylon, Panicum repens, Brachiaria ramosa,* sedges like *Cyperus iria, Cyperus rotundus* and broad - leaved weeds like *Cleome viscosa, Sida acuta, Leucas aspera* and *Cassia occidentale* were the weeds which dominated the experimental area during the summer season of 1994-1995.

2 Monocot weeds accounted for the major share of total weed count throughout the crop growth period. Monocot weeds accounted for 77 per cent, while the dicot weeds constituted 23 per cent of total weed flora.

3 The monocot weed population was kept to the least till harvest by application of pendimethalin at 1.0 Kg ai ha^{-1} along with hand weeding at 30 DAS and was comparable with alachlor application at 1.5 Kg ai ha^{-1} combined with hand weeding at 30 DAS.

4 The dicot weed population could be suppressed effectively by the application of herbicides than the adoption of cultural practices. Although in the early stages, hand weeding twice at 20 and 30 DAS was comparable with herbicide application, at later stages application of alachlor at 1.5 Kg ai ha^{-1} or pendimethalin at 1.0 Kg ai ha^{-1}, each followed by hand weeding at 30 DAS were the best treatments in recording lower dicot weed counts.

5 The total weed population could be suppressed effectively by herbicidal application integrated with hand weeding. In the early stages, hand weeding twice at 20 and 30 DAS was significantly superior to other treatments in recording lower weed counts except the weed free check. At later stages, application of alachlor at 1.5 Kg ai ha^{-1} or pendimethalin at 1.0 Kg ai ha^{-1}, each combined with hand weeding at 30 DAS reduced the total weed population to the minimum and was comparable with two hand weedings at 20 and 30 DAS.

6 The weed dry weight was maximum with unweeded control while it was minimum under weed free check at all stages of crop growth. In the early stages, hand weeding twice at 20 and 30 DAS was more efficient than the herbicidal

application, but were comparable with each other. At later stages, application of pendimethalin at 1.0 Kg ai ha^{-1}, or alachlor at 1.5 Kg ai ha^{-1}, each supplemented with hand weeding at 30 DAS was more efficient than two hand weedings, these treatments being comparable with each other at these stages also.

7 Weed control efficiency was highest with weed free check. Next to weed free check, application of pendimethalin at 1.0 Kg ai ha $^{-1}$ or alachlor at 1.5 Kg ai ha^{-1} , each integrated with hand weeding at 30 DAS (87.3 and 86.2 percent respectively) and hand weeding twice at 20 and 30 DAS. (83.8 percent) were equally effective in recording high weed control efficiency.

8 Weed index was superior for hand weeding twice at 20 and 30 DAS (11.26 per cent) and application of pendimethalin at 1.0 Kg ai ha^{-1} combined with hand weeding at 30 DAS (12.54 per cent), next to weed free check.

9 Plant height at 30 DAS was not influenced by different weed control treatments, while at 60 DAS and at harvest, the crops grew taller with hand weeding twice at 20 and 30 DAS, application of pendimethalin at 1.0 Kg ai ha^{-1} or alachlor at 1.5 Kg ai ha^{-1}, each coupled with hand weeding at 30 DAS and shorter in unweeded control.

10 The number of branches per plant was more in weed free check and hand weeding twice at 20 and 30 DAS followed by application of pendimethalin or alachlor, each combined with hand weeding at 30 DAS, while it was low in unweeded check.

11 Leaf area index was not significantly influenced by the different weed control treatments at any of the crop growth stages.

12 There was significant influence of different weed control treatments on crop dry matter production at all stages of growth. At 30 DAS, more crop dry matter was produced in unweeded control plots (623.1 Kg ha^{-1}), while at 60 DAS and at harvest; next to weed free check, hand weeding twice at 20 and 30 DAS (2449.2 and 2275.5 Kg ha^{-1} at 60 DAS and at harvest respectively), application of pendimethalin or alachlor, each supplemented with hand weeding, hoeing twice at 15 and 25 DAS recorded higher crop dry matter production.

13 The yield attributing character like 50 percent flowering was superior with weed free check (40.7 days) and hand weeding twice at 20 and 30 DAS (41.3 days), closely followed by application of pendimethalin at 1.0 Kg ai ha^{-1} integrated with hand weeding at 30 DAS (42 days).

14 The other yield contributing characters like number of pods per plant and 1000 seed weight at harvest were also highest with the treatment involving hand weeding twice at 20 and 30 DAS (104.2 pods per plant and 2.8 g respectively) application of pendimethalin at 1.0 Kg ai ha^{-1} or alachlor at 1.5 Kg ai ha^{-1}, each supplemented with hand weeding at 30 DAS.

