STUDIES ON THE CHEMICAL AND NON-CHEMICAL WEED MANAGEMENT PRACTICES IN IRRIGATED COTTON (*Gossypium hirsutum* L.) (MCU 5)

Thesis submitted in part fulfilment of the requirements for the award of the degree of **DOCTOR OF PHILOSOPHY (Agriculture)** in AGRONOMY to the Tamil Nadu Agricultural University, Coimbatore-3.

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CERTIFICATE

This is to certify that the thesis entitled **"STUDIES ON THE CHEMICAL AND NON-CHEMICAL WEED MANAGEMENT PRACTICES IN IRRIGATED COTTON (*Gossypium hirsutum L.*) (MCU 5)"** submitted in part fulfilment of the requirements for the award of the degree of **DOCTOR OF PHILOSOPHY (Agriculture)** in **AGRONOMY** to the Tamil Nadu Agricultural University, Coimbatore is a record of bonafide research work carried out by **Mr. C. SIVAKUMAR** under my supervision and guidance and that no part of this thesis has been submitted for the award of any other degree, diploma, fellowship or other similar titles, prizes and that the work has not been published in part or full in any scientific or popular journal or magazine.

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ABSTRACT

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STUDIES ON THE CHEMICAL AND NON-CHEMICAL WEED MANAGEMENT PRACTICES IN IRRIGATED COTTON (*Gossypium hirsutum* L.) (MCU 5)

By

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Field experiments were conducted at Agricultural College and Research Institute, Tamil Nadu Agricultural University, Coimbatore from August 1998 to January 2000 to develop efficient chemical and non-chemical weed management practices for irrigated cotton (MCU 5) and to study the residual effect of herbicides applied on succeeding cowpea, greengram, sorghum and soybean crops.

Field experiments were laid out in a randomized block design with three replications. The treatments consisted of two doses of cinmethylin @ 0.5 and 0.6 kg ha^{-1} with and without hand weeding at 40 days after sowing (DAS). The different doses of cinmethylin were compared with the recommended herbicide, pendimethalin @ 1.0 kg ha^{-1} + HW at 40 DAS, allelopathic treatments such as parthenium incorporation @ 2 t ha^{-1} and whole plant extract spray (10%) with and without hand weeding at 40 DAS, growing of weed smother crops such as

cowpea, pearlmillet and greengram upto 40 DAS, hand weeding twice (20 and 40 DAS) and unweeded control (weedy check). The residual effect of cinmethylin and pendimethalin on crops were studied in field and polybag experiments. In the field experiment, the carry over effect of cinmethylin and pendimethalin were studied by growing of cowpea, greengram, sorghum and soybean upto 30 DAS and in polybag experiment, growing of susceptible crop like cucumber upto 30 DAS.

The broad leaved weeds dominated in the experimental field followed by annual and perennial grasses and perennial sedges. Thirteen species of weeds were observed. Among the broad leaved weeds *Digera arvensis, Trianthema portulacastrum*, among the grasses *Dactyloctenium aegyptium, Echinochloa colonum, Chloris barbata, Cynodon dactylon* and *Cyperus rotundus* among sedges were dominated in the experimental field.

Among the different weed management practices, pre-emergence application of cinmethylin @ 0.6 and 0.5 kg ha^{-1} followed by hand weeding at 40 DAS gave excellent control of grasses such as *Dactyloctenium aegyptium, Echinochloa colonum, Chloris barbata*, sedges and some broad leaved weeds. These treatments effectively reduced the total weed population, weed DMP, nutrient removal by weeds and increased weed control efficiency as compared to other treatments. These treatments were comparable with recommended practices of pendimethalin @ 1.0 kg ha^{-1} followed by hand weeding at 40 DAS, which effectively controlled the broad leaved weeds and grasses than sedges. Growing of greengram and cowpea as smother intercrops in cotton upto 40 DAS effectively controlled the total weed population, weed DMP, nutrient removal by weeds and increased the weed control efficiency as compared to other treatments.

The results of relative density, relative dry weight and summed dominance ratio revealed that application of cinmethylin @ 0.5 and 0.6 kg ha^{-1} followed by hand weeding at 40 DAS reduced the relative values of grasses and sedges than broad leaved weeds. Whereas application of recommended herbicide pendimethalin @ 1.0 kg ha^{-1} followed by hand weeding at 40 DAS reduced the relative values of grasses and broad leaved weeds than sedges.

Pre-emergence application of cinmethylin @ 0.5 kg ha^{-1} followed by hand weeding at 40 DAS was effective on all the categories of weeds and enhanced the growth parameters like plant height, leaf area index, dry matter production and nutrient uptake of cotton. This was followed by pendimethalin @ 1.0 kg ha^{-1} followed by hand weeding at 40 DAS. The higher dose of cinmethylin @ 0.6 kg ha^{-1} followed by hand weeding at 40 DAS reduced the crop growth, cleared the way for fast growth of weeds thereby decreased plant height, leaf area index, dry matter production and nutrient uptake of the crop. Growing of greengram and cowpea as smother crops upto 40 DAS suppress the weed growth and enhanced growth parameters *viz.,* plant height, leaf area index, dry matter production, nutrient uptake by the crop.

Among the weed management practices, application of cinmethylin @ 0.5 kg ha^{-1} followed by hand weeding at 40 DAS enhanced the yield parameters like number of sympodial branches $plant^{-1}$, number of bolls $plant^{-1}$ and boll weight. All these factors collectively contributed for higher seed cotton yield. This was followed by pendimethalin @ 1.0 kg ha^{-1} + HW at 40 DAS, which increased yield parameters and thereby enhanced the seed cotton yield. Growing of greengram and cowpea as smother crops along with cotton reduced weed growth and enhanced yield parameters and seed cotton yield.

Application of cinmethylin @ 0.5 kg ha^{-1} followed by hand weeding at 40 DAS recorded higher seed cotton yield and thereby increased net return and benefit-cost ratio. The higher dose of cinmethylin 0.6 kg ha^{-1} + HW at 40 DAS gave lower seed cotton yield thereby decreased the net return and benefit-cost ratio. The pre-emergence application of pendimethalin @ 1.0 kg ha^{-1} + HW at 40 DAS registered higher economic return as compared to higher dose of cinmethylin. Growing of greengram and cowpea as smother crops along with cotton upto 40 DAS increased net return and benefit-cost ratio due to the lower cost of weed management.

The microbial population of bacteria, fungi and actinomycetes were comparable with each other at 90 days after herbicide application in treatments like cinmethylin @ 0.5 kg ha^{-1} with and without handweeding at 40 DAS, hand weeding twice and unweeded control. Whereas application of pendimethalin recorded lesser microbial population due to longer persistence of pendimethalin in the soil than cinmethylin.

The determination of herbicide residue in cotton seed due to application of cinmethylin and pendimethalin revealed that the residue was well below the maximum residue limit. Cotton being a long duration crop, the herbicide could not persist in the soil beyond the season. The bio-assay study indicated that the germination percentage, plant height and dry matter production of cucumber revealed that the applied herbicide did not affect the succeeding sensitive crop. As the cotton crop occupied the field for more than five months, the herbicide applied at normal rate did not have residues in field by the end of cropping period.

The germination and plant growth characters like plant height and dry matter production of succeeding crops such as cowpea, greengram, sorghum and soybean were not affected by application of cinmethylin at 0.5 and 0.6 kg ha^{-1} as well as pendimethalin @ 1.0 kg ha^{-1} to the preceding cotton which revealed that there was no residual effect of herbicides.

From the above results, it could be concluded that, application of cinmethylin @ 0.5 kg ha^{-1} followed by hand weeding at 40 DAS effectively controlled the weeds and thereby gave higher seed cotton yield, net return and benefit-cost ratio. This next best treatment was pendimethalin @ 1.0 kg ha^{-1} + HW at 40 DAS. This was comparable with cinmethylin @ 0.6 kg ha^{-1} + HW at 40 DAS. These treatments were followed by growing of weed smothering crops such as greengram and cowpea along with cotton upto 40 DAS, which effectively checked the growth of weeds and higher seed cotton yield. Considering the net return and benefit-cost ratio, this is comparable with the recommended practice of pendimethalin @ 1.0 kg ha^{-1} followed by hand weeding at 40 DAS.

CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

LIST OF APPENDICES

LIST OF ABBREVIATIONS USED

a.i.	active ingredient
BC ratio	Benefit-Cost ratio
BLW	Broad Leaved Weeds
CD	Critical Difference
°C	Celsius
cm	centimeter
DAS	Days After Sowing
DMP	Dry Matter Production
dSm^{-1}	decisiemen per meter
EC	Emulsifiable Concentration
GC	Gas Chromatography
g	Gram
ha^{-1}	per hectare
HPLC	High Performance Liquid Chromatography
HW	Hand Weeding
kg	kilogram
LAI	Leaf Area Index
mha	million hectares
mm	millimeter
Mpa	Mega pascal
MRL	Maximum Residue Limit
mt	million tonnes
m^{-2}	per square meter
No.	Number
NS	Not Significant
ppm	parts per million

RD	Relative Density
RDW	Relative Dry Weight
Rs	Rupees
SDR	Summed Dominance Ratio
SEd	Standard Error difference
t	tonnes
viz.,	namely
WCE	Weed Control Efficiency
WI	Weed Index
@	at the rate of
%	Percentage

INTRODUCTION

CHAPTER I
INTRODUCTION

Cotton (*Gossypium hirsutum* L.) being an important commercial crop, it earns valuable foreign exchange and provides employment to millions of people. In India, it occupies nearly 9.17 million ha. with a production of 17.7 million bales of lint and productivity of 328 kg seed cotton ha^{-1}. In Tamil Nadu, cotton is cultivated in an area of 2.7 lakh ha. with a production and productivity of 6.0 lakh bales and 378 kg seed cotton ha^{-1} (Bardhan, 1998).

Weeds in cotton crop are the major production constraint. Cotton is very sensitive to weed competition in the first 60 days of the crop growth. The estimated yield loss varying from 16 to 68 per cent in cotton is only due to weeds (Sankaran *et al.,* 1993). Availability of agricultural labourer for timely weeding may be inadequate during peak season. In view of these, weed control gets neglected due to labour scarcity and many fields are either inadequately weeded or they are weeded too late. The labour intensive manual and mechanical methods are less effective, laborious, costly, time consuming and need to be repeated at different intervals. Manual weeding is always not possible, because of greater demand for labour and heavy rainfall in monsoon season resulting in severe weed competition. Hence, chemical control provide an alternative solution for effective and economic weed control.

Indiscriminate use of herbicides for weed control will lead to injury to sensitive crops in a crop rotation and resulting very serious ecological and environmental hazards (FAO, 1970). The recent awareness is to minimise the use of herbicides and adoption of eco-friendly approaches like cultural and biological methods for weed management due to higher cost of cultivation (weeding). This needs to initiate research on new weed control strategies using naturally occurring herbicides, allelopathic effect and growing of smother crops which become more attractive in the field of weed management.

Cinmethylin is a new class of herbicide which is naturally occurring, volatile monoterpene chemical produced by several plant species. It is found in the oils of *Laurus nobilis* (L.), *Salvia leucophylla* (Greene), *Rosmarinus officinalis* (L.), *Eucalyptus polybractea* (Bak.), *Artemisia maritima* (L.) and *Piper cubeba*(L.). Cinmethylin selectively control annual grasses (El-Deck and Hess, 1986) and also suppress the growth of broad leaved weeds (Russell *et al.,*1990) by inhibiting mitosis in meristematic tissues of weed shoot and roots.

Allelopathy is the direct or indirect effect of one plant on another through production of chemical compounds that escape into the environment (Rice, 1987). Occurrence and release of small quantities of allelochemicals into the environment either through root exudation or aerial foliage is recorded in plant species to equip each species with survival mechanisms. Therefore, suppression of weeds through enhancing allelopathic potential of crops and weeds are gaining more importance. Since, most of the research work on allelopathic effect has involved testing of aqueous extracts under laboratory conditions, it requires elaborate validation procedures under field condition.

Parthenium hysterophorus (L.) commonly known as carrot grass, belongs to the family, Asteraceae. It is a deadly weed, infesting cropped and non-cropped areas causing various alergies to animals and human beings. Its detrimental allelopathic potential, interacts with the growth of crop and weed species has been reported earlier by Narwal (1994). The allelochemicals leached out of *parthenium* residue appear to have inhibited the treated najas plants (*Najas graminea* Del.) by affecting the cellular and membrane integrity (Pandey, 1997). Parthenin was extracted from dried leaves of parthenium and it serves as a potential bio-herbicide to check the germination and growth of *Ageratum conyzoides* (L.). Positive allelopathic effect of parthenium on other weeds can be utilized for developing eco-friendly, cheap and effective bio herbicide. Intercropping of pearlmillet with main crop reduced the density of *Trianthema portulacastrum*, *Amaranthus* spp. and other minor weeds (Narwal *et al.*, 1992). Exudates from roots of pearl millet may reduce the germination and growth of most of the annual weeds.

Besides herbicide application, intercropping of wide spaced crops with fast growing pulses such as cowpea and greengram to suppress the weeds vegetatively is gaining momentum due to their smothering effects and also as a eco-friendly weed control measure. Weed suppression by the intercrops depends on many factors *viz.,* component crops, their growth habit, planting pattern, fertility and moisture status of soil (Moody and Shetty, 1981). Intercropping was proved to be superior to component crops in its weed suppressing ability and thus it provides an opportunity to utilize crops themselves as tools of weed management (Shetty and Rao, 1979). Even though intercropping can be a potential biological agent to manage weeds, the system alone would not ensure adequate weed control as it can reduce the use of herbicide and cost of weeding.

Hence, the present investigation was mooted to study the possibilities of developing most efficient, eco-friendly and economically viable chemical and non-chemical weed management practices for cotton under irrigated condition with the following objectives:

* To evaluate different chemical and non-chemical weed management practices for irrigated cotton.
* To fix the optimum dose of herbicide (cinmethylin) for weed management in cotton.

* To study the allelopathic potential of parthenium and to evaluate weed smothering effect of pulses (greengram and cowpea).

* To workout the economics of different chemical and non-chemical weed management practices and also estimate various weed indices.

* To assess the residual effect of different herbicide treatments through bio-assay, growing of residual crops and its influence on soil microbial population.

REVIEW OF LITERATURE

CHAPTER II
REVIEW OF LITERATURE

Cotton being a wide spaced, slow growing crop in the early stages is subjected to severe weed competition that results in yield loss by 30-70 per cent. Due to their high competitive ability, weeds compete for resources thereby affecting the productivity of cotton. Hence, cotton requires weed free condition during early stages in order to minimize the yield loss. Mechanical weeding although effective is cumbersome and frequent rains make mechanical weeding impossible. Pre-emergence application of herbicides and growing of smother crops takes care of weeds during the early part of crop growth. A brief review of work done on the use of chemical and non-chemical methods in cotton are presented here under.

2.1. Weed spectrum in cotton

Weed species in cotton field differ widely due to soil and environmental types. To evolve a successful weed management practice, identification of weeds associated with cotton crop is important. Balasubramanian and Sankaran (1976) reported that *Cyperus rotundus* (L.), *Dactyloctenium aegyptium* (Beauv.) and *Cynodon dactylon* (L. Pers) were the monocot weeds, *Trianthema portulacastrum* (L.), *Digera arvensis* (Forsk.), *Flaveria australasica* (Hook.), *Gynandrophis pentaphylla* (DC.), *Datura metal* (L.) and *Corchorus olitorius* (L.) were dicot weeds predominantly found in cotton field. Balasubramanian (1985) described that *Trianthema portulacastrum* (L.), *Dactyloctenium aegyptium* (Beauv.), *Echinochloa colonum* (L.) and *Cyperus rotundus* (L.) were dominant weeds in sandy loam soils of Coimbatore. The dominant weed flora in cotton growing belt were *Cynodon dactylon* (Pers.,) *Cyperus rotundus* (L.), *Panicum* spp., *Paspalum* spp., *Dinbra arabica* (Jacq.), *Setaria* spp., *Commelina benghalensis* (L.)

and *Digitaria* spp. among monocots while dicot weeds were *Boerhaavia diffusa* (L.), *Legasca mollis* (Cav.) *Abutilon indicum* (Swelt.,), *Corchorus* spp., *Alysicarpus* spp., *Convolvulus arvensis* (L.), *Amaranthus* spp., *Achyranthus aspera* (L.), *Argemone mexicana* (L.) and *Solanum nigrum* (L.) (Jain *et al.,*1985). At Coimbatore major broad leaved weeds in cotton crop were *Trianthema portulacastrum* (L.), *Amaranthus viridis* (L.), *Euphorbia prostrata* (L.) and *Boerhaavia diffusa* (L.) (AICRPWC, 1987). In cotton-wheat rotation the population of broad leaved weeds was much higher than narrow leaved weeds (Balyan *et al.,*1988). Vireshwar Singh *et al.* (1988) reported that *Echinochloa colonum* (L.), *Cyperus rotundus*.(L.), *Trianthema portulacastrum* (L.), *Ageratum conyzoides* (L.) were the most dominant weed species in Haryana. Tiwana and Brar (1990) reported that *Cyperus rotundus* (L.), *Cynodon dactylon* (L.), *Sorghum halepense* (L.), *Tribulus terrestris* (L.), *Trianthema portulacastrum* (L.), *Eleusine aegypticum* (L.) and *Eleusine indica* (L.) were dominant weeds of cotton in Punjab. Shelke and Bhosle (1991) stated that *Cynodon dactylon* (Pers.,), *Brachiaria eruciformis, Dinbra retroflexa* (Vehl.), *Acalypha indica* (L.), *Phyllanthus medraspatensis* (L.), *Cyperus rotundus* (L.) and *Celosia argentea* (L.) were the dominant weeds in Parbhani.

Balasubramanian (1992) observed that there were nearly 14 broad leaved weeds commonly associated with cotton crop, these are *Abutilon indicum* (L.), *Amaranthus viridis* (L.), *Amaranthus spinosus* (L.), *Boerhaavia diffusa* (L.), *Cleome viscosa* (L.), *Commelina benghalensis* (L.), *Corchorus olitorius* (L.), *Datura fastuosa* (L.), *Digera arvensis* (Forsk.), *Euphorbia prostrata* (Ait.), *Flaveria australasica* (Hook), *Parthenium hysterophorus* (L.), *Portulaca oleracea* (L.) and *Trianthema portulacastrum* (L.) five species of grasses namely *Chloris barbata* (Sw.), *Cynodon dactylon* (Pers.), *Dactyloctenium aegyptium* (Beavu.), *Echinochloa colonum* (L.) and *Panicum repens* (L.). and the only sedge weed found was *Cyperus rotundus* (L.).

Solaiappan *et al.* (1992) described that *Echinochloa colonum* (L.), *Echinochloa crusgalli* (L.), *Cyperus rotundus* (L.), *Paspalum dilatatum*, *Corchorus* spp., *Boerhaavia diffusa* (L.) were the predominant weed flora in rice fallow cotton. Important weeds of cotton field were *Trianthema portulacastrum* (L.), *Echinochloa colonum* (L.), *Cyperus rotundus* (L.), *Digera arvensis* (L.), *Dactyloctenium aegyptium* (L.), *Phyllanthus niruri* (L.), *Celosia argentea* (L.) and *Physalis minima* (L.) (Panwar and Malik, 1992; Samunder Singh and Malik, 1993; Chander *et al.*, 1994). Alwar Arunachalam (1993) found that the weed flora such as *Cynodon dactylon* (Pers.) *Cyperus rotundus* (L.), *Dactyloctenium aegyptium* (Beauv.), *Amaranthus viridis* (L.), *Cleome viscosa* (L.), *Chloris barbata* (Sw.), *Croton sparsiflorus* (Morung.), *Abutilon indicum* (L. Sweet), *Vernonia cinerea* Boss and Bal. and *Parthenium hystrophorus* (L.), were the major weeds in irrigated cotton. *Echinochloa colonum* (L.), *Cyperus rotundus* (L.), *Digera arvensis* (L.), *Phyllanthus niruri* (L.), *Celosia argentea* (L.) and *Physalis minima* (L.) were commonly observed in sandy loam soils at Hisar during rainy season (Singh and Malik, 1993; Panwar *et al.*, 1995).

Dadari *et al.* (1994) reported that major weed flora in cotton field were *Cynodon dactylon* (L.), *Chloris pilosa* (sw.), *Rottboellia exalata* (L.f.), *Crotalaria senagalensis* (L.), *Amaranthus spinosus* (L.), *Vernonia galamensis, Digitaria horizontallis, Acanthospermum hispidum, Tridax procumbens* (L.), *Eleusine indica* (L.), *Cassia occidentalis* in Nigeria. Fred *et al.* (1995) found that the weeds like *Digitaria* spp., *Echinochloa crusgalli* (L.) *Cyperus rotundus* (L.), *Sorghum halepense* (L.) Pers., *Echinochloa colonum* (L.), *Xanthium* spp., *Amaranthus retroflexus* (L.), *Ipomoea* spp., *Portulaca* spp., *Setaria* spp., *Commelina communis* (Clarke), *Cynodon dactylon* (L.), *Paspalum* spp., *Abutilon theophrasti,Chenopodium* spp., *Amaranthus viridis* (L.), *Convolvulus arvensis* (L.) and *Trianthema* spp. were the major weeds in the nine countries *viz.*, Brazil, China, Egypt, India, Mali, Mexico, Pakisthan, Tanzania and Uzbekisthan. Jadhav et al. (1995) reported that *Digera arvensis* (Forsk.), *Abutilon indicum* (L. Sweet), *Dinbra retraferea, Parthenium hysterophorus* (L.) and *Cyperus rotundus* (L.) were observed in rainfed cotton in Maharashtra.

In Punjab, the dominant weed flora were *Trianthema portulacastrum* (L.), *Eleusine indica* (L.), *Cyperus rotundus* (L.), *Celosia argentia* (L.), *Digera arvensis* (L.), *Tribulus terrestris* (L.), *Xanthium strumarium* (L.) and *Amaranthus viridis* (L.) associated with the cotton crop (Thind *et al.,* 1995). Giri and Bhosle (1997) reported that the dominant weeds associated with cotton crop were *Abutilon indicum* (L.) Sweet, *Acalypha indica* (L.), *Ischaemum pilosum* (L.) *Vicia indica* (L.), *Amischophacelous cucullata, Dinbra retroflexa* (Vahl) Panzer, *Merremia emarginata* (Burm.) Hall., *Phyllanthus medraspatensis* (L.), *Digera arvensis* (Forsk.), *Corchorus acutangulus* (Lomk.,), *Alysicarpus ragosus* De, *Alleteropsis cimicina* (L.) stapf, *Crozophora rottleri* (Gies), *Eragrostis namaguensis*, *Eclipta alba* (L.), *Euphorbia hirta* (L.) and *Tridax procumbens* (L.) At Punjab, the dominant weeds were *Trianthema portulcastrum* (L.), *Eleusine indica* (L.) Gaerth and *Cyperus rotundus* (L.), *Xanthium strumarium* (L.), *Tribulus terrestris* (L.) and *Cenchrus catharticus* (Brar *et al.,* 1995; Brar *et al.,* 1998).

Rout and Satapathy (1998) stated that the cotton field was infested with grasses, *viz., Cynodon dactylon* (Pers.), *Digitaria setigerus, Digitaria ciliaris* (Nees.), *Eleusine indica* (Gaertn.), *Paspalum scorbiculatum* (L.), *Sedges viz., Cyperus rotundus* (L.) and *Cyperus iria* (L.), broad leaved weeds *viz., Celosia argentea* (L.), *Commelina benghalensis* (L.), *Sida acuta* (Burm.), *Aeschynomene indica* (L.) and *Mimosa pudica* (L.) were dominant in Orissa. Satato *et al.* (1998) reported that the major monocot weeds associated with cotton were *Eragrostis minor, Dinbra retroflexa, Digitaria sanguinalis* (L.) Scop and the dicot species were *Celosia argentea* (L.), *Commelina benghalensis* (L.), *Digera arvensis*

(Forask.), *Euphorbia geniculta* (Orteg.), *Euphorbia hirta* (L.), *Physalis minima* (L.),, *Lagasca mollis* (Cav.), *Achyranthes aspera* (L.), *Phyllanthus niruri* (Hook.f.) and *Parthenium hysterophorus* (L.), perennial weeds were *Cynodon dactylon* (L.), and *Cyperus rotundus* (L.) at Akola. Kakade *et al.* (1999) suggested that dominant weed flora in the cotton field comprised of *Digera arvensis* (Forsk.), *Commelina benghalensis, Lagasca mollis* (Cav.), *Euphorbia hirta* (L.), *Parthenium hysterophorus* (L.) as the dicot weeds and *Eragrostis minor, Dinbra arabica* (Jacq.) as the annual grassy weeds and *Cynodon dactylon* and *Cyperus rotundus* as the perennial weeds. The dominant weed flora in the cotton field were *Cyperus rotundus* (L.), *Cynodon dactylon* (L.), *Phyllanthus niruri* (Hook.f.), *Abutilon indicum* (L.) Sweet, *Euphorbia hirta* (L.), *Amaranthus viridis* (L.), *Tridax procumbens* (L.) and *Leucas aspera* (Willd.) Spreng. at Raichur (Satayanarayana Rao *et al.,* 2000).

2.1.1. Critical period of crop-weed competition

Nieto *et al.* (1968) reported that the critical period of weed control defined as the point after which growth of the crop will no longer affect the crop yield. Kerkhovan (1964) reported that the first fifty days of cotton crop was the critical period for crop - weed competition. Martinez and Nieto (1968) found that the cotton yield was maximum when the crop was kept weed free for the first 60 days after sowing in Mexico. Thomas and Schwerzel (1968) found that the critical crop period competition was 2 to 4 weeks during summer season in Zimbabwe. The more acute weed competition effects were reported from 15 to 55 days after germination (Chokhey Singh *et al.,*1971; Arle and Hamilton, 1973; Buchanan and McLaughlin, 1975). The weed free condition upto 3 to 5 weeks after sowing was required to get maximum yield (Carson, 1975; Dason *et al.,* 1975; Blaco and Oliveira,1976; Mohamed Ali and Bhanumurthy, 1985).

The period upto 70 days from sowing was most critical period for weed - cotton competition (Sankaran,1977; Drennen and Jennings, 1977; Balyan *et al.,* 1983; Salome, 1984; Bir and Sindhu,1984; Zeman,1985). The critical period for weed control was between 20 and 60 DAS (Nankar, 1985; Higgins *et al.,* 1986; Shelke *et al.,* 1988; Saraswat, 1989; Shelke and Bhosle, 1990; Jayakumar *et al.,*1990; Bhan and Mishra, 1993). Panwar and Malik (1991) reported that the competition of *Trianthema portulacastrum* was higher upto 50 DAS whereas competition for *Echinochloa* was 50 to 100 DAS and hence, first 60 DAS was the most critical period for crop-weed competition. The critical crop-weed competition for bermuda grass in cotton was proved to be 4 to 7 weeks (Vencill *et al.,* 1993). Wn Jian Rong *et al.* (1999) found that the period of weed interference, crop damage and the critical time of crop-weed competition were 30 to 90 days which occupied 50 per cent of the whole cotton growing period.

2.1.1.1. Competition for light, moisture and nutrients

Among plant communities, each plant is in a state of continuous competition with its neighbouring plants for varied growth elements both above and under the ground. Our concern here is with such a competition between weeds and crops. Within a short span of time or a over all growth period, weeds compete more with the crop plants and removes very high amount of moisture, nutrients, light and space. According to Prentice (1971) the weeds primarily compete for nutrient, moisture and sunlight more in the early stage than in the later stages. The cotton yield was adversely affected by the weeds due to their competition for nutrients, light and space (Sharma *et al.*,1988). Stressful levels of environmental factors such as nutrient availability, water, light and temperature influence crop-weed interaction and also interfere with weed control and weed management strategies (Patterson, 1995).

2.1.1.1.1. Competition for moisture

According to Schwerzel and Thomas (1971) soil moisture removed by weeds was 3 to 5 times more than that of cotton and further observed that less competition was found in dry season than in wet season. If weeds were allowed to compete with cotton after first and second irrigation the yield loss will be 16 and 12 per cent respectively (Smith *et al.,* 1971). Coble *et al.* (1981) described that water stress or moisture availability also may influence the duration of critical weed free period for crops. Patterson (1995) reported that the weeds compete with the crops for water, reduce the amounts of soil water available to support crop growth and thereby resulting in crop water stress.

2.1.1.1.2. Competition for light

Schwerzel and Thomas (1971) found that cotton crop took 16 weeks for canopy development to cover 95 per cent whereas weeds took only 8 weeks and the weeds are able to produce more growth and efficiently compete for light. According to Patterson (1982) both purple and yellow nut sedge (*Cyperus rotundus* and *Cyperus esculentus*) shading to 60 and 30 % of full sunlight reduced dry matter production, leaf area production, rhizome and tuber formation. Aldrich (1984) reported that the proportion of total canopy LAI contributed by crop and weed and their relative height or vertical disposition of the crop and weed components of the total canopy are the most critical factors affecting competition for light. Plant height and vertical leaf distribution define effective components of the competitive struggle for light (Graf and Hill, 1992). Gupta (1998) suggested that light competition may commence very early in the crop season if a dense weed growth smother the crop seedlings, crop like cotton is prone to heavy weed growth at their seedling stages and consequently suffer badly at the hands of shading effect of weeds.

2.1.1.1.3. Competition for nutrients

Competition for nutrients constitutes an important aspect for weed-crop competition and yield loss. According to Singh *et al.* (1971) weed control within 15 days after germination of cotton crop have less competition for nutrients. Schwerzel and Thomas (1971) suggested that weeds present during 4-6 weeks in summer and 6-8 weeks in winter competes for more nutrients. Balasubramanian (1975) found that weeds removed 40.9 kg N ha^{-1} in the unweeded plot, whereas it reduced to 14.4 kg N ha^{-1} due to herbicide application. Balasubramanian and Sankaran (1978) reported that N, P, K uptake of crops was increased by three times if proper weed control measures were taken up. According to Jain *et al.* (1981) weeds removed 5-6 times N, 5-12 times P and 2-5 times K under upland condition. At low weed densities high N rates can markedly increase crop yield and minimise weed competition (Moody, 1981). Paterson and Nalewaja (1992) concluded that increased uptake of minerals by weeds often resulted in a competitive advantage over crop species. Tomaso (1995) found that weeds accumulate higher concentrations of mineral nutrients than crops, thus depleting soil nutrient levels more quickly and reducing crop yield. Balasubramaniam and Ravichandran (1996) stated that high levels of N, P, K increased the population of grassy weeds unlike broad leaved weeds but pigweed population was generally unaffected by any treatment except the addition of phosphorus. Gupta (1998) reported that weeds usually absorb mineral nutrients faster than many of our crop plants and accumulate in their tissues in relatively large amounts.

The above review shows that the availability of nutrients for crop growth is substantially reduced in the presence of weeds and hence nutrient use efficiency can be enhanced through the proper choice of weed management practices.

2.1.2. Effect of weed competition on cotton crop

2.1.2.1. Growth parameters

Plant height was unaffected even when the crop was left unweeded (Schwerzel and Thomas, 1971; Sankaran and Rethinam, 1974). The dry matter production of cotton per unit area was the lowest under unweeded condition (Sankaran and Rethinam, 1974; Tripathi and Singh, 1978; Singh, 1983). Decrease in plant height was observed due to weed competition (Balasubramanian and Sankaran, 1976; Rangiah *et al.,* 1976; Singh, 1983; Rushing *et al.,* 1984). Dominguez *et al.* (1981) suggested that pendimethalin and trifluralin applied at double and triple rates of recommended dose, reduced the height of cotton plants. Plant height and stem diameter (major contributers of dry matter production) were reduced by weed competition (Snipes *et al.,* 1982). Balyan *et al.* (1983) found that oxadiazon at 0.50, 1.00, 1.50 kg ha^{-1} affected cotton crop growth, height, number of branches and dry matter production. Muruganandam (1984) reported that application of oxyflourfen at 0.10 kg ha^{-1} and fluchloralin at 1.00 kg ha^{-1} with one hand weeding increased the plant height, leaf area index and dry matter production. According to Vireshwar Singh *et al.* (1987) application of pendimethalin increased the dry matter production of cotton. Manjunath and Panchal (1989) stated that increased LAI, leaf area duration, CGR, NAR, higher dry matter production, yield and yield components were obtained due to effective weed control with fluchloralin 1.5 kg ha^{-1} and fluazifop butyl 0.5 kg ha^{-1} as post emergence. Hussain *et al.* (1989) concluded that application of pendimethalin and dalapan increased the plant height and number of bolls $plant^{-1}$. Balasubramanian (1992) reported that application of pendimethalin at 1.25 kg ha^{-1} increased the plant height, DMP, number of bolls $plant^{-1}$, boll weight and kapas yield of cotton. Velayutham (1996) stated that application of metolachlor @ 1.00 kg ha^{-1} as herbigation + HW at 40 DAS increased the plant height, leaf area and DMP of cotton. Rout and Satapathy (1998) found that application of metolachlor @ 1.25 kg ha^{-1} as pre-emergence increased the plant height whereas glyphosate @ 0.4 kg ha^{-1} reduced the plant height of cotton severely.

2.1.2.2. Yield parameters

Singh *et al.* (1971) reported that lower boll numbers, seed cotton yield per plant and boll size were obtained where no weed control measures were taken up while the boll size did not differ significantly due to different periods of weed control. Decrease in number of bolls $plant^{-1}$ and boll setting was 45 to 85 per cent as observed due to severe weed infestation (Singh and Katti, 1972; Sankaran and Rethinam, 1974; Rangiah *et al.*,1976; Tripathi and Singh, 1978; Virk *et al.*,1982; Singh, 1983). Reduction in number of sympodial branches and fruiting points were observed due to severe weed infestation (Balasubramanian and Sankaran, 1976; Tripathi and Singh, 1978; Virk *et al.,* 1982; Mohamed Ali and Banumurthy, 1985; Singh, 1983). Nehra *et al.* (1988) found that on an average, plants under weed free condition produced 45 per cent more bolls than unweeded control. Solaiappan *et al.* (1992) concluded that plots treated with diethyl ether @ 1.5 kg ha^{-1} increased the boll number, boll weight and seed cotton yield. Thakar Singh *et al.* (1992) found that application of pendimethalin and fluchloralin decreased the boll numbers, boll weight and seed cotton yield. The seed cotton yield increased from 1890 to 3021 kg ha^{-1} as the initial weed free period was extended from 30 days to full growing season (Thind *et al.,* 1995). Panwar *et al.* (1998) stated that application of trifluralin or pendimethalin @ 1.0 kg ha^{-1} followed by one hoeing after first irrigation increased the number of bolls $plant^{-1}$ and finally contributed in the increase of seed cotton yield. According to Rout and Satapathy (1998) pre-emergence application of metolachlor @ 1.25 kg ha^{-1} to cotton increased the number of bolls $plant^{-1}$ and thereby increased the seed cotton yield. Satato *et al.* (1998) observed that the maximum number of bolls $plant^{-1}$ and seed cotton yield with sequential application of alachlor 2.0 kg ha^{-1} as pre-plant incorporation followed by glyphosate 1.025 kg ha^{-1} on 35 DAS. The number of bolls plant,$^{-1}$ boll weight and seed cotton yield were increased due to pre-emergence application of butachlor @ 1.0 kg ha^{-1} combined with one hand weeding at 40 DAS (AICCIP, 1999). Kakade *et al.* (1999) reported that farmer's practice (3 hoeings + 3 weedings) gave 508 per cent increase in seed cotton yield over weedy check because of significant increase in number of bolls, boll weight and seed cotton weight plant^{-1}. Pawar *et al.* (1999) described that the farmer's practice of thrice hoeing and weeding at 20, 40 and 60 DAS recorded the best control of monocot and dicot weeds with maximum number of bolls and weight of seed cotton plant^{-1}.

2.1.2.3. Yield loss

The physical loss of produce was nearly 8 per cent (USDA, 1965). The overall loss of produce was 14.6 per cent due to weeds (Cramer, 1967). The yield of cotton was adversely affected as compared to vegetative growth and stand of crop due to severe weed competition in the initial stages of crop growth (Buchanan and Burns,1970). According to Davis and James (1972) the yield loss due to weeds was 3 to 5 per cent per annum in USA. Arle and Hamilton (1973) reported that the weeds allowed to compete after the first or second irrigation significantly reduced yield of cotton by 16 and 12 per cent, respectively. Sankaran (1977) found that the loss in seed cotton yield was to the extent of 70 per cent due to uncontrolled weeds. The physical loss of produce by weeds was 11.5 per cent (Fryer, 1982). Unchecked weed growth in Nigerian Savanna causes 71 to 99 per cent loss in seed cotton yield (Choudhary, 1983).

Yield reduction was to the tune of 30 per cent due to inadequate weeding (Virk *et al.*,1982; Balyan *et al.*, 1983; Waugh *et al.*, 1992). Reduction in seed cotton yield under irrigated condition is primarily due to nutrient depletion caused by weeds and vary from 10 to 90 per cent (Deshpande *et al.*, 1987; Vireshwar Singh *et al.*, 1987). Byrd and Coble (1991) reported that the competition from

Xanthium strumarium and *Datura stramanium* reduced cotton yield 28 and 15 per cent, respectively. The cotton kapas yield reduction to the tune of 14.2 per cent with 100 *Trianthema portulacastrum* m^{-2} whereas 42.4 per cent yield reduction with 200 weeds m^{-2} present in the field for 50 days (AICRPWC, 1997). Season long competition of yellow nutsedge (*Cyperus esculentus*) reduced seed cotton yield upto 34 per cent (Jody and William, 1998; Rout and Satapathy, 1998).

2.1.2.4. Quality characters

The quality of cotton was unaffected by weed infestation (Klingman, 1973; Buendia *et al.,* 1976; Rushing *et al.,* 1984). Buchanan and Burns (1970) on the contrary reported that the quality characters of cotton was adversely affected as compared to vegetative growth and stand of the crop due to severe weed competition in the initial stages of the crop growth. Cia *et al.* (1978) found that the adverse effects on the quality characters like fibre percentage, seed weight, fibre uniformity, micronaire and pressely indices due to weed competition in cotton. Weed competition did not affect ginning percentage of cotton (Sayed *et al.,* 1979; Singh and Nagwekar, 1989). Balasubramanian and Sankaran (1981) observed that application of alachlor as pre-emergence at 2.0 kg ha^{-1} had a positive influence on mean halo length but decreased the ginning percentage. El-Deen *et al.* (1982) stated that fibre quality of cotton did not affect due to application of alachlor, dinitramine, fluchloralin, fluometuron, trifluralin, MSMA, diuron and pendimethalin. Egorov (1982) reported that fluometuron or prometryn at 1.5 kg ha^{-1} did not affect fibre quality and seed germination. Application of trifluralin, pendimethalin and fluchloralin reduced the quality of cotton (Abernathy *et al.,* 1983). Muruganandam (1984) stated that none of the chemicals either fluchloralin or oxyfluorfen at different concentrations did not affect cotton lint characters. Derting (1985) described that the fibre quality was not affected by the application of alachlor, fluchloralin and pendimethalin. According to Byrd and York (1987) the pre-sowing incorporation of pendimethalin, trifluralin, sethoxydim and fluazifop did not affect the maturity and fibre quality of cotton. Moorman and Koskinen (1990) found that the application of fluometuron and their metabolites did not have adverse effect on fibre span length and strength.