15 Highest seed yield was obtained with weed free check (752.17 Kg ha^{-1}). The next best treatments for superior seed yield were hand weeding twice at 20 and 30 DAS (659.3 Kg ha^{-1}), application of pendimethalin at 1.0 Kg ai ha^{-1} or alachlor at 1.5 Kg ai ha^{-1}, each coupled with hand weeding at 30 DAS (648.3 and 591.5 Kg ha^{-1} respectively). The harvest index did not show significant difference with different weed control treatments.

16 The qualitative parameter like protein content of seed did not exhibit significant difference with different weed control treatments.

17 The oil content was maximum with weed free check (51.7 per cent). The other best treatments were hand weeding twice at 20 and 30 DAS, application of pendimethalin at 1.0 Kg ai ha^{-1} along with hand weeding at 30 DAS and hoeing twice at 15 and 25 DAS.

18 The nutrient removal by weeds was significantly influenced by all weed control treatments. The highest removal of nutrients by weeds was with unweeded control and lowest with weed free check at all growth stages of crop growth. Among other treatments, the removal of nutrients by weeds at 30 DAS was minimum with hand weeding twice at 20 and 30 DAS and application of either pendimethalin at 1.0 Kg ai ha^{-1} alone or combined with hand weeding at 30 DAS. At 60 DAS and at harvest, the application of pendimethalin at 1.0 Kg ai ha^{-1} or alachlor at 1.5 Kg ai ha^{-1}, each coupled with hand weeding at 30 DAS, hand weeding twice at 20 and 30 DAS and application of metolachlor at 1.25 Kg ai ha^{-1} along with hand weeding at 30 DAS, resulted in the minimum removal of nitrogen, phosphorus and potassium by weeds.

19 The uptake of nutrients by crop was improved by all the weed control treatments when compared with unweeded control. The uptake of nitrogen and phosphorus by the crop at 30 DAS was more with application of pendimethalin at 1.0 Kg ai ha^{-1} alone (16.78 Kg N ha^{-1} and 4.18 Kg P_2O_5 ha^{-1}), while the potassium uptake was not influenced at this stage by the weed control treatments. At 60 DAS and at harvest, higher uptake of nitrogen, phosphorus and potassium by the crop was recorded with hand weeding twice at 20 and 30 DAS

(65.16 Kg N ha^{-1}, 10.8 Kg $P_2 O_5$ ha^{-1} and 20.95 Kg K_2O ha^{-1} at 60 DAS and 56.6 Kg N ha^{-1}, 8.32 Kg P_2O_5 ha^{-1} and 16.87 Kg K_2O,8.32Kg $P_2O_5h^{-1}$ at harvest), application of pendimethalin at 1.0 Kg ai ha^{-1} or alachlor at 1.5 Kg ai ha^{-1}, each integrated with hand weeding at 30 DAS.

20 The content of nitrogen in the soil after the experiment was more with hand weeding twice at 20 and 30 DAS (212.95 Kg ha^{-1}) closely followed by hoeing twice at 15 and 25 DAS and pendimethalin application at 1.0 Kg ai ha^{-1} along with hand weeding at 30 DAS. Hand weeding twice at 20 and 30 DAS recorded higher content of phosphorus in soil (42.56 Kg ha^{-1}) next to weed free check, while the potassium content did not show significant difference with weed control treatments.

21 The soil bacterial, fungal and actinomycete population at 5 days after herbicidal treatment were significantly higher for treatments involving weed free check, hand weeding twice at 20 and 30 DAS, unweeded control and hoeing twice at 15 and 25 DAS, while the herbicidal application could not be compared with these superior treatments. At 30 days after treatment, the bacterial, fungal and actinomycete population were maximum with weed free check, unweeded control, hand weeding twice, hoeing twice and

application of pendimethalin at 1.0 Kg ai ha^{-1} either alone or combined with hand weeding at 30 DAS and also alachlor application at 1.5 Kg ai ha^{-1} supplemented with hand weeding at 30 DAS.

22 Application of pendimethalin at 1.0 Kg ai ha^{-1} integrated with hand weeding at 30 DAS recorded the highest net income (Rs.5680.00). This treatment was closely followed by application of alachlor as spray at 1.5 Kg ai ha^{-1} along with hand weeding at 30 DAS.

23 The net returns per rupee invested was maximum with application of pendimethalin at 1.0 Kg ai ha^{-1} supplemented with hand weeding at 30 DAS (28 paise). The next best treatment was application of alachlor at 1.5 Kg ai ha^{-1} integrated with hand weeding at 30 DAS.

24 The benefit-cost ratio was also highest with application of pendimethalin at 1.0 Kg ai ha^{-1} along with hand weeding at 30 DAS (1.28) and was closely followed by application of alachlor at 1.5 Kg ai ha^{-1} with hand weeding at 30 DAS.