According to Balasubramanian (1992) application of lower doses of pendimethalin at 0.5 to 2.25 kg ha^{-1} produced finer fibres as compared to higher dose of 2.5 and 3.0 kg ha^{-1}. Landivar *et al.* (1994) stated that the application of glyphosate to cotton crop did not have significant effect on lint yield and fibre quality. Keeling *et al.* (1996) reported that application of trifluralin and pendimethalin to cotton did not affect the stand counts, lint yield and fibre quality but it varied year to year due to environmental conditions. Velayutham (1996) found that application of metolachlor at 1.00 kg ha^{-1} and pendimethalin at 1.00 kg ha^{-1} as herbigation to cotton did not have adverse effect on the quality of fibre. Dimitrova and Gueorgieva (1997) found that infestation of field bind weed (*Convolvulus arvensis* L.) adversely affected the quality of cotton fibre. According to El-Din (1997a) application of pendimethalin and fluometuron to cotton did not affect the fibre quality. Seed weight and fibre per cent were also unaffected by weed infestation (Nobrega *et al.,* 1997). Culpepper and York (1998) reported that the pre-plant incorporation of trifluralin and pre-emergence application of fluometuron followed by fluometuron plus MSMA as post emergence on 3 to 4 weeks after planting and cyanazine plus MSMA as post emergence on 6 to 7 weeks after planting did not affect the fibre quality in cotton.

2.1.2.5. Nutrient uptake

Balasubramanian (1975) found that the weeds removed 40.9 kg N ha^{-1} in the unweeded plot whereas it was reduced to 14.4 kg N ha^{-1} due to herbicide application. Lower uptake of NPK were observed in crop and higher uptake by weeds with unweeded control (Mani, 1975; Detroja *et al.,* 1992). Singh (1976) reported that the poor utilization of nitrogen is associated with the losses caused by weeds as cotton poorly responds to nitrogen in the presence of weeds. According to Subramanian (1976) the yield reduction of 11-92 kg ha^{-1} was observed in cotton for every kg of N removed by weeds. Sankaran (1977) found that during first 45 days weeds removed 41, 6 and 29 kg NPK ha^{-1} while cotton removed 20, 3 and 9 kg NPK ha^{-1}. Shanmugam and Meenakshisundaram (1977) suggested that fluchloralin applied as pre-emergence to cotton crop reduced the weed removal to 8 kg N ha^{-1} upto flowering stage. Balasubramanian and Sankaran (1978) reported that the NPK uptake of crop increased by 3 times if proper weed control measures were done.

According to Rethinam (1978) herbicides reduced nutrient uptake by weeds during the critical period of crop-weed competition, weeds removed about 76 kg, 10.6 kg and 9.6 kg of N ha^{-1} in unweeded check, chemical weed control and integrated method of weed control, respectively. Jain *et al.* (1981) described that the weeds removed 5 to 6 times N, 5 to 12 times P and 2 to 5 times K compared to nutrient uptake by cotton under upland condition. Ali *et al.* (1987) stated that the pre-emergence application of fluchloralin @ 1.0 kg ha^{-1} resulted in the higher nutrient uptake in cotton and thereby reduced nutrient uptake by weeds. According to Singh and Verma (1988) reported that the nitrogen use efficiency was higher in cotton due to application of pendimethalin than conventional weed control methods. Vireshwar Singh *et al.* (1987) suggested that the pre-emergence application of pendimethalin increased the NPK uptake by cotton and reduced the nutrient removal by weeds. According to Kundra *et al.* (1991) the effective weed management through pre-plant incorporation of fluchloralin 0.75 kg ha^{-1} resulted in higher uptake of 111.4, 22.7 and 97.5 kg ha^{-1} NPK respectively by crop and allowed only 3.1, 0.7 and 4.1 kg ha^{-1} NPK to be depleted by weeds. Chander *et al.* (1994) found that the dry weight and nutrient uptake of weeds were reduced due to herbicide application alone or in combination with one hand weeding.

Nadanassababady (1999) reported that application of pendimethalin @ 1.0 kg ha^{-1} reduced the NPK uptake by weeds than the unweeded control.

2.2. Weed management in cotton

A wider range, intensity, growth habit and life cycle of weed flora occurred in irrigated cotton crop. Therefore, no single weed control method gives continuous and effective weed control. Cultural methods of weed control widely adopted by the farmers are expensive, labour and time consuming. On the other hand, herbicide applied at the time of sowing seldom provide season long control of weeds in long duration crop like cotton.

2.2.1. Mechanical weed control

Hand pulling of weeds was an effective method of eliminating annual and biennial weeds which could not recover again (Crafts and Robbins, 1973; King, 1974; Parker and Fryer, 1975). Thakur (1977) reported that hand hoeing, ploughing, mowing and harrowing were important methods to control most of weeds. Raikwar *et al.* (1982) found that hand hoeing and weeding effectively controlled weeds besides it pulvarized the soil and promoted better root aeration. Cultural weed control measure was better in controlling weeds and increased seed cotton yield over other weed control methods (Singh, 1983; Shelke *et al.*, 1984). According to Jain *et al.* (1985) two intercultivation along with two hand weedings at 30 and 60 DAS resulted in best weed control thereby obtained maximum yield of seed cotton. Shelke and Bhosle (1989) stated that hand weeding and hoeings on 3, 6 and 9 weeks after sowing recorded 65 to 95 per cent control of weeds with maximum seed cotton yield.

Tiwana and Brar (1990) observed that the kapas yield of 2140 kg ha^{-1} and weed control efficiency of 63.6 per cent were obtained under hand weeding twice. Nehra *et al.* (1992) reported that the higher yield parameters and kapas yield were observed under hand weeding twice treatment than chemical weed control methods. According to Snipes *et al.* (1992) two intercultivations were sufficient for effective weed control and to get maximum kapas yield. Waugh *et al.* (1992) reported that the nutrient uptake by weeds was least in hand weeding + hoeing twice and pre-emergence application of herbicides. Pagar *et al.* (1995) suggested that the weed free check (mechanical weeding) resulted maximum weed control efficiency and seed cotton yield as compared to all other treatments. Higher kapas yield with two hand hoeings at 30 and 60 DAS was recorded compared to chemical weed control methods (Jadhav *et al.*, 1995; Panwar *et al.*, 1995; Yadav *et al.*, 1995; Patil *et al.*, 1997). El-Din (1997b) stated that the weed biomass reduced with increased number of hoeings but the difference between 2 and 4 hoeings was significant.

2.2.2. Weed management through herbicide

Mechanical weed control method was partially effective because most of weeds, those growing in intra rows, escaped weeds and incessant rains make the manual weeding impossible which resulted inadequate weed control and low kapas yield in cotton (Rajeswari and Charyulu, 1996). Thus, weed management through chemical became a promising means to control weeds at initial stages of crop growth.

2.2.2.1. Pendimethalin

Pendimethalin @ 0.6 to 1.5 kg ha^{-1} incorporated pre sowing, gave excellent weed control in cotton (Sprankle, 1974). Goddard *et al.* (1976) observed that this chemical provided excellent control of *Panicum dichotomiflorum, Brachiaria* spp. and *Digitaria* spp. in USA. Pendimethalin @ 1.9 kg ha^{-1} gave satisfactory control of annual grassy weeds whereas broad leaved weeds control was moderate (Hamdoun, 1978). According to Parshutin *et al.* (1980) pre-emergence application of this chemical @ 2.0 kg ha^{-1} recorded effective weed control compared to trifluralin 2.0 kg ha^{-1} and fluometuron 1.2 kg ha^{-1} . Application of pendimethalin @ 1.75 kg ha^{-1} as pre sowing, without incorporation controlled most of the weeds in cotton (Frans *et al.*, 1981; Rubin *et al.*, 1982). According to Balyan *et al.* (1983) application of this chemical @ 1.0, 1.5 and 2.0 kg ha^{-1} at the time of first irrigation effectively controlled *Echinochloa colonum, Cyperus rotundus, Digera arvensis* and *Trianthema portulacastrum.*

It is a pre-emergence herbicide used to control grasses and broad leaved weeds in many field crops including cotton (Balyan *et al.,*1983; Panwar and Malik, 1991). Chandler (1984) described that dinitroaniline herbicides controlled most of the annual grasses and broad leaved weeds except perennial weeds. Malik *et al.* (1984) stated that the higher seed cotton yield and weed control efficiency were registered with application of pendimethalin @ 4.84 lit. ha^{-1}. Jain *et al.* (1985) observed that sequential application of this chemical @ 1.5 kg ha^{-1} followed by fluchloralin at 1.5 kg ha^{-1} was required for effective control of weeds in cotton except *Cynodon dactylon* and *Cyperus rotundus*. According to Akhtar *et al.* (1986) application of this chemical @ 5 lit. ha^{-1} has more effective in controlling broad leaved weeds in cotton and gave higher kapas yield compared to other herbicide and hand weeding treatments.

Byrd and York (1987) described that pre-emergence application of this chemical did not give satisfactory control of annual grasses. Panwar *et al.* (1988) stated that application of this chemical @ 1.0 kg ha^{-1} along with fluchloralin @ 1.0 kg ha^{-1} performed better control of *Trianthema portulacastrum* in cotton but less effective on *Echinochloa colonum.* Vireshwar Singh and Verma (1988) concluded that three hoeings or intercultivation was superior to pendimethalin @ 6 lit. ha^{-1} + one inter row cultivation in increasing dry matter production and CGR. According to Vireshwar Singh *et al.* (1988) application of this chemical @ 1.8 kg ha^{-1} + one intercultivation recorded lower kapas yield as compared to fluchloralin 1.1 - 2.0 kg ha^{-1} + one intercultivation. Hussain *et al.* (1989) reported that satisfactory weed control and increased seed cotton yield with this chemical @ 3.7 lit. ha^{-1} as pre-emergence application. Pendimethalin as well as trifluralin had less persistence and no adverse effect on cotton plant (Elegtherohorinos and Kotoulasyka, 1990). According to Singh and Brar (1990) pre-emergence application of tank mix consisting of diuron + pendimethalin each at 0.5 kg ha^{-1} markedly increased kapas yield.

Balasubramanian (1992) concluded that pre-emergence application of this chemical @ 1.25 to 3.0 kg ha^{-1} controlled most of broad leaved and grassy weeds effectively, however, pendimethalin 2.75 and 3.0 kg ha^{-1} was not selective and caused 19 to 42 per cent stand reduction in cotton. According to Balasubramanian (1992) deep tillage + pendimethalin @ 1.25 kg ha^{-1} + manual weeding on 40 DAS was most effective weed management practice in cotton. Application of pendimethalin @ 1.5 kg ha^{-1} produced adverse effect on cotton yield (Nehra *et al.*, 1992; Rout and Satapathy, 1998). Panwar and Malik (1992) reported that the best weed control and higher kapas yield were obtained with application of this chemical @ 3.0 kg ha^{-1}. According to Thakar Singh *et al.* (1992) sequential application of this chemical @ 0.75 kg ha^{-1} as pre-plant incorporation and diuron @ 0.5 kg ha^{-1} as pre-emergence herbicide effectively controlled most of the weeds in cotton. Pendimethalin @ 1.5 kg ha^{-1} + one hoeing at 45 DAS produced higher kapas yield (Samunder Singh and Malik, 1993; Subhash Chander *et al.,* 1994). Wilcut *et al.* (1993) concluded that application of this chemical could not control large seeded broad leaved weeds and yellow nut sedge in Southern United States. Pagar *et al.* (1995) concluded that application of this chemical @ 1.05 kg ha^{-1} proved effective than fluchloralin @1.125 kg ha^{-1} as pre-emergence spray in combination with one hoeing and thereby increased seed cotton yield.

Panwar *et al.*(1995) reported that application of this chemical @ 1.5 kg ha^{-1} as pre-plant incorporation reduced weed density, weed biomass and increased seed cotton yield. El-Naggar *et al.* (1996) stated that application of pendimethalin @ 3.0 kg ha^{-1} provided best weed control upto 75 DAS and increased kapas yield. According to Velayutham (1996) application of this herbicide @ 0.75 kg ha^{-1} as a pre-emergence spray + hand weeding produced higher kapas yield which was comparable with hand weeding twice. Panwar *et al.* (1997) found that application of this herbicide @ 1.5 kg ha^{-1} without supplement hoeing increased kapas yield. Patil *et al.* (1997) concluded that pre-emergence application of pendimethalin @ 1.0 kg ha^{-1} followed by post emergence application of glyphosate 0.5 kg ha^{-1} recorded lower kapas yield as compared to hoeing thrice.

Tomlin (1997) suggested that it is a selective herbicide, absorbed by roots and leaves which inhibits cell division as well as elongation, ultimately plants die shortly after germination from soil. Pre-plant application of 1.0 and 1.5 kg ha^{-1} pendimethalin and trifluralin followed by one hoeing controlled weeds and increased yield by 47 to 92 per cent (Brar *et al.*,1998; Panwar *et al.*, 1998). Pre-emergence application of pendimethalin @ 1.0 kg ha^{-1} + one hand weeding resulted maximum weed control in cotton (AICCIP, 1999).

Kakade *et al.* (1999) described that pre-emergence herbicides (pendimethalin @ 1.0 kg ha^{-1} + diuron 0.5 kg ha^{-1}) gave yield similar to that due to hoeing and weeding at 40 DAS. According to Nadanassababady (1999) pre-emergence application of this herbicide @ 1.0 kg ha^{-1} + hand weeding did not prove successful and recorded lower kapas yield as compared to glyphosate @ 2.05 kg ha^{-1} and weed free treatment.

2.2.2.2. Cinmethylin

It is a recently introduced herbicide . Forney *et al.* (1985) concluded that application of this herbicide as pre-emergence @ 0.2 to 0.7 kg acre^{-1} gave excellent control of most of annual grasses in soybean at USA. Wilson and Holems (1985) found that weed species *Bromus diandrus, Hordeum geniculatum, Lolium rigidum* and *Vulpia bronoides* were effectively controlled in wheat by 1.1 kg ha^{-1} of this herbicide. Bozarth *et al.* (1986) described that the cotton showed high degree of tolerance to 0.5 to 0.75 kg ha^{-1} and gave excellent weed control. Chase and Putnam (1986) stated that crop tolerance was excellent and yield of direct seeded cucumber was not reduced by cinmethylin applied @ 1.1 kg ha^{-1} and the weeds such as *Setaria glauca, Ambrosia artemisifolia, Portulaca oleracea, Chenopodium album, Solanum ptycanthum, Mollugo verticillata* were effectively controlled.

Motsenbocker and Bonanno (1988) concluded that soil applied herbicide @ 1.1 kg ha^{-1} reduced musk melon root and shoot weight. Wilson (1989) stated that herbicide @ 0.1 to 1.6 kg ha^{-1} resulted in good control of annual grasses and controlled few of annual broad leaved weeds in tropical legumes. Azmi and Supaad (1990) described that application of this herbicide @ 0.05 to 0.1 kg ha^{-1} was found to be comparable to those obtained by manual weeding twice at 20 and 40 DAS in direct seeded rice. Jones (1990) found that application of this herbicide @ 300 g ha^{-1} have excellent control of weeds and increased rice yield upto 106 per cent. Liu *et al.* (1990) suggested that cinmethylin alone @ 2.05 and 4.1 lit. ha^{-1} poor against broad leaved weeds but showed improved results followed by paraquat @ 2.35 lit. ha^{-1} as post emergence in Yam.

Russell *et al.* (1991) concluded that application of this herbicide @ 0.3, 0.6 and 0.9 kg ha^{-1} through dry and moist sandy loam soil did not affect germination and growth of peanut, cotton, soybean, tobacco and snap bean. In transplanted rice, application of cinmethylin @ 0.08 kg ha^{-1} alone and cinmethylin + 2,4-DEE (0.08 and 0.4 kg ha^{-1}) significantly reduced total weed density, weed dry weight and recorded higher weed control efficiency (Venkata Ramana *et al.,* 1992; Govinda Singh and Gupta, 1992). Vaughn and Spencer (1993) stated that, this herbicide has been successfully used in wide range of crops to control weeds including soybean, alfalfa and wheat. Blackshaw (1994) noticed that application of this herbicide @ 0.6, 0.8 and 1.0 kg ha^{-1} did not control *Bromus tectorum* in winter wheat and rye. Weed species such as *Echinochloa colonum, E. crusgalli, E. oryzicola, E. glabrescens, Alisma canaliculatum, Cyperus iria, Dopatrium junceum, Elatine triandra, Rotala indica*, Perennials like *Elocharis acicularis, Scirpus juncoides, Lolium multiflorum, Digitaria sangunalis, Amaranthus retroflexus* and *Abutilon theopharasti* were effectively controlled by this herbicide (Anonymous, 1997).

Rao *et al.*(1996) reported that application of cinmethylin (80 g) and 2, 4-D EE (400 g) recorded higher grain yield of transplanted rice. Brar et al. (1997) reported that application of this herbicide @ 0.08 and 0.1 kg ha^{-1} recorded higher number of productive tillers and grain yield in transplanted rice. Baum *et al.* (1998) found that, this herbicide was morphogenetically active herbicide that inhibits primary root growth and induces abnormal nodule like lateral roots on *Arabidopsis thaliana* seedlings. Tomlin (1999) suggested that it was effective on weeds such as *Echinochloa* spp., *Monochoria vaginalis* and *Cyperus difformis* which was absorbed from paddy water through shoots and roots of germinating or emerging weeds, moves upward through the plant and disrupt meristematic development in growing points of roots and shoots.

2.2.3.Weed management through allelopathic effect of parthenium

According to Kanchan (1975) found that presence of inhibitors in root, leaf, inflorescence and fruit of matured plant of *Parthenium hysterophorus* shows inhibition of coleoptile growth and dry matter accumulation of seedlings of plant. Pandey (1994) described that the parthenin was one of the main allelochemical responsible for the inhibitory effect of parthenium leaf extract on *Salvinia molesta*. Das and Das (1995) reported that the leaf and inflorescence extract were strongly inhibited the seed germination, seedling growth, cell survival and chlorophyll content of plant. Adkins and Sowerby (1996) found that aqueous leachate of parthenium reduced germination of climbing buck wheat, liver seed grass, buffel grass and parthenium. Asha Gupta and Gupta (1996) stated that the aqueous leachates of *P. hysterophorus* were found to be inhibitory to the growth of *Ageratum gengeticus* seedlings.

Dhawan *et al.* (1996) stated that the aqueous extracts of *Prosopis juliflora* inhibited seed germination, early seedling growth and fresh weight of *P. hysterophorus* by 69.95 per cent. According to Arunachalam (1997) parthenium whole plant extract was found to suppress *Cyperus* population at 40 DAS under field condition. Batish *et al.* (1997) reported that the parthenin from *P. hysterophorus* inhibited germination of *Ageratum conyzoides* at concentration ranging from 0.02 to 0.1 mg ml^{-1}. Oudhia and Tripathi (1997) found that the extracts of different parts of parthenium failed to produce detrimental effect on targeted weeds. According to Pandey (1997) the allelochemicals leaching out of parthenium residue appeared to have inhibited najas plants by affecting cellular membrane integrity.

The presence of inhibitory chemicals parthenin, caffeic acid, p-coumaric acid, ferulic acid, vanillic acid and anisic acid in parthenium have reduced seed germination, growth and dry weight of seedlings of *Cassia tora*, *C. occidentalis* and *C. sophera* (Acharia and Rahman, 1997; Rahman,1998; Rahman and Acharia, 1998). Umapathy *et al.* (1998) reported that parthenium incorporation @ 5 t ha^{-1} effectively controlled *Trianthema portulacastrum* and *Cyperus rotundus* in blackgram. Kandasamy and Raja (1999) observed that the allelopathic weed suppression was expected from the incorporation of *Parthenium hysterophorus* but the weed biomass was greater than in other weed control method. Venkataiah *et al.* (1999) found that parthenin is the major constituent of *Parthenium hysterophorus* which posses allelopathic effect on other plants. Gupta (2000) reported that root extracts of parthenium inhibited the seed germination and DMP of *Cyamopsis psoraliodes* (L.), *Hibiscus esculentus* (L.) and *Amaranthus gengeticus* (L.).

2.2.4. Weed management through smothering crop

Intercropping itself act as a biological tool for controlling of weeds in wide spaced crops. According to Chacko and Aravind Reddy (1981) complete suppression of weed growth for a period of 70 days when cowpea was intercropped with banana. Dhillon and Klerk (1981) found that the greengram intercropped with sugarcane reduced weed number. According to Moody and Shetty (1981) legume crops differ in their relative growth rate, spreading habit, canopy structure, height and inherent characters accordingly differ the weed suppressing abilities, weed suppression depends upon many factors such as component crops, their growth habit, planting pattern, fertility and moisture status of the soil. Rao and Shetty (1981a) reported that the intercropping of groundnut in pearl millet caused 50 to 75 per cent reduction in weed infestation.

Intercropping of sorghum with cowpea and greengram smothered weeds and reduced hand weeding cost as compared to sole sorghum (Rao and Shetty, 1981b; Solaimalai, 1996). Abraham and Singh (1983) suggested that the intercrops reduced the nutrient uptake by weeds in sorghum based intercropping system. Patel *et al.* (1983) concluded that two rows of greengram and one row of blackgram effectively suppressed weeds in pigeonpea. Cotton + greengram intercropping system resulted maximum weed control efficiency (Muruganandam, 1984; Prasad and Srivatsava, 1990). Reduction in weed population and biomass were observed in maize + cowpea intercropping system (Mutanal and Hosmani, 1985).

According to Balasubramanian (1985) cowpea and lab-lab in cotton as smother intercrops to be effective for suppression of weeds during the critical period of crop-weed competition. Chandra (1987) found that reduction in weed count and biomass with higher weed smothering efficiency were recorded in sorghum + cowpea intercropping systems. Gangwar (1986) stated that the sorghum + cowpea (1:1 ratio) in normal planting had lowest weed weight than sole sorghum under rice fallow condition. Sundaramoorthy (1987) concluded that intercropping of clusterbean or mungbean with pearl millet effectively suppressed weed growth by smothering effect. Parkinson *et al.* (1987) reported that the reduction in striga population was observed in maize + soybean intercropping system.

Masood Ali (1988) described that the short duration legumes such as cowpea, urdbean and mungbean intercropped with pigeonpea suppressed weed flora by 20 to 45 per cent over sole pigeon pea under unweeded situation in rainfed condition. Hosmani *et al.* (1991) found that the larger canopy cover obtained by cowpea intercepted much of incident light and competed better for other inputs creating an environment unfavourable for weed growth.

Purushothaman (1991) stated that in cotton + greengram, the effect of weed control due to intercrops may be due to allelopathic effect of companion crops. According to Singh and Patel (1991) maize + groundnut intercropping system considerably suppressed weed growth compared to sole crop of maize. In upland rice with green manure crops such as *Crotalaria juncea, Sesbania rostrata, Vigna sinensis* and *Glycine max* when intercropped followed by one inter cultivation at 15 days after emergence effectively suppressed weeds (Annual Report, 1994). Deshweer and Agrawal (1994) described that the lowest weed dry matter accumulation was registered in maize + blackgram (2:1 ratio) intercropping system with paired row planting. According to Paradkar *et al.* (1994) maize + soybean intercropping system resulted lower weed density and dry weight. Savithri *et al.* (1994) suggested that intercropping of cowpea in coconut + banana multitier cropping resulted significant reduction in weed population and weed DMP. Solaiappan *et al.* (1994) found that lowest weed density and higher weed control efficiency was obtained with cotton + blackgram intercropping system in rainfed vertisols.

Mahadevamurthy *et al.* (1995) concluded that presence of cowpea at 3,14, 22 and 30 plants m^{-2} reduced the weed biomass by 16, 50, 62 and 79 per cent over monoculture. Prasad *et al.* (1995) reported that the mixed crop sequence involving maize + soybean - wheat + Indian mustard intercropping system proved most effective in reducing population and DMP of weeds as compared to sole crop sequence of maize - wheat and soybean - Indian mustard. Rainfed groundnut was grown in association with sunflower (4:1 ratio) resulted decrease in weed population and nitrogen removed by weeds (Subbaiah *et al.*, 1995; Subbaiah *et al.*, 1997). According to Tewari (1995) concluded that integration of cowpea as an intercrop with maize caused 40 and 35 per cent reduction in *Cyperus rotundus* shoots and number of tubers, respectively in maize + cowpea - potato - mustard cropping system.

Hussain and Gogoi (1996) stated that intercropping of fodder cowpea and greengram lowered the population and dry matter accumulation of weeds when intercropped with direct seeded upland rice. Pradeep and Shanmugasundaram

(1996) reported that weed count and DMP were higher in sole sunflower as compared with intercropped cowpea under rainfed condition. Prasad and Rafey (1996) described that intercropping of maize with soybean either in 1:1 ratio or 1:2 ratio effectively reduced the weed density and weed dry weight than the sole crop stand. In USA, medicas (*Medicago* spp.) sown with maize at a high enough to consistently suppress weeds and reduced weed dry weight about 14 weeks after emergence by 14 to 69 per cent compared with monoculture maize (Haan *et al.*, 1997). According to Buhler *et al.* (1998) plants such as caliph medic (*Medicago truncatulata*), berseem (*Trifolium alexandrinum*), yellow mustard (*Brassica hirta*) were intercropped with corn and soybean which were having a weed suppression potential ranged from 19 to 90 per cent. Seavers and Wright (1999) stated that growing of winter cereals such as barley, oat and wheat suppresses the growth of *Galium aparine* L. and among the suppressive abilities of crop species, oat being most suppressive, followed by barley and then wheat.

2.2.5. Weed management through allelopathic crop plants

According to Gliessman (1989) intercropping of barley + *Vicia faba* and rye + *Vicia faba* provided almost complete weed control and later was most effective due to release of allelochemicals from root exudates during crop growth. Narwal *et al.* (1992) reported that pearl millet genotypes HHB - 67 and 88004 A x 833-2 caused maximum reduction in weed population and biomass. Sarmah (1992) observed that sorghum considerably smothered weed growth over fallow while pearl millet completely controlled weeds including major weed *Trianthema portulacastrum* due to root exudates. The pearl millet proved most smothering crop and suppressed the weed population from 80.7 to 94.0 per cent as compared to fallow through their allelopathic effect (Narwal and Sarmah, 1996). According to Rajavel (1998) intercropping of cotton + pearl millet (1:1 ratio) recorded lower weed population and dry matter production as compared to unweeded control through their root exudates.

2.3. Effect of herbicides on soil microorganisms

Exposure of soil to herbicide caused either no change or reduction in microbial activity.

2.3.1. Bacterial population

Majority of herbicides have no effect on bacterial population when they were applied at normal doses (Grossbard, 1974). These includes fluchloralin and alachlor (Mohammed,1984). trifluralin (Tyunyaeva *et al.,* 1974), glyphosate and triallate (Tanski *et al.,* 1984), propham, pyrazon, DNOC, TCA, TCPA, PCP and substituted ureas (Audus, 1970). However few herbicides such as dichlobenil (Grossbard, 1976) and Dalapon (Kruglov *et al.,* 1973) inhibited the bacterial population. Enhanced bacterial growth under glyphosate application was observed by Roslychy (1982).

Sandhu *et al.* (1990) reported that *Pseudomonas* spp. multiplied profusely in soil treated with glyphosate, fluchloralin @ 1.2 kg ha^{-1} and Isoproturon 0.93 kg ha^{-1} enhanced bacterial population in soil. Nalayini and Sankaran (1992) concluded that flurochloridone @ 0.5 kg ha^{-1}, pendimethalin @ 1.0 kg ha^{-1} and flurochloridone @ 0.25 kg ha^{-1} + pendimethalin 0.5 kg ha^{-1} registered significant reduction in bacterial population counts at 5^{th} day after herbicide application and population recorded at 25 days after herbicide application on par with all herbicide treated plot.

2.3.2. Fungal population

Herbicide such as trifluralin (Tyunyaeva *et al.,* 1974); Sodium chloride (Karki *et al.,* 1973) at normal dosage did not affect the over all soil fungal population. The antifungal effects of glyphosate might be largely due to the herbicide ingredients (Quilty and Geoghegan, 1975; Harris and Grossbard, 1979). In contrary, counts of fungal colonies were considerably higher with soil application of glyphosate as round up (Quilty and Geoghegan, 1976; Roslychy, 1982). Herbicide such as pyramin (Todorovic *et al.,* 1983) and fluchloralin (Mohammed, 1984) were found to stimulate the fungal growth.

2.3.3. Actinomycetes population

Herbicide that did not affect the population of actinomycetes include simazine (Kulinska, 1967), paraquat (Camper *et al.,* 1973) and trifluralin (Tyunyaeva *et al.,* 1974). Randhawa *et al.* (1979) reported that the population of fungi, bacteria and actinomycetes obtained from fluchloralin + propanil applied soil were on par with control. Ashraf and Sen (1981) found that pre-emergence application of atrazine increased microbial activity whereas fluchloralin did not influence the soil microbial population. Youssef *et al.* (1987) stated that the herbicides applied to cotton increased the population of fungi, bacteria and actinomycetes in rhizosphere soil. Actinomycetes population was enhanced by fluchloralin application @ 1.2 kg ha^{-1} (Sandhu *et al.,* 1990). According to Balasubramanian (1992) application of pendimethalin @ 1.0 kg ha^{-1} and fluchloralin @ 1.0 kg ha^{-1} did not affect the number of microbial colonies in the rhizosphere soil after 60 days in cotton crop.

Selvamani and Sankaran (1993) observed that 25 days after application of pendimethalin @ 1.0 kg ha^{-1} and fluchloralin 1.0 kg ha^{-1}, the microbial colonies recorded on par with control in groundnut crop. N fixing bacteria recovered fully at 28 days after application of butachlor (Yu *et al.,* 1993). Cohen *et al.* (1996) found that soil application of acetochlor at 0.1 - 1.0 mg g^{-1} of soil had little or no effect on growth of microbes. According to Velayutham (1996) metolachlor application @ 1.0 kg ha^{-1} did not affect the microbial population in soil at 90 days after sowing. Raut *et al.* (1997) reported that the population of bacteria, fungi and actinomycetes were not altered due to butachlor application @ 1.5 kg ha^{-1}.

2.4. Herbicide residue in plant and soil

After application of herbicide to the soil a part of herbicide undergoes decomposition and part of it is taken by plants which is accumulated in the economic produce. The accumulation of herbicide residue should not exceed maximum residue limit (MRL). Each herbicide leaves residue in the environment. A recovery of 0.018 ppm of residue in the soil could be noticed due to application of pendimethalin @ 1.5 kg ha^{-1} (Kirkland, 1979). Small quantity of butachlor was observed in grain and straw (Chen, 1981).

Devi and Gowda (1985) reported that a recovery of 0.018 ppm of pendimethalin residue in the soil could be noticed in pendimethalin when applied @ 1.5 kg ha^{-1}, at lower concentration no residue either in soil or in grain has been noticed. Utulu *et al.* (1986) found that only traces of pendimethalin was observed at 12 weeks after herbicide application in the 0-5 cm soil layer. According to Balasubramanian (1992) pendimethalin residue was detected in soil particularly at 2.0 and 3.0 kg ha^{-1} after harvest of cotton but the residue level was not detectable in cotton seed. Singh and Vaishya (1992) evaluated that the herbicide residue was recorded in post harvest soil samples after french bean harvest.

Muthusankaranarayanan (1994) reported that the residual level of pendimethalin and metolachlor applied to chilli based intercropping system at 0.75 and 1.0 kg ha^{-1} both in soil and edible parts *viz.,* chilli dry pod, coriander leaves and onion bulb were very low as compared to the prescribed maximum residue limit (MRL). Velayutham (1996) found that higher residue was observed in soybean grain followed by cowpea grain and cotton seed in cotton based intercropping system applied with metolachlor and pendimethalin @ 0.75 and 1.0 kg ha^{-1} but the residue was below the maximum residue limit (MRL). Parmar *et al.* (1998) observed that pendimethalin was applied at 0.6 - 0.9 per cent to bidi tobacco which left residue level in leaves at harvesting ranged from 0.198 to 0.376 μg/g. Jagannathan and Nadanam (1999) observed that residue of pendimethalin could be detected in soil as well as in tuber of tapioca which showed its longer persistence.

2.5. Residual effect of herbicide on succeeding crop

According to Balasubramanian (1975) alachlor, fluometuron, dichlormate and fluchloralin applied to cotton had no phytotoxic residues on the test crops like sorghum, finger millet, cowpea and lab-lab. Kulandaivelu (1979) reported that alachlor, nitrofen and pendimethalin did not show any residual toxicity symptoms on the succeeding crops viz., sorghum, cotton, pearl millet, greengram and sunflower. No deleterious effect was observed due to butachlor and thiobencarb on the succeeding crop (Ali and Sankaran,1984). Muruganandam (1984) found that application of fluchloralin and oxyfluorfen to cotton had no adverse effect on succeeding sorghum crop. Cucumber was found to be more sensitive to the residues of fluchloralin @ 1.0 kg ha^{-1} and pendimethalin @ 1.25 kg ha^{-1} were applied to cotton crop (Jayakumar *et al.,* 1985; Jayakumar *et al.,* 1988).

Ramamoorthy and Ali (1988) observed that the succeeding crops of cowpea and greengram, reduction in weed population and weed DMP were noticed with residues of pendimethalin which was applied at 1.25 kg ha^{-1} in rice grown in upland. Rajvir Sharma and Metha (1989) found that the residues detected in soil at harvest stage of onion with the concentrations of 0.75 to 1.00 kg ha^{-1} of pendimethalin were well below the permissible limit of 0.1 ppm. Bainade (1990) reported that pendimethalin @ 1.0 kg ha^{-1}, isoproturon @ 1.0 kg ha^{-1}, anilophos @ 0.4 kg ha^{-1}, fluchloralin @ 1.0 kg ha^{-1} as pre-emergence herbicide applied to preceding wheat crop did not leave residue in soil to affect the succeeding greengram adversely. Residual effect of fluchloralin after 234 days on sorghum (Ashok Yadav *et al.,* 1991). Mahalle and Seth (1991) reported that fluchloralin at

0.65 kg ha^{-1} as pre-sowing application in sorghum had no residual toxicity to succeeding crops.

According to Singh *et al.* (1991) the herbicides, pendimethalin 1.0 kg ha^{-1}, fluchloralin 0.75 kg ha^{-1}, oxadiazon 0.50 kg ha^{-1}, thiobencarb 2.5 kg ha^{-1} and butachlor 1.5 kg ha^{-1} applied to transplanted rice did not show any toxic residual effect on succeeding wheat crop. Balasubramanian (1992) reported that residual effect of pendimethalin @ 0.5 - 2.25 kg ha^{-1} and fluchloralin @1.0 kg ha^{-1} was not observed on germination, growth and yield attributes and yield of succeeding soybean and blackgram. Balasubramanian *et al.* (1992) stated that application of isoproturon at 0.5 kg ha^{-1} to sorghum based cropping system had no residual toxicity to succeeding crops. High doses of pendimethalin, alachlor and fluchloralin applied to lentil and gram did not persist for more than 110 days (Quayum and Srivatsava, 1992; Singh and Vaishya, 1992; Samunder Singh *et al.*, 1992). Sandhu *et al.* (1997) reported that the wheat yield was not affected by the application of pendimethalin to the preceding cotton crop.

2.6. Economics of weed management

Herbicides were most effective and economical as compared to manual weeding (Ahlawat, 1978). Maximum seed cotton yield and net profit was obtained by resorting to cultural method than the chemical method of weed control (Tanakar and Mundhe, 1982; Shelke *et al.*, 1984). Patel *et al.* (1985) reported that highest marginal returns of Rs.6.77 per rupee invested with fluchloralin @ 1.25 kg ha^{-1} as pre-planting combined with post emergence application of diuron @ 0.75 kg ha^{-1} and suggested that the chemical weed control in cotton is more economical than mechanical weed control method. Byrd and York (1987) reported that soil application of fluometuron followed by foliage spray of fluazifop or sethoxydim resulted in higher net returns in cotton. Shelke and

Bhosale (1989) found that maximum net return was obtained in cotton due to hand weeding and hoeings at 3,6 and 9 weeks after sowing.

Higher net profit was obtained in cotton with use of herbicides *viz.*, pendimethalin and fluometuron (Wilcut *et al.,* 1988). Higher net return was recorded due to the application of herbicides in cotton (Hussain *et al.,* 1989). Lower net return from pendimethalin 1.5 kg ha^{-1} followed by hand weeding (30 DAS) than interculture and 2 hoeings (Tiwana and Brar, 1990; Detroja *et al.,* 1992; Giri *et al.,* 1998a). According to Solaiappan *et al.* (1992) the higher benefit-cost ratio of 2.92 was obtained with chemical weed control using diethyl ether 1.5 kg ha^{-1} in cotton. Jadhav *et al.* (1995) reported that the pre-sowing application of fluchloralin + 2 hand weeding + 3 hoeings recorded higher cost-benefit ratio in cotton. Patil *et al.* (1997) observed that higher net return was obtained in cotton due to application of fluchloralin @ 1.0 kg ha^{-1} as PPI and glyphosate @ 0.5 kg ha^{-1} (35 DAS) compared to hand weeding twice, but lower than hoeing and hand weeding thrice at 20, 40 and 60 DAS.

Giri *et al.* (1998b) reported that higher monetary return was obtained in cotton by using pendimethalin @ 0.75 kg ha^{-1} supplemented with hand weeding and hoeing at 6 weeks after sowing. Satato *et al.* (1998) stated that sequential application of alachlor @ 2.0 kg ha^{-1} followed by glyphosate @ 1.025 kg ha^{-1} recorded the highest monetary return in cotton.

From the above review it is very essential that for the long duration crop like cotton, combination of more than one weed management practice such as chemical weeding combined with one hand weeding or use of non-chemical weed management practices like, growing of smother crops are necessary to evolve an economic and efficient weed management practice in cotton.

MATERIALS AND METHODS

CHAPTER III
MATERIALS AND METHODS

Field experiments were conducted at Agricultural College and Research Institute, Tamil Nadu Agricultural University, Coimbatore during the winter seasons of 1998-1999 and 1999-2000 to evaluate the efficiency of different chemical and non-chemical methods for weed management in irrigated cotton (MCU 5). The details of the experimental materials used and the methods followed are presented in this chapter.

3.1. Materials

3.1.1. Location of the experimental site

The field experiments were conducted in Field No.37F during 1998-1999 and Field No.36E during 1999-2000 in the eastern block of Central Farm at Tamil Nadu Agricultural University, Coimbatore. The farm is situated at 11°N latitude and 77°E longitude at an altitude of 426.72 m above mean sea level.

3.1.2. Climate and weather conditions

The mean annual rainfall of Coimbatore is 670.6 mm distributed in 47 rainy days. The mean maximum and minimum temperatures are 30.6 and 20.9°C respectively. During 1998-1999, maximum temperature during the crop period of cotton ranged from 26.0 to 32.2°C with a mean of 29.1°C. The minimum temperature ranged from 14.2 to 23.4°C with a mean of 18.8°C. The relative humidity ranged from 74 to 92 per cent with a mean of 83 per cent. The total rainfall received during crop period was 676.9 mm in 21 rainy days. During 1999-2000, maximum temperature during the crop period ranged from 26.2 to 33.7°C with a mean of 29.95°C and the minimum temperature ranged from 16.9 to 23.1°C with a mean of 20.0°C. The relative humidity ranged from 78 to

Fig.1.Weather parameters during the cropping season 1998-1999 (I Crop)

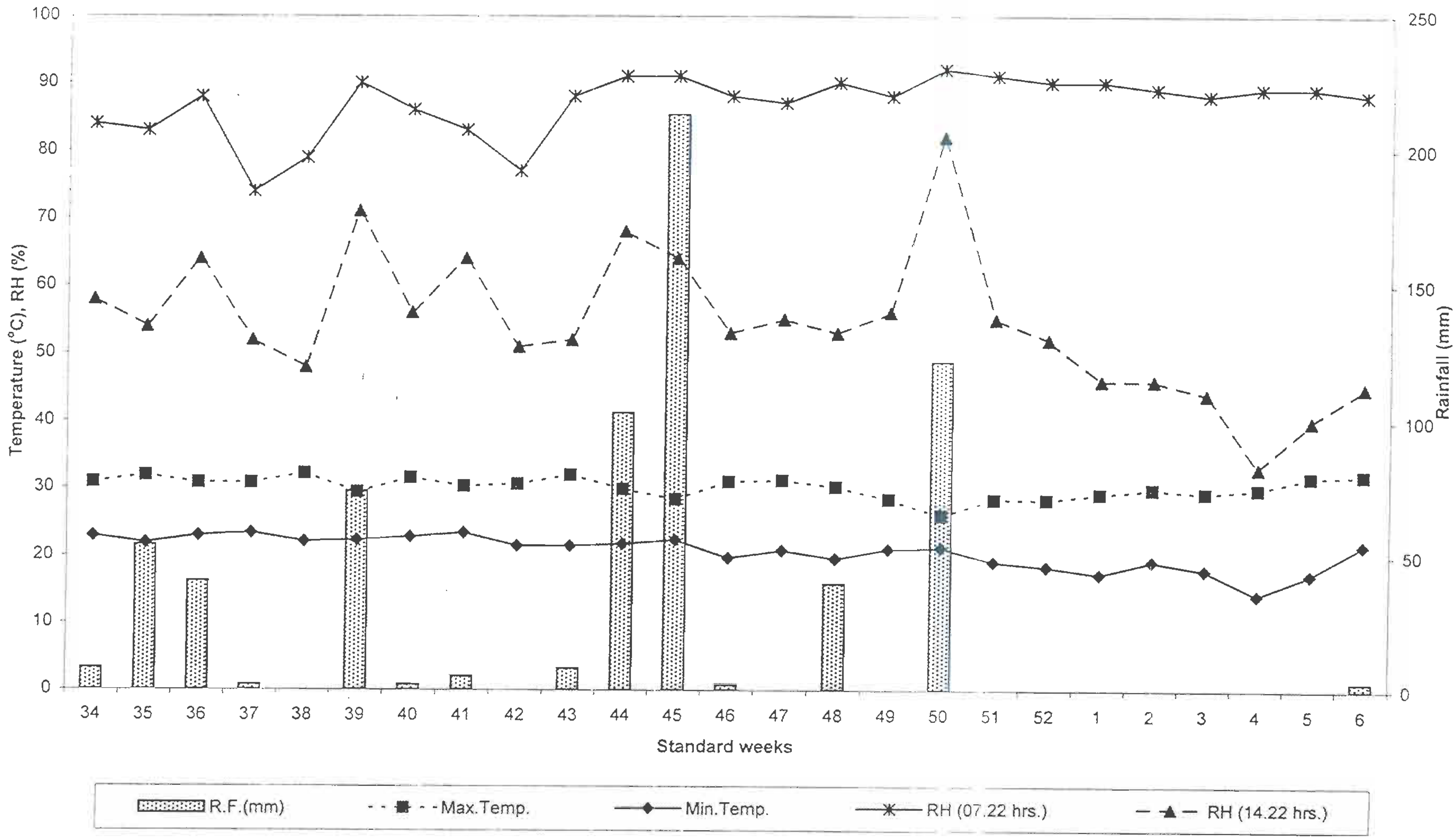
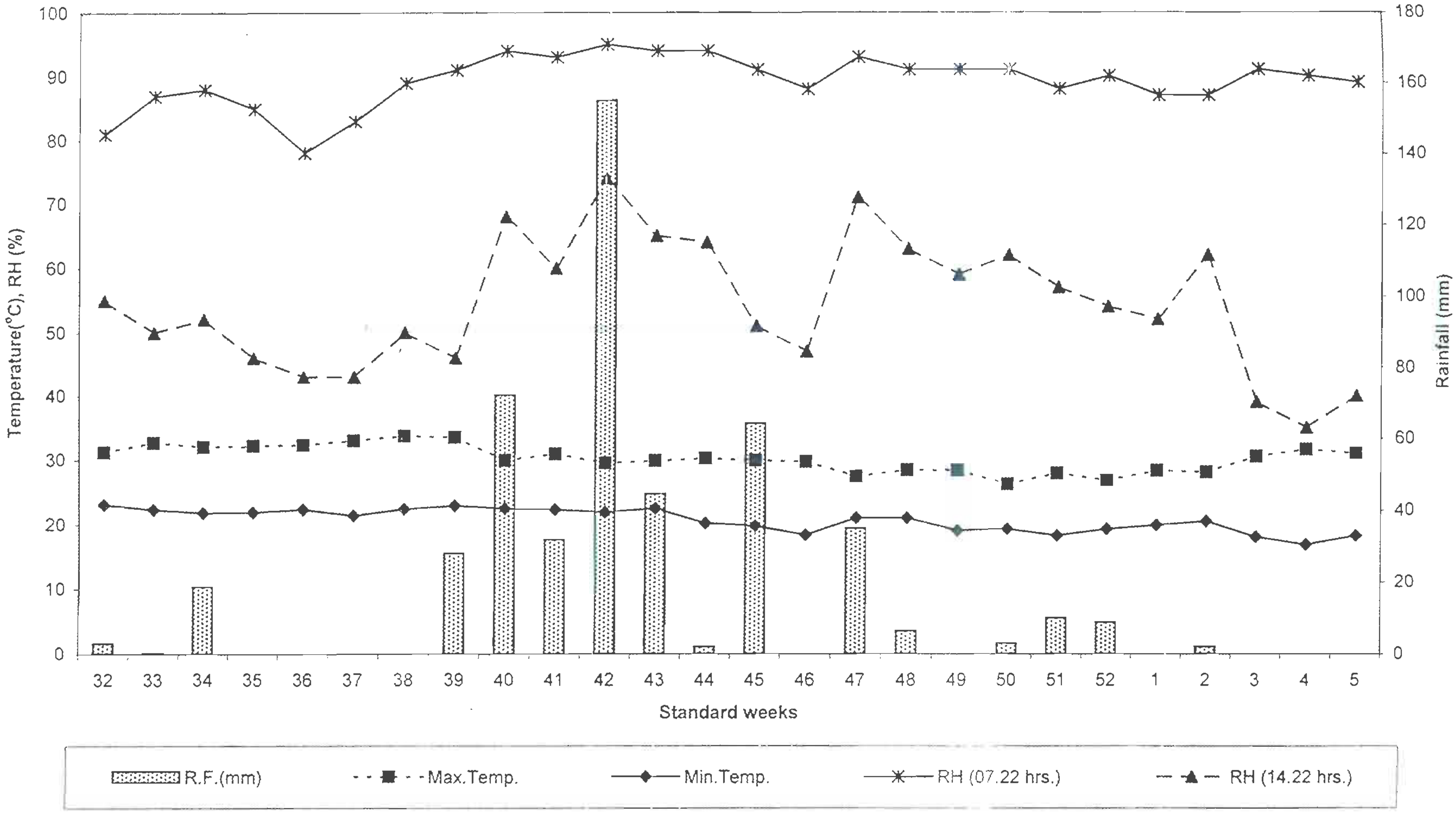


Fig.2. Weather parameters during the cropping season 1999-2000 (II crop)



95 per cent with a mean of 86.5 per cent. The total rainfall received during crop period was 485.4 mm in 29 rainy days. The weather data during the cropping period for both years are presented in Appendix I to II and Fig .1 and 2.

3.1.3. Soil characteristics

Both the experiments were carried out in two separate fields. The soil of the experimental area is sandy clay loam in texture with low in available nitrogen, medium in available phosphorus and high in available potassium. The soil characteristics of the experimental fields are furnished in Table 1.

3.2. Methods

3.2.1. Preliminary screening trial for herbicide

Before start of the main experiment, a preliminary herbicide screening trial (non-replicated) was laid out during (November - December 1998) to evaluate the cinmethylin under three levels of application. The herbicide was applied as pre-emergence after sowing of seed followed by immediate irrigation. The crops were maintained upto 30 days and observations on phytotoxicity rating and weed count were taken. The treatments compared in the preliminary screening trial are as given below:

Herbicide	Dose (kg ha^{-1})	Notation
Cinmethylin	0.4	H_1
Cinmethylin	0.6	H_2
Cinmethylin	0.8	H_3
Control	-	H_4

Table 1. Soil characteristics of the experimental field

Particulars	Composition	
	37F	36E
I. **Mechanical analysis** (Piper, 1966)		
Clay (%)	24.5	22.2
Silt (%)	26.6	28.9
Coarse sand (%)	17.4	19.3
Fine sand (%)	31.5	29.6
Texture	Sandy clay loam	Sandy clay loam
II. **Chemical analysis**		
Available N (kg ha^{-1}) (Subbiah and Asija, 1956)	187.6	215.3
Available P_2O_5 (kg ha^{-1}) (Olsen *et al.*, 1954)	14.0	15.7
Available K_2O(kg ha^{-1}) (Stanford and English, 1949)	420.1	524.0
pH (1:1 soil-water suspension) (Jackson, 1973)	7.9	8.0
EC (dSm^{-1}) (Jackson, 1973)	0.4	0.4
Organic carbon (%) (Walkley and Black, 1934)	0.42	0.50

Based on the preliminary screening trial, the main experiments for testing chemical and non-chemical weed management in irrigated cotton were conducted during the winter seasons of (Aug.-Feb.) 1998-1999 and 1999-2000. The residue crops were raised during the month of Feb. to March of 1999. The details of the main experiment were given in Table 2.

Table 2. Details of the main experiment – seasonwise

Sl. No.	Particulars	1998-99 winter season	1999-2000 winter season
1.	Date of sowing	24.8.98	12.8.99
2.	Date of removal of intercrop (smother crop)	2.10.98	20.9.99
3.	Date of earthing up operation	7.10.98	27.9.99
4.	Date of 1st kapas picking	4.1.99	28.12.99

3.2.2. Crops and varieties

Cotton (*Gossypium hirsutum* L.) variety MCU 5 was used for this study during both the seasons. This variety is a multiple cross between 08928 x 059840. It has long staple fibre. It matures in 160-165 days. The varietal characters are given in Table 3.

Table 3. **Characteristics of the cotton cv. MCU 5**

Year of release	:	1968
Parentage	:	Multiple cross between 08928 x 059840
Season	:	Aug. - Sep. to Jan. - Feb.
Morphological characters		
Type of branching	:	Long
Number of sympodia	:	18-20
Number of monopodia	:	2-3
Plant height	:	100-120 cm
No. of bolls $plant^{-1}$	:	30 - 40
Size and shape of bolls	:	Medium, Ovoid, Smooth, 3-4 locules
Economic characters		
Yield of seed cotton $plant^{-1}$ (g)	:	40 - 45
Yield of seed cotton (kg ha^{-1})	:	1850
Lint yield (kg ha^{-1})	:	656
Ginning percentage	:	34.0
Fibre fineness (Millitex)	:	126
Micronaire value	:	3.2
Maturity co-efficient	:	0.67
Spinning (HSC)	:	70
2.5 (%) span length (mm)	:	32.5
Uniformity ratio	:	41
Duration (days)	:	160 - 165

3.2.3. Experimental design

The experiment was laid out in a randomized block design replicated thrice. Layout plans of the experimental fields are furnished in Fig.3 and 4.

3.2.4. Treatment details

The treatments followed in the experiments are as follows.

Fig 3. Layout plan of the experimental field (main experiment) 1998-1999

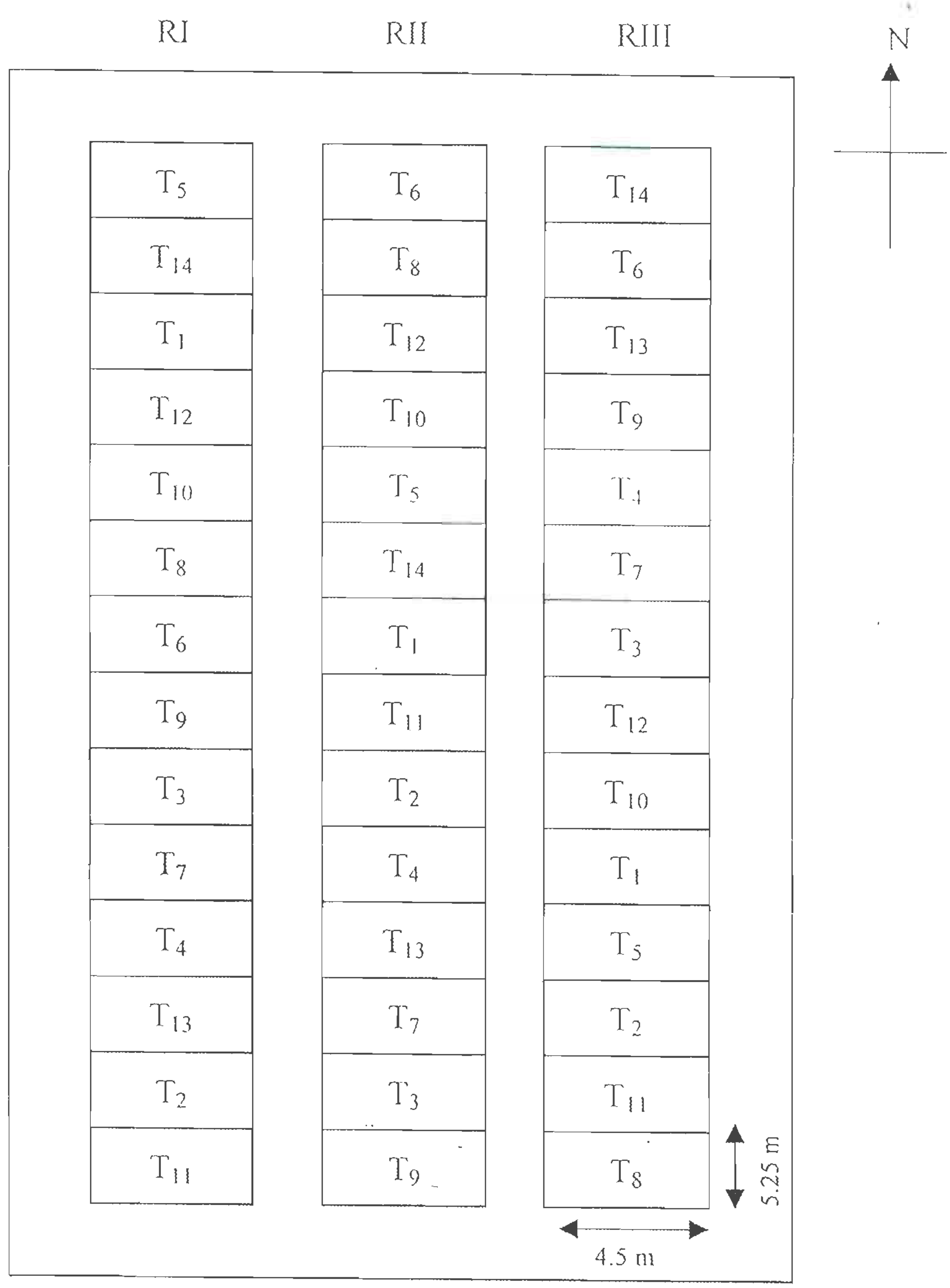
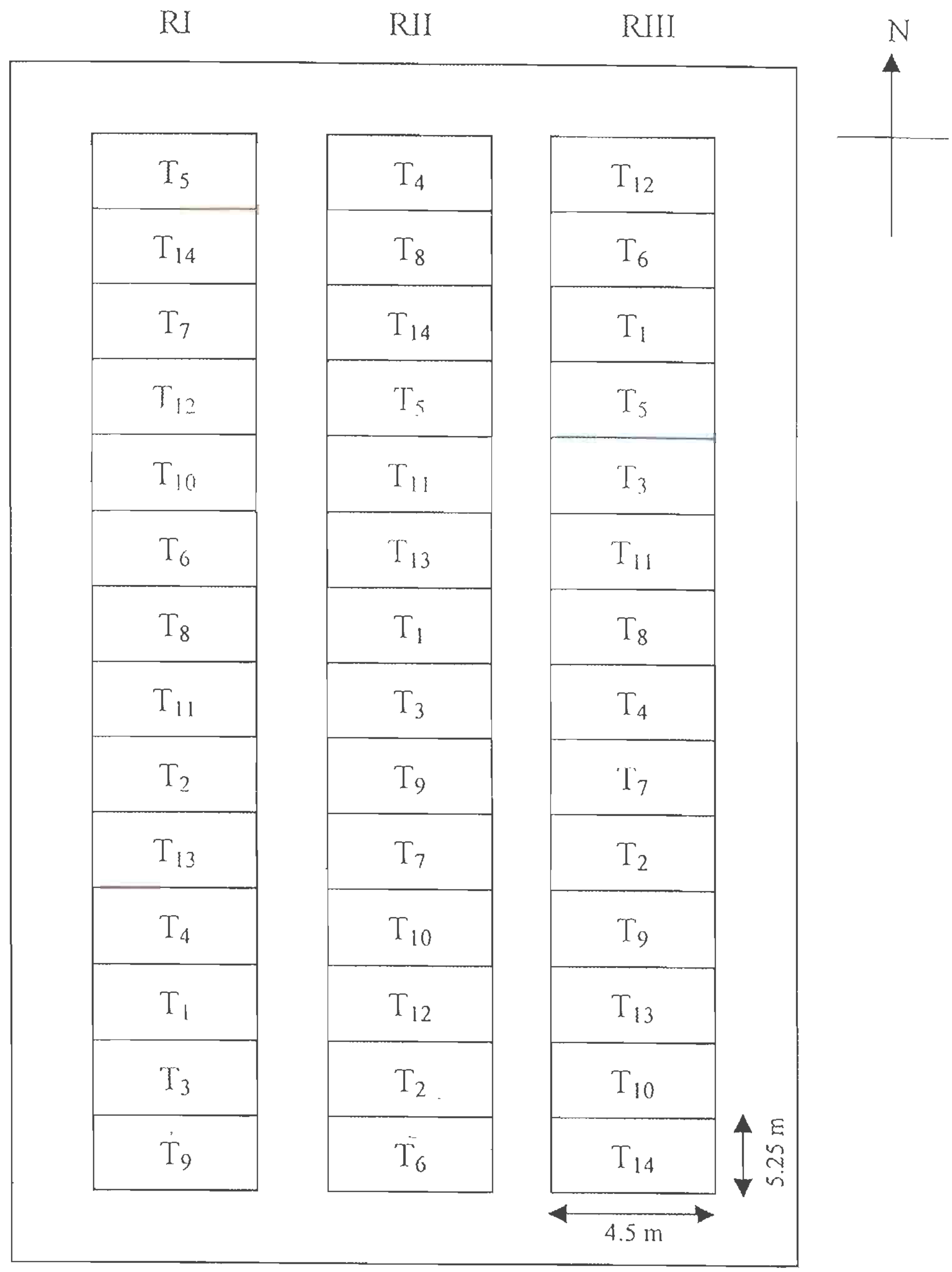


Fig 4. Layout plan of the experimental field (main experiment) 1999-2000



Treatment details

T_1 - Unweeded control

T_2 - Hand weeding twice (HW) (20 and 40 DAS)

T_3 - Pendimethalin (Recom.dose) 1.0 kg a.i. ha^{-1} + HW at 40 DAS

T_4 - Cinmethylin 0.5 kg a.i. ha^{-1}

T_5 - Cinmethylin 0.5 kg a.i. ha^{-1} + HW at 40 DAS

T_6 - Cinmethylin 0.6 kg a.i. ha^{-1}

T_7 - Cinmethylin 0.6 kg a.i. ha^{-1} + HW at 40 DAS

T_8 - Parthenium incorporation @ 2 t ha^{-1}

T_9 - Parthenium whole plant extract spray (10%)

T_{10} - Parthenium incorporation @ 2 t ha^{-1} + HW at 40 DAS

T_{11} - Parthenium whole plant extract spray (10%) + HW at 40 DAS

T_{12} - Cowpea as smother intercrop upto 40 DAS (1:1)

T_{13} - Pearl millet as smother intercrop upto 40 DAS (1:1)

T_{14} - Greengram as smother intercrop upto 40 DAS (1:1)

The gross plot size was 5.25 x 4.50 m while the net plot size was 3.75 x 3.30 m. The field layout plan is given in Fig.3 and Fig.4.

3.2.5. Herbicides used for the study

The herbicides such as cinmethylin and pendimethalin were used in this study and their properties are given in Appendix III.

3.3. Crop culture

3.3.1. Field preparation

The field was ploughed with tractor drawn mould board plough, harrowed and levelled. Ridges were formed with a spacing of 75 cm apart using ridge plough and later rectified with manual labourers. Irrigation channels were made in between the plots.

3.3.2. Soil incorporation of parthenium

The required quantity of parthenium plants (2 t ha^{-1}) were cut into pieces of 10 cm length and incorporated as per the treatments schedule, one week before sowing for partial decomposition.

3.3.3. Seeds and sowing

Cotton seeds were initially delinted with commercial concentrated sulphuric acid @ 100 ml kg^{-1} of seed. Delinted seeds (7.5 kg ha^{-1}) were dibbled on one side of the ridge @ 2 seeds $hill^{-1}$ adopting a spacing of 75 x 30 cm. Smother intercrops *viz.,* cowpea (Co. 4), pearl millet (Co. 7) and greengram (Co. 4) were sown in one row between the cotton rows by adopting a spacing of 10 cm between plants. The planting pattern of sole crop and smother intercrop were given in Fig.5.

3.3.4. Thinning

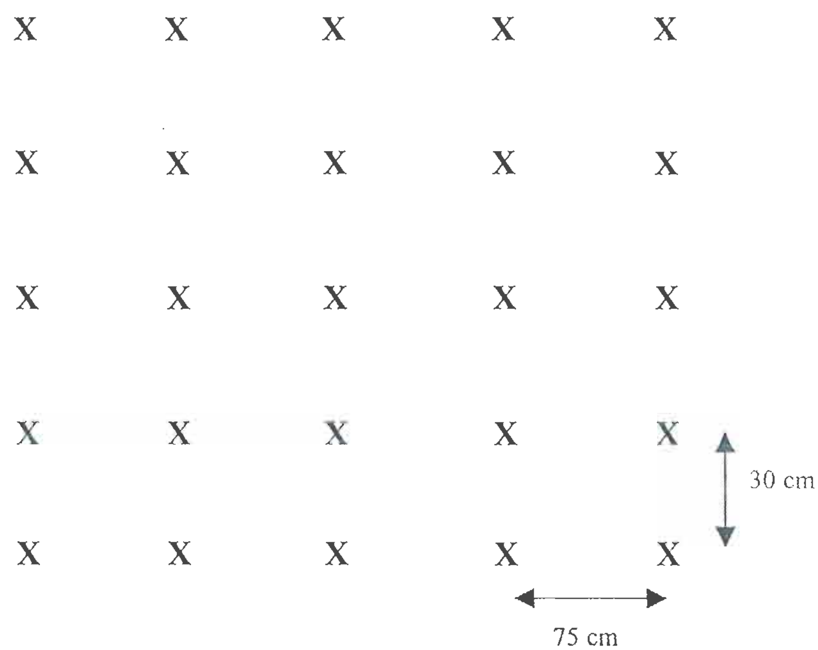
Thinning was done at the early stage of crop development i.e. 15th day after sowing to maintain one healthy seedling $hill^{-1}$ for main and smother crops.

3.3.5. Fertilizer application

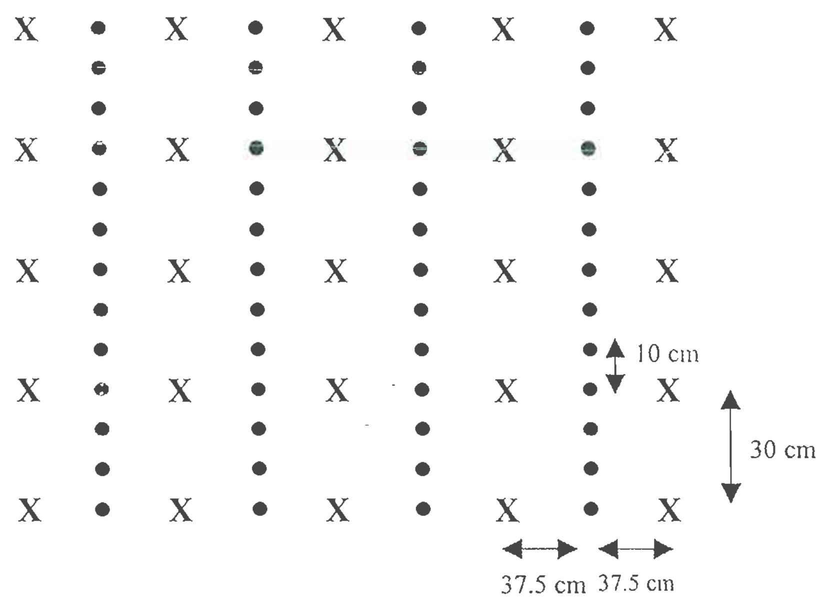
The recommended dose of 80:40:40 kg NPK ha^{-1} was applied to cotton crop in the form of urea, super phosphate and muriate of potash, respectively. A basal dressing of 40 kg N ha^{-1} was applied as band placement 5 cm away from the seed row and 5 cm below soil. The other nutrients P_2O_5 and K_2O were applied each at 40 kg ha^{-1} as basal dose for all the plots. The balance dose of N was applied as top dressing at the time of square initiation (45 DAS) along with earthing up operation.

Fig.5. The planting pattern of sole crop and cotton with smother intercrop.

Sole crop



Cotton with smother intercrop



3.3.6. Herbicide application

(a) Pendimethalin and cinmethylin spraying

The amount of water required to cover the area to be sprayed was calibrated. From this the amount of water required to spray the gross plot area was calculated and the herbicide was sprayed as per the treatments. The spray fluid required was 500 litres ha^{-1}. Herbicide dosages were calculated and applied as pre-emergence after sowing, followed by immediate irrigation. Further, herbicide mixing and spraying was carried out in the order, by beginning with lowest concentration first followed by progressively with higher concentrations as per the treatment requirements. For applying herbicides, knapsack sprayer was used. The sprayer was fitted with a flat fan nozzle.

(b) Preparation of parthenium leachate and spraying

Fresh parthenium plant samples were collected from the fields and cleaned for other unwanted dirt and soils. A ratio of 1:10 i.e. one part of plant material with ten parts of distilled water on fresh weight / volume (w/v) basis was followed for soaking. Plant samples were soaked for 24 hours in distilled water and filtered through muslin cloth. The filtered plant extract was sprayed as per the treatment schedule using 500 litres water by knapsack sprayer immediately after sowing the crop.

3.3.7. Irrigation

First irrigation was given immediately after sowing. The life irrigation was given on third day after sowing to ensure proper germination. Third irrigation was given on seventh day after sowing for initial establishment. The subsequent irrigations were given as per requirements.

3.3.8. After cultivation

Earthing up was done on 45 DAS. The ridges were broken and loosened, and soil was thrown on both sides of the plants in rows. This facilitated to control weeds as well as in supporting the plants against heavy winds. Adequate prophylactic plant protection measures were taken up to control the sucking pests like aphids, jassids and pink boll worms and thereby to ensure a healthy crop.

3.3.9. Harvest

The seed cotton was harvested in four pickings. The border rows (one on both side) were harvested first. The net plot was separately harvested and the yield was recorded.

3.4. Biometric observations on cotton

In each treatmental plot five plants were selected at random from the net area and tagged. The observations were recorded on the tagged plants.

3.4.1. Growth characters

3.4.1.1. Germination percentage

Germination was recorded by counting the number of hills germinated at 10 DAS in each net plot and expressed as percentage to total hills sown.

3.4.1.2. Plant height

The height of the cotton plant was taken at 20,40,80 and 120 DAS from the zero node to the tip of the last opened leaf and the average was expressed in cm.

3.4.1.3. Leaf area index (LAI)

The leaf area index was arrived by using the following formula as suggested by Williams (1946).

$$\text{LAI} = \frac{\text{Leaf area of plant}}{\text{Ground area occupied}}$$

3.4.1.4. Dry matter production (DMP)

Five plant samples were collected randomly by cutting close to the ground level from the sampling rows of each plot outside of the net plot area. The samples collected were first air dried, then oven dried at 80°C till a constant weight was obtained. Dry weight of samples were recorded and expressed in kg ha^{-1}. The dried plants were then ground and used for chemical analysis.

3.4.2. Yield contributing characters

3.4.2.1. Number of monopodial and sympodial branches $plant^{-1}$

The number of monopodial and sympodial branches $plant^{-1}$ were counted from the randomly selected five tagged plants and mean was worked out and expressed as number per plant.

3.4.2.2. Number of bolls $plant^{-1}$

Number of bolls from the tagged plants were counted at every picking and total number of bolls per plant was computed and expressed as number $plant^{-1}$.

3.4.2.3. Boll weight

The weight of fully opened and matured bolls picked from five plants were recorded separately and the mean boll weight was recorded and expressed as grams $boll^{-1}$.

3.4.2.4. Yield of seed cotton

The seed cotton yield obtained from the net plot area at each picking (four pickings) after shade drying was pooled and total weight was recorded and expressed in kg ha^{-1}.

3.4.3. Quality characters

Assessment of quality of cotton was carried out to find out the possible effects of the herbicides.

3.4.3.1. Ginning percentage

This was calculated by the following formula as ginning percentage suggested by Santhanam (1976).

$$\text{Ginning percentage} = \frac{\text{Weight of lint}}{\text{Weight of seed cotton}} \times 100$$

3.4.3.2. Seed index

The weight of hundred seeds selected at random after ginning was recorded and expressed in grams (Santhanam, 1976).

3.4.3.3. Lint index

The lint obtained from ginning of hundred seed cotton was weighed and expressed in grams (Santhanam, 1976).

3.4.3.4. Fibre length

The mean fibre length was determined as per the procedure given by Sundaram (1974).

3.4.3.5. Fibre fineness

Weight (g) per unit length (cm) of the fibre is generally taken as a measure of fineness. This was determined by air flow method with the help of micronaire as suggested by Sundaram (1974).

3.4.3.6. Bundle strength

It is the ratio of the breaking strength of a bundle of fibre to its own weight. It was determined by a stelometer using the standard test method as suggested by Sundaram (1979) and expressed in tenacity at 1/8" guage.

3.4.3.7. Maturity co-efficient

It is the ratio of mature, half matured and immature fibre in a sample of lint. It was determined by air flow method using micronaire instrument as suggested by Sundaram (1974).

3.5. Observation on residual crop (Cowpea, Greengram, Sorghum, Soybean)

3.5.1. Germination percentage

Germination was recorded by counting the number of hills germinated at 10 DAS and expressed as percentage to total hills sown.

3.5.2. Plant height

The height of the residue crops *viz.,* Cowpea, greengram, sorghum and soybean were measured at 30 DAS on tagged plants and mean was worked out and expressed in cm.

3.5.3. Dry matter production

Five randomly selected plants were taken at 30 DAS. The samples were air dried and then oven dried at 80^{o}C till a constant weight was obtained. The dry weight of samples were recorded and expressed in kg ha^{-1}.

3.6. Observation on weeds

3.6.1. Weed control rating

Following the scale of 0 (no control of weeds) to 10 (perfect weed control) as proposed by Moody (1990), weed control rating was done at 20 DAS.

3.6.2. Weed flora

The common and predominant weeds were recorded species wise at 20 and 40 days after sowing.

3.6.3. Weed population count

The weed count was recorded at 20, 40, 80 and 120 DAS specieswise using 0.25 sq.m. quadrat from the four, peg marked places in each plot and expressed as number m^{-2} as suggested by Burnside and Wicks (1965). The weeds were classified specieswise and as grasses, sedges and broad leaved weeds.

3.6.4. Weed dry matter production

In each plot the quadrat was put in four places at random and the above ground portion of the enclosed weeds are removed. The weed samples were sun dried and then oven dried at $80^{\circ}C$ till a constant weight was obtained and expressed as kg ha^{-1}. The weed samples were then chopped, ground and used for chemical analysis.

3.6.5. Weed Control Efficiency (WCE %)

Weed control efficiency was calculated and expressed in per cent as per the formula suggested by Mani *et al.* (1973).

$$\text{WCE (\%)} = \frac{W_1 - W_2}{W_1} \times 100$$

where,

W_1 = Dry weight of weeds in control plot

W_2 = Dry weight of weeds in treated plot.

3.6.6. Weed Index (WI)

Weed index was calculated as per the method suggested by Gill and Vijayakumar (1969).

$$\text{WI} = \frac{X - Y}{X} \times 100$$

where,

X = Yield from minimum weed competition plot

Y = Yield from treated plot for which WI is to be worked out.

3.6.7. Weed vegetation analysis

The following analysis were made by using the procedure suggested by Bhandari (1981).

3.6.7.1. Relative density (RD)

The relative density was worked out using the following formula:

$$RD = \frac{\text{Absolute density of given species}}{\text{Total absolute density of all species}} \times 100$$

3.6.7.2. Relative dry weight (RDW)

The relative dry weight was worked out using the following formula:

$$RDW = \frac{\text{Dry weight of a given species}}{\text{Total dry weight of all species}} \times 100$$

3.6.7.3. Summed dominance ratio (SDR)

The summed dominance ratio was worked out using the following formula:

$$SDR = \frac{RD + RDW}{2}$$

where,

RD = Relative density

RDW = Relative dry weight

3.7. Plant analysis

The crop plants and weed species collected for dry matter production were ground using willey mill and analysed for uptake of N, P and K using the methods given below.

Nutrient analysed	Method	Suggested by
N	Microkjeldhal method	Yoshida *et al.* (1971)
P	Triple acid digestion (colorimetry)	Jackson (1973)
K	Triple acid digestion (flame photometer)	Jackson (1973)

3.8. Soil nutrient analysis

Soil samples was taken before the start of the experiment by using screw auger at 30 cm depth. The soil samples were air dried, powdered, sieved through 2 mm sieve and analysed for nitrogen as suggested by Subbiah and Asija (1956); for phosphorus as proposed by Olsen *et al.* (1954); for potassium as described by Stanford and English (1949); for electrical conductivity by Jackson (1973), for soil reaction (pH) by Piper (1966) and for organic carbon by Walkley and Black (1934).

3.9. Herbicide residue analysis

Determination of pendimethalin residue in cotton seed was analysed by using Gas Chromatography (GC) as suggested by Sankaran *et al.* (1993) and determination of cinmethylin residue in cotton seed was analysed by High Performance Liquid Chromatography (HPLC).

3.9.1. Pendimethalin

(a) Extraction

Finely ground cotton seed 25 g was blended with 100 ml of 10 % methanol in chloroform for five minutes. The solvent was filtered in a buchner funnel under suction and evaporated to dryness. The residue was dissolved in 25 ml of hexane and transferred to a 250 ml separating funnel. The evaporation flask was rinsed with 25 ml of acetonitrile and was combined with hexane in separating funnel. One drop of conc. HCl was added and shaked for 30 seconds. The acetonitrile was drawn off into an evaporating flask. The partition was again carried out with another 25 ml of acetonitrile and were combined. The contents were dried in a rotary evaporator.

(b) Clean up

The contents in the evaporating flask were dissolved in 10 ml hexane and transferred to a 7 cm florisil column and was washed with 50 ml hexane. The beaker was replaced below the column was eluted with 100 ml of 60 % of benzene in hexane . The elute collected was evaporated to dryness in a rotary evaporator and the residue was dissolved in 5 ml benzene.

(c) GC determination

Detector : Electron Capture Detector (ECD)

Column : 1.5% OV 17 +1.95 QF 1 on Gas chrome Q (100/120 mesh)

Temperature conditions :

Column	:	200°C
Injection	:	220°C
Detector	:	240°C
Carrier gas flow (N_2)	:	50 ml min^{-1}

3.9.2. Cinmethylin

(a) Extraction

Twenty five grams of cotton seed was macerated and extracted with 100 ml of acetonitrile for 30 minutes in an end-over-end shaker and filtered. Repeated the extraction with 100 ml of acetonitrile and filtered.

(b) Partition

The combined filtrate was concentrated to 25 ml in a rotary vacuum evaporator (below 50°C). The residue was diluted with 50 ml of sodium chloride solution and partitioned with 100 ml of hexane twice and collected the organic phase. The combined organic layer was filtered through anhydrous Na_2SO_4 and concentrated to dryness. The samples collected in acetonitrile were analysed by high performance liquid chromatography for cinmethylin.

HPLC (High Performance Liquid Chromatography) model Hitachi equipped with L 6200 intelligent pump, UV-visible detector and D-2500 chromato integrator.

Chromatographic separation parameters

Column used	:	Reverse phase C 18 ODS 2
Mobile phase	:	Acetonitrile : Water (75:25)
Detector	:	UV-Visible detector
Wave length	:	225 nm
Detector sensitivity	:	0.002 A.O.F.S.
Flow rate	:	1.9 ml / min.
Injected volume	:	20 μ l
Retention time	:	6.0 min.
Minimum detectable concentration	:	0.05 ppm

(c) Calibration details - Linearity check

Different known concentrations *viz.,* 10 μg/ml, 1 μg/ml, 0.1 μg/ml, 0.05 μg/ml of cinmethylin were prepared in residue grade acetonitrile by diluting the stock solution. Injected 20 μl of each standard solution and measured the peak height resulting from the elution of compound adhering to the strict absorbance of peak retention. A calibration curve has been plotted for concentration of the standards injected versus height observed and the curve is found linear upto the lowest concentration range 0.05 μg/ml for cinmethylin.

(d) Sample analysis

During the process of routine sample analysis wherever necessary, the concentration of sample solution was adjusted and injected. To assure the integrity of the sample analysis, standards were injected after each seven sample injections.

(e) Method of calculation

$$\text{Residue mg/kg (ppm)} = \frac{A_1 \times V \times C}{A_2 \times M}$$

where,

A_1 - Peak height of the sample
A_2 - Peak height of the standard
V - Volume of the sample (ml)
C - Concentration of the standard (ppm)
M - Mass of the sample initially taken for extraction (g)

(f) Recovery and fortification details

Untreated control samples were fortified with 1 µl of different known concentrations of the chemical. Samples were processed as described above and analysed.

Recovery	: > 80%
Sensitivity	: 1 ppm
Minimum detectable level	: 0.4 ppm

3.10. Studies on soil microorganisms

To find out the effects of the herbicides on microbes, soil samples were collected at 90 DAS of the cotton crop. The samples were analysed for the population of total bacteria, fungi and actinomycetes using soil nutrient agar medium (Allen, 1953), Martin's rose bengal agar medium (Martin, 1950) and Kenknight's agar medium (Allen, 1953) respectively. The composition of the media used for microbial enumeration are given in Appendix IV.

3.11. Bio-assay of herbicide through pot culture experiment

Bio-assay study was conducted to find out the residual effect of herbicides applied to the cotton on the test crop of cucumber which is highly sensitive to herbicides was conducted after the removal of cotton stalks. Post harvest soil samples were taken at 0-20 cm depth and shade dried. One kg of soil was filled up in clean polyethylene bag. Ten cucumber seeds were sown in each container and watered regularly. Germination count was taken at seven days after sowing. Plant height and DMP of cucumber plants were recorded 30 days after sowing.