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* Orginals not seen

APPENDIX

APPENDIX I

Weather data during the crop period (7.2.1995 to 4.5.1995)

Sl NO	Standard Week Number	Dates	Temp(°C) Max	Min	RH(%) 730 h	Total rainfall (mm)
1	6	5-11 Feb	34.8	21.7	91	000.0
2	7	12-18	33.5	22.5	93	001.2
3	8	19-25	33.6	22.9	94	000.0
4	9	26-4 March	33.5	22.3	95	003.2
5	10	5-11	34.3	22.6	93	001.5
6	11	12-18	34.2	23.6	95	084.6
7	12	19-25	34.2	23.2	90	000.0
8	13	26-1 April	33.7	24.3	91	010.0
9	14	2-8	34.0	23.8	88	022.5
10	15	9-15	33.0	23.6	91	147.3
11	16	16-22	33.1	24.0	93	028.6
12	17	23-29	33.7	23.8	93	086.5
13	18	30-6 May	32.5	23.9	93	016.6

Source:- Central Plantation Crops Research Institute,

Kayamkulam

WEED MANAGEMENT IN SESAMUM

(Sesamum indicum L.)

By

REENA V. V.

Abstract of the Thesis
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Abstract

An experiment entitled "Weed management in sesamum (*Sesamum indicum* L.)" was conducted in the summer rice fallows of Rice Research Station, Kayamkulam during 1995. The experiment was laid out in randomised block design with twelve treatments in three replications. The crop was sown on 7.2.1995 and harvested on 4.5.1995. The variety under the experiment was Thilak. The weather condition during the crop growing season was congenial for crop growth and herbicidal treatments.

The monocot weeds predominated the experimental area at all stages of crop growth. Next to weed free check, the total weed population till harvest was effectively kept under check and thereby weed control efficiency was maximum with the application of pendimethalin at 1.0 Kg ai ha^{-1}, or alachlor at 1.5 kg ai ka^{-1} each combined with hand weeding at 30 DAS. But hand weeding twice at 20 and 30 DAS was comparable with these treatments in early stages of crop growth. Weed index was found to be superior with hand weeding twice at 20 and 30 DAS followed by application of pendimethalin at 1.0 Kg ai ha^{-1} or alachlor at 1.5 Kg ai ha^{-1}, each integrated with hand weeding at 30 DAS. The

plant height was unaffected by weed control at early stages of plant growth. But the plant height at later stages and also the number of branches per plant at all stages of crop growth were maximum with application of pendimethalin at 1.0 Kg ai ha^{-1} or alachlor at 1.5 Kg ai ha^{-1},each supplemented with hand weeding at 30 DAS. Leaf area index was not influenced by weed control treatments. The dry matter production of crop at early stages was more with unweeded control, while at later stages hand weeding twice at 20 and 30 DAS followed by the application of pendimethlin at 1.0 Kg ai ha^{-1} or alachlor at 1.5 Kg ai ha^{-1} along with hand weeding at 30 DAS.

The yield attributing characters like 50 per cent flowering, number of pods per plant, 1000 seed weight and seed yield was superior with hand weeding twice at 20 and 30 DAS closely followed by application of pendimethalin at 1.0 Kg ai ha^{-1} or alachlor at 1.5 Kg ai ha^{-1},each coupled with hand weeding at 30 DAS. Although the seed yield and haulm yield were superior with herbicide treatments, the harvest index was not influenced by these treatments. The uptake of nutrients by the weeds were reduced by the weed control treatments which in turn increased the uptake by crop.

The nitrogen and phosphorus content of soil was influenced by weed control treatments. The soil bacterial, fungal and actinomycete population at 5 days after herbicidal treatment were significantly superior with cultural practices than the herbicide application. But at 30 days after herbicide application, the bacterial, fungal and actinomycete population in plots receiving cultural methods of weed control were comparable with the corresponding population under some of the herbicide treated plots.

With regard to economics of cost of cultivation, higher net income, net returns per rupee invested and benefit-cost ratio were realised with the treatments involving application of pendimethalin at 1.0 Kg ai ha^{-1} or alachlor at 1.5 Kg ai ha^{-1}, each integrated with hand weeding at 30 DAS.

From the present study, it can thus be concluded with recommendation that the application of either pendimethalin at 1.0 Kg ai ha^{-1} or alachlor at 1.5 kg ai ha^{-1}, each coupled with one hand weeding at 30 DAS would be effective in maximising the yields of sesamum by the efficient control of weeds. These integrated approaches are economically also more suitable over the cultural practices of hand weeding or hoeing in areas with scarcity of labour and high labour cost.