3.12. Bio-assay of herbicide residue through field experiment

To assess the residual effect of herbicides applied to cotton crop on cowpea (Co.4), greengram (Co.4), sorghum (Co.26) and soybean (Co.1) were raised as a residual crops without disturbing the layout of cotton experiment. After the removal of cotton plants, the residue crops such as cowpea, greengram, sorghum and soybean were sown with recommended package of practices.

3.13. Economics

Details pertaining to cost of cultivation, gross return, and net return ha^{-1} for each treatment were worked out based on the prevailing market price for inputs and output. Benefit-Cost Ratio (BCR) was also worked out by using the formula as suggested by Palaniappan (1985):

$$\text{BCR} = \frac{\text{Gross return}}{\text{Total cost of cultivation}}$$

3.14. Statistical analysis

The data of various observations and characters studied were statistically analysed following the procedure suggested by Panse and Sukhatme (1967) for the randomized block design. Since, the data on weed count, weed DMP showed high variation, they were subjected to log (x+2) transformation before statistical analysis as suggested by Bartlett (1947). Data on germination per cent were subjected to Arc sine transformation and data on microbial population was subjected to logarithmic transformation before statistical analysis. Wherever, the F values were significant, critical differences at 5 per cent probability level was calculated.

EXPERIMENTAL RESULTS

CHAPTER IV

EXPERIMENTAL RESULTS

Field experiments were conducted at Tamil Nadu Agricultural University, Coimbatore from August 1998 to January 2000 in order to develop efficient weed management practices for irrigated cotton and to study the residual effect of different weed management practices to cotton on succeeding crops of cowpea, greengram, sorghum and soybean. The separate preliminary experiment was carried out to screen the cinmethylin levels in cotton. The results of field experiments were presented in this chapter.

4.1. Preliminary screening experiment

The field experiments were conducted to study the bio-efficacy of cinmethylin at different levels *viz.,* 0.4, 0.6 and 0.8 kg ha^{-1} (with unweeded control) for its suitability to cotton under irrigated condition. Phytotoxicity ratings at 7, 15 and 30 days after sowing (DAS), weed control rating at 20 DAS, weed population and weed control efficiency at 30 DAS were assessed in the preliminary experiment.

4.1.1. Phytotoxicity rating (Table 4)

Among the different levels tried, application of cinmethylin @ 0.4 kg ha^{-1} recorded moderate weed control whereas cinmethylin @ 0.6 kg ha^{-1} gave better weed control at the same time it caused slight injury to cotton crop. Therefore, a dose was selected in between these doses i.e. 0.5 kg ha^{-1}. It was found to be selective. Higher doses (0.6 and 0.8 kg ha^{-1}) of cinmethylin caused slight injury (Pytotoxicity ratings of 2, 1 and 0 for 0.6 kg ha^{-1} and 3,2 and 1 for 0.8 kg ha^{-1}) to cotton crop on 7, 15 and 30 DAS. Application of 0.4 kg ha^{-1} of cinmethylin did not cause any injury to cotton at all the three stages of phytotoxicity rating.

Table 4. Phytotoxicity rating of herbicide in preliminary screening experiment

	Treatments	Phytotoxicity rating on 7th day	Phytotoxicity rating on 15th day	Phytotoxicity rating on 30th day
H_1	Control	0	0	0
H_2	Cinmethylin 0.4 kg ha^{-1}	0	0	0
H_3	Cinmethylin 0.6 kg ha^{-1}	2	1	0
H_4	Cinmethylin 0.8 kg ha^{-1}	3	2	1

0 : No injury

1-3 : Less injury

4-6 : Moderate injury

7-9 : Severe injury

10 : All plants killed

4.1.2. Weed control rating (Table 5)

Among the three levels of cinmethylin higher weed control rating of 9.24 was recorded with cinmethylin applied @ 0.8 kg ha^{-1}. While application of cinmethylin @ 0.4 kg ha^{-1} registered lower weed control rating of 8.00.

4.1.3. Weed density

The data on weed population at 15 and 30 DAS are presented in Table 5. Weed density was maximum (144 and 162.0 m^{-2} at 15 and 30 DAS) under unweeded control. Application of cinmethylin @ 0.8 kg ha^{-1} recorded lesser weed population of 10.0 and 12.0 m^{-2} at 15 and 30 DAS, respectively. The data on weed density grouped under grasses, sedges and broad leaved weeds observed at 15 and 30 DAS. Among the weed species, the density of grasses was almost nil in cinmethylin applied plots whereas unweeded check recorded 16.0 and 20 m^{-2} at 15 and 30 DAS, respectively. The moderate control of sedges and broad leaved weeds were observed in cinmethylin applied plots.

4.1.4. Weed Control Efficiency (WCE %)

The data on weed control efficiency was presented in Table 5. Application of cinmethylin @ 0.8 kg ha^{-1} recorded higher weed control efficiency of 90.32 per cent followed by cinmethylin applied @ 0.6 kg ha^{-1} (83.87). The lower dose of (0.4 kg ha^{-1}) of cinmethylin showed minimum weed control efficiency of 66.94 per cent at 30 DAS.

4.1.5. Plant height of cotton

The data on plant height of cotton at 30 DAS is presented in Table 5. Cinmethylin application @ 0.6 kg ha^{-1} gave higher plant height (26.7 cm) of cotton and it was followed by cinmethylin @ 0.4 kg ha^{-1}. While unweeded control registered minimum plant height (18.7 cm).

Table 5. **Weed control visual rating, weed density (No. m^{-2}), WCE (%) and plant height (cm) in preliminary screening trial**

Treatments	Weed control rating	Weed density (No.m^{-2}) 15th day				Weed density (No. m^{-2}) 30th day				WCE (%)	Plant height (cm)
		Grasses	Sedges	BLW	Total weed population	Grasses	Sedges	BLW	Total weed population		
H_1 - Control	0.00	16.0	16.0	112.0	144.0	20.0	18.0	124.0	162.0	-	18.7
H_2 - Cinmethylin 0.4 kg ha^{-1}	8.00	-	6.0	32.0	38.0	-	8.0	33.0	41.0	66.94	24.4
H_3 - Cinmethylin 0.6 kg ha^{-1}	8.85	-	4.0	14.0	18.0	-	6.0	14.0	20.0	83.87	26.7
H_4 - Cinmethylin 0.8 kg ha^{-1}	9.24	-	3.0	7.0	10.0	-	4.0	8.0	12.0	90.32	23.8

Weed control rating scale: BLW : Broad leaved weeds

0 : No control

10 : Complete control

Based on the preliminary experiment, even though application of cinmethylin @ 0.8 kg ha^{-1} recorded higher weed control rating and weed control efficiency, it caused considerable phytotoxicity to cotton plants. While cinmethylin @ 0.4 kg ha^{-1} failed to give satisfactory weed control. Hence, cinmethylin @ 0.5 and 0.6 kg ha^{-1} were taken for further investigation with other weed management practices in the main field experiment.

4.2. Weed management in irrigated cotton (main experiments)

4.2.1. Weed flora of the experimental field (Table 6)

The weed flora of the experimental field was presented in Table 6. The weed population were grouped into individual weed species, grasses, sedges and broad leaved weeds. Among the weed species the predominant weed flora were *Dactyloctenium aegyptium* (Beauv.), *Echinochloa colonum* (L.), *Chloris barbata* (SW.), *Cynodon dactylon* (L.) Pers. in grasses, *Cyperus rotundus* (Linn.) in sedges and *Digera arvensis* (Forsk.), *Trianthema portulacastrum* (L.) in broad leaved weeds.

4.2.2. Weed composition in irrigated cotton (Fig. 6 and 7)

In the first crop (1998-99), among the weed composition the broad leaved weeds were dominated at the tune of 45 per cent followed by grasses (43 per cent) and sedges (12 per cent) at 20 DAS. At 40 DAS, the broad leaved weeds occupied 50 per cent followed by grasses (37 per cent) and sedges (13 per cent).

In the second crop (1999-2000) also the weed composition was in the same trend. The broad leaved weeds were dominated at the tune of 46 per cent followed by grasses (41 per cent) and sedges (13 per cent) at 20 DAS. At 40 DAS, the broad leaved weeds were occupied 48 per cent followed by grasses (39 per cent) and sedges (13 per cent).

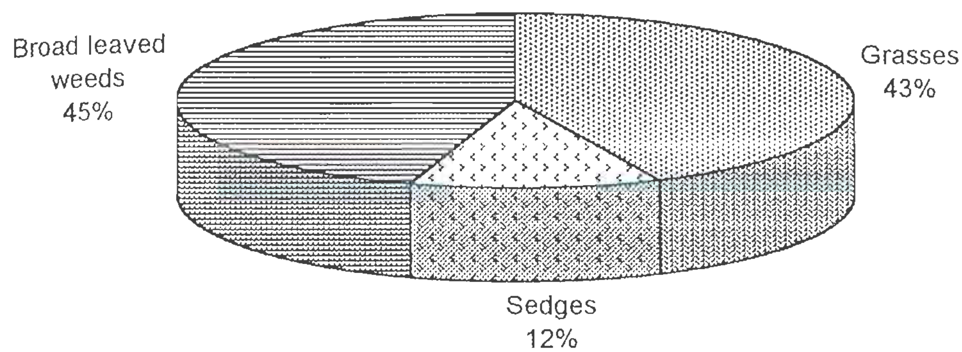
Table 6. Weed flora of the experimental field

Botanical name	Common name	Habit	Family
A. Grasses			
Dactyloctenium aegyptium Beauv.	Crow foot grass	Annual	Graminae
Cynodon dactylon (L.) Pers.	Bermuda grass	Perennial	Graminae
Chloris barbata Sw.	Mailkondaipul*	Perennial	Graminae
Panicum repens (L.)	Injipullu*	Perennial	Graminae
Echinochloa colonum (L.) Link	Jungle grass	Annual	Graminae
B. Sedge			
Cyperus rotundus (L.)	Nut grass	Perennial	Cyperaceae
C. Broad leaved weeds			
Trianthema portulacastrum (L.)	Carpet weed	Annual	Aizoaceae
Digera arvensis (Forsk.)	Thoyya Keerai*	Annual	Amaranthaceae
Parthenium hysterophorus	Congress grass	Annual	Asteraceae
Flaveria australasica (Hook)	Manja pudu*	Annual	Compositae
Commelina benghalensis (L.)	Kanan Keerai*	Annual	Commelinaceae
Phyllanthus maderaspatensis (L.)	Melanelli*	Annual	Euphorbiaceae
Amaranthus viridis (L.)	Slender amaranthus (Kuppai keerai)*	Annual	Amaranthaceae

*Tamil Name

Fig. 6. Percentage distribution of grasses, sedges and broad leaved weeds in cotton (1998-1999)

20 DAS



40 DAS

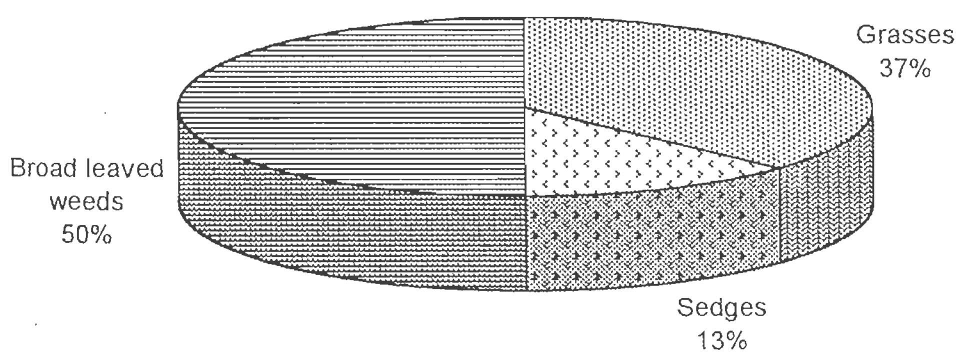
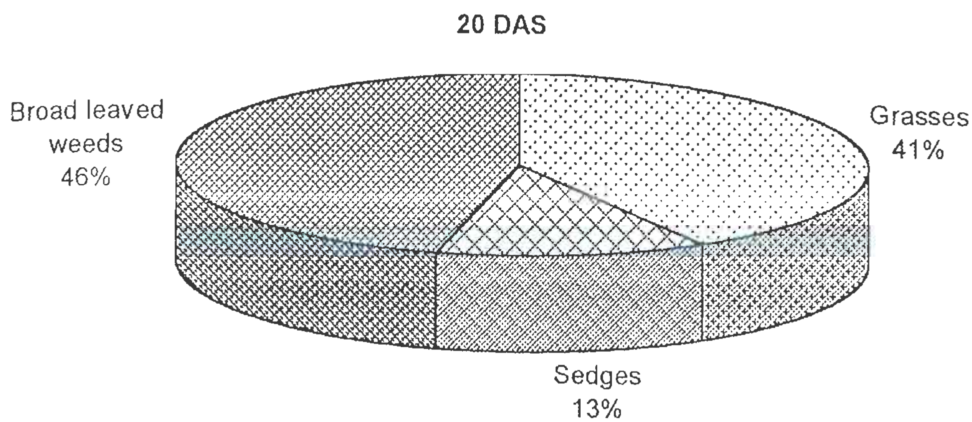
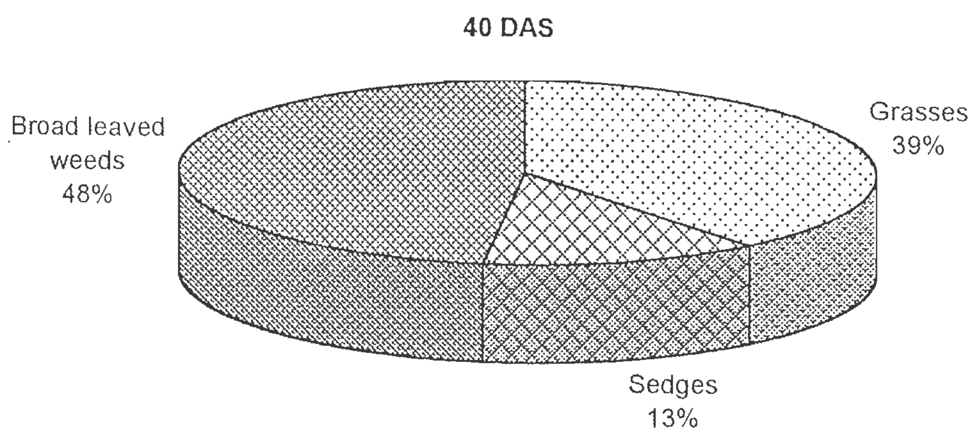


Fig. 7. Percentage distribution of grasses, sedges and broad leaved weeds in cotton (1999-2000)





4.2.3. Weed population

In both the years, the dominant weeds were broad leaved weeds followed by grasses and sedges. The effect of weed management treatments was studied an individual weed species as well as grouped into grasses, sedges and broad leaved weeds.

4.2.3.1. Grass weeds (Table 7) (Fig. 8 and 9)

In the first crop of cotton (MCU 5), pre-emergence application of cinmethylin @ 0.6 kg ha^{-1} + HW (T_7) recorded significantly lower grass weed population of 3.23, 7.19, 3.70 and 2.24 m^{-2} at 20, 40, 80 and 120 DAS, respectively, which was closely followed by the application of cinmethylin @ 0.5 kg ha^{-1} + HW (T_5). This was comparable with pendimethalin @ 1.0 kg ha^{-1} + HW (T_3) and HW twice (T_2) treatments.

Greengram (T_{14}) as a smother crop registered lower grass weed population of 39.21, 21.42, 6.22 and 5.45 m^{-2} at 20, 40, 80 and 120 DAS, respectively, which was comparable to cowpea (T_{12}). The highest grass weed population of 74.04, 82.61, 62.12 and 66.18 m^{-2} was observed in unweeded control (T_1) at 20, 40, 80 and 120 DAS, respectively. The allelopathic treatments such as parthenium incorporation @ 2 t ha^{-1} (T_8) and parthenium whole plant extract spray (T_9) did not exhibit any significant effect on grass weed control irrespective of the stages.

Similar trend was noticed in the second crop of cotton with respect to grass weed control by application of cinmethylin and pendimethalin and HW twice. Among the smother crops, greengram (T_{14}) registered lower grass weed population of 41.17, 23.67, 6.87 and 6.08 m^{-2} at 20, 40, 80 and 120 DAS, respectively, which was closely followed with the smother crop of cowpea (T_{12}). The highest weed population was recorded irrespective of the stages in the unweeded control plot (T_1) as in the case of first crop of cotton. Parthenium

Table 7. **Effect of treatments on population of grasses (No. m^{-2}) in cotton**

Treat-ments	First crop (1998-1999)				Second crop (1999-2000)			
	20 DAS	40 DAS	80 DAS	120 DAS	20 DAS	40 DAS	80 DAS	120 DAS
T_1	74.04 (1.88)	82.61 (1.93)	62.12 (1.81)	66.18 (1.83)	77.08 (1.90)	98.66 (2.00)	70.23 (1.86)	69.41 (1.85)
T_2	73.07 (1.88)	5.83 (0.89)	6.13 (0.91)	5.36 (0.87)	75.92 (1.89)	6.20 (0.91)	6.49 (0.93)	5.99 (0.90)
T_3	8.14 (1.01)	9.53 (1.06)	6.05 (0.91)	8.00 (1.00)	9.69 (1.07)	11.66 (1.14)	8.28 (1.01)	6.13 (0.91)
T_4	4.07 (0.78)	8.25 (1.01)	6.22 (0.92)	5.75 (0.89)	4.74 (0.83)	9.81 (1.07)	8.92 (1.04)	8.14 (1.01)
T_5	3.44 (0.74)	8.47 (1.02)	4.50 (0.81)	5.02 (0.85)	4.65 (0.82)	9.20 (1.05)	4.05 (0.78)	3.39 (0.73)
T_6	3.21 (0.72)	7.39 (0.97)	7.52 (0.98)	6.63 (0.94)	3.82 (0.76)	8.06 (1.00)	9.42 (1.06)	8.02 (1.00)
T_7	3.23 (0.72)	7.19 (0.96)	3.70 (0.76)	2.24 (0.63)	3.67 (0.75)	8.21 (1.01)	4.08 (0.78)	2.75 (0.68)
T_8	73.84 (1.88)	16.75 (1.27)	12.17 (1.15)	10.58 (1.10)	76.23 (1.89)	18.66 (1.32)	12.66 (1.17)	11.04 (1.12)
T_9	52.94 (1.74)	14.96 (1.22)	11.10 (1.12)	9.90 (1.07)	54.96 (1.76)	16.82 (1.28)	11.72 (1.14)	7.27 (0.97)
T_{10}	76.36 (1.89)	17.23 (1.28)	11.63 (1.13)	10.09 (1.08)	78.08 (1.90)	18.49 (1.31)	12.08 (1.15)	7.05 (0.96)
T_{11}	53.13 (1.74)	16.14 (1.26)	7.04 (0.96)	6.06 (0.91)	55.46 (1.76)	16.70 (1.27)	7.54 (0.98)	6.83 (0.95)
T_{12}	41.67 (1.64)	23.26 (1.40)	6.80 (0.94)	5.92 (0.90)	44.42 (1.67)	26.18 (1.45)	7.09 (0.96)	6.71 (0.94)
T_{13}	56.39 (1.71)	36.82 (1.59)	8.85 (1.04)	6.83 (0.95)	59.88 (1.79)	39.22 (1.62)	9.26 (1.05)	7.50 (0.98)
T_{14}	39.21 (1.62)	21.42 (1.37)	6.22 (0.92)	5.45 (0.87)	41.17 (1.64)	23.67 (1.41)	6.87 (0.95)	6.08 (0.91)
SEd	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
CD (P=0.05)	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02

(Figures in parenthesis indicate log (x+2) transformed value)

Fig. 8. Effect of weed management methods on the grasses, sedge and broad leaved weeds population in cotton at 20 DAS (1998-1999)

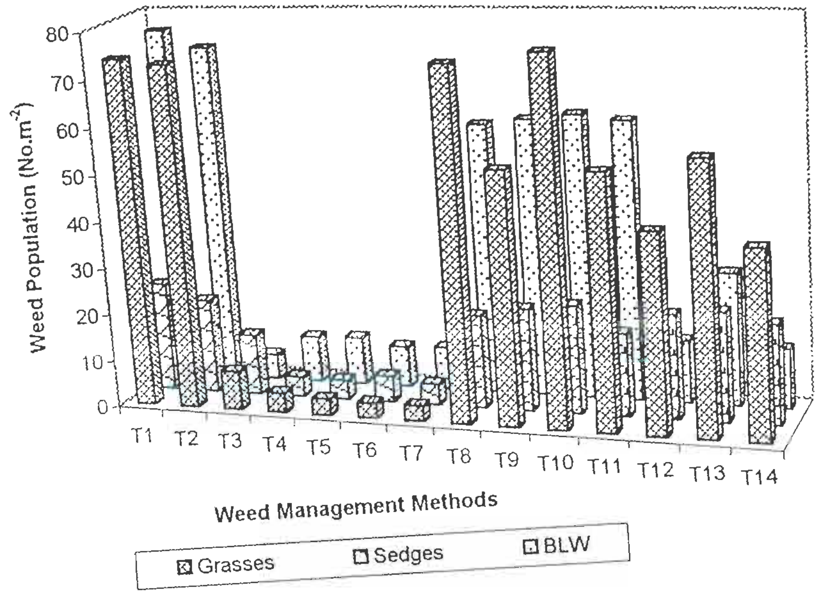
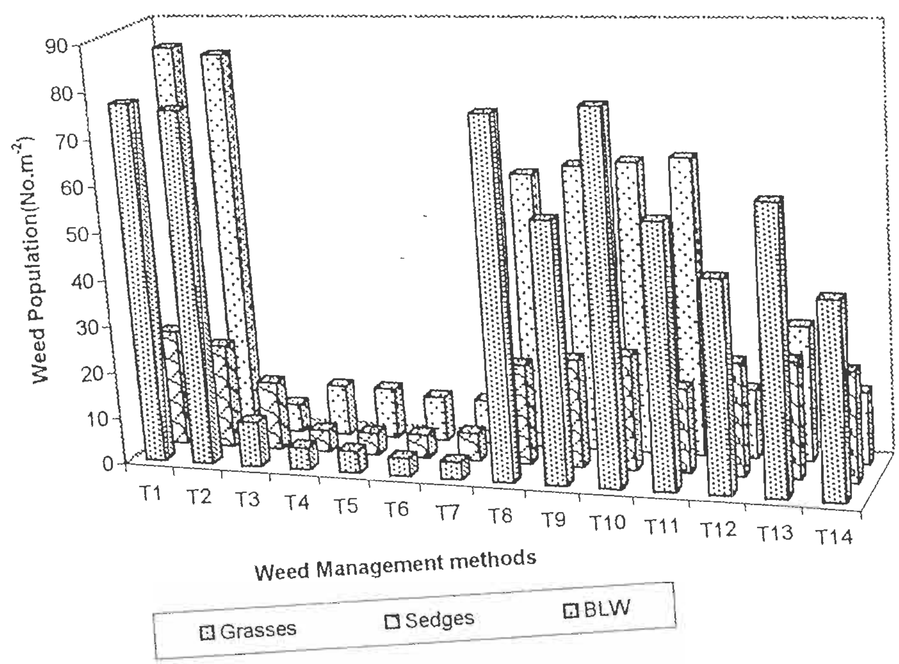


Fig. 9. Effect of weed management methods on the grasses, sedge and broad leaved weeds population in cotton at 20 DAS (1999-2000)



incorporation @ 2 t ha^{-1} (T_8) and parthenium whole plant extract (10%) spray (T_9) did not show any significant weed control in all the stages. In general, the grass weed population was maximum in the second crop as compared to first crop.

4.2.3.1.1. *Dactyloctenium aegyptium* (Table 8)

Weed management practices were effective in controlling *D. aegyptium* significantly in all the stages in both the years studied. In the first crop, cinmethylin @ 0.6 kg ha^{-1} + HW (T_7) recorded significantly lower weed population of 0.45, 1.20, 0.52 and 0.20 m^{-2} at 20 40, 80 and 120 DAS, respectively, which was comparable with the application of cinmethylin @ 0.5 kg ha^{-1} + HW (T_5). This treatment was closely followed by pendimethalin 1.0 kg ha^{-1} followed by one hand weeding at 40 DAS (T_3) and HW twice (T_2) treatments.

Growing of greengram (T_{14}) as a smother crop gave lower weed population of 8.52, 4.59, 2.94 and 2.28 m^{-2} at 20, 40, 80 and 120 DAS, respectively, which was comparable with the cowpea (T_{12}) as a smother crop. The highest weed population of 21.20, 50.40, 31.24 and 32.84 m^{-2} was observed in the unweeded control (T_1) at 20, 40, 80 and 120 DAS, respectively. Parthenium incorporation (T_8) and whole plant extract spray (T_9) did not show any significant effect on weed control irrespective of the stages.

In the second crop, among the weed management practices, the similar trend was noticed with respect to weed control by pre-emergence application of cinmethylin @ 0.6 kg ha^{-1} + HW (T_7), cinmethylin @ 0.5 kg ha^{-1} + HW (T_5), pendimethalin 1.0 kg ha^{-1} + HW and HW twice (T_2).

Greengram (T_{14}) as a smother crop registered lower weed population of 11.03, 3.76, 3.02 and 2.62 m^{-2} at 20, 40, 80 and 120 DAS, respectively, which was

Table 8. **Effect of treatments on population of *Dactyloctenium aegyptium* ($No.m^{-2}$) in cotton**

Treat-ments	First crop (1998-1999)				Second crop (1999-2000)			
	20 DAS	40 DAS	80 DAS	120 DAS	20 DAS	40 DAS	80 DAS	120 DAS
T_1	21.20 (1.37)	50.4 (1.72)	31.24 (1.52)	32.84 (1.54)	22.11 (1.38)	51.12 (1.73)	33.27 (1.55)	33.27 (1.55)
T_2	20.75 (1.36)	0.20 (0.34)	1.02 (0.48)	1.00 (0.48)	21.28 (1.37)	0.28 (0.36)	1.11 (0.49)	0.99 (0.48)
T_3	2.50 (0.65)	1.25 (0.51)	1.15 (0.50)	1.42 (0.53)	2.73 (0.67)	1.33 (0.52)	1.69 (0.57)	1.24 (0.51)
T_4	0.75 (0.44)	1.30 (0.52)	1.26 (0.51)	1.52 (0.55)	0.88 (0.46)	1.45 (0.54)	1.72 (0.57)	1.89 (0.59)
T_5	0.65 (0.42)	1.28 (0.52)	0.84 (0.45)	0.94 (0.47)	0.79 (0.45)	0.31 (0.36)	0.47 (0.39)	0.72 (0.44)
T_6	0.52 (0.40)	1.12 (0.49)	1.24 (0.51)	1.05 (0.48)	0.61 (0.42)	1.14 (0.50)	2.51 (0.65)	1.76 (0.58)
T_7	0.45 (0.39)	1.20 (0.51)	0.52 (0.40)	0.20 (0.34)	0.57 (0.41)	1.26 (0.54)	0.52 (0.40)	0.33 (0.37)
T_8	20.42 (1.35)	3.05 (0.70)	1.24 (0.51)	1.84 (0.58)	19.25 (1.33)	3.23 (0.72)	1.28 (0.52)	1.79 (0.58)
T_9	12.32 (1.16)	2.15 (0.62)	1.10 (0.49)	2.25 (0.63)	11.73 (1.14)	2.45 (0.65)	1.06 (0.49)	0.82 (0.45)
T_{10}	16.20 (1.26)	3.02 (0.70)	1.15 (0.50)	2.24 (0.63)	21.99 (1.38)	3.14 (0.71)	1.14 (0.50)	0.76 (0.44)
T_{11}	13.52 (1.19)	2.25 (0.63)	1.20 (0.51)	0.58 (0.41)	10.55 (1.10)	2.21 (0.62)	0.68 (0.43)	0.51 (0.40)
T_{12}	9.82 (1.07)	2.05 (0.61)	3.24 (0.72)	2.62 (0.67)	11.21 (1.12)	4.08 (0.78)	3.42 (0.73)	2.99 (0.70)
T_{13}	9.50 (1.06)	8.54 (1.02)	1.45 (0.54)	1.54 (0.55)	8.76 (1.03)	9.28 (1.01)	1.48 (0.54)	1.10 (0.49)
T_{14}	8.52 (1.02)	4.59 (0.82)	2.94 (0.69)	2.28 (0.63)	11.03 (1.12)	3.76 (0.76)	3.02 (0.70)	2.62 (0.67)
SEd	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.004
CD (P=0.05)	0.01	0.01	0.01	0.01	0.01	0.03	0.01	0.01

(Figures in parenthesis indicate log (x+2) transformed value)

closely followed by cowpea (T_{12}). The highest weed population was found irrespective of stages in the unweeded control plot (T_1) as in the case of first crop. The allelopathic treatments did not show any significant weed control in all the stages. In general, the *D. aegyptium* population was maximum in the second crop as compared to first crop.

4.2.3.1.2. *Chloris barbata* and *Echinochloa colonum* (Table 9)

In the first crop, weed control treatments significantly altered the density of *Chloris barbata* irrespective of the stages. Application of cinmethylin @ 0.6 kg ha^{-1} + HW (T_7) registered lower weed population of 0.21, 1.05, 0.34 and 0.18 m^{-2} at 20, 40, 80 and 120 DAS, respectively, which was closely followed by cinmethylin @ 0.5 kg ha^{-1} + HW (T_5). This was comparable with application of pendimethalin @ 1.0 kg ha^{-1} + HW and HW twice treatments.

Growing of greengram (T_{14}) as a smother crop recorded lower weed population of 13.54, 10.54, 2.60 and 2.12 m^{-2} at 20, 40, 80 and 120 DAS, respectively, which was on par with the cowpea (T_{12}). The highest weed population of 14.25, 22.23, 14.23 and 15.48 m^{-2} was observed in the unweeded control (T_1) at 20, 40, 80 and 120 DAS, respectively.

In the second crop, weed control treatments significantly altered the population of *Echinochloa colonum* irrespective of all the stages. The pre-emergence application of cinmethylin @ 0.6 kg ha^{-1} + HW (T_7) registered lower weed population of 0.23, 1.30, 0.49 and 0.21 m^{-2} at 20, 40, 80 and 120 DAS, respectively. It was comparable with the application of cinmethylin @ 0.5 kg ha^{-1} + HW (T_5). Application of pendimethalin @ 1.0 kg ha^{-1} followed by hand weeding (T_3) and HW twice (T_2) treatments were comparable.

Table 9. Effect of treatments on population of *Chloris barbata* (No.m^{-2}) and *Echinochloa colonum* (No.m^{-2}) in cotton

Treatments	First crop (1998-1999)				Second crop (1999-2000)			
	Chloris barbata				*Echinochloa colonum*			
	20 DAS	40 DAS	80 DAS	120 DAS	20 DAS	40 DAS	80 DAS	120 DAS
T_1	14.25 (1.21)	22.23 (1.38)	14.23 (1.21)	15.48 (1.24)	14.43 (1.22)	25.44 (1.44)	16.51 (1.27)	16.42 (1.27)
T_2	13.42 (1.19)	0.45 (0.39)	0.58 (0.41)	0.82 (0.45)	13.69 (1.20)	0.53 (0.40)	0.77 (0.44)	0.72 (0.43)
T_3	1.20 (0.51)	1.84 (0.58)	1.20 (0.51)	1.52 (0.55)	1.15 (1.48)	2.28 (0.63)	1.44 (0.54)	0.95 (0.47)
T_4	0.32 (0.37)	1.54 (0.55)	0.84 (0.45)	0.95 (0.47)	0.38 (0.38)	1.71 (0.57)	0.95 (0.47)	1.23 (0.51)
T_5	0.32 (0.37)	1.24 (0.51)	0.42 (0.38)	0.78 (0.44)	0.31 (0.36)	1.63 (0.56)	0.38 (0.38)	0.56 (0.41)
T_6	0.20 (0.34)	1.15 (0.50)	1.15 (0.50)	1.15 (0.50)	0.27 (0.36)	1.22 (0.51)	1.72 (0.57)	1.14 (0.50)
T_7	0.21 (0.34)	1.05 (0.48)	0.34 (0.37)	0.18 (0.34)	0.23 (0.35)	1.30 (0.52)	0.49 (0.40)	0.21 (0.34)
T_8	12.39 (1.16)	3.58 (0.75)	0.82 (0.45)	1.54 (0.55)	13.09 (1.18)	4.27 (0.80)	0.94 (0.47)	1.25 (0.51)
T_9	9.24 (1.05)	3.04 (0.70)	0.74 (0.44)	1.28 (0.52)	8.27 (1.01)	3.72 (0.76)	0.75 (0.44)	0.67 (0.43)
T_{10}	14.24 (1.21)	3.94 (0.77)	0.56 (0.41)	1.62 (0.56)	14.36 (1.21)	4.10 (0.79)	0.87 (0.46)	0.55 (0.41)
T_{11}	9.26 (1.05)	3.52 (0.74)	0.48 (0.39)	0.85 (0.46)	8.01 (1.00)	3.65 (0.75)	0.31 (0.36)	0.26 (0.35)
T_{12}	12.22 (1.15)	12.32 (1.16)	2.14 (0.62)	2.24 (0.63)	11.94 (1.44)	13.22 (1.18)	2.34 (0.64)	2.71 (0.67)
T_{13}	8.42 (1.02)	12.45 (1.16)	1.54 (0.55)	1.02 (0.48)	7.53 (0.98)	12.45 (1.16)	1.09 (0.49)	0.83 (0.45)
T_{14}	13.54 (1.19)	10.54 (1.10)	2.60 (0.66)	2.12 (0.62)	11.77 (1.14)	11.56 (1.13)	2.55 (0.66)	2.40 (0.64)
SEd	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.004
CD (P=0.05)	0.02	0.02	0.01	0.01	0.02	0.02	0.01	0.01

(Figures in parenthesis indicate log (x+2) transformed value)

Regarding smother crops, greengram (T_{14}) registered lower weed population of 11.77, 11.56, 2.55 and 2.40 m^{-2} at 20, 40, 80 and 120 DAS, respectively. This was closely followed with the cowpea (T_{12}) as smother crop. The highest weed population was registered in the unweeded control (T_1). In general, the weed population was maximum in the second crop as compared to first crop.

4.2.3.1.3. *Cynodon dactylon* (Table 10)

Data showed that in the first crop, among the weed management practices, application of cinmethylin @ 0.6 kg ha^{-1} + HW (T_7) registered lowest weed population of 2.33, 4.35, 2.51 and 1.54 m^{-2} at 20, 40, 80 and 120 DAS, respectively. At 80 and 120 DAS, less weed population was registered irrespective of treatments as compared to 20 and 40 DAS. This was comparable with the application of cinmethylin @ 0.5 kg ha^{-1} + HW (T_5). This was followed by pendimethalin @ 1.0 kg ha^{-1} + HW (T_3) and HW twice (T_2) treatments.

Growing of greengram (T_{14}) registered lesser population of 12.48, 5.54, 0.78 and 0.95 m^{-2} at 20, 40, 80 and 120 DAS, respectively, which was followed by cowpea (T_{12}) as smother crop. The highest weed population was registered in unweeded control (T_1). The allelopathic treatment did not exhibit significant weed control.

The similar trend was noticed in the second crop with respect to weed control by pre-emergence application of cinmethylin, pendimethalin and HW twice. Among the smothering crops, greengram (T_{14}) recorded less weed population of 14.68 and 6.90 at 20 and 40 DAS, respectively. At 40 and 80 DAS, less weed population was registered as compared to herbicide treatments. Which was comparable with cowpea (T_{12}) as smother crop. The highest weed population of 38.66, 13.28, 12.66 and 10.60 m^{-2} was recorded in unweeded control plot (T_1)

Table 10. **Effect of treatments on population of *Cynodon dactylon* (No.m^{-2}) in cotton**

Treat-ments	First crop (1998-1999)				Second crop (1999-2000)			
	20 DAS	40 DAS	80 DAS	120 DAS	20 DAS	40 DAS	80 DAS	120 DAS
T_1	38.20 (1.60)	12.52 (1.16)	13.62 (1.19)	9.25 (1.05)	38.66 (1.61)	13.28 (1.18)	12.66 (1.17)	10.60 (1.10)
T_2	36.42 (1.58)	4.22 (0.79)	4.20 (0.79)	3.24 (0.72)	36.15 (1.58)	4.91 (0.84)	3.23 (1.72)	3.06 (0.70)
T_3	4.10 (0.79)	5.24 (0.86)	3.42 (0.73)	4.84 (0.84)	4.60 (0.82)	5.99 (0.90)	4.36 (0.80)	3.68 (0.75)
T_4	2.15 (0.62)	4.98 (0.84)	3.74 (0.76)	3.05 (0.70)	2.92 (0.69)	5.06 (0.85)	5.85 (0.90)	4.42 (0.81)
T_5	2.95 (0.70)	5.02 (0.85)	2.95 (0.70)	3.10 (0.70)	2.84 (0.68)	4.95 (0.84)	2.20 (0.62)	1.88 (0.59)
T_6	2.45 (0.65)	4.52 (0.81)	4.52 (0.81)	4.24 (0.80)	2.56 (0.66)	4.50 (0.81)	4.66 (0.82)	4.33 (0.80)
T_7	2.33 (0.64)	4.35 (0.80)	2.51 (0.65)	1.54 (0.55)	2.51 (0.65)	4.61 (0.82)	2.30 (0.63)	1.98 (0.60)
T_8	33.32 (1.55)	8.45 (1.02)	9.82 (1.07)	6.28 (0.92)	37.51 (1.60)	10.03 (1.08)	8.93 (1.04)	7.36 (1.97)
T_9	25.23 (1.44)	7.79 (0.99)	8.56 (1.02)	5.98 (0.90)	30.28 (1.51)	9.79 (1.07)	8.65 (1.03)	5.29 (0.86)
T_{10}	37.24 (1.59)	8.84 (1.04)	9.28 (1.05)	6.02 (0.90)	36.52 (1.59)	9.95 (1.08)	8.79 (1.03)	5.10 (0.85)
T_{11}	26.20 (1.45)	9.92 (1.08)	5.02 (0.85)	4.48 (0.81)	29.47 (1.50)	9.66 (1.07)	5.53 (0.88)	5.24 (0.86)
T_{12}	13.45 (1.19)	8.42 (1.02)	0.54 (0.41)	0.92 (0.47)	14.80 (1.23)	7.43 (0.97)	0.94 (0.47)	0.91 (0.46)
T_{13}	30.20 (1.51)	12.32 (1.16)	5.34 (0.87)	3.96 (0.78)	37.90 (1.60)	13.00 (1.18)	6.02 (0.90)	4.63 (0.82)
T_{14}	12.48 (1.61)	5.54 (0.88)	0.78 (0.44)	0.95 (0.47)	14.68 (1.22)	6.90 (0.95)	0.89 (0.46)	0.86 (0.46)
SEd	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.004
CD (P=0.05)	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.01

(Figures in parenthesis indicate log (x+2) transformed value)

in 20, 40, 80 and 120 DAS, respectively. The allelopathic treatments did not exhibit significant weed control.

4.2.3.2. Sedge weed (*Cyperus rotundus*) (Table 11) (Fig. 8 and 9)

Weed control treatments exerted significant influence on the density of *C.rotundus* in all the stages. In the first crop, among the weed management practices, cinmethylin @ 0.6 kg ha^{-1} + HW (T_7) showed lower weed population of 4.42, 3.36, 2.48 and 1.39 m^{-2} at 20, 40, 80 and 120 DAS respectively followed by cinmethylin @ 0.5 kg ha^{-1} + HW (T_5) (4.02, 4.13, 4.37 and 2.88 m^{-2} at 20, 40, 80 and 120 DAS, respectively) which was closely followed by pendimethalin @ 1.0 kg ha^{-1} + HW and HW twice treatments.

Greengram (T_{14}) as a smother crop showed partial control of *C.rotundus* of 20.96, 18.25, 8.01 and 6.05 m^{-2} at 20, 40, 80 and 120 DAS, respectively, which was closely followed by cowpea (T_2) as smother crop. The highest weed population of 23.17, 28.41, 33.06 and 25.60 m^{-2} was found in unweeded control (T_1) at 20, 40, 80 and 120 DAS, respectively. The allelopathic treatments did not exhibit significant weed control.

In the second crop, similar trend was observed with respect to weed control by pre-emergence application of cinmethylin and pendimethalin and HW twice.

Greengram (T_{14}) as a smother crop registered partial control of *C.rotundus* of 23.24, 19.41, 8.45 and 4.27 m^{-2} at 20, 40, 80 and 120 DAS, respectively. The highest weed population of 24.86, 32.04, 37.71 and 29.22 m^{-2} was recorded in unweeded control (T_1) at 20, 40, 80 and 120 DAS, respectively. The allelopathic treatments did not show any significant weed control. In general, the *C.rotundus* population was more in the second crop as compared to first crop.

Table 11. Effect of treatments on population of sedge (*Cyperus rotundus*) (No.m^{-2}) in cotton

Treat-ments	First crop (1998-1999)				Second crop (1999-2000)			
	20 DAS	40 DAS	80 DAS	120 DAS	20 DAS	40 DAS	80 DAS	120 DAS
T_1	23.17 (1.36)	28.41 (1.48)	33.06 (1.55)	25.60 (1.44)	24.86 (1.43)	32.04 (1.53)	37.71 (1.60)	29.22 (1.49)
T_2	20.03 (1.34)	16.08 (1.26)	7.88 (1.00)	6.08 (0.91)	22.19 (1.38)	22.43 (1.39)	8.62 (1.03)	17.83 (1.30)
T_3	12.83 (1.17)	14.94 (1.23)	11.77 (1.14)	9.65 (1.07)	14.67 (1.22)	16.43 (1.27)	14.42 (1.22)	12.05 (0.15)
T_4	4.22 (0.79)	5.02 (0.85)	9.67 (1.07)	7.05 (0.96)	4.69 (0.83)	5.33 (0.85)	7.20 (0.96)	5.60 (0.88)
T_5	4.02 (0.78)	4.13 (0.79)	4.37 (0.80)	2.88 (0.69)	4.71 (0.83)	4.74 (0.83)	3.87 (0.77)	3.13 (0.71)
T_6	5.49 (0.87)	3.42 (0.73)	5.14 (0.85)	4.21 (0.79)	5.00 (0.85)	4.00 (0.78)	6.55 (0.93)	4.29 (0.80)
T_7	4.42 (1.81)	3.36 (0.73)	2.48 (0.65)	1.39 (0.53)	6.01 (0.90)	3.90 (0.77)	2.99 (0.70)	1.77 (0.58)
T_8	19.61 (1.34)	10.55 (1.10)	13.33 (1.19)	11.86 (1.14)	21.30 (1.37)	12.46 (1.16)	14.66 (1.22)	12.18 (1.15)
T_9	21.55 (1.37)	9.04 (1.04)	8.42 (1.02)	6.15 (0.91)	23.00 (1.40)	9.81 (1.07)	9.79 (1.07)	2.92 (0.69)
T_{10}	22.73 (1.39)	10.91 (1.11)	9.91 (1.08)	7.33 (0.97)	24.33 (1.42)	11.72 (1.14)	10.56 (1.10)	8.09 (1.00)
T_{11}	17.42 (1.29)	9.93 (1.08)	10.86 (1.11)	8.84 (1.04)	18.05 (1.30)	10.83 (1.11)	11.11 (1.12)	2.26 (0.63)
T_{12}	21.89 (1.38)	19.06 (1.32)	6.49 (0.93)	5.89 (0.90)	24.00 (1.42)	20.41 (1.35)	7.08 (0.96)	5.47 (0.87)
T_{13}	22.94 (1.40)	25.56 (1.44)	10.15 (1.08)	7.01 (0.96)	24.82 (1.43)	27.30 (1.47)	11.73 (1.14)	6.35 (0.92)
T_{14}	20.96 (1.36)	18.25 (1.31)	8.01 (1.00)	6.05 (0.91)	23.24 (1.40)	19.41 (1.33)	8.45 (0.02)	4.27 (0.80)
SEd	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
CD (P=0.05)	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02

(Figures in parenthesis indicate log (x+2) transformed value)

4.2.3.3. Broad leaved weeds (Table 12) (Fig. 8 and 9)

In the first crop, among the weed management practices, pendimethalin @ 1.0 kg ha^{-1} + HW (T_3) registered less weed population of 5.24 and 5.55 at 20 and 40 DAS, respectively. At 80 and 120 DAS the weed population of HW twice (T_2) was found less (3.82 and 3.02 m^{-2}). This treatment was followed by cinmethylin @ 0.6 kg ha^{-1} + HW(T_7) and cinmethylin @ 0.5 kg ha^{-1} + HW (T_5) treatments.

Growing of greengram (T_{14}) as a smother crop registered less weed population of 12.58, 10.39, 19.93 and 17.27 in 20, 40, 80 and 120 DAS, respectively, which was comparable with cowpea (T_{12}) as a smother crop. The highest weed population of 76.12, 111.28, 93.29 and 38.33 m^{-2} was found in unweeded control (T_1) at 20, 40, 80 and 120 DAS, respectively. The allelopathic treatments did not exhibit significant weed control.

In the second crop, pendimethalin @ 1.0 kg ha^{-1} + HW (T_3) recorded less weed population of 6.06 and 6.99 m^{-2} in 20 and 40 DAS, respectively. At 80 and 120 DAS, HW twice (T_2) was found to have less weed population of 5.25 and 3.51 m^{-2} respectively. This treatment was followed by cinmethylin @ 0.6 kg ha^{-1} + HW (T_7) and cinmethylin 0.5 kg ha^{-1} + HW (T_5).

Greengram (T_{14}) as a smother crop registered less weed population of 15.30, 11.24, 26.65 and 23.37 m^{-2} in 20, 40, 80 and 120 DAS, respectively, which was comparable with the smother crop of cowpea (T_{12}). The highest weed population of 84.51, 116.60, 97.16 and 46.77 m^{-2} was registered in unweeded control (T_1) at 20, 40, 80 and 120 DAS, respectively. The weed population was higher in second crop as compared to first crop.

Table 12. Effect of treatments on population of broad leaved weeds (No.m^{-2}) in cotton

Treat-ments	First crop (1998-1999)				Second crop (1999-2000)			
	20 DAS	40 DAS	80 DAS	120 DAS	20 DAS	40 DAS	80 DAS	120 DAS
T_1	76.12 (1.89)	111.28 (2.05)	93.29 (1.98)	38.33 (1.61)	84.51 (1.94)	116.60 (2.07)	97.16 (2.00)	46.77 (1.69)
T_2	72.56 (1.87)	9.37 (1.06)	3.82 (0.77)	3.02 (1.70)	83.08 (1.93)	10.33 (1.09)	5.25 (0.86)	3.51 (0.74)
T_3	5.24 (0.86)	5.55 (0.88)	4.50 (0.81)	3.09 (0.71)	6.06 (0.91)	6.99 (0.95)	6.63 (0.94)	5.55 (0.88)
T_4	9.72 (1.07)	15.20 (1.24)	15.27 (1.24)	13.62 (1.19)	10.81 (1.11)	16.63 (1.27)	25.59 (1.44)	18.66 (1.32)
T_5	10.02 (1.08)	16.32 (1.26)	9.41 (1.06)	7.14 (0.96)	10.73 (1.10)	17.99 (1.30)	12.84 (1.17)	9.77 (1.07)
T_6	8.62 (0.03)	14.82 (1.23)	18.26 (1.31)	17.61 (1.29)	9.49 (1.06)	16.21 (1.26)	22.97 (1.40)	19.39 (1.33)
T_7	8.99 (1.04)	15.34 (1.24)	7.91 (1.00)	6.54 (0.93)	9.35 (1.05)	16.34 (1.26)	9.55 (1.06)	8.11 (1.01)
T_8	57.10 (1.77)	35.14 (1.57)	35.94 (1.58)	30.50 (1.51)	58.49 (1.78)	36.33 (1.59)	39.99 (1.62)	36.64 (1.59)
T_9	58.39 (1.78)	34.11 (1.56)	32.60 (1.54)	29.96 (1.50)	60.52 (1.80)	36.48 (1.59)	35.81 (1.58)	32.66 (1.54)
T_{10}	59.64 (1.79)	33.61 (1.55)	34.12 (1.56)	26.08 (1.45)	61.56 (1.80)	36.61 (1.59)	38.32 (1.61)	34.71 (1.57)
T_{11}	58.62 (1.78)	32.77 (1.54)	25.28 (1.44)	22.46 (1.39)	62.64 (1.81)	36.35 (1.59)	29.33 (1.50)	27.19 (1.47)
T_{12}	13.18 (1.18)	9.97 (1.08)	23.04 (1.40)	20.81 (1.36)	14.64 (1.23)	10.39 (1.09)	26.47 (1.45)	22.24 (1.38)
T_{13}	27.82 (1.47)	19.51 (1.33)	26.72 (1.46)	24.93 (1.43)	28.56 (1.49)	21.46 (1.37)	32.71 (1.54)	29.42 (1.50)
T_{14}	12.58 (1.16)	10.39 (1.09)	19.93 (1.34)	17.27 (1.29)	15.30 (1.24)	11.24 (1.22)	26.65 (1.46)	23.37 (1.40)
SEd	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
CD (P=0.05)	0.02	0.02	0.02	0.02	0.02	0.03	0.02	0.02

(Figures in parenthesis indicate log (x+2) transformed value)

4.2.3.3.1. *Digera arvensis* (Table 13)

In the first crop, the pre-emergence application of pendimethalin @ 1.0 kg ha^{-1} + HW (T_3) recorded less weed population of 3.10 and 3.75 m^{-2} in 20 and 40 DAS, respectively. At 80 and 120 DAS the HW twice (T_2) recorded less weed population of 1.20 and 0.76 m^{-2}, respectively. This was followed by cinmethylin 0.6 kg ha^{-1} + HW (T_7) and cinmethylin 0.5 kg ha^{-1} + HW (T_5) treatments.

Cotton + greengram (T_{14}) registered lesser weed population of 6.94, 5.84, 11.54 and 10.24 m^{-2} at 20, 40, 80 and 120 DAS, respectively, which was comparable with cowpea (T_{12}) as smother crop. The highest weed population of 48.25, 59.28, 34.54 and 23.24 was observed in unweeded control (T_1) plot. The allelopathic treatments did not exhibit significant weed control.

In the second crop, application of pendimethalin @ 1.0 kg ha^{-1} + HW (T_3) recorded less weed population of 1.68 and 3.94 m^{-2} in 20 and 40 DAS, respectively. At 80 and 120 DAS the less weed population of 1.29 and 0.96 m^{-2} was observed in HW twice (T_2). This treatment was followed by cinmethylin 0.6 kg ha^{-1} + HW (T_7) and cinmethylin 0.5 kg ha^{-1} + HW (T_5) treatments.

Lower weed population was observed in greengram (T_{14}) which was comparable with cowpea (T_{12}), it registered 7.20, 5.56, 17.03 and 15.99 m^{-2} at 20, 40, 80 and 120 DAS, respectively. The unweeded control (T_1), recorded highest weed population of 48.61, 66.26, 38.16, 26.92 m^{-2} at 20, 40, 80 and 120 DAS, respectively. In general, the weed population was maximum in the second crop as compared to first crop.

Table 13. **Effect of treatments on population of *Digera arvensis* (No.m^{-2}) in cotton**

Treat-ments	First crop (1998-1999)				Second crop (1999-2000)			
	20 DAS	40 DAS	80 DAS	120 DAS	20 DAS	40 DAS	80 DAS	120 DAS
T_1	48.25 (1.70)	59.28 (1.79)	34.54 (1.56)	23.24 (1.40)	48.61 (1.70)	66.26 (1.83)	38.16 (1.60)	26.92 (1.45)
T_2	47.25 (1.69)	4.95 (0.84)	1.20 (0.51)	0.76 (0.44)	46.45 (1.69)	5.33 (0.87)	1.29 (0.52)	0.96 (0.47)
T_3	3.10 (0.71)	3.75 (0.76)	3.12 (0.71)	1.38 (0.53)	1.68 (0.57)	3.94 (0.77)	3.11 (0.71)	3.11 (0.71)
T_4	6.54 (0.93)	9.24 (1.05)	8.84 (1.04)	7.86 (0.99)	4.42 (0.81)	10.08 (1.08)	12.97 (1.18)	10.74 (1.11)
T_5	6.12 (0.91)	9.84 (1.07)	4.35 (0.81)	4.25 (0.80)	4.06 (0.78)	10.91 (1.11)	7.44 (0.98)	5.45 (0.87)
T_6	5.21 (0.86)	8.85 (0.04)	9.82 (1.07)	9.33 (1.05)	3.98 (0.78)	9.79 (1.07)	11.31 (1.12)	9.52 (1.06)
T_7	4.95 (0.84)	9.54 (1.06)	3.68 (0.75)	3.53 (0.74)	3.89 (0.77)	10.37 (1.10)	4.29 (0.80)	3.96 (0.78)
T_8	36.42 (1.58)	23.24 (1.40)	22.42 (1.39)	20.42 (1.35)	35.66 (1.58)	24.14 (1.42)	27.16 (1.47)	25.28 (1.44)
T_9	37.54 (1.60)	23.32 (1.39)	21.54 (1.37)	20.64 (1.36)	36.04 (1.58)	22.54 (1.39)	25.23 (1.44)	23.53 (1.41)
T_{10}	38.21 (1.60)	21.22 (1.37)	22.24 (1.38)	15.52 (1.24)	36.27 (1.58)	24.75 (1.43)	26.94 (1.46)	21.27 (1.37)
T_{11}	37.89 (1.60)	19.54 (1.33)	17.98 (1.30)	14.24 (1.21)	36.43 (1.58)	22.42 (1.39)	21.66 (1.37)	20.64 (1.36)
T_{12}	7.15 (0.96)	5.54 (0.88)	15.32 (1.24)	15.67 (1.25)	7.20 (0.96)	5.56 (0.88)	17.03 (1.28)	15.99 (1.26)
T_{13}	14.52 (1.22)	10.24 (1.09)	18.25 (1.31)	18.33 (1.31)	15.72 (1.25)	11.30 (1.12)	22.48 (1.39)	18.66 (1.32)
T_{14}	6.94 (0.95)	5.84 (0.89)	11.54 (1.13)	10.24 (1.09)	7.35 (0.97)	5.88 (0.90)	16.45 (1.27)	16.25 (1.26)
SEd	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
CD (P=0.05)	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02

(Figures in parenthesis indicate log (x+2) transformed value)

4.2.3.3.2. *Trianthema portulacastrum* **(Table 14)**

In the first crop, pendimethalin @ 1.0 kg ha^{-1} + HW (T_3) recorded less weed population of 2.00 and 1.65 m^{-2} at 20 and 40 DAS, respectively. At 80 and 120 DAS, HW twice (T_2) recorded less weed population of 1.89 and 1.84 m^{-2} respectively. This was closely followed by cinmethylin @ 0.5 kg ha^{-1} (T_4) and cinmethylin 0.6 kg ha^{-1} (T_6) upto 40 DAS. The treatments such as cinmethylin 0.5 kg ha^{-1} + HW (T_5) and cinmethylin 0.6 kg ha^{-1} + HW (T_7) gave significant weed control in all the stages.

Greengram (T_{14}) as a smother crop with cotton recorded less weed population of 5.42, 3.52, 6.24 and 6.14 m^{-2} in 20, 40, 80 and 120 DAS, respectively, which was on par with cowpea (T_{12}). Unweeded control (T_1) recorded highest weed population of 23.24, 38.24, 42.28 and 9.33 m^{-2} at 20, 40, 80 and 120 DAS, respectively. The allelopathic treatment did not show significant weed control.

In the second crop, pendimethalin @ 1.0 kg ha^{-1} + HW (T_3) registered lesser weed population of 3.83, 1.89 and 2.02 at 20, 40 and 80 DAS, respectively. The treatments such as cinmethylin 0.5 kg ha^{-1} (T_4) and cinmethylin @ 0.6 kg ha^{1} (T_6) were comparable with cinmethylin @ 0.5 kg ha^{-1} + HW (T_5) and cinmethylin @ 0.6 kg ha^{-1} + HW (T_7) upto 40 DAS. At all stages cinmethylin 0.5 kg ha^{-1} + HW (T_5) and 0.6 kg ha^{-1} + HW (T_7) recorded lesser weed population.

Growing of greengram (T_{14}) as a smother crop recorded lesser weed population of 4.22, 3.90, 6.39 and 6.50 m^{-2} in 20, 40, 80 and 120 DAS, respectively, which was closely followed by cowpea (T_{12}) upto 80 DAS. The highest weed population of 26.17, 44.84, 46.41 and 11.08 was found in unweeded

Table 14. Effect of treatments on population of *Trianthema portulacastrum* (No.m^{-2}) in cotton

Treat-ments	First crop (1998-1999)				Second crop (1999-2000)			
	20 DAS	40 DAS	80 DAS	120 DAS	20 DAS	40 DAS	80 DAS	120 DAS
T_1	23.24 (1.40)	38.24 (1.60)	42.28 (1.65)	9.33 (1.05)	26.17 (1.45)	44.84 (1.67)	46.41 (1.68)	11.08 (1.12)
T_2	22.54 (1.39)	3.58 (0.75)	1.89 (0.59)	1.84 (0.58)	24.29 (1.42)	4.06 (0.78)	3.64 (0.75)	2.24 (0.63)
T_3	2.00 (0.60)	1.65 (0.56)	3.10 (0.71)	1.25 (0.51)	3.83 (0.77)	1.89 (0.59)	2.02 (0.60)	1.49 (0.54)
T_4	3.24 (0.72)	4.95 (0.84)	5.24 (0.86)	5.52 (0.88)	5.06 (0.85)	5.72 (0.89)	9.45 (1.06)	8.91 (1.04)
T_5	3.12 (0.71)	5.20 (0.86)	3.50 (0.74)	2.62 (0.67)	4.91 (0.84)	5.95 (0.90)	3.81 (0.76)	2.60 (0.66)
T_6	3.25 (0.72)	4.84 (0.84)	7.58 (0.98)	7.67 (0.99)	4.83 (0.84)	5.34 (0.87)	8.97 (1.04)	8.04 (1.00)
T_7	3.05 (0.70)	5.22 (0.86)	3.05 (0.70)	2.67 (0.67)	4.75 (0.83)	5.46 (0.87)	3.64 (0.75)	3.09 (0.71)
T_8	17.25 (1.28)	11.24 (1.12)	9.95 (1.08)	9.28 (1.05)	16.61 (1.27)	10.21 (1.09)	8.90 (1.04)	7.65 (0.98)
T_9	17.44 (1.29)	10.54 (1.10)	8.42 (1.02)	7.26 (0.97)	17.18 (1.28)	12.18 (1.15)	7.06 (0.96)	6.88 (0.95)
T_{10}	18.12 (1.30)	11.38 (1.13)	9.56 (1.06)	9.00 (1.04)	17.44 (1.29)	10.29 (1.09)	8.70 (1.03)	10.20 (1.09)
T_{11}	17.62 (1.29)	12.26 (1.15)	6.82 (0.95)	5.58 (0.88)	17.67 (1.29)	12.11 (1.15)	5.82 (0.89)	4.82 (0.83)
T_{12}	5.24 (0.86)	3.46 (0.74)	6.54 (0.93)	4.33 (0.80)	4.11 (0.79)	3.63 (0.75)	6.78 (0.94)	4.91 (0.84)
T_{13}	11.42 (1.13)	7.24 (0.97)	7.52 (0.98)	5.38 (0.87)	9.30 (1.05)	8.27 (1.01)	8.15 (1.01)	5.84 (0.89)
T_{14}	5.42 (0.87)	3.52 (0.74)	6.24 (0.92)	6.14 (0.91)	4.22 (0.79)	3.90 (0.77)	6.39 (0.92)	6.50 (0.93)
SEd	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
CD (P=0.05)	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02

(Figures in parenthesis indicate log (x+2) transformed value)

control (T_1) at 20, 40, 80 and 120 DAS, respectively. The allelopathic treatments (T_8, T_9, T_{10} and T_{11}) did not exhibit significant weed control in all stages.

4.2.3.4. Total weed population (Table 15)

Data showed that in the first crop of cotton (MCU 5), cinmethylin @ 0.6 kg ha^{-1} + HW (T_7) registered significantly lower weed population of 16.64, 25.89, 14.09 and 10.17 m^{-2} at 20, 40, 80 and 120 DAS, respectively. It was followed by cinmethylin @ 0.5 kg ha^{-1} + HW (T_5). This treatment was comparable with the application of pendimethalin @ 1.0 kg ha^{-1} + HW (T_3) and HW twice (T_2).

Greengram (T_{14}) as a smother crop registered lesser weed population of 86.64, 50.06, 34.6 and 28.77 m^{-2} at 20, 40, 80 and 120 DAS, respectively, which was on par with cowpea (T_{12}). The highest weed population of 171.33, 222.3, 188.47 and 130.11 m^{-2} was recorded in unweeded control (T_1) at 20, 40, 80 and 120 DAS, respectively. The allelopathic treatments such as parthenium incorporation @ 2 t ha^{-1} (T_8) and whole plant extract (10%) (T_9) did not exhibit any significant effect on weed control irrespective of the stages.

Similar trend was noticed in the second crop of cotton with respective to weed control by cinmethylin @ 0.6 kg ha^{-1} + HW (T_7), cinmethylin @ 0.5 kg ha^{-1} + HW (T_5), pendimethalin @ 1.0 kg ha^{-1} + HW (T_3) and HW twice (T_2) treatments.

Growing of greengram (T_{14}) as a smother crop recorded lower weed population of 92.71, 54.32, 41.97 and 33.72 m^{-2} in 20, 40, 80 and 120 DAS, respectively, which was on par with the cowpea (T_{12}). The highest weed population was recorded at all stages in the unweeded control plot (T_1) as in the case of first crop of cotton. The allelopathic treatment parthenium incorporation

Table 15. **Effect of treatments on total weed population (No.m^{-2}) in cotton**

Treatments	First crop (1998-1999)				Second crop (1999-2000)			
	20 DAS	40 DAS	80 DAS	120 DAS	20 DAS	40 DAS	80 DAS	120 DAS
T_1	171.33 (2.24)	222.3 (2.35)	188.47 (2.28)	130.11 (2.12)	186.45 (2.28)	247.36 (2.40)	205.10 (2.32)	145.40 (2.17)
T_2	165.66 (2.22)	31.28 (1.52)	18.51 (1.31)	14.46 (1.22)	181.19 (2.26)	38.96 (1.61)	20.36 (1.35)	27.33 (1.47)
T_3	26.21 (1.45)	30.02 (1.51)	21.64 (1.37)	20.74 (1.36)	30.42 (1.52)	35.08 (1.57)	29.33 (1.50)	23.73 (1.41)
T_4	18.01 (1.30)	28.47 (1.48)	31.16 (1.52)	26.42 (1.45)	20.24 (1.35)	31.77 (1.53)	41.71 (1.64)	32.40 (1.54)
T_5	17.48 (1.29)	28.92 (1.49)	18.28 (1.31)	15.04 (1.23)	20.09 (1.34)	31.93 (1.53)	24.07 (1.42)	16.29 (1.26)
T_6	17.32 (1.29)	25.63 (1.44)	30.92 (1.52)	28.45 (1.48)	18.31 (1.31)	28.27 (1.48)	38.94 (1.61)	33.28 (1.55)
T_7	16.64 (1.27)	25.89 (1.45)	14.09 (1.21)	10.17 (1.09)	19.03 (1.32)	28.45 (1.48)	16.62 (1.27)	12.63 (1.17)
T_8	150.55 (2.18)	62.44 (1.81)	61.44 (1.80)	52.94 (1.74)	156.02 (2.20)	67.45 (1.84)	67.31 (1.84)	59.66 (1.79)
T_9	132.88 (2.13)	58.11 (1.78)	52.12 (1.73)	46.01 (1.68)	138.48 (2.15)	63.11 (1.81)	57.32 (1.77)	42.85 (1.65)
T_{10}	158.73 (2.21)	61.75 (1.80)	55.66 (1.76)	43.50 (1.66)	163.97 (2.22)	66.82 (1.84)	60.96 (1.80)	49.85 (1.72)
T_{11}	129.32 (2.12)	58.84 (1.78)	43.18 (1.65)	37.36 (1.60)	136.15 (2.14)	63.88 (1.82)	47.98 (1.70)	36.28 (1.58)
T_{12}	89.79 (1.96)	52.29 (1.74)	36.33 (1.58)	32.62 (1.54)	97.18 (2.00)	56.98 (1.77)	40.64 (1.63)	34.42 (1.56)
T_{13}	125.17 (2.10)	81.89 (1.92)	45.72 (1.68)	38.77 (1.61)	130.44 (2.12)	87.98 (1.95)	53.70 (1.75)	43.27 (1.66)
T_{14}	86.64 (1.95)	50.06 (1.72)	34.16 (1.56)	28.77 (1.49)	92.71 (1.98)	54.32 (1.75)	41.97 (1.64)	33.72 (1.55)
SEd	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
CD (P=0.05)	0.03	0.03	0.03	0.03	0.02	0.03	0.03	0.03

(Figures in parenthesis indicate log (x+2) transformed value)

(T_8) and whole plant extract (T_9) did not exhibit any significant weed control in all the stages. In general, the total weed population was higher in the second crop as compared to first crop.

4.2.3.5. Relative density

The relative density values of grasses, sedges and broad leaved weeds at 20, 40, 80 and 120 DAS are shown in Tables 16 to 19.

The proportion of relative density was varied irrespective of all the stages. At 20 DAS, the relative density of broad leaved weeds were dominated in unweeded control (T_1) and HW twice (T_2). The relative density of grasses were less in cinmethylin treated plots than pendimethalin. In pendimethalin treated plots sedges were dominated than the grasses and broad leaved weeds in both the years. In allelopathic treated plots, (T_8, T_9, T_{10} and T_{11}) grasses and broad leaved weeds were more or less equally distributed than sedges. Growing of smother crops, grasses and sedges were dominated than broad leaved weeds in both the years.

At 40 DAS, grasses showed declining trend over broad leaved weeds and sedges. The proportion of total weed density of broad leaved weeds at 40 DAS was increased in both the years. In unweeded check, broad leaved weeds were dominant over grasses and sedges irrespective of all stages in both the years. In respect of hand weeding twice treatment, the relative density of sedges were dominant over other grasses and broad leaved weeds. The relative density values of broad leaved weeds was lower with pendimethalin applied plots. The relative density of grasses as well as sedges were less in cinmethylin applied plots than broad leaved weeds in both the years. In allelopathic treatments, the relative density of broad leaved weeds were dominant than grasses and sedges. Growing of smother crops, the relative density of grasses were dominant than the sedges and broad leaved weeds.

Table 16. Relative density (per cent) of weeds as influenced by weed management practices in cotton on 20 DAS

Treatments	First crop (1998-1999)			Second crop (1999-2000)		
	Grasses	Sedges	BLW	Grasses	Sedges	BLW
T_1	43.21	12.36	44.43	41.32	13.33	45.31
T_2	44.11	12.09	43.80	41.90	12.25	45.85
T_3	31.06	48.95	19.99	31.85	48.20	19.95
T_4	19.68	23.00	57.20	23.42	23.17	53.41
T_5	22.60	23.43	53.94	23.15	23.44	53.41
T_6	19.41	26.56	54.03	20.86	27.30	51.84
T_7	18.53	31.70	49.77	19.29	31.58	49.13
T_8	49.05	13.03	37.92	48.86	13.65	37.89
T_9	39.84	16.22	43.94	39.69	16.61	43.70
T_{10}	48.11	14.32	37.57	47.61	14.84	37.55
T_{11}	41.08	13.47	45.45	40.73	13.26	46.01
T_{12}	46.41	40.03	13.56	45.71	38.92	15.37
T_{13}	45.05	32.72	22.23	45.91	32.00	22.09
T_{14}	45.26	40.27	14.47	44.41	39.09	16.50

Table 17. Relative density (per cent) of weeds as influenced by weed management practices in cotton on 40 DAS

Treatments	First crop (1998-1999)			Second crop (1999-2000)		
	Grasses	Sedges	BLW	Grasses	Sedges	BLW
T_1	37.16	12.78	50.06	39.89	12.96	47.15
T_2	18.64	51.41	29.96	15.91	57.57	26.52
T_3	31.75	49.77	18.49	33.24	46.84	19.92
T_4	28.98	17.63	53.39	30.88	16.78	52.34
T_5	29.29	14.28	56.43	28.81	14.84	56.35
T_6	28.83	13.34	57.82	28.51	14.15	57.34
T_7	27.77	12.98	59.25	28.86	13.71	57.43
T_8	26.83	16.90	56.27	27.66	18.47	53.87
T_9	25.74	15.56	58.70	26.65	15.54	57.81
T_{10}	27.90	17.67	54.43	27.67	17.54	55.81
T_{11}	27.43	16.88	55.69	26.14	16.95	56.91
T_{12}	44.48	36.45	19.07	45.95	35.82	18.23
T_{13}	44.96	31.21	23.83	44.58	31.03	24.39
T_{14}	42.79	36.46	20.75	43.58	35.73	20.69

Table 18. Relative density (per cent) of weeds as influenced by weed management practices in cotton on 80 DAS

Treatments	First crop (1998-1999)			Second crop (1999-2000)		
	Grasses	Sedges	BLW	Grasses	Sedges	BLW
T_1	33.01	17.54	49.50	34.24	18.39	47.37
T_2	33.12	42.47	24.41	31.88	42.34	25.78
T_3	27.96	54.39	17.65	28.23	49.16	22.61
T_4	19.96	31.03	49.01	21.38	17.26	61.35
T_5	32.79	18.44	48.77	30.58	16.08	53.34
T_6	24.32	16.62	59.06	24.19	16.99	58.82
T_7	26.26	17.60	56.14	25.19	17.99	56.82
T_8	19.81	21.70	58.49	18.81	21.78	59.41
T_9	21.30	16.16	62.54	20.45	17.08	62.47
T_{10}	20.90	17.81	61.29	19.82	17.32	62.86
T_{11}	16.30	25.15	58.55	15.71	23.16	61.13
T_{12}	18.72	17.86	63.42	17.45	17.42	65.13
T_{13}	19.36	22.20	58.44	17.24	21.84	60.92
T_{14}	18.21	23.45	58.34	16.37	20.13	63.50

Table 19. Relative density (per cent) of weeds as influenced by weed management practices in cotton on 120 DAS

Treatments	First crop (1998-1999)			Second crop (1999-2000)		
	Grasses	Sedges	BLW	Grasses	Sedges	BLW
T_1	50.87	19.68	29.45	47.74	20.10	32.16
T_2	37.07	42.05	20.88	21.92	65.23	12.85
T_3	38.57	46.53	14.90	25.83	50.78	23.39
T_4	21.76	26.68	51.56	25.12	17.28	57.60
T_5	30.28	17.15	52.53	20.81	19.21	59.98
T_6	23.30	14.80	61.90	24.10	12.89	63.01
T_7	22.03	13.67	64.30	21.77	14.01	64.22
T_8	19.98	22.40	57.62	18.50	20.42	61.08
T_9	21.52	13.37	65.11	16.97	6.81	76.22
T_{10}	23.20	16.85	59.95	14.14	16.23	69.63
T_{11}	16.22	23.66	60.12	18.83	6.23	74.94
T_{12}	18.15	18.06	63.79	19.49	15.89	64.62
T_{13}	17.62	18.08	64.30	17.33	14.68	67.99
T_{14}	19.35	21.03	59.62	18.03	12.66	69.31

At 80 and 120 DAS, the relative density of grasses was declined over sedges and broad leaved weeds. The proportion of relative density of broad leaved weeds were increased over grasses and sedges in both the years. In unweeded check, the relative density of broad leaved weeds were dominant than grasses and sedges in both the years. In respect of HW twice, the relative density of sedges were dominant over grasses and broad leaved weeds in both the years. The relative density values of broad leaved weeds were decreased in pendimethalin applied plots. The relative density values of grasses and sedges were decreased in cinmethylin applied plots than broad leaved weeds in both the years. In allelopathic treatments, the relative density of broad leaved weed were dominant than the grasses and sedges. Growing of smother crops, the relative density of broad leaved weeds were dominant than sedges and grasses at 80 and 120 DAS observation in both the years.

4.2.4. Weed dry matter production (Weed DMP)

4.2.4.1. Grass weeds (Table 20)

In the first crop, cinmethylin @ 0.6 kg ha^{-1} + HW (T_7) registered significantly lower weed DMP of 4.70, 13.92, 7.14 and 6.87 kg ha^{-1} in 20, 40, 80 and 120 DAS, respectively, which was closely followed by cinmethylin @ 0.5 kg ha^{-1} + HW (T_5). This was comparable with pendimethalin @ 1.0 kg ha^{-1} + HW (T_3) and HW twice (T_2) treatments.

Greengram (T_{14}) as a smother crop registered lower weed DMP of 46.47, 58.61, 12.95 and 13.53 kg ha^{-1} in 20, 40, 80 and 120 DAS, respectively, which was comparable with the smother crop of cowpea (T_{14}). The highest weed DMP of 183.47, 231.58, 194.29 and 216.72 kg ha^{-1} was found in unweeded control (T_1) at 20, 40, 80 and 120 DAS respectively. The allelopathic treatments (T_8, T_9, T_{10} and T_{11}) did not exhibit any significant effect on weed DMP.

Table 20. **Dry matter production (DMP) of grasses as influenced by weed management practices in cotton (kg ha^{-1})**

Treat-ments	First crop (1998-1999)				Second crop (1999-2000)			
	20 DAS	40 DAS	80 DAS	120 DAS	20 DAS	40 DAS	80 DAS	120 DAS
T_1	183.47 (2.27)	231.58 (2.37)	194.29 (2.29)	216.72 (2.34)	185.85 (2.27)	243.50 (2.39)	216.10 (2.34)	222.95 (2.35)
T_2	171.50 (2.24)	10.43 (1.09)	11.78 (1.14)	12.92 (1.17)	180.21 (2.26)	9.57 (1.06)	12.54 (1.16)	10.88 (1.11)
T_3	12.94 (1.17)	17.07 (1.28)	9.65 (1.07)	18.35 (1.31)	17.22 (1.28)	23.20 (1.40)	11.30 (1.12)	11.12 (1.12)
T_4	5.33 (0.86)	17.02 (1.28)	13.82 (1.20)	15.26 (1.24)	6.61 (0.94)	20.80 (1.36)	47.81 (1.70)	22.27 (1.39)
T_5	6.01 (0.90)	16.62 (1.27)	10.99 (1.11)	7.83 (0.99)	6.72 (0.94)	19.92 (1.34)	11.27 (1.12)	7.12 (0.96)
T_6	4.78 (0.83)	14.10 (1.21)	15.50 (1.24)	16.15 (1.26)	5.43 (0.87)	15.95 (1.25)	23.43 (1.41)	18.33 (1.31)
T_7	4.70 (0.83)	13.92 (1.20)	7.14 (0.96)	6.87 (0.95)	5.18 (0.86)	17.45 (1.29)	9.60 (1.06)	6.30 (0.92)
T_8	73.61 (1.88)	81.82 (1.92)	31.48 (1.53)	34.02 (1.56)	69.98 (1.86)	94.61 (1.99)	31.11 (1.52)	33.63 (1.55)
T_9	49.58 (1.71)	70.04 (1.86)	29.34 (1.50)	31.63 (1.53)	50.76 (1.72)	81.16 (1.92)	27.93 (1.48)	21.91 (1.38)
T_{10}	75.11 (1.89)	93.86 (1.98)	29.78 (1.50)	35.34 (1.57)	66.76 (1.84)	99.33 (2.01)	29.47 (1.50)	18.88 (1.32)
T_{11}	56.41 (1.77)	76.11 (1.89)	15.24 (1.24)	15.87 (1.25)	49.47 (1.71)	78.98 (1.91)	17.76 (1.30)	20.82 (1.36)
T_{12}	49.37 (1.71)	73.30 (1.87)	14.14 (1.21)	12.88 (1.17)	53.29 (1.74)	77.40 (1.90)	14.72 (1.22)	15.25 (1.24)
T_{13}	103.19 (2.02)	162.96 (2.22)	25.97 (1.45)	20.65 (1.36)	103.96 (2.03)	170.38 (2.34)	23.05 (1.40)	21.99 (1.38)
T_{14}	46.47 (1.69)	58.61 (1.78)	12.95 (1.18)	13.53 (1.19)	49.58 (1.71)	66.39 (1.84)	12.86 (1.17)	14.07 (1.21)
SEd	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.001
CD (P=0.05)	0.03	0.03	0.02	0.02	0.01	0.03	0.03	0.02

(Figures in parenthesis indicate log (x+2) transformed value)

In the second crop, cinmethylin @ 0.6 kg ha^{-1} + HW(T_7) showed significantly lower weed DMP of 5.18, 17.45, 9.60 and 6.30 kg ha^{-1} in 20, 40, 80 and 120 DAS, respectively. It was followed by application of cinmethylin 0.5 kg ha^{-1} + HW (T_5) registered less weed DMP of 6.72, 19.92, 11.27 and 7.12 in 20, 40, 80 and 120 DAS, respectively. This was comparable with the application of pendimethalin @ 1.0 kg ha^{-1} + HW (T_3) and HW twice (T_2).

Growing of greengram (T_{14}) as a smother crop showed lesser weed DMP of 49.58, 66.39, 12.86 and 14.07 in 20, 40, 80 and 120 DAS, respectively, which was closely followed by cowpea (T_{12}). The highest weed DMP was observed irrespective of stages in unweeded control plots (T_1) as in the case of first crop. In general, the weed DMP was higher in the second crop as compared to first crop.

4.2.4.2. Sedge weeds (Table 21)

Weed management practices significantly influenced the sedge weed DMP in both the years at four stages. In the first crop, the cinmethylin and pendimethalin reduced the sedge weed DMP over hand weeding twice and unweeded control. Application of cinmethylin @ 0.6 kg ha^{-1} + HW (T_7) registered less weed DMP of 11.18, 6.37, 5.46 and 4.88 kg ha^{-1} in 20, 40, 80 and 120 DAS respectively. It was closely followed by cinmethylin @ 0.5 kg ha^{-1} + HW (T_5) which was comparable with the pendimethalin @ 1.0 kg ha^{-1} + HW (T_3) and HW twice (T_2) treatments.

Cotton + cowpea (T_{12}) showed high smothering ability, which recorded less weed DMP of 37.79, 13.26 and 12.79 in 20, 80 and 120 DAS, respectively. Cotton + greengram (T_{14}) was the next best treatment. Weeds from unweeded control (T_1) offered great competition with crops as evidenced from the progressively increased highest weed DMP of 44.21, 63.16, 77.43 and

Table 21. **Dry matter production (DMP) of sedge as influenced by weed management practices in cotton (kg ha^{-1})**

Treat-ments	First crop (1998-1999)				Second crop (1999-2000)			
	20 DAS	40 DAS	80 DAS	120 DAS	20 DAS	40 DAS	80 DAS	120 DAS
T_1	44.21 (1.67)	63.16 (1.81)	77.43 (1.90)	81.58 (1.92)	47.14 (1.69)	72.05 (1.87)	89.95 (1.96)	92.22 (1.97)
T_2	39.07 (1.61)	32.55 (1.54)	20.08 (1.34)	16.32 (1.26)	44.82 (1.67)	42.71 (1.63)	21.95 (1.38)	37.26 (1.59)
T_3	28.43 (1.48)	32.74 (1.54)	22.55 (1.39)	24.17 (1.42)	33.66 (1.55)	37.57 (1.60)	27.87 (1.48)	24.69 (1.43)
T_4	9.14 (1.05)	11.39 (1.13)	25.26 (1.44)	21.75 (1.38)	9.49 (1.06)	12.02 (1.15)	16.00 (1.26)	14.76 (1.22)
T_5	9.46 (1.06)	8.06 (1.00)	6.99 (0.95)	5.36 (0.87)	10.87 (1.11)	10.32 (1.09)	6.55 (0.93)	6.42 (0.93)
T_6	10.02 (1.09)	6.84 (0.95)	12.01 (1.15)	11.43 (1.13)	10.34 (1.09)	8.40 (1.02)	14.45 (1.22)	10.48 (1.10)
T_7	11.18 (1.12)	6.37 (0.92)	5.46 (0.87)	4.88 (0.84)	14.03 (1.21)	8.19 (1.01)	7.00 (0.95)	3.34 (0.73)
T_8	18.54 (1.31)	50.98 (1.72)	37.15 (1.60)	33.74 (1.55)	18.94 (1.32)	63.19 (1.81)	39.13 (1.61)	32.64 (1.54)
T_9	21.29 (1.37)	43.38 (1.66)	22.18 (1.38)	17.76 (1.30)	22.52 (1.39)	48.15 (1.70)	24.17 (1.42)	8.80 (1.03)
T_{10}	21.82 (1.38)	58.94 (1.79)	26.34 (1.45)	24.30 (1.42)	20.48 (1.35)	62.48 (1.81)	26.87 (1.46)	22.40 (1.39)
T_{11}	16.77 (1.27)	47.99 (1.70)	29.31 (1.50)	25.44 (1.44)	18.43 (1.31)	52.69 (1.74)	28.56 (1.49)	6.54 (0.93)
T_{12}	37.79 (1.60)	58.60 (1.78)	13.26 (1.18)	12.79 (1.17)	43.89 (1.66)	58.13 (1.78)	14.68 (1.22)	14.52 (1.22)
T_{13}	42.68 (1.65)	61.88 (1.81)	29.36 (1.50)	21.32 (1.37)	43.98 (1.66)	66.52 (1.84)	30.54 (1.51)	20.87 (1.36)
T_{14}	40.24 (1.63)	48.46 (1.70)	18.12 (1.30)	15.14 (1.23)	42.45 (1.65)	52.63 (1.74)	16.97 (1.28)	11.02 (1.11)
SEd	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
CD (P=0.05)	0.03	0.03	0.02	0.02	0.03	0.03	0.02	0.02

(Figures in parenthesis indicate log (x+2) transformed value)

81.58 kg ha^{-1} at 20, 40, 80 and 120 DAS, respectively. Among the allelopathic treatments, parthenium incorporation @ 2 t ha^{-1} (T_8) and whole plant extract (10%) (T_9) registered less weed DMP as compared to smother crops at 20 DAS.

In the second crop, similar trend was noticed with respect to weed DMP by application of cinmethylin, pendimethalin and HW twice.

Greengram (T_{14}) as a smother crop in cotton was capable of suppressing the growth of weeds and proved to be the best smother crop as evidenced from the lowest weed DMP of 42.45, 52.63, 16.97 and 11.02 kg ha^{-1} at 20, 40, 80 and 120 DAS, respectively. The cowpea (T_{12}) was the next best smother crop consistently suppressing the DMP irrespective of all the stages. The unweeded check (T_1) registered highest weed DMP of 47.14, 72.05, 89.95 and 92.22 kg ha^{-1} at 20, 40, 80 and 120 DAS, respectively.

4.2.4.3. Broad leaved weeds (Table 22)

The dry matter production of broad leaved weeds as influenced by the weed management practices showed significant variation. In the first crop, pendimethalin @ 1.0 kg ha^{-1} + HW (T_3) registered significantly lower weed DMP of 22.84, 26.02, 16.62 and 18.02 kg ha^{-1} at 20, 40, 80 and 120 DAS, respectively. This was followed by HW twice (T_2) registering lesser weed DMP except 20 DAS. This was comparable with the cinmethylin @ 0.6 kg ha^{-1} + HW (T_7) and 0.5 kg ha^{-1} + HW (T_5).

Cotton + greengram (T_{14}) was capable of suppressing the growth of weeds and proved to be the best smother crop evidenced from the lowest weed DMP of 33.05, 48.27, 67.51 and 67.09 kg ha^{-1} at 20, 40, 80 and 120 DAS, respectively. This was followed by cotton + cowpea (T_{12}) as a smother crop. The highest weed

Table 22. **Dry matter production (DMP) of broad leaved weeds as influenced by weed management practices in cotton (kg ha^{-1})**

Treat-ments	First crop (1998-1999)				Second crop (1999-2000)			
	20 DAS	40 DAS	80 DAS	120 DAS	20 DAS	40 DAS	80 DAS	120 DAS
T_1	211.50 (2.33)	277.73 (2.45)	227.08 (2.36)	167.05 (2.23)	233.17 (2.37)	317.54 (2.50)	238.55 (2.38)	193.66 (2.29)
T_2	195.30 (2.30)	39.79 (1.62)	24.84 (1.43)	19.09 (1.32)	222.46 (2.35)	39.28 (2.62)	26.80 (1.46)	22.31 (1.42)
T_3	22.84 (1.40)	26.02 (1.45)	16.62 (1.27)	18.02 (1.30)	25.18 (1.43)	33.10 (1.55)	25.66 (1.44)	26.60 (1.46)
T_4	33.71 (1.55)	47.56 (1.70)	55.21 (1.76)	58.76 (1.78)	33.49 (1.55)	50.74 (1.72)	40.47 (1.63)	71.52 (1.87)
T_5	28.88 (1.49)	45.74 (1.68)	30.79 (1.52)	27.20 (1.47)	29.45 (1.50)	52.78 (1.74)	35.37 (1.57)	30.28 (1.51)
T_6	30.45 (1.52)	45.32 (1.68)	56.78 (1.77)	60.90 (1.81)	33.04 (1.54)	49.14 (1.71)	58.98 (1.79)	68.01 (1.85)
T_7	26.69 (1.46)	44.23 (1.67)	29.81 (1.50)	24.96 (1.43)	29.38 (1.50)	46.05 (1.68)	33.43 (1.55)	28.49 (1.48)
T_8	83.51 (1.93)	228.05 (2.36)	125.61 (2.11)	127.53 (2.11)	86.48 (1.95)	238.48 (2.38)	132.36 (2.13)	142.54 (2.16)
T_9	91.23 (1.97)	197.53 (2.30)	105.20 (2.03)	120.84 (2.09)	92.41 (1.98)	212.74 (2.33)	118.71 (2.08)	127.84 (2.11)
T_{10}	90.37 (1.97)	237.37 (2.38)	119.86 (2.09)	114.24 (2.07)	84.48 (1.94)	255.60 (2.41)	127.67 (2.11)	127.57 (2.11)
T_{11}	88.47 (1.96)	189.82 (2.28)	91.89 (1.97)	87.34 (1.95)	92.82 (1.98)	208.71 (2.32)	98.57 (2.00)	109.76 (2.05)
T_{12}	35.77 (1.58)	50.71 (1.72)	74.84 (1.89)	72.84 (1.87)	36.28 (1.58)	49.68 (1.71)	85.38 (1.94)	4.17 (1.88)
T_{13}	60.98 (1.80)	98.12 (2.00)	100.47 (2.01)	103.60 (2.02)	67.62 (1.84)	104.54 (2.03)	109.12 (2.05)	112.91 (2.06)
T_{14}	33.05 (1.55)	48.27 (1.70)	67.51 (1.84)	67.09 (1.84)	37.13 (1.59)	51.27 (1.73)	79.72 (1.91)	76.93 (1.90)
SEd	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
CD (P=0.05)	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03

(Figures in parenthesis indicate log (x+2) transformed value)

DMP of 211.50, 277.73, 227.08 and 167.05 kg ha^{-1} was registered in unweeded control (T_1) at 20, 40, 80 and 120 DAS, respectively.

In the second crop, pendimethalin @ 1.0 kg ha^{-1} + HW (T_3) recorded significantly lower weed DMP of 25.18, 33.10, 25.66 and 26.60 kg ha^{-1} at 20, 40, 80 and 120 DAS, respectively, which was closely followed by HW twice (T_2), (39.28, 26.80 and 22.31 kg ha^{-1} at 40, 80 and 120 DAS, respectively). Cinmethylin @ 0.6 kg ha^{-1} + HW (T_7) and 0.5 kg ha^{-1} + HW (T_5) were the next best treatments, which were consistently reduced the weed DMP irrespective of all stages.

Greengram in cotton (T_{14}) was capable of suppressing weed growth and proved to be best smother crop. This was followed by cotton + cowpea (T_{12}) cropping system. Unweeded control (T_1) registered the highest weed DMP of 233.17, 317.54, 238.55 and 193.66 kg ha^{-1} at 20, 40, 80 and 120 DAS, respectively. The allelopathic treatments did not exhibit any significant effects on weed DMP irrespective of all stages.

4.2.4.4. Total weed dry matter production (Table 23) (Fig. 10)

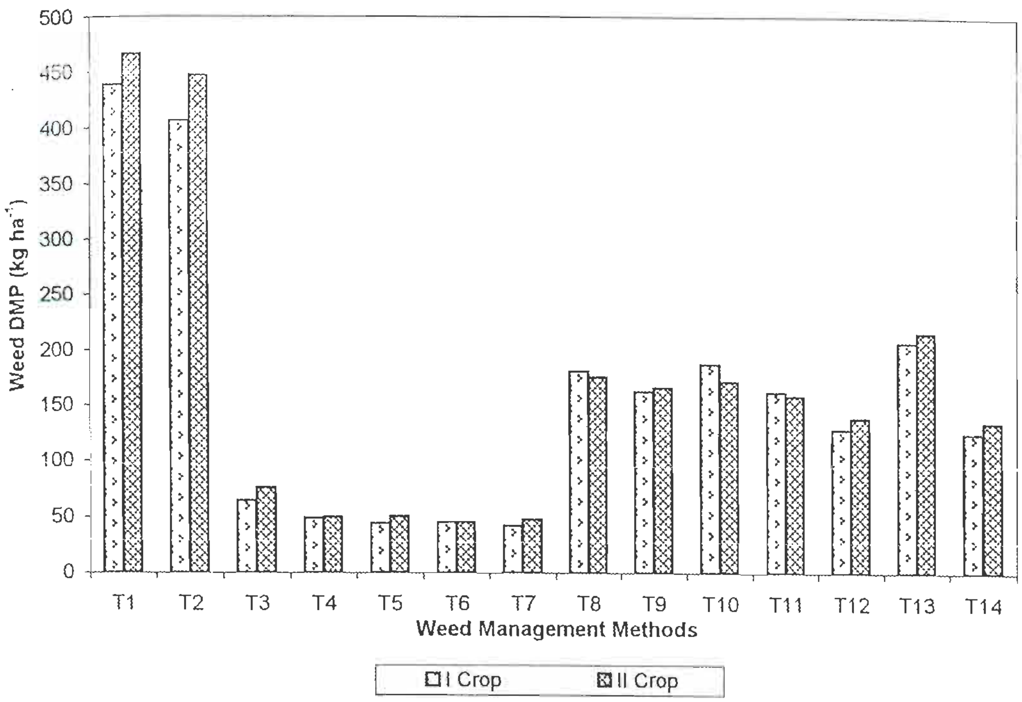
Significant variations were observed among the weed management practices with regard to weed DMP. At 20 DAS, application of cinmethylin and pendimethalin reduced the total weed DMP significantly over hand weeding twice and unweeded control. In the first crop, cinmethylin @ 0.6 kg ha^{-1} + HW (T_7) was recorded significantly lesser total weed DMP of 41.57, 64.52, 42.41 and 35.71 kg ha^{-1} at 20, 40, 80 and 120 DAS, respectively. This was comparable with the cinmethylin @ 0.5 kg ha^{-1} + HW (T_5) (44.28, 70.42, 44.40 and 38.46 kg ha^{-1} at 20, 40, 80 and 120 DAS, respectively). This was followed by pendimethalin @ 1.0 kg ha^{-1} + HW (T_3) and HW twice (T_2) treatments.

Table 23. **Total weed dry matter production (DMP) as influenced by weed management practices in cotton (kg ha^{-1})**

Treat-ments	First crop (1998-1999)				Second crop (1999-2000)			
	20 DAS	40 DAS	80 DAS	120 DAS	20 DAS	40 DAS	80 DAS	120 DAS
T_1	438.60 (2.64)	572.48 (2.76)	498.45 (2.70)	465.35 (2.67)	466.16 (2.67)	633.08 (2.80)	543.52 (2.74)	508.90 (2.71)
T_2	405.87 (2.61)	82.76 (1.93)	56.71 (1.77)	48.33 (1.77)	447.49 (2.65)	91.56 (1.97)	61.28 (1.80)	72.45 (1.87)
T_3	64.21 (1.82)	79.82 (1.91)	48.82 (1.71)	60.54 (1.80)	76.05 (1.89)	90.86 (1.97)	64.82 (1.83)	62.41 (1.81)
T_4	48.44 (1.70)	75.98 (1.89)	94.28 (1.98)	96.51 (1.99)	49.59 (1.71)	83.56 (1.93)	104.28 (2.03)	10.8.54 (2.04)
T_5	44.28 (1.67)	70.42 (1.86)	44.40 (1.67)	38.46 (1.61)	50.63 (1.72)	83.01 (1.93)	53.19 (1.74)	43.82 (1.66)
T_6	45.25 (1.67)	66.28 (1.83)	84.28 (1.94)	90.77 (1.97)	45.23 (1.67)	73.50 (1.88)	96.85 (2.00)	96.82 (2.00)
T_7	41.57 (1.64)	64.52 (1.82)	42.41 (1.65)	35.71 (1.58)	47.58 (1.70)	74.35 (1.88)	50.03 (1.72)	38.14 (1.60)
T_8	180.66 (2.26)	360.85 (2.56)	194.23 (2.29)	195.29 (2.30)	175.37 (2.25)	396.29 (2.60)	202.60 (2.31)	208.81 (2.32)
T_9	162.11 (2.22)	310.95 (2.50)	168.22 (2.23)	170.24 (2.24)	165.69 (2.22)	342.05 (2.54)	170.81 (2.24)	158.55 (2.21)
T_{10}	187.30 (2.28)	390.28 (2.59)	175.98 (2.25)	173.88 (2.25)	171.73 (2.24)	413.20 (2.62)	181.01 (2.27)	168.85 (2.23)
T_{11}	161.65 (2.21)	313.92 (2.50)	136.44 (2.14)	128.65 (2.12)	158.28 (2.21)	340.38 (2.53)	144.90 (2.17)	137.12 (2.14)
T_{12}	127.93 (2.11)	187.28 (2.28)	102.24 (2.02)	98.51 (2.00)	138.46 (2.15)	190.21 (2.28)	112.98 (2.06)	103.95 (2.03)
T_{13}	206.85 (2.32)	306.85 (2.49)	154.81 (2.20)	145.57 (2.17)	215.56 (2.34)	326.10 (2.52)	162.71 (2.22)	155.77 (2.20)
T_{14}	124.76 (2.10)	160.34 (2.21)	98.58 (2.00)	95.75 (1.99)	134.17 (2.13)	175.28 (2.25)	109.12 (2.05)	102.85 (2.02)
SEd	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
CD (P=0.05)	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03

(Figures in parenthesis indicate log (x+2) transformed value)

Fig.10. Effect of weed management methods on total dry matter production of weeds at 20 DAS during 1998-1999 and 1999-2000



Cotton + greengram (T_{14}) was capable of suppressing the weeds thereby reduced the total weed DMP of 124.76, 160.34, 98.58 and 95.75 kg ha^{-1} at 20, 40, 80 and 120 DAS, respectively. This was comparable with the cotton + cowpea (T_{12}). The unweeded control (T_1) registered the highest total weed DMP of 438.60, 572.48, 498.45 and 465.35 kg ha^{-1} at 20, 40, 80 and 120 DAS, respectively.

In the second crop, among the weed management practices, similar trend was noticed with respect to total weed DMP by application of cinmethylin with 2 doses, recommended dose of pendimethalin and HW twice treatments.

In cotton, greengram as smother crop (T_{14}) was capable of reducing weeds. It records lesser weeds and thereby decreased total weed DMP of 134.17, 175.28, 109.12 and 102.85 kg ha^{-1} at 20, 40, 80 and 120 DAS, respectively. This was on par with the cowpea (T_{12}) as a smother crop. The highest total weed DMP of 466.16, 633.08, 543.52 and 508.90 kg ha^{-1} was registered in unweeded control (T_1) at 20, 40, 80 and 120 DAS, respectively. The allelopathic treatments such as parthenium incorporation @ 2 t ha^{-1} (T_8) and whole plant extract (10%) (T_9) did not exhibit significant weed control. In over all view, the total weed DMP of second crop was maximum as compared to total DMP of first crop.

4.2.4.5. Relative dry weight (Tables 24 to 27)

The relative dry weight of grasses, sedges and broad leaved weeds as influenced by different weed management practices.

Generally in both the years the DMP of broad leaved weeds to the total weeds were in the range of 30.12 to 75.60 per cent which was higher than grasses (10.9 to 42.3 per cent) and sedges (9.63 and 41.4 per cent). At 20 DAS, the relative dry weight of broad leaved weeds were higher followed by grasses in

Table 24. Relative dry weight (per cent) of weeds as influenced by weed management practices in cotton on 20 DAS

Treatments	First crop (1998-1999)			Second crop (1999-2000)		
	Grasses	Sedges	BLW	Grasses	Sedges	BLW
T_1	41.83	10.08	48.22	39.87	10.11	50.02
T_2	42.25	9.63	48.12	38.32	11.50	50.21
T_3	21.15	38.28	40.57	23.64	38.25	38.11
T_4	12.00	18.87	68.59	12.30	20.10	67.40
T_5	13.57	20.36	66.22	12.27	20.47	67.26
T_6	11.56	22.14	66.29	13.01	23.86	63.33
T_7	11.31	23.49	65.20	10.89	28.36	60.75
T_8	36.75	10.26	52.99	35.90	10.80	53.31
T_9	30.58	13.13	56.28	32.64	13.59	53.77
T_{10}	37.10	11.65	51.25	36.87	11.93	51.19
T_{11}	32.90	10.37	56.73	30.25	11.64	59.64
T_{12}	33.59	33.45	32.96	34.49	35.31	30.20
T_{13}	32.22	28.30	39.48	33.95	29.68	36.37
T_{14}	32.25	36.26	31.49	31.95	35.37	32.67

Table 25. **Relative dry weight (per cent) of weeds as influenced by weed management practices in cotton on 40 DAS**

Treatments	First crop (1998-1999)			Second crop (1999-2000)		
	Grasses	Sedges	BLW	Grasses	Sedges	BLW
T_1	40.45	11.03	48.51	38.46	11.38	50.16
T_2	11.60	36.33	52.79	11.45	40.65	47.90
T_3	20.39	36.02	43.60	25.53	33.04	41.43
T_4	20.40	14.99	64.60	25.89	13.38	60.72
T_5	25.60	11.45	62.95	22.99	13.43	63.58
T_6	21.27	10.32	68.38	22.70	12.43	64.85
T_7	21.57	11.87	66.55	21.47	13.49	64.94
T_8	21.67	14.13	64.20	22.87	15.95	61.18
T_9	22.52	12.95	64.52	22.73	14.07	63.20
T_{10}	23.05	14.10	62.82	23.04	15.12	61.90
T_{11}	23.25	14.29	62.46	22.20	14.48	63.32
T_{12}	34.13	33.78	32.08	36.69	33.19	30.12
T_{13}	35.07	33.20	31.73	34.98	27.96	37.06
T_{14}	31.55	33.34	35.10	32.88	32.88	34.25

Table 26. Relative dry weight (per cent) of weeds as influenced by weed management practices in cotton on 80 DAS

Treatments	First crop (1998-1999)			Second crop (1999-2000)		
	Grasses	Sedges	BLW	Grasses	Sedges	BLW
T_1	38.98	15.53	45.56	39.76	16.55	43.88
T_2	19.77	36.41	43.80	20.46	30.82	48.73
T_3	19.77	41.19	39.04	17.43	37.99	44.58
T_4	14.66	25.79	59.56	40.85	15.34	43.80
T_5	19.75	14.74	65.51	20.19	13.31	66.50
T_6	19.39	15.25	65.37	22.19	14.92	62.90
T_7	17.84	13.87	68.29	20.19	13.99	65.82
T_8	17.21	20.13	62.67	17.36	19.31	63.33
T_9	18.44	17.19	64.37	17.35	16.15	66.50
T_{10}	17.92	15.96	66.00	17.02	14.60	68.38
T_{11}	13.17	21.48	65.35	13.27	19.74	67.12
T_{12}	15.83	13.97	70.20	14.03	13.99	71.98
T_{13}	16.78	18.97	64.90	15.39	18.78	65.43
T_{14}	15.14	16.12	68.48	12.79	15.55	71.06

Table 27. **Relative dry weight (per cent) of weeds as influenced by weed management practices in cotton on 120 DAS**

Treatments	First crop (1998-1999)			Second crop (1999-2000)		
	Grasses	Sedges	BLW	Grasses	Sedges	BLW
T_1	41.57	17.53	40.90	38.81	18.12	43.05
T_2	25.73	33.77	40.50	15.02	41.43	43.55
T_3	30.31	34.92	34.77	18.82	38.56	42.62
T_4	17.58	21.54	60.88	22.52	13.60	63.89
T_5	15.36	15.94	68.72	20.25	14.65	65.10
T_6	17.79	12.59	69.62	18.93	12.82	68.24
T_7	16.43	15.67	67.90	18.52	10.75	70.70
T_8	18.42	18.28	63.30	17.11	15.63	67.26
T_9	18.58	12.43	68.98	13.82	10.55	75.46
T_{10}	20.32	14.98	64.70	11.18	13.27	75.55
T_{11}	14.34	19.77	65.89	14.18	10.77	75.05
T_{12}	14.07	14.98	70.94	14.67	13.97	71.35
T_{13}	16.19	14.65	69.17	14.12	13.40	72.49
T_{14}	14.13	16.81	69.06	13.68	12.52	73.80

unweeded control and HW twice in both the years. In pendimethalin treated plot, the relative dry weight of sedges and broad leaved weeds were dominant at 20 and 40 DAS. Regarding broad leaved weeds, the relative dry weight showed distinct increase at 20 and 40 DAS in cinmethylin treated plots in both years. Growing of smother crops, the relative dry weight of grasses, sedges and broad leaved weeds were equally distributed in 20 and 40 DAS. Regarding allelopathic treatments, the relative dry weight of broad leaved weeds was more as compared to sedges and grasses at 20 and 40 DAS. Similar trend was observed in second year also.

At 80 and 120 DAS, In general the relative dry weight of broad leaved weeds were more as compared to grasses and sedges irrespective of all treatments. In unweeded control plot the relative dry weight of grasses and broad leaved weeds were more or less equally distributed at 80 and 120 DAS. In pendimethalin treated plots, the relative dry weight of sedges and broad leaved weeds were equally distributed than the grasses. Regarding broad leaved weeds, the relative DMP showed distinct increase at 80 and 120 DAS in cinmethylin treated plots. With respect to smothering crops and allelopathic treatments also higher relative dry weight of broad leaved weeds were recorded. Similar trend was observed in second year also.

4.2.4.6. Summed Dominance Ratio (SDR) (Tables 28 to 31)

At 20 and 40 DAS, it was found that lower values of summed dominance ratio for grasses and sedges with cinmethylin and for broad leaved weeds with pendimethalin. Higher values of summed dominance ratio of sedges was found in pendimethalin treated plots. At 20 DAS, with regard to smothering crops and allelopathic treatments, the grasses and broad leaved weeds were having equal values of summed dominance ratio. At 40 DAS, higher values of summer dominance ratio of broad leaved weeds were found irrespective of all treatments. Similar trend was observed in second crop also.

Table 28. Summed dominance ratio of weeds as influenced by weed management practices in cotton on 20 DAS

Treatments	First crop (1998-1999)			Second crop (1999-2000)		
	Grasses	Sedges	BLW	Grasses	Sedges	BLW
T_1	42.52	11.22	46.33	39.60	12.72	47.68
T_2	43.18	10.86	45.96	40.11	11.87	48.03
T_3	26.11	43.62	30.28	27.74	43.23	29.03
T_4	15.84	20.94	62.90	17.86	21.63	60.41
T_5	18.09	21.90	60.08	17.71	21.96	60.34
T_6	15.49	24.35	60.16	16.93	25.58	57.79
T_7	14.92	27.60	57.49	15.09	29.97	54.94
T_8	42.50	11.65	45.46	42.38	12.33	45.60
T_9	35.21	14.68	50.11	36.17	15.10	48.74
T_{10}	42.61	12.99	44.41	42.24	13.38	44.37
T_{11}	36.99	11.92	51.09	35.49	12.45	52.06
T_{12}	40.00	36.74	23.26	40.10	37.12	22.79
T_{13}	38.64	30.51	30.86	39.93	30.84	29.23
T_{14}	38.76	38.27	22.98	38.18	37.23	24.58

Table 29. **Summed dominance ratio of weeds as influenced by weed management practices in cotton on 40 DAS**

Treatments	First crop (1998-1999)			Second crop (1999-2000)		
	Grasses	Sedges	BLW	Grasses	Sedges	BLW
T_1	38.81	11.91	49.29	39.18	12.17	48.66
T_2	15.12	43.87	41.38	13.68	49.11	37.21
T_3	26.07	42.90	31.05	29.38	39.94	30.68
T_4	24.69	16.31	59.00	28.39	15.08	56.33
T_5	27.45	12.87	59.69	25.90	14.14	59.97
T_6	25.05	11.83	63.10	25.61	13.29	61.10
T_7	24.67	12.43	62.90	25.17	13.60	61.19
T_8	24.25	15.52	60.24	25.27	17.21	57.53
T_9	24.13	14.26	61.61	24.69	14.81	60.51
T_{10}	25.48	15.89	58.63	25.36	16.33	58.86
T_{11}	25.34	15.59	59.08	24.17	15.72	60.12
T_{12}	39.31	35.12	25.58	41.32	34.51	24.18
T_{13}	40.02	31.71	27.78	39.78	29.51	30.73
T_{14}	37.17	34.90	27.93	38.23	34.31	27.47

Table 30. Summed dominance ratio of weeds as influenced by weed management practices in cotton on 80 DAS

Treatments	First crop (1998-1999)			Second crop (1999-2000)		
	Grasses	Sedges	BLW	Grasses	Sedges	BLW
T_1	36.00	16.55	47.53	37.00	17.57	45.63
T_2	26.45	39.44	34.12	26.17	31.58	37.26
T_3	23.87	47.79	28.35	22.83	43.58	33.60
T_4	17.31	28.41	54.29	45.75	16.30	37.95
T_5	26.27	16.59	57.14	25.39	14.70	59.92
T_6	21.86	15.94	62.22	23.19	15.96	60.86
T_7	22.05	15.74	62.22	22.69	15.99	61.32
T_8	18.51	20.92	60.58	18.09	20.55	61.37
T_9	19.87	16.68	63.46	19.05	16.62	64.49
T_{10}	19.41	16.89	63.65	18.42	15.96	65.62
T_{11}	14.74	23.32	61.95	14.49	21.45	64.13
T_{12}	17.28	15.92	66.81	15.74	15.71	68.56
T_{13}	18.07	20.59	61.67	16.32	20.31	63.18
T_{14}	16.68	19.79	63.41	14.58	17.84	67.28

Table 31. Summed dominance ratio of weeds as influenced by weed management practices in cotton on 120 DAS

Treatments	First crop (1998-1999)			Second crop (1999-2000)		
	Grasses	Sedges	BLW	Grasses	Sedges	BLW
T_1	46.22	18.61	35.18	43.28	19.11	37.61
T_2	31.40	37.91	30.69	18.47	53.33	28.20
T_3	34.44	40.73	24.84	22.33	44.67	33.01
T_4	19.67	24.11	56.22	23.82	15.44	60.75
T_5	22.82	16.55	60.63	20.53	16.93	62.54
T_6	20.55	13.70	65.76	21.52	12.86	65.63
T_7	19.23	14.67	66.10	20.15	12.38	67.46
T_8	19.20	20.34	60.46	17.81	18.03	64.17
T_9	20.05	12.90	67.05	15.40	8.68	75.82
T_{10}	21.76	15.92	62.33	12.66	14.75	72.59
T_{11}	15.28	21.72	63.01	16.51	8.50	75.00
T_{12}	16.11	16.52	67.37	17.08	14.93	67.99
T_{13}	17.16	16.37	66.74	15.73	14.04	70.24
T_{14}	16.74	18.92	64.34	15.86	12.59	71.56

Application of pendimethalin showed lower values of summed dominance ratio for broad leaved weeds and grasses than sedges at 80 and 120 DAS. Cinmethylin application showed lesser values of summed dominance ratio for grasses and sedges than broad leaved weeds at 80 and 120 DAS. Among the smothering crops and allelopathic treatments higher values of summed dominance ratio were registered for broad leaved weeds than grasses and sedges at 80 and 120 DAS. Irrespective of treatments higher values of summed dominance ratio were recorded for broad leaved weeds at all the stages in both the seasons.

4.2.4.7. Weed Control Efficiency (WCE %)(Tables 32 and 33) (Fig. 11 and 12)

In the first crop, highest degree of weed control efficiency was registered in cinmethylin @ 0.6 kg ha^{-1} + HW (T_7) (90.51, 88.72, 91.49 and 92.30 per cent at 20, 40, 80 and 120 DAS, respectively). This was closely followed by cinmethylin @ 0.6 kg ha^{-1} (T_6) upto 40 DAS. This treatment was comparable with cinmethylin @ 0.5 kg ha^{-1} + HW (T_5) (89.91, 87.38, 90.93 and 91.76 per cent at 20, 40, 80 and 120 DAS, respectively) followed by pendimethalin @ 1.0 kg ha^{-1} + HW (T_3) recorded the degree of WCE of 85.35, 86.06, 90.59 and 86.98 per cent at 20, 40, 80 and 120 DAS, respectively.

Highest WCE of 71.56, 71.96, 80.22 and 79.39 per cent were registered in cotton + greengram (T_{14}) at 20, 40, 80 and 120 DAS, respectively. This was closely followed by cowpea (T_{12}) as smother crop in cotton. The allelopathic treatments were registered lower degree of WCE.

Similar trend was noticed in the second crop. Cinmethylin @ 0.6 kg ha^{-1} + HW (T_7) recorded higher WCE of 90.23, 88.61, 90.79 and 92.50 per cent at 20, 40, 80 and 120 DAS, respectively. This was closely followed by cinmethylin

Table 32. Weed Control Efficiency (WCE) and Weed Index (WI) as influenced by weed management practices in cotton during 1998-1999

Treatments	Weed control efficiency (per cent)				Weed index (per cent)
	20 DAS	40 DAS	80 DAS	120 DAS	
T_1	*	*	*	*	60.05
T_2	*	85.53	88.61	89.60	11.93
T_3	85.35	86.06	90.59	86.98	5.66
T_4	88.96	86.43	79.75	79.31	16.33
T_5	89.91	87.38	90.93	91.76	*
T_6	89.67	88.41	81.51	80.48	14.95
T_7	90.51	88.72	91.49	92.30	10.09
T_8	58.81	36.88	60.99	57.97	54.70
T_9	62.98	45.68	66.25	63.37	49.46
T_{10}	57.29	34.74	64.67	62.59	39.27
T_{11}	63.09	45.09	72.63	72.31	32.58
T_{12}	70.83	67.31	79.46	78.83	14.00
T_{13}	52.77	46.35	68.94	68.69	55.63
T_{14}	71.56	71.96	80.22	79.39	12.58

Table 33. **Weed Control Efficiency (WCE) and Weed Index (WI) as influenced by weed management practices in cotton during 1999-2000**

Treatments	Weed control efficiency (per cent)				Weed index (per cent)
	20 DAS	40 DAS	80 DAS	120 DAS	
T_1	*	*	*	*	61.85
T_2	*	85.52	88.71	85.75	11.21
T_3	83.58	85.65	88.07	87.72	6.24
T_4	89.08	86.78	79.79	78.67	17.07
T_5	89.29	86.89	90.20	91.39	*
T_6	89.73	88.26	81.16	80.95	15.35
T_7	90.23	88.61	90.79	92.5	9.89
T_8	62.11	37.30	62.69	58.95	56.44
T_9	64.25	45.90	68.57	68.82	50.91
T_{10}	62.91	34.73	66.11	66.78	40.43
T_{11}	65.81	46.19	73.34	73.03	32.89
T_{12}	70.09	69.94	79.19	79.55	14.07
T_{13}	50.99	48.49	69.06	69.36	57.11
T_{14}	71.04	72.28	80.92	79.77	12.99

Fig.11. Effect of weed management methods on Weed Control Efficiency (WCE) of cotton at 20 and 40 DAS (1998-1999)

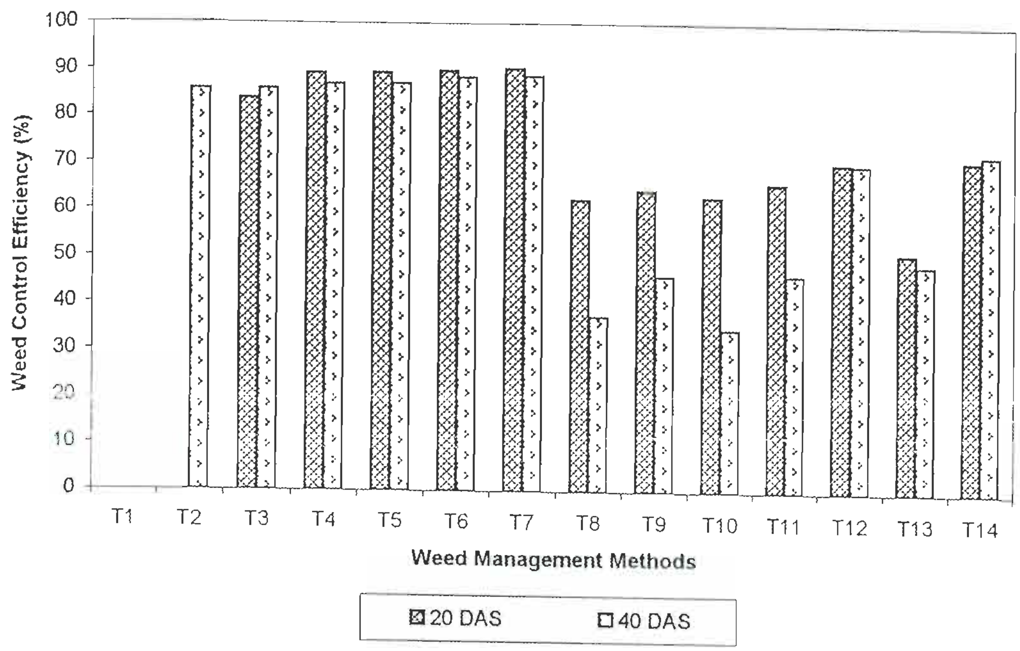
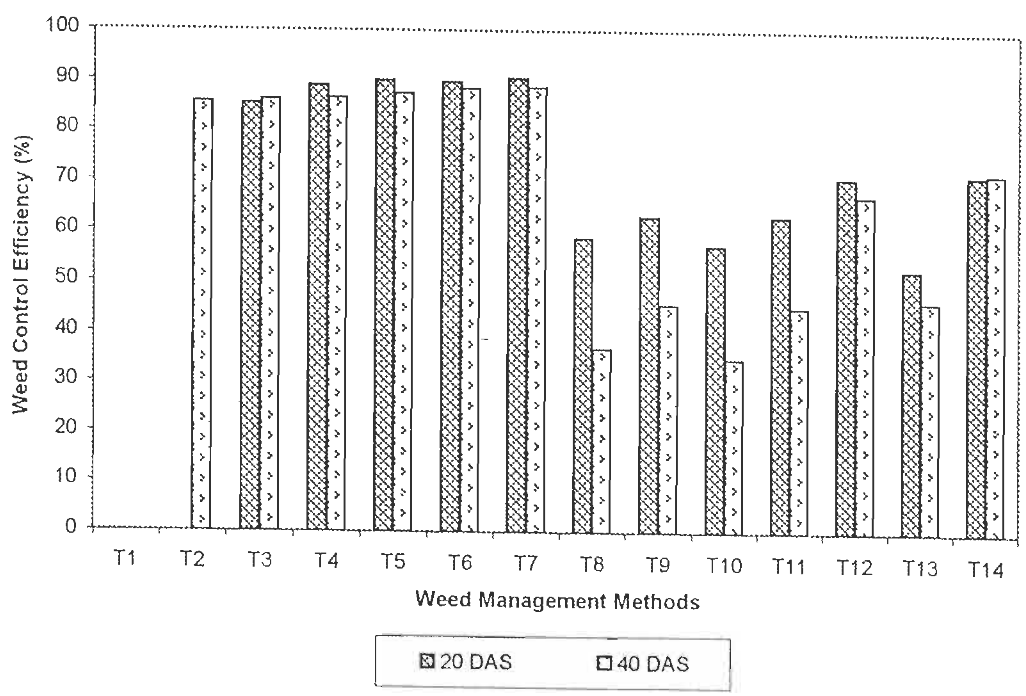


Fig.12. Effect of weed management methods on Weed Control Efficiency (WCE) of cotton at 20 and 40 DAS (1999-2000)



@ 0.5 kg ha^{-1} + HW (T_5) and HW twice (T_2) (except 20 DAS) followed by pendimethalin @ 1.0 kg ha^{-1} + HW (T_3) was registered the WCE of 83.58, 85.65, 88.07 and 87.72 per cent at 20, 40, 80 and 120 DAS, respectively.

Cotton + greengram (T_{14}) registered higher WCE of 71.04, 72.28, 80.92 and 79.77 per cent at 20, 40, 80 and 120 DAS, respectively and this was closely followed by smother crop of cotton + cowpea (T_{12}).

4.2.4.8. Weed Index (WI) (Tables 32 and 33) (Fig. 13)

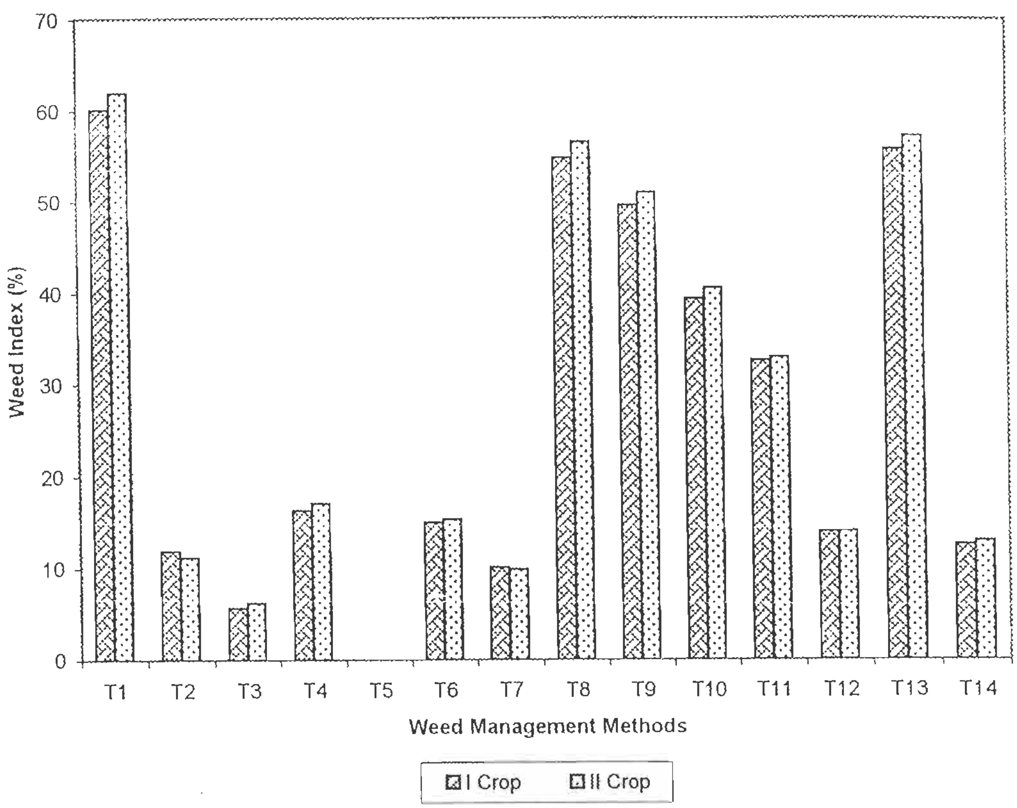
Cinmethylin at 0.5 kg ha^{-1} + HW (T_5) was taken as base for computing weed index. In both the years pendimethalin @ 1.0 kg ha^{-1} HW (T_3) recorded the lowest weed index of 5.66 and 6.24 per cent followed by cinmethylin at 0.6 kg ha^{-1} + HW (T_7), which recorded 10.09 and 9.89 per cent in the first and second crop, respectively.

Greengram as smothering crop, in cotton (T_{14}) registered lowest weed index of 12.58 and 12.99 per cent followed by cowpea (T_{12}) as a smother crop (14.00 and 14.07 per cent in the first and second crop, respectively). Unweeded control (T_1) showed higher weed index of 60.05 and 61.85 per cent, while hand weeding recorded 11.93 and 11.21 per cent. Among the allelopathic treatments, the weed index varies from 32.58 to 54.70 per cent and 32.89 to 56.44 per cent in the first and second crop, respectively.

4.2.5. Nutrient depletion by weeds

The data on the depletion of major plant nutrient *viz.,* N, P and K by weeds at 20, 40, 80 and 120 DAS are presented below.

Fig.13. Effect of weed management methods on Weed Index (WI) of cotton during 1998-1999 and 1999-2000



4.2.5.1. Nitrogen (Table 34) (Fig. 14 to 17)

Weed management practices significantly reduced the uptake of N by weeds. At 20 DAS, cinmethylin and pendimethalin application reduced the N removal by weeds as compared to hand weeding twice and unweeded control.

In the first crop, data showed that application of cinmethylin @ 0.6 kg ha^{-1} + HW (T_7) registered lowest N removal by weeds (1.08, 1.76, 1.32 and 1.02 kg ha^{-1} at 20, 40, 80 and 120 DAS, respectively) followed by cinmethylin @ 0.5 kg ha^{-1} + HW (T_5) (1.12, 1.98, 1.22 and 1.10 kg ha^{-1} at 20, 40, 80 and 120 DAS, respectively). Next best treatments were pendimethalin @ 1.0 kg ha^{-1} + HW (T_3) and HW twice (T_2) both were comparable with each other. Regarding smother crops, greengram (T_{14}) registered the lowest N depletion of 2.96, 3.04, 2.40 and 2.12 kg ha^{-1} at 20, 40, 80 and 120 DAS, respectively, which was comparable with cowpea (T_{12}) as a smother crop. The highest depletion of N by weeds of 9.02, 16.92, 15.28 and 17.28 kg ha^{-1} was found in unweeded control (T_1) at 20, 40, 80 and 120 DAS, respectively. The allelopathic treatments, parthenium incorporation @ 2 t ha^{-1} (T_8) and whole plant extract (10%) (T_9) were showed higher degree of N depletion by weeds.

Similar trend was noticed in the second crop with respect to N depletion by weeds in cinmethylin at 0.6 kg ha^{-1} + HW (T_7) (1.04, 1.97, 1.40 and 1.10 kg ha^{-1} at 20, 40, 80 and 120 DAS, respectively), cinmethylin 0.5 kg ha^{-1} + HW (T_5), pendimethalin @ 1.0 kg ha^{-1} + HW (T_3) and HW twice (T_2).

With respect to smothering crops, greengram (T_{14}) showed the lowest N depletion of 3.19, 3.82, 2.90 and 2.82 kg ha^{-1} at 20, 40, 80 and 120 DAS, respectively, which was closely followed by smother crop of cowpea (T_{12}). The unweeded control (T_1) recorded highest degree of N depletion of 9.79, 17.73,

Table 34. **Nitrogen uptake by weeds as influenced by weed management practices in cotton (kg ha^{-1})**

Treat-ments	First crop (1998-1999)				Second crop (1999-2000)			
	20 DAS	40 DAS	80 DAS	120 DAS	20 DAS	40 DAS	80 DAS	120 DAS
T_1	9.02	16.92	15.28	17.28	9.79	17.73	16.26	17.96
T_2	8.89	2.53	1.54	1.98	9.27	2.79	1.63	2.02
T_3	1.58	2.28	1.28	1.95	1.49	2.56	1.74	1.90
T_4	1.35	2.15	2.30	2.89	1.11	2.34	2.79	3.04
T_5	1.12	1.98	1.22	1.10	1.04	2.00	1.46	1.17
T_6	1.17	2.02	2.12	2.29	1.13	2.08	2.68	2.71
T_7	1.08	1.76	1.32	1.02	1.04	1.97	1.40	1.10
T_8	4.31	10.89	4.89	5.43	4.27	11.09	5.15	5.79
T_9	3.58	8.76	4.20	4.45	3.90	9.67	4.73	4.44
T_{10}	4.41	9.84	4.68	4.02	4.17	10.72	5.11	4.25
T_{11}	3.65	7.94	3.26	3.98	3.77	8.53	3.85	3.76
T_{12}	3.03	3.84	2.98	2.56	3.30	4.24	3.07	2.91
T_{13}	4.89	7.56	4.12	4.18	5.19	8.42	4.55	4.27
T_{14}	2.96	3.04	2.40	2.12	3.19	3.82	2.90	2.82
SEd	0.13	0.22	0.15	0.16	0.14	0.23	0.16	0.17
CD (P=0.05)	0.27	0.45	0.31	0.33	0.28	0.48	0.33	0.35

Fig. 14. Effect of weed management methods on NPK uptake of weeds and crop at 20 DAS (1998-1999)

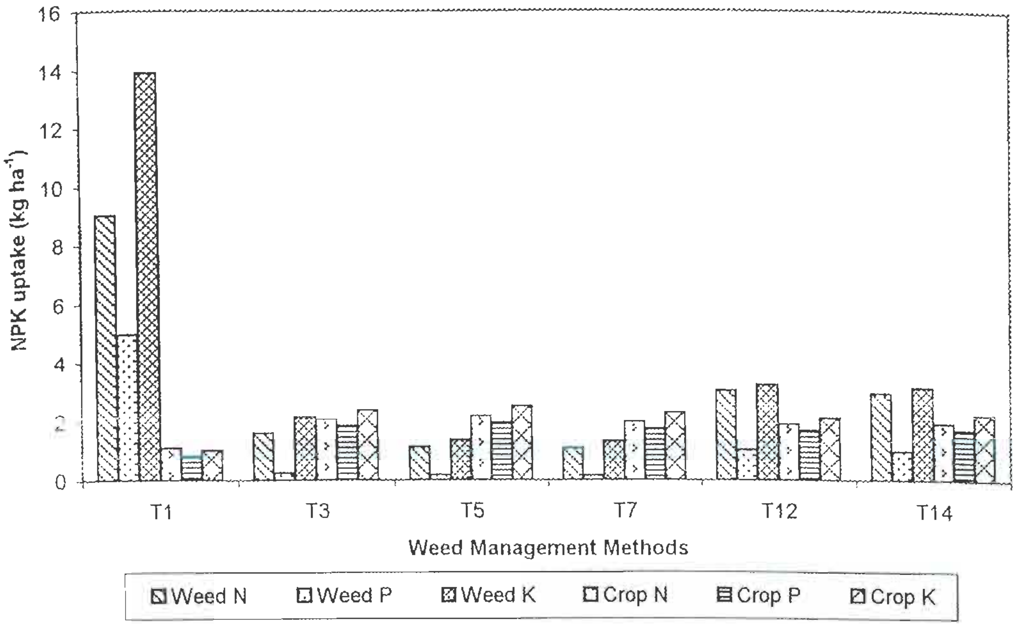


Fig. 15. Effect of weed management methods on NPK uptake of weeds and crop at 40 DAS (1998-1999)

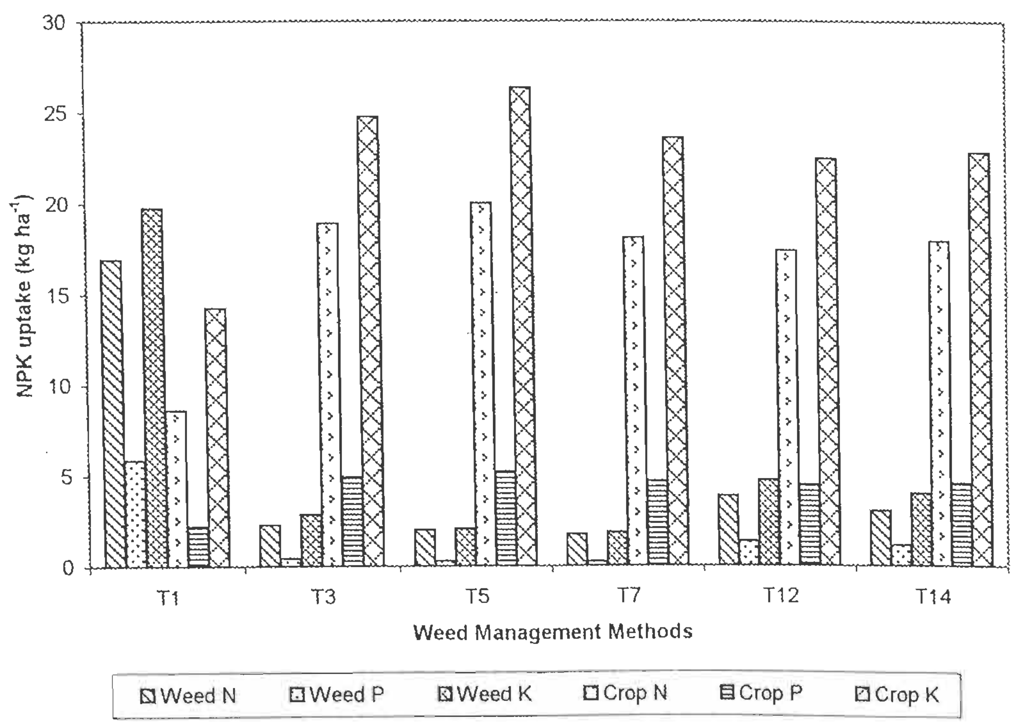


Fig. 16. Effect of weed management methods on NPK uptake of weeds and crop at 20 DAS (1999-2000)

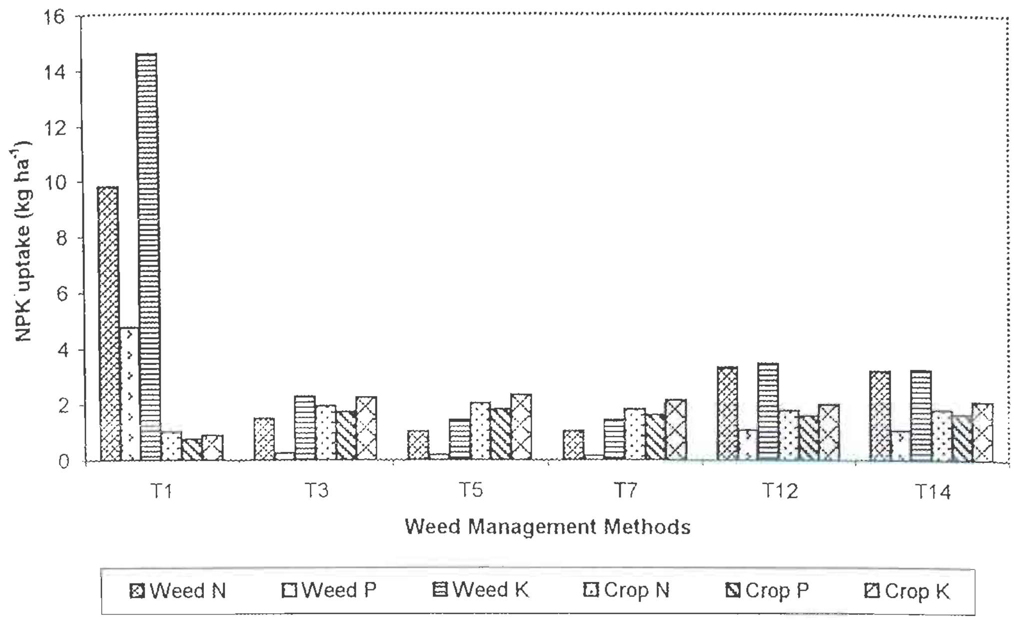
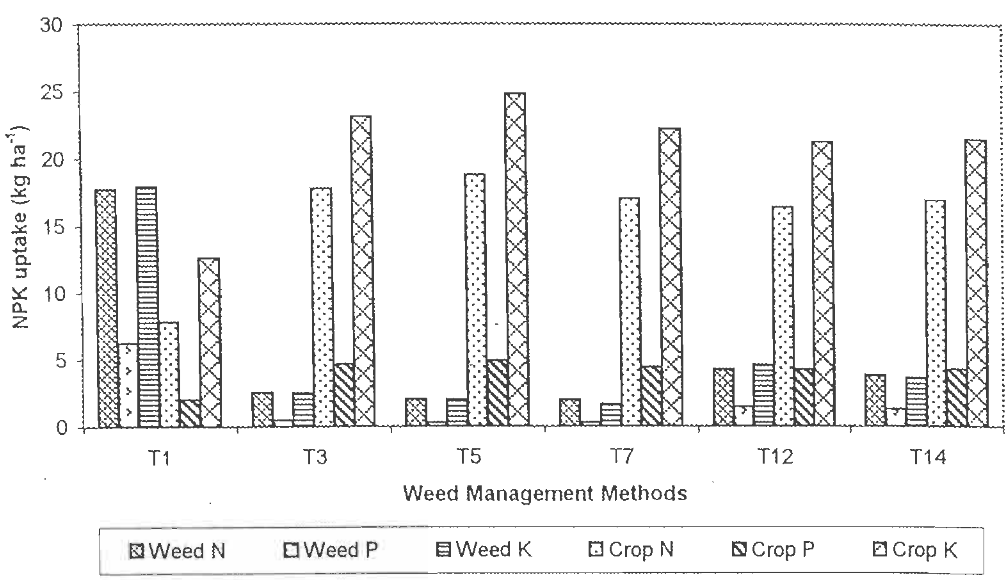


Fig. 17. Effect of weed management methods on NPK uptake of weeds and crop at 40 DAS (1999-2000)



16.26 and 17.96 at 20, 40, 80 and 120 DAS, respectively. The allelopathic treatments did not exhibit any effect on reducing N depletion by weeds. In over all view, the N depletion by weeds was maximum in the second crop as compared to first crop.

4.2.5.2. Phosphorus (Table 35) (Fig. 14 to 17)

Different weed management practices significantly reduced the uptake of P by weeds. At 20 DAS, application of cinmethylin and pendimethalin reduced the P removal by weeds over hand weeding twice and unweeded control in both the crops.

In the first crop, application of cinmethylin at 0.6 kg ha^{-1} + HW (T_7) observed lowest P removal by weeds (0.16, 0.25, 0.20 and 0.29 kg ha^{-1} at 20, 40, 80 and 120 DAS, respectively) followed by cinmethylin at 0.5 kg ha^{-1} + HW (T_5) (0.18, 0.27, 0.26 and 0.30 kg ha^{-1} at 20 40, 80 and 120 DAS, respectively). This treatment was comparable with pendimethalin @ 1.0 kg ha^{-1} + HW (T_3) and HW twice (T_2).

Growing of greengram (T_{14}) as a smother crop showed the lowest removal of P by weeds of 0.98, 1.15, 0.69 and 0.87 at 20, 40, 80 and 120 DAS, respectively. This treatment was comparable with cowpea (T_{12}) as a smother crop. The unweeded control (T_1) showed highest degree of P depletion of 4.97, 5.84, 5.21 and 6.02 kg ha^{-1} at 20, 40, 80 and 120 DAS, respectively. The allelopathic treatments did not show significant difference irrespective of all stages.

Similar trend was obtained in the second crop with respect to P depletion by weeds in cinmethylin at 0.6 kg ha^{-1} + HW (T_7) (0.15, 0.27, 0.25 and 0.28 kg ha^{-1} at 20, 40, 80 and 120 DAS, respectively), cinmethylin at 0.5 kg ha^{-1} + HW (T_5) (0.19, 0.30, 0.29 and 0.32 kg ha^{-1} at 20, 40, 80 and 120 DAS,

Table 35. **Phosphorus uptake by weeds as influenced by weed management practices in cotton (kg ha^{-1})**

Treat-ments	First crop (1998-1999)				Second crop (1999-2000)			
	20 DAS	40 DAS	80 DAS	120 DAS	20 DAS	40 DAS	80 DAS	120 DAS
T_1	4.97	5.84	5.21	6.02	4.76	6.26	5.34	6.21
T_2	3.84	0.40	0.34	0.40	4.49	0.45	0.35	0.42
T_3	0.23	0.42	0.29	0.38	0.25	0.47	0.32	0.35
T_4	0.20	0.30	0.48	0.59	0.21	0.34	0.53	0.61
T_5	0.18	0.27	0.26	0.30	0.19	0.30	0.29	0.32
T_6	0.19	0.29	0.45	0.48	0.18	0.31	0.47	0.54
T_7	0.16	0.25	0.20	0.29	0.15	0.27	0.25	0.28
T_8	1.61	3.26	2.15	2.12	1.73	3.52	2.24	2.15
T_9	1.49	2.82	1.89	1.86	1.59	2.95	1.89	1.89
T_{10}	1.35	2.48	1.45	2.02	1.42	2.56	1.52	2.10
T_{11}	1.28	2.05	1.29	1.58	1.34	2.20	1.34	1.66
T_{12}	1.02	1.35	0.79	1.00	1.09	1.43	0.84	1.03
T_{13}	2.04	2.28	1.45	2.01	2.12	2.45	1.56	2.00
T_{14}	0.98	1.15	0.69	0.87	1.07	1.31	0.79	0.98
SEd	0.06	0.07	0.05	0.06	0.06	0.07	0.05	0.06
CD (P=0.05)	0.12	0.14	0.11	0.12	0.13	0.15	0.11	0.13

respectively), pendimethalin @ 1.0 kg ha^{-1} + HW (T_3) and HW twice (T_2) treatments.

With regard to greengram as smothering crop in cotton (T_{14}) showed lowest P removal of 1.07, 1.31, 0.79 and 0.98 kg ha^{-1} at 20, 40, 80 and 120 DAS, respectively, which was on par with the smother crop of cowpea (T_{12}). The highest P removal of 4.76, 6.26, 5.34 and 6.21 was found in unweeded control (T_1) at 20, 40, 80 and 120 DAS, respectively. With respect to allelopathic treatments, did not give much difference as compared to herbicide treatments and smothering crops.

4.2.5.3. Potassium (Table 36) (Fig. 14 to 17)

Significant variations in K uptake by weeds were observed among the weed management practices. In the first crop, cinmethylin @ 0.6 kg ha^{-1} + HW (T_7) recorded lowest K removal of 1.32, 1.86, 1.31 and 1.18 kg ha^{-1} at 20, 40, 80 and 120 DAS, respectively. This was on par with the application of cinmethylin @ 0.5 kg ha^{-1} + HW (T_5) irrespective of the stages. Pendimethalin @ 1.0 kg ha^{-1} + HW (T_3) and HW twice (T_2) both were on par with each other.

Regarding smother crops, greengram (T_{14}) received lower K removal of 3.15, 3.98, 2.32 and 2.52 kg ha^{-1} at 20, 40, 80 and 120 DAS, respectively. This was comparable with cowpea (T_{12}) as a smother crop. The highest K removal of 13.89, 19.78, 15.82 and 13.98 kg ha^{-1} was registered in unweeded control (T_1) at 20, 40, 80 and 120 DAS, respectively.

Trend was similar with respect to second crop, K removal of weeds by application of cinmethylin @ 0.6 kg ha^{-1} + HW (T_7) (1.42, 1.64, 1.38 and 1.23 kg ha^{-1} at 20, 40, 80 and 120 DAS, respectively) followed by cinmethylin @ 0.5 kg ha^{-1} + HW (T_5), pendimethalin @ 1.0 kg ha^{-1} + HW (T_3) and HW twice (T_2) treatments.

Table 36. **Potassium uptake by weeds as influenced by weed management practices in cotton (kg ha^{-1})**

Treat-ments	First crop (1998-1999)				Second crop (1999-2000)			
	20 DAS	40 DAS	80 DAS	120 DAS	20 DAS	40 DAS	80 DAS	120 DAS
T_1	13.89	19.78	15.82	13.98	14.57	17.89	16.54	14.02
T_2	12.45	2.86	2.04	1.65	13.98	2.74	2.08	2.00
T_3	2.12	2.84	2.07	1.68	2.28	2.48	2.12	1.72
T_4	1.40	2.40	2.68	2.52	1.52	2.24	2.86	2.78
T_5	1.35	2.07	1.38	1.12	1.43	1.99	1.66	1.28
T_6	1.39	1.93	2.39	2.38	1.41	1.87	2.66	2.54
T_7	1.32	1.86	1.31	1.18	1.42	1.64	1.38	1.23
T_8	5.24	10.89	5.23	5.15	5.48	9.87	5.57	5.24
T_9	4.28	9.53	4.98	4.26	4.35	8.92	5.06	4.16
T_{10}	5.22	10.33	5.15	4.16	5.28	9.82	5.33	4.22
T_{11}	3.87	8.51	3.87	3.48	3.96	7.68	3.98	3.60
T_{12}	3.24	4.76	2.89	2.65	3.46	4.58	3.11	2.72
T_{13}	5.28	8.28	4.23	3.54	5.39	8.15	4.47	3.89
T_{14}	3.15	3.98	2.32	2.52	3.22	3.62	2.40	2.65
SEd	0.19	0.24	0.16	0.14	0.19	0.22	0.16	0.14
CD (P=0.05)	0.38	0.50	0.33	0.29	0.39	0.46	0.33	0.30

Growing of greengram (T_{14}) as a smother crop recorded lower K depletion of 3.22, 3.62, 2.40 and 2.65 kg ha^{-1} at 20, 40, 80 and 120 DAS, respectively, which was closely followed by cowpea (T_{12}) as smother crop except at 80 DAS. The unweeded control (T_1) registered highest K removal of 14.57, 17.89, 16.54 and 14.02 kg ha^{-1} at 20, 40, 80 and 120 DAS, respectively. Regarding allelopathic treatments of parthenium incorporation and whole plant extract did not show much variation with compared to herbicides and smother crops. In general, the K depletion was maximum in the second crop as compared to first crop.

4.3. Studies on cotton

4.3.1. Growth characters of cotton

4.3.1.1. Germination of cotton (percentage) (Tables 37 and 38)

There were no significant difference in germination of cotton due to different treatments evaluated. These results showed that application of cinmethylin at 0.6 kg ha^{-1} and 0.5 kg ha^{-1} did not cause any toxic effect to cotton plant in both the years. However, application of cinmethylin @ 0.6 kg ha^{-1} showed lesser germination compared to other herbicide treatment such as pendimethalin @ 1.0 kg ha^{-1} in both the years.

4.3.1.2. Plant height

The data on plant height recorded at 20, 40, 80 and 120 DAS are presented in tables 37 and 38. The trend in plant height taken at different stages indicated that there was a continuous increment in plant height from 20 to 120 DAS.

Weed management practices exerted a significant positive effect on plant height of cotton irrespective of all stages in both the crops. In the first crop, cinmethylin @ 0.5 kg ha^{-1} followed by hand weeding at 40 DAS (T_5) registered higher plant height irrespective of all stages (18.51, 39.08, 76.41 and 109.10 cm at 20, 40, 80 and 120 DAS, respectively). This treatment was closely followed by

Table 37. Effect of weed management practices on germination percentage and plant height (cm) of cotton during 1998-1999

Treatments	Germination (%)	Plant height (cm)			
		20 DAS	40 DAS	80 DAS	120 DAS
T_1	96.00 (78.69)	11.30	26.08	56.58	74.23
T_2	95.67 (78.19)	12.44	34.37	68.87	98.61
T_3	95.57 (78.04)	17.61	37.63	73.62	105.40
T_4	94.80 (76.98)	17.58	37.08	65.63	93.98
T_5	96.43 (79.40)	18.51	39.08	76.41	109.10
T_6	93.67 (75.54)	15.85	33.98	67.06	96.03
T_7	92.93 (74.67)	16.80	35.96	70.37	100.75
T_8	96.10 (78.85)	12.52	28.17	60.63	80.13
T_9	95.67 (78.19)	13.39	28.85	62.59	82.53
T_{10}	96.23 (79.08)	14.49	30.49	63.37	85.29
T_{11}	94.60 (76.71)	15.45	31.23	64.16	89.06
T_{12}	95.57 (78.04)	16.10	34.86	67.44	96.53
T_{13}	95.73 (78.30)	12.36	27.45	59.71	78.40
T_{14}	95.90 (78.79)	16.34	35.02	68.44	97.99
SEd	2.40	0.46	0.99	2.00	1.69
CD(P=0.05)	NS	0.95	2.03	4.12	3.48

(Figures in parenthesis indicate Arc sine transformed value)

Table 38. Effect of weed management practices on germination percentage and plant height (cm) of cotton during 1999-2000

Treatments	Germination (%)	Plant height (cm)			
		20 DAS	40 DAS	80 DAS	120 DAS
T_1	95.67 (78.19)	10.06	22.76	48.43	67.92
T_2	94.60 (76.71)	11.02	32.36	63.02	94.17
T_3	93.53 (75.37)	15.98	34.41	67.36	100.40
T_4	94.70 (76.84)	15.89	34.22	60.71	90.06
T_5	95.30 (77.66)	16.72	36.07	70.49	104.19
T_6	93.33 (75.14)	14.38	31.59	61.93	91.23
T_7	93.13 (74.90)	15.18	33.44	65.13	95.71
T_8	94.53 (76.57)	11.31	26.05	55.71	75.93
T_9	95.10 (77.38)	12.09	26.63	57.58	81.37
T_{10}	94.30 (76.32)	13.09	28.05	58.23	81.45
T_{11}	94.40 (76.43)	13.95	28.73	59.02	84.70
T_{12}	93.53 (75.37)	14.57	32.07	62.03	92.07
T_{13}	94.53 (76.61)	11.00	25.39	54.99	72.91
T_{14}	96.23 (79.07)	14.78	32.37	63.00	94.32
SEd	2.07	0.41	0.91	1.84	2.64
CD (P=0.05)	NS	0.85	1.87	3.78	5.42

(Figures in parenthesis indicate Arc sine transformed value)

application of pendimethalin @ 1.0 kg ha^{-1} followed by hand weeding at 40 DAS (T_3) recorded higher plant height of 17.61, 37.63, 73.62 and 105.40 cm at 20, 40, 80 and 120 DAS, respectively. Cinmethylin 0.6 kg ha^{-1} + HW (T_7) and HW twice (T_2) both were at par with each other except 20 DAS.

Regarding smother crops, greengram (T_{14}) registered higher plant height of 16.34, 35.02, 68.44 and 97.99 cm at 20, 40, 80 and 120 DAS, respectively, which was on par with the cowpea (T_{12}) as a smother crop. The lowest plant height of 11.30, 26.08, 56.58 and 74.23 cm were recorded in unweeded control (T_1) at 20, 40, 80 and 120 DAS, respectively. Among the allelopathic studies, parthenium incorporation @ 2 t ha^{-1} + HW (T_{10}) and whole plant extract (10%) (T_{11}) followed by hand weeding at 40 DAS (T_{11}) recorded higher plant height.

In the second crop, different weed management practices significantly influenced the plant height, cinmethylin 0.5 kg ha^{-1} followed by hand weeding at 40 DAS (T_5) recorded highest plant height of 16.72, 36.07, 70.49 and 104.19 cm at 20, 40, 80 and 120 DAS, respectively. This was on par with the application of pendimethalin @ 1.0 kg ha^{-1} + HW (T_3) recorded the plant height of 15.98, 34.41, 67.36 and 100.40 cm at 20, 40, 80 and 120 DAS , respectively. Cinmethylin @ 0.5 kg ha^{-1} (T_4) recorded higher plant height upto 40 DAS. Application of cinmethylin @ 0.6 kg ha^{-1} with or without hand weeding were on par with each other regarding plant height.

Greengram and cowpea as smother crops registered higher plant height and both were comparable with each other. The unweeded control (T_1) showed lower plant height of 10.06, 22.76, 48.43 and 67.92 cm at 20, 40, 80 and 120 DAS, respectively. With regard to allelopathic effect of parthenium, it did not having much influence on plant height.

4.3.1.3. Leaf area index (LAI)

The data on mean leaf area index evaluated for four stages (20, 40, 80 and 120 DAS) are presented in Tables 39 and 40. The results showed that there was an increment in LAI from 20 to 120 DAS for all the treatments evaluated similar to performance in plant height.

In the first crop, cinmethylin @ 0.5 kg ha^{-1} followed by hand weeding at 40 DAS (T_5) recorded higher LAI of 0.083, 0.39, 2.32 and 3.88 at 20, 40, 80 and 120 DAS, respectively. This treatment was closely followed by pendimethalin @ 1.0 kg ha^{-1} + HW (T_3) irrespective of all the stages except 80 DAS. At 40 and 120 DAS, application of cinmethylin @ 0.6 kg ha^{-1} + HW (T_7) and HW twice (T_2) were comparable with each other.

Greengram in cotton (T_{14}) registered highest LAI of 0.072, 0.33, 2.15 and 3.52 at 20, 40, 80 and 120 DAS, respectively, which are closely followed by cowpea (T_{12}) as a smother crop. The lowest LAI of 0.056, 0.23, 1.37 and 2.62 was found in unweeded control (T1) at 20, 40, 80 and 120 DAS, respectively. Regarding to allelopathic treatments, parthenium incorporation and whole plant extract spray with manual weeding at 40 DAS showed partial increment of LAI.

In the second crop, application of cinmethylin @ 0.5 kg ha^{-1} + HW (T_5) recorded highest LAI of 0.079, 0.36, 2.26 and 3.81 at 20, 40, 80 and 120 DAS, respectively. This was on par with pendimethalin @ 1.0 kg ha^{-1} + HW (T_3) at 40, 80 and 120 DAS except 20 DAS. At 40, 80 and 120 DAS, application of cinmethylin @ 0.6 kg ha^{-1} + HW (T_7) and HW twice (T_2) were comparable with each other except at 20 DAS.

Cotton + greengram (T_{14}) registered highest LAI of 0.069, 0.32, 2.11 and 3.47 at 20, 40, 80 and 120 DAS, respectively. This was comparable at 40 and

Table 39. **Effect of weed management practices on leaf area index (LAI) of cotton during 1998-1999**

Treatments	Leaf area index			
	20 DAS	40 DAS	80 DAS	120 DAS
T_1	0.056	0.23	1.37	2.62
T_2	0.058	0.34	2.17	3.55
T_3	0.080	0.37	2.20	3.76
T_4	0.079	0.34	2.03	3.43
T_5	0.083	0.39	2.32	3.88
T_6	0.075	0.32	2.05	3.45
T_7	0.076	0.35	2.31	3.60
T_8	0.063	0.27	1.92	2.94
T_9	0.065	0.29	1.94	3.26
T_{10}	0.066	0.30	1.98	3.32
T_{11}	0.067	0.31	2.01	3.36
T_{12}	0.071	0.32	2.11	3.50
T_{13}	0.062	0.25	1.68	2.88
T_{14}	0.072	0.33	2.15	3.52
SEd	0.003	0.01	0.04	0.06
CD (P=0.05)	0.015	0.02	0.07	0.12

Table 40. **Effect of weed management practices on leaf area index (LAI) of cotton during 1999-2000**

Treatments	Leaf area index			
	20 DAS	40 DAS	80 DAS	120 DAS
T_1	0.049	0.20	1.29	2.49
T_2	0.052	0.32	2.12	3.48
T_3	0.075	0.34	2.17	3.69
T_4	0.075	0.29	2.01	3.38
T_5	0.079	0.36	2.26	3.81
T_6	0.068	0.31	2.03	3.41
T_7	0.074	0.33	2.24	3.54
T_8	0.059	0.25	1.85	2.88
T_9	0.063	0.26	1.87	3.20
T_{10}	0.064	0.28	1.92	3.28
T_{11}	0.064	0.29	1.98	3.31
T_{12}	0.067	0.31	2.08	3.45
T_{13}	0.058	0.23	1.59	2.78
T_{14}	0.069	0.32	2.11	3.47
SEd	0.003	0.01	0.06	0.10
CD (P=0.05)	0.010	0.02	0.12	0.21

120 DAS with cowpea (T_{12}) as smother crop. The unweeded control (T_1) recorded lower LAI of 0.049, 0.20, 1.29 and 2.49 at 20, 40, 80 and 120 DAS, respectively. Among the allelopathic treatments, integration of hand weeding at 40 DAS with parthenium showed moderate increase in LAI. In general, the leaf area index was maximum in first crop as compared to second crop.

4.3.1.4. Dry matter production (DMP) (Tables 41 and 42) (Fig. 18)

Weed management practices caused significant variation in DMP at all four stages in both crops. In the first crop, data showed that application of cinmethylin @ 0.5 kg ha^{-1} + HW (T_5) recorded higher DMP of 77, 714, 2699 and 5245 kg ha^{-1} at 20, 40, 80 and 120 DAS, respectively. Next best treatment was pendimethalin @ 1.0 kg ha^{-1} + HW (T_3) (2545 and 4951 kg ha^{-1} at 80 and 120 DAS, respectively). Application of cinmethylin @ 0.6 kg ha^{-1} followed by hand weeding at 40 DAS (T_7) and HW twice (T_2) treatments both were on par with each other irrespective of all stages.

Greengram as smother crop in cotton (T_{14}) registered highest DMP of 69, 642, 2354 and 4612 kg ha^{-1} at 20, 40, 80 and 120 DAS, respectively. This was closely followed by cowpea (T_{12}) as a smother crop. The lowest DMP of 37, 307, 1232 and 2398 kg ha^{-1} was recorded in unweeded control (T_1) at 20, 40, 80 and 120 DAS, respectively. Among the allelopathic treatments, the DMP was increased when hand weeding was integrated with parthenium incorporation and whole plant extract spray.

In second crop, cinmethylin @ 0.5 kg ha^{-1} followed by hand weeding at 40 DAS (T_5) found to record higher DMP of 74, 685, 2589, 4995 kg ha^{-1} at 20, 40, 80 and 120 DAS, respectively. At 20 and 40 DAS, this was comparable with application of cinmethylin @ 0.5 kg ha^{-1} (T_4). The next best treatment was

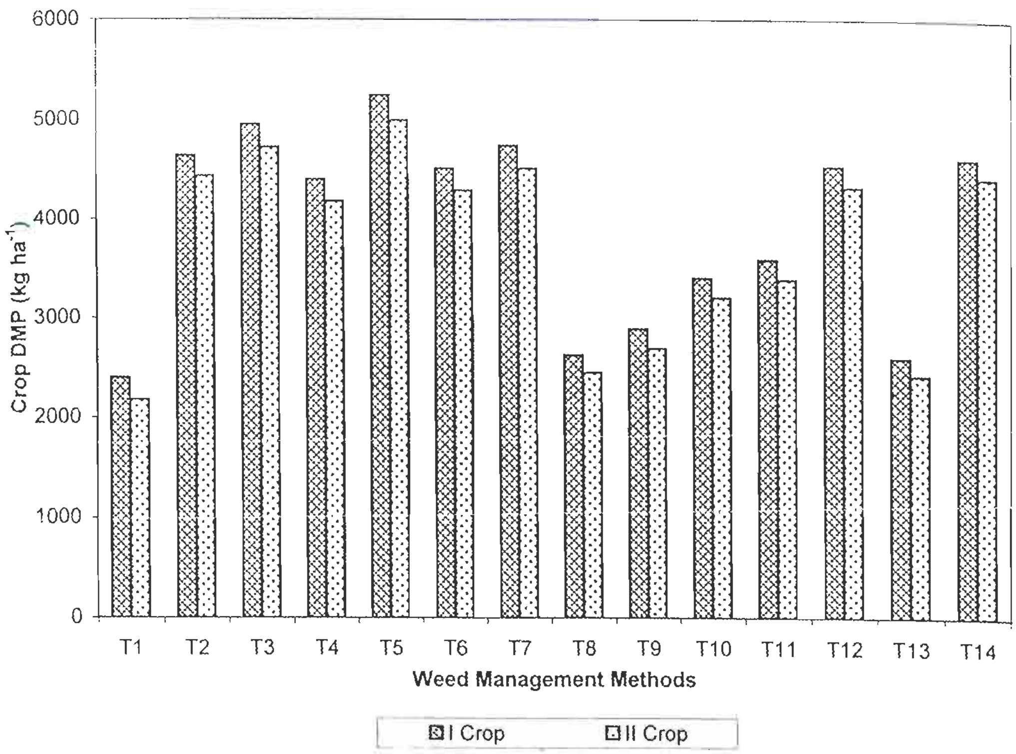
Table 41. **Effect of weed management practices on dry matter production (kg ha^{-1}) of cotton during 1998-1999**

Treatments	Dry matter production (kg ha^{-1})			
	20 DAS	40 DAS	80 DAS	120 DAS
T_1	37	307	1232	2398
T_2	39	632	2369	4638
T_3	73	675	2545	4951
T_4	76	702	2269	4401
T_5	77	714	2699	5245
T_6	68	619	2310	4513
T_7	70	646	2426	4741
T_8	48	343	1364	2628
T_9	50	380	1395	2893
T_{10}	49	360	1656	3405
T_{11}	54	400	1839	3592
T_{12}	68	622	2324	4535
T_{13}	41	336	1348	2598
T_{14}	69	642	2354	4612
SEd	2	16	63	122
CD (P=0.05)	4	33	128	251

Table 42. Effect of weed management practices on dry matter production ($kg\ ha^{-1}$) of cotton during 1999-2000

Treatments	Dry matter production ($kg\ ha^{-1}$)			
	20 DAS	40 DAS	80 DAS	120 DAS
T_1	32	275	1147	2178
T_2	35	608	2278	4436
T_3	69	650	2446	4721
T_4	71	660	2164	4181
T_5	74	685	2589	4995
T_6	66	598	2211	4291
T_7	68	622	2316	4513
T_8	42	325	1244	2453
T_9	43	380	1284	2693
T_{10}	45	350	1550	3209
T_{11}	49	400	1709	3391
T_{12}	64	598	2219	4325
T_{13}	37	315	1238	2423
T_{14}	65	618	2253	4420
SEd	2	16	59	116
CD (P=0.05)	3	33	122	238

Fig.18. Effect of weed management methods on dry matter production of crops at 120 DAS during 1998-1999 and 1999-2000



pendimethalin @ 1.0 kg ha^{-1} + HW (T_3) comparable with cinmethylin @ 0.6 kg ha^{-1} + HW (T_7) at 20, 40 and 120 DAS, respectively.

Cotton + greengram (T_{14}) recorded higher DMP of 65, 618, 2253 and 4420 kg ha^{-1} at 20, 40, 80 and 120 DAS, respectively, which was closely followed by smother intercropping of cotton + cowpea (T_{12}). The lowest DMP of 32, 275, 1147 and 2178 kg ha^{-1} was found in unweeded control (T_1) at 20, 40, 80 and 120 DAS, respectively. With respect to allelopathic treatments, combination of hand weeding with parthenium incorporation and whole plant extract spray significantly increased the DMP of crop irrespective of all the stages. In general, the DMP of first crop was maximum as compared to second crop.

4.3.2. Yield contributing characters

4.3.2.1. Monopodial branches plant^{-1}

The mean data on monopodial branches plant $^{-1}$ recorded at 120 DAS are given in Table 43.

Monopodial branches plant^{-1} at 120 DAS was significantly different among the different weed management treatments, more monopodial branches were observed in cinmethylin @ 0.5 kg ha^{-1} followed by hand weeding at 40 DAS (T_5) (1.65 and 1.61 at first and second crop, respectively). This was closely followed by pendimethalin @ 1.0 kg ha^{-1} + HW (T_3) (1.59 and 1.55 in the first and second crop, respectively) and cinmethylin @ 0.6 kg ha^{-1} followed by hand weeding at 40 DAS (T_7) (1.62 and 1.59 at first and second crop, respectively).

Cotton + greengram (T_{14}) registered highest monopodial branches plant^{-1} of 1.53 and 1.48 in the first and second crop, respectively, which was closely followed by HW twice (T_2) and cowpea (T_{12}) as smother crop. The unweeded control (T_1) showed lower monopodial branches plant^{-1} of 1.08 and 1.05 in the first and second crop, respectively. Among the allelopathic treatments,

Table 43. Effect of weed management practices on number of sympodial and monopoidal branches plant^{-1} during 1998-1999 and 1999-2000

Treatments	Sympodial branches plant^{-1}		Monopodial branches plant^{-1}	
	1998-1999	1999-2000	1998-1999	1999-2000
T_1	9.02	8.34	1.08	1.05
T_2	15.78	15.02	1.56	1.51
T_3	16.86	16.04	1.59	1.55
T_4	14.93	14.08	1.46	1.43
T_5	17.82	16.96	1.65	1.61
T_6	15.25	14.47	1.49	1.45
T_7	16.12	15.52	1.62	1.59
T_8	10.42	9.79	1.35	1.30
T_9	10.82	10.04	1.39	1.35
T_{10}	11.76	11.16	1.41	1.37
T_{11}	12.14	11.49	1.43	1.41
T_{12}	15.59	14.91	1.51	1.46
T_{13}	9.49	8.86	1.24	1.19
T_{14}	15.68	15.05	1.53	1.48
SEd	0.42	0.40	0.04	0.04
CD (P=0.05)	0.86	0.82	0.09	0.09

parthenium incorporation as well as whole plant extract spray did not exhibit significant difference compared to herbicide treatments.

4.3.2.2. Sympodial branches plant^{-1} (Table 43) (Fig. 19)

Significant increase was observed under the weed management practices over unweeded control in both the crops. It could be seen that development of sympodial branches followed similar trend as that of monopodial branches at 120 DAS. Application of cinmethylin @ 0.5 kg ha^{-1} followed by hand weeding at 40 DAS (T_5) registered highest sympodial branches plant^{-1} of 17.82 and 16.96 during first and second crop, respectively. This was followed by pendimethalin @ 1.0 kg ha^{-1} + HW (T_3) (16.86 and 16.04 during first and second crop, respectively). Cinmethylin @ 0.6 kg ha^{-1} + HW (T_7) and HW twice (T_2) treatments both were on par with each other.

Regarding smother crops, greengram (T_{14}) recorded more number of sympodial branches plant^{-1} (15.68 and 15.05 in the first and second crop, respectively). Which was followed by cowpea (T_{12}) as smother crop. Unweeded control (T_1) registered the lowest sympodial branches plant $^{-1}$ (9.02 and 8.34 in the first and second crop, respectively) than rest of the treatments. The allelopathic treatments did not exhibit favourable effect on sympodial branches plant^{-1}.

4.3.2.3. Number of bolls plant^{-1} (Tables 44 and 45) (Fig. 20)

Weed management practices increased the boll numbers plant^{-1} significantly over the unweeded check. Number of bolls plant^{-1} varies at 120 DAS from 9.96 to 22.15 and 8.89 to 21.13 bolls plant^{-1} in first and second crop, respectively.

In both the crops, application of cinmethylin @ 0.5 kg ha^{-1} followed by hand weeding at 40 DAS (T_5) was comparatively superior over all other treatments

Fig.19. Effect of weed management methods on number of sympodial branches plant^{-1} of cotton during 1998-1999 and 1999-2000

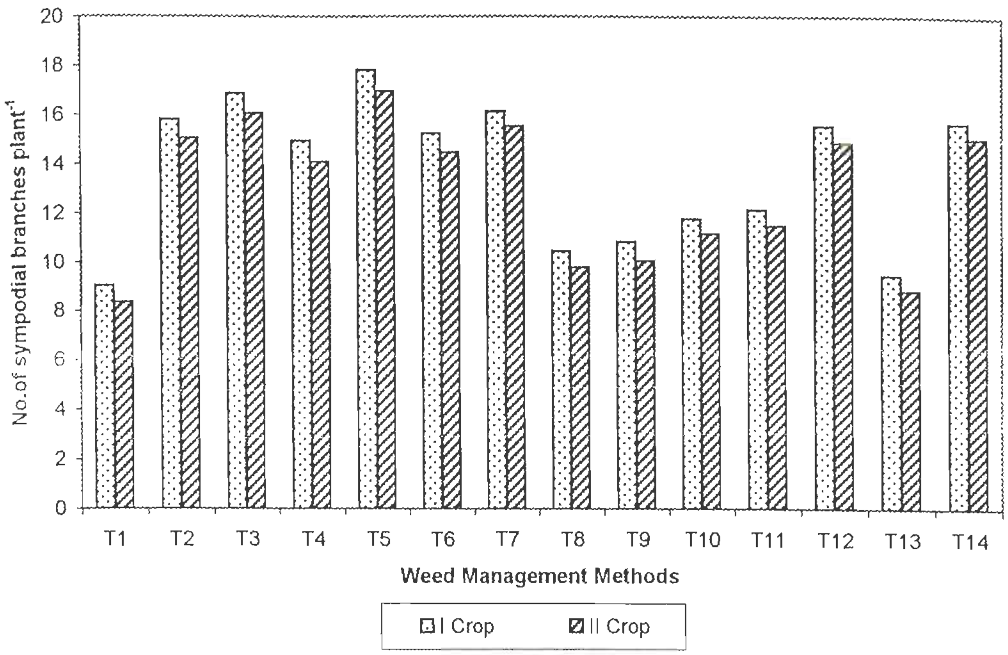


Fig. 20. Effect of weed management methods on number of bolls plant^{-1} of cotton during 1998-1999 and 1999-2000

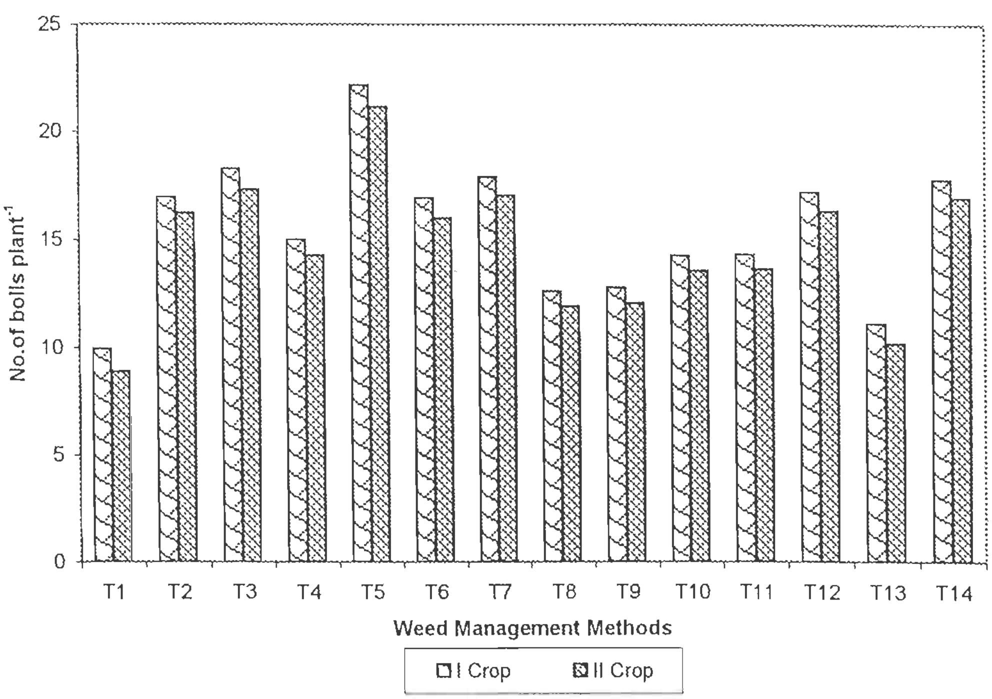


Table 44. **Effect of weed management practices on number of bolls $plant^{-1}$, boll weight ($g\ boll^{-1}$) and seed cotton yield ($kg\ ha^{-1}$) of cotton during 1998-1999**

Treatments	Number of bolls $plant^{-1}$	Boll weight ($g\ boll^{-1}$)	Seed cotton yield ($kg\ ha^{-1}$)
T_1	9.96	3.87	754
T_2	16.93	4.38	1651
T_3	18.26	4.49	1764
T_4	15.00	4.30	1569
T_5	22.15	4.53	1878
T_6	16.92	4.32	1595
T_7	17.87	4.31	1688
T_8	12.62	4.26	850
T_9	12.80	4.23	948
T_{10}	14.27	4.17	1137
T_{11}	14.33	4.15	1266
T_{12}	17.20	4.10	1615
T_{13}	11.14	3.96	832
T_{14}	17.78	4.36	1640
SEd	0.48	0.08	42
CD (P=0.05)	0.98	0.16	85

Table 45. Effect of weed management practices on number of bolls plant^{-1}, boll weight (g boll^{-1}) and seed cotton yield (kg ha^{-1}) of cotton during 1999-2000

Treatments	Number of bolls plant^{-1}	Boll weight (g boll^{-1})	Seed cotton yield (kg ha^{-1})
T_1	8.89	3.74	678
T_2	16.23	4.27	1556
T_3	17.31	4.36	1669
T_4	14.28	4.15	1490
T_5	21.13	4.42	1781
T_6	15.98	4.19	1505
T_7	17.02	4.21	1604
T_8	11.93	4.06	775
T_9	12.08	4.11	873
T_{10}	13.58	4.14	1059
T_{11}	13.67	4.12	1195
T_{12}	16.35	4.08	1530
T_{13}	10.23	3.85	763
T_{14}	16.93	4.24	1548
SEd	0.45	0.13	38
CD (P=0.05)	0.93	0.26	78

(22.15 and 21.13 bolls plant^{-1} during first and second crop, respectively). This was followed by pendimethalin @ 1.0 kg ha^{-1} followed by hand weeding at 40 DAS (T_3). Cinmethylin @ 0.6 kg ha^{-1} + HW (T_7) and HW twice (T_2) were on par with each other regarding number of bolls plant^{-1}. With respect to smother crops, greengram (T_{14}) registered higher number of bolls plant^{-1} of 17.78 and 16.93 during first and second crop, respectively, which was closely followed by cowpea (T_{12}) as smother crop. Unweeded control (T_1) recorded less number of bolls plant^{-1} of 9.96 and 8.89 in both the crops. Parthenium incorporation and whole plant extract spray integrated with one hand weeding at 40 DAS (T_{10} and T_{11}) considerably increased the number of bolls plant^{-1}.

4.3.2.4. Boll weight (Tables 44 and 45)

All the weed management practices exhibited significant improvement in boll weight over unweeded control (T_1) in both the crops.

In both the crops, cinmethylin @ 0.5 kg ha^{-1} + HW (T_5) recorded high boll weight of 4.53 and 4.42 g boll^{-1} in first and second crop, respectively. This was closely followed by application of pendimethalin @ 1.0 kg ha^{-1} + HW (T_3) recording the boll weight of 4.49 and 4.36 g boll^{-1} in first and second crop, respectively. Application of cinmethylin @ 0.6 kg ha^{-1} + HW (T_7) and HW twice (T_2) were registered high boll weight over unweeded control (T_1). Both treatments were closely related with each other.

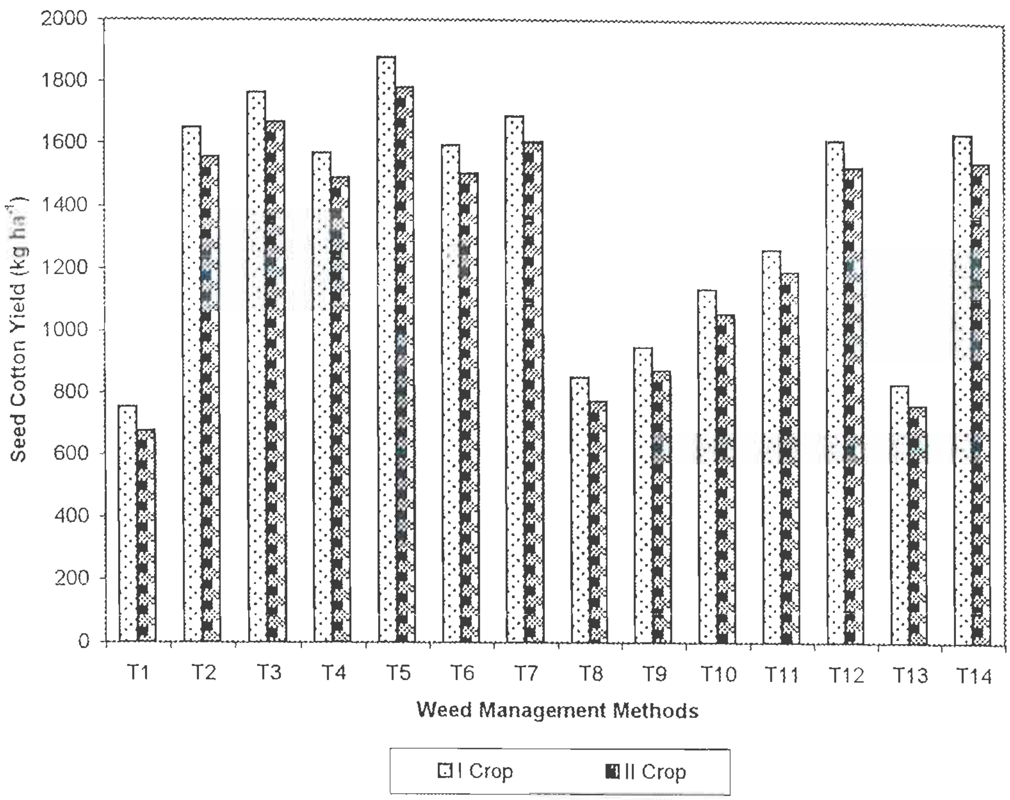
Growing of greengram (T_{14}) as a smother crop showed high boll weight of 4.36 and 4.24 g boll^{-1} during first and second crop, respectively, which was comparable with cowpea (T_{12}) as smother crop. The lowest boll weight of 3.87 and 3.74 g boll^{-1} was observed in unweeded control (T_1). With respect to allelopathic treatments, they moderately influenced the boll weight. In over all view, the boll weight of first crop was higher as compared to second crop.

4.3.2.5. Seed cotton yield (Tables 44 and 45) (Fig. 21)

All the weed management practices significantly improved the seed cotton yield over unweeded control. In both the crops, application of cinmethylin @ 0.5 kg ha^{-1} followed by hand weeding at 40 DAS (T_5) registered higher seed cotton yield of 1878 and 1781 kg ha^{-1} which was significantly superior over pendimethalin application and HW twice. Pendimethalin @ 1.0 kg ha^{-1} followed by hand weeding at 40 DAS (T_3) was next best recording seed cotton yield of 1764 and 1669 kg ha^{-1} in first and second crop, respectively. The herbicide treatments such as cinmethylin @ 0.5 kg ha^{-1} (T_4) (1569 and 1490 kg ha^{-1}) cinmethylin @ 0.6 kg ha^{-1} (T_6) (1595 and 1505 kg ha^{-1}) and HW twice (T_2) (1651 and 1556 kg ha^{-1}) which were comparable with each other.

Smother crop of greengram upto 40 DAS (T_{14}) recorded highest seed cotton yield of 1640 and 1548 kg ha^{-1} in first and second crop, respectively. This was on par with cowpea (T_{12}) as smother crop (1615 and 1530 kg ha^{-1}). These smother crops are comparable with cinmethylin 0.5 kg ha^{-1} (T_4), cinmethylin 0.6 kg ha^{-1} (T_6) without hand weeding and HW twice (T_2). The lowest seed cotton yield of 754 and 678 kg ha^{-1} was recorded in unweeded control (T_1) during first and second crop, respectively. With respect to allelopathic treatments, parthenium incorporation @ 2 t ha^{-1} and whole plant extract (10%) spray were integrated with manual weeding at 40 DAS (T_{10} and T_{11}), significantly increased the seed cotton yield compared to where there was no hand weeding. In general view, the seed cotton yield of first crop was maximum as compared to second crop.

Fig. 21. Effect of weed management methods on seed cotton yield of cotton during 1998-1999 and 1999-2000



4.3.3. Quality characters

4.3.3.1. Ginning percentage

The mean data on cotton ginning percentage are given in Tables 46 and 47. The differences among the treatments did not differ significantly in both the crops. Among the weed management practices, appliction of cinmethylin @ 0.5 kg ha^{-1} followed by hand weeding at 40 DAS (T_5) registered numerically higher ginning percentage in both the crops. The unweeded control (T_1) registered lowest ginning percentage.

4.3.3.2. Seed index

The mean data on seed index are presented in tables 46 and 47.

In both the crops, adoption of different weed management practices of application of herbicides such as cinmethylin, pendimethalin, growing of smother crops and allelopathic treatments statistically did not differ significantly with regard to seed index.

4.3.3.3. Lint index

The mean data on lint index are presented in tables 46 and 47. The weed management practices did not cause any significant difference in the lint index in both the crops.

4.3.3.4. Fibre fineness (Tables 46 and 47)

Significant improvement in fibre fineness was observed in both the crops due to the adoption of different weed management practices. Application of pendimethalin @ 1.0 kg ha^{-1} + HW (T_3) registered higher fibre fineness of 3.84 and 3.62 in first and second crop, respectively. This treatment was comparable with other herbicide treatments like cinmethylin @ 0.5 kg ha^{-1} + HW (T_5) and cinmethylin @ 0.6 kg ha^{-1} + HW (T_7).

Table 46. Effect of weed management practices on ginning percentage, seed index, lint index, fibre fineness (micronaire 10^{-6} g $inch^{-1}$) and fibre length (cm) of cotton during 1998-1999

Treatments	Ginning percentage	Seed index	Lint index	Fibre fineness (micronaire)	Mean fibre length (cm)
T_1	33.48	9.61	5.19	3.06	29.82
T_2	33.83	9.72	5.30	3.16	30.84
T_3	34.67	9.79	5.28	3.84	31.20
T_4	33.93	9.75	5.38	3.52	30.24
T_5	34.75	9.93	5.40	3.63	31.27
T_6	33.95	9.78	5.25	3.60	30.44
T_7	33.93	9.89	5.32	3.48	31.16
T_8	33.83	9.79	5.22	3.23	30.12
T_9	33.86	9.70	5.35	3.18	30.25
T_{10}	34.11	9.77	5.27	3.13	30.89
T_{11}	33.73	9.63	5.24	3.20	31.04
T_{12}	33.66	9.76	5.22	3.72	31.20
T_{13}	33.57	9.68	5.20	3.18	30.12
T_{14}	33.65	9.75	5.24	3.85	31.40
SEd	0.62	0.34	0.10	0.06	0.55
CD (P=0.05)	NS	NS	NS	0.12	1.12

Table 47. **Effect of weed management practices on ginning percentage, seed index, lint index, fibre fineness (micronaire 10^{-6} g inch^{-1}) and fibre length (cm) of cotton during 1999-2000**

Treatments	Ginning percentage	Seed index	Lint index	Fibre fineness (micronaire)	Mean fibre length (cm)
T_1	33.18	9.57	5.10	3.02	29.57
T_2	33.54	9.69	5.12	3.12	30.63
T_3	34.45	9.47	5.19	3.62	30.98
T_4	33.68	9.70	5.31	3.34	29.99
T_5	34.54	9.88	5.35	3.42	31.04
T_6	33.67	9.72	5.15	3.40	30.24
T_7	33.53	9.83	5.22	3.45	30.98
T_8	33.58	9.75	5.32	3.14	29.93
T_9	33.62	9.63	5.15	3.11	30.10
T_{10}	33.80	9.74	5.17	3.08	30.64
T_{11}	33.38	9.60	5.14	3.13	30.82
T_{12}	33.48	9.72	5.18	3.68	31.02
T_{13}	33.36	9.62	5.12	3.12	29.87
T_{14}	33.44	9.71	5.22	3.72	31.19
SEd	1.02	0.29	0.16	0.10	0.90
CD (P=0.05)	NS	NS	NS	0.21	NS

Greengram as smother intercrop in cotton (T_{14}) recorded high fibre fineness of 3.85 and 3.72 in first and second crop, respectively, which was closely followed by cowpea (T_{12}) as smother crop. Unweeded control (T_1) showed lower fibre fineness of 3.06 and 3.02 in first and second crop, respectively. The allelopathic treatments (T_8, T_9, T_{10} and T_{11}) did not exhibit any significant effect on fibre fineness in both the crops.

4.3.3.5. Mean fibre length (Tables 46 and 47)

Weed management practices significantly increased the fibre length in first year. But in second crop, the weed management practices were statistically did not influence the fibre length.

In the first crop, application of cinmethylin @ 0.5 kg ha^{-1} + HW (T_5) registered higher fibre length of 31.27 cm followed by pendimethalin @ 1.0 kg ha^{-1} + HW (T_3) (31.20 cm) and cinmethylin @ 0.6 kg ha^{-1} + HW (T_7) (31.16 cm).

Regarding smother crops, greengram in cotton (T_{14}) recorded highest fibre length of 31.40 cm in the first crop, which was higher than the herbicide treatments. This treatment was comparable with cowpea (T_{12}) as smother crop. The unweeded control (T_1) recorded lowest mean fibre length of 29.82 cm in the first crop. The allelopathic treatments did not differ significantly with respect to mean fibre length.

4.3.3.6. 2.5(%) span length (Tables 48 and 49)

Weed management practices significantly increased the span length in some herbicide treatments. But in second crop, the weed management practices did not influence the span length.

Table 48. **Effect of weed management practices on 2.5(%) span length, maturity co-efficient, bundle strength (1/8" gauge tenacity) and uniformity ratio of cotton during 1998-1999**

Treatments	2.5(%) span length	Maturity co-efficient	Bundle strength	Uniformity ratio
T_1	30.87	0.68	22.12	40.50
T_2	31.93	0.70	22.97	41.63
T_3	32.03	0.71	23.23	41.61
T_4	31.60	0.69	22.53	41.50
T_5	32.16	0.71	23.69	41.83
T_6	31.83	0.69	22.50	40.58
T_7	32.40	0.70	22.42	41.17
T_8	31.50	0.69	23.47	41.10
T_9	31.37	0.69	23.63	41.58
T_{10}	31.23	0.70	22.30	40.84
T_{11}	31.77	0.71	23.13	41.28
T_{12}	31.36	0.70	23.00	40.52
T_{13}	31.43	0.69	21.37	41.37
T_{14}	32.16	0.71	22.17	41.48
SEd	0.55	0.02	0.40	0.72
CD(P=0.05)	1.14	NS	0.82	NS

Table 49. **Effect of weed management practices on 2.5(%) span length, maturity co-efficient, bundle strength (1/8" gauge tenacity) and uniformity ratio of cotton during 1999-2000**

Treatments	2.5(%) span length	Maturity co-efficient	Bundle strength	Uniformity ratio
T_1	30.78	0.66	22.02	40.28
T_2	31.84	0.68	22.79	41.42
T_3	31.95	0.70	23.05	41.38
T_4	31.52	0.68	22.35	41.23
T_5	32.08	0.70	23.43	41.58
T_6	31.78	0.68	22.28	40.35
T_7	32.29	0.69	22.19	41.04
T_8	31.38	0.67	23.28	40.84
T_9	31.28	0.67	23.36	41.32
T_{10}	31.14	0.68	22.13	40.62
T_{11}	31.68	0.69	22.88	41.12
T_{12}	31.25	0.70	22.71	40.42
T_{13}	31.32	0.68	21.15	41.18
T_{14}	31.89	0.70	22.28	41.24
SEd	0.96	0.02	0.68	1.24
CD(P=0.05)	NS	NS	1.40	NS

In first crop, application of cinmethylin @ 0.6 kg ha^{-1} + HW (T_7) registered higher span length of 32.40. This was followed by cinmethylin @ 0.5 kg ha^{-1} + HW (T_5) (32.16) and pre-emergence application of pendimethalin @ 1.0 kg ha^{-1} + HW (T_3) (32.03) both were comparable with each other.

Greengram (T_{14}) as a smother crop recorded higher span length of 32.16. Unweeded control (T_1) showed lesser span length in both the crops. The allelopathic treatments did not exhibit significant difference among the treatments.

4.3.3.7. Maturity co-efficient

The mean data on maturity co-efficient are given in Tables 48 and 49.

In both the crops, among the different weed management practices, application of herbicides such as cinmethylin, pendimethalin, growing of smother crops and allelopathic treatments did not differ significantly with regard to maturity co-efficient.

4.3.3.8. Bundle strength (Tables 48 and 49)

Some of the weed management practices increased the bundle strength over unweeded control (T_1) in both the years. But most of the treatments did not differ significantly.

Application of cinmethylin @ 0.5 kg ha^{-1} + hand weeding at 40 DAS (T_5) obtained higher bundle strength (23.69 and 23.43 in first and second crop, respectively), which was comparable with the application of pendimethalin @ 1.0 kg ha^{-1} + HW (T_3) and HW twice (T_2) treatments.

Cotton + cowpea (T_{12}) received higher bundle strength of 23.00 and 22.71 in the first crop and second crop, respectively. Unweeded control (T_1) recorded lower bundle strength of 22.12 and 22.02 in the first and second crop, respectively.

4.3.3.9. Uniformity ratio

The mean data on uniformity ratio are presented in Tables 48 and 49.

In both the crops, among the different weed management practices, application of herbicides such as cinmethylin and pendimethalin, growing of smother crops and allelopathic treatments did not give significant differences with regard to uniformity ratio.

4.3.4. Nutrient uptake by cotton

Nutrient uptake of nitrogen, phosphorus and potassium by cotton was analysed at 20, 40, 80 and 120 DAS and presented in Tables 50 to 55.

4.3.4.1. Nitrogen (Tables 50 and 51) (Fig. 14 to 17)

All the weed management practices showed significant variation on N uptake. In the first crop, application of cinmethylin @ 0.5 kg ha^{-1} + HW (T_5) obtained higher N uptake of 2.16, 20,00, 75.57 and 146.86 kg ha^{-1} at 20, 40, 80 and 120 DAS, respectively, which was followed by application of pendimethalin @ 1.0 kg ha^{-1} with later hand weeding at 40 DAS (T_3) registering higher N uptake irrespective of all the stages (2.05, 18.90, 71.27 and 138.63 kg ha^{-1} at 20, 40, 80 and 120 DAS, respectively). Application of cinmethylin @ 0.6 kg ha^{-1} + HW (T_7) and HW twice (T_2) both were on par with each other irrespective of all the stages except 20 DAS regarding N uptake. Application of cinmethylin at 0.5 kg ha^{-1} (T_4) and 0.6 kg ha^{-1} (T_6) were comparable with each other with respect to N uptake irrespective of all stages.

Greengram in cotton as smother crop (T_{14}) showed high N uptake of 1.93, 17.96, 65.93 and 129.14 kg ha^{-1} at 20, 40, 80 and 120 DAS, respectively, which

Table 50. Effect of weed management practices on nitrogen uptake ($kg\ ha^{-1}$) of cotton during 1998-1999

Treatments	Nitrogen uptake ($kg\ ha^{-1}$)			
	20 DAS	40 DAS	80 DAS	120 DAS
T_1	1.09	8.59	34.47	67.14
T_2	1.32	17.69	66.34	129.86
T_3	2.05	18.90	71.27	138.63
T_4	1.85	17.70	63.55	123.23
T_5	2.16	20.00	75.57	146.86
T_6	1.89	17.33	64.69	126.36
T_7	1.96	18.07	67.94	132.74
T_8	1.16	9.60	38.22	73.58
T_9	1.29	10.64	39.08	81.00
T_{10}	1.36	12.66	46.36	95.34
T_{11}	1.51	14.06	51.50	100.58
T_{12}	1.90	17.42	65.08	126.98
T_{13}	1.14	9.42	38.76	72.74
T_{14}	1.93	17.96	65.93	129.14
SEd	0.05	0.45	1.01	1.75
CD(P=0.05)	0.10	0.92	2.07	3.60

Table 51. Effect of weed management practices on nitrogen uptake (kg ha^{-1}) of cotton during 1999-2000

Treatments	Nitrogen uptake (kg ha^{-1})			
	20 DAS	40 DAS	80 DAS	120 DAS
T_1	1.04	7.83	32.38	59.04
T_2	1.21	16.59	63.82	122.34
T_3	1.93	17.77	68.67	130.53
T_4	1.74	16.65	60.80	115.98
T_5	2.04	18.80	72.47	138.34
T_6	1.78	16.28	61.93	119.11
T_7	1.83	17.02	65.29	124.53
T_8	1.08	8.96	36.24	67.46
T_9	1.20	9.93	37.07	75.48
T_{10}	1.27	11.81	44.05	89.11
T_{11}	1.42	13.10	48.94	94.06
T_{12}	1.78	16.36	62.13	119.46
T_{13}	1.07	8.74	36.81	67.52
T_{14}	1.80	16.88	62.95	121.04
SEd	0.05	0.44	1.68	3.13
CD(P=0.05)	0.10	0.90	3.45	6.44

was closely followed by the cowpea (T_{12}) as smother crop. The lowest N uptake of 1.09, 8.59, 34.47, 67.14 kg ha^{-1} was found in unweeded control (T_1) at 20, 40, 80 and 120 DAS, respectively. Integration of allelopathic treatments with manual weeding at 40 DAS recorded higher N uptake irrespective of all the stages.

In second crop, all the treatments showed significant variation in N uptake. Application of cinmethylin @ 0.5 kg ha^{-1} + HW (T_5) registered high N uptake of 2.04, 18.80, 72.47 and 138.34 kg ha^{-1} at 20, 40, 80 and 120 DAS, respectively, which was followed by application of pendimethalin @ 1.0 kg ha^{-1} with later hand weeding at 40 DAS (T_3) obtained high N uptake of 1.93, 17.77, 68.67 and 130.53 kg ha^{-1} at 20, 40, 80 and 120 DAS, respectively. Application of cinmethylin @ 0.6 kg ha^{-1} + HW (T_7) and HW twice (T_2) were on par with each other with respect to N uptake in all the stages except 20 DAS. Application of cinmethylin @ 0.5 kg ha^{-1} (T_4) and @ 0.6 kg ha^{-1} (T_6) without manual weeding were on par with each other in all the stages.

Growing of greengram (T_{14}) as intercrop in cotton upto 40 DAS considerably increased N uptake (1.80, 16.88, 62.95 and 121.04 at 20, 40, 80 and 120 DAS, respectively), which was closely followed by growing of cowpea (T_{12}) as smother crop in cotton. The unweeded control (T_1) recorded lesser N uptake of 1.04, 7.83, 32.38 and 59.04 at 20, 40, 80 and 120 DAS, respectively. Regarding to allelopathic treatments, parthenium incorporation and whole plant extract spray integrated with one hand weeding at 40 DAS (T_{10} and T_{11}) increased the N uptake by cotton crop irrespective of all the stages.

4.3.4.2. Phosphorus (Tables 52 and 53) (Fig. 14 to 17)

Weed management practices involving herbicides and hand weeding twice significantly improved the P uptake over unweeded control in both the crops at all the stages. In the first crop, cinmethylin @ 0.5 kg ha^{-1} followed by hand weeding

Table 52. Effect of weed management practices on phosphorus uptake (kg ha^{-1}) of cotton during 1998-1999

Treatments	Phosphorus uptake (kg ha^{-1})			
	20 DAS	40 DAS	80 DAS	120 DAS
T_1	0.82	2.20	10.72	13.50
T_2	1.02	4.59	17.05	22.25
T_3	1.84	4.91	18.18	24.10
T_4	1.64	4.33	16.21	19.13
T_5	1.95	5.20	19.24	25.40
T_6	1.68	4.42	16.61	20.19
T_7	1.75	4.69	17.42	22.91
T_8	1.10	2.92	13.03	14.26
T_9	1.22	3.23	13.40	15.11
T_{10}	1.45	3.82	14.34	17.03
T_{11}	1.54	4.04	15.14	17.95
T_{12}	1.69	4.49	16.70	21.30
T_{13}	1.07	2.86	12.78	14.08
T_{14}	1.71	4.56	16.94	21.73
SEd	0.04	0.17	0.49	0.59
CD(P=0.05)	0.09	0.34	1.00	1.21

Table 53. **Effect of weed management practices on phosphorus uptake (kg ha^{-1}) of cotton during 1999-2000**

Treatments	Phosphorus uptake (kg ha^{-1})			
	20 DAS	40 DAS	80 DAS	120 DAS
T_1	0.76	2.02	9.96	12.22
T_2	0.82	4.36	16.09	20.73
T_3	1.72	4.65	17.17	22.48
T_4	1.53	4.10	15.36	17.92
T_5	1.82	4.89	18.12	24.08
T_6	1.57	4.16	15.76	18.97
T_7	1.64	4.42	16.52	21.68
T_8	1.02	2.71	12.30	13.28
T_9	1.14	3.01	12.77	14.10
T_{10}	1.35	3.56	13.52	16.02
T_{11}	1.44	3.83	14.22	16.89
T_{12}	1.58	4.22	15.72	20.07
T_{13}	0.99	2.68	12.12	13.23
T_{14}	1.63	4.28	15.98	20.62
SEd	0.04	0.12	0.44	0.55
CD(P=0.05)	0.08	0.24	0.90	1.14

at 40 DAS (T_5) obtained higher P uptake of 1.95, 5.20, 19.24 and 25.40 kg ha^{-1} at 20, 40, 80 and 120 DAS, respectively. Next best treatment of pendimethalin @ 1.0 kg ha^{-1} followed by hand weeding at 40 DAS (T_3) registered high P uptake of 1.84, 4.91, 18.18 and 24.10 kg ha^{-1} at 20, 40, 80 and 120 DAS respectively, whereas cinmethylin @ 0.6 kg ha^{-1} + HW (T_7) and HW twice (T_2) were comparable in P uptake. Cinmethylin @ 0.5 kg ha^{-1} (T_4) and 0.6 kg ha^{-1} (T_6) without manual weeding were comparable with each other regarding P uptake in all the stages.

Growing of greengram (T_{14}) along with cotton crop recorded higher P uptake of 1.71, 4.56, 16.94 and 21.73 kg ha^{-1} at 20, 40, 80 and 120 DAS, respectively, which was on par with the cowpea (T_{12}) as smother crop. The lowest P uptake of 0.82, 2.20, 10.72 and 13.50 kg ha^{-1} was recorded in unweeded control (T_1) at 20, 40, 80 and 120 DAS, respectively. Regarding allelopathic treatments, parthenium whole plant extract (10%) + HW (T_{11}) spray increased the P uptake of 1.54, 4.04, 15.14 and 17.95 kg ha^{-1} at 20, 40, 80 and 120 DAS, respectively.

In second crop, different weed management practices significantly influence the P uptake. Application of cinmethylin @ 0.5 kg ha^{-1} + HW (T_5) registered higher P uptake of 1.82, 4.89, 18.12 and 24.08 kg ha^{-1} at 20, 40, 80 and 120 DAS, respectively. This was followed by pendimethalin @ 1.0 kg ha^{-1} + HW (T_3), which recorded P uptake of 1.72, 4.65, 17.17 and 22.48 kg ha^{-1} at 20, 40, 80 and 120 DAS, respectively. Both application of cinmethylin @ 0.6 kg ha^{-1} + HW (T_7) and HW twice (T_2) were comparable with each other except 20 DAS. Application of cinmethylin @ 0.5 kg ha^{-1} (T_4) and 0.6 kg ha^{-1} (T_6) without manual weeding on par with each other irrespective of the stages.

With regard to smothering crops, greengram (T_{14}) registered higher P uptake of 1.63, 4.28, 15.98 and 20.62 kg ha^{-1} at 20, 40, 80 and 120 DAS, respectively, which was closely followed by growing cowpea (T_{12}) as smother crop with cotton. The lowest P uptake of 0.76, 2.02, 9.96 and 12.22 was found in unweeded control (T_1) at 20, 40, 80 and 120 DAS, respectively. Regarding allelopathic treatments, parthenium incorporation and whole plant extract spray integrated with hand weeding at 40 DAS (T_{10} and T_{11}) recorded higher P uptake irrespective of the stages. In general, P uptake was higher in the first crop as compared to second crop.

4.3.4.3. Potassium (Tables 54 and 55) (Fig. 14 to 17)

Weed management practices significantly influenced the K uptake in cotton. In the first crop, cinmethylin @ 0.5 kg ha^{-1} followed by hand weeding at 40 DAS (T_5) significantly increased the K uptake of 2.50, 26.34, 51.24 and 82.25 kg ha^{-1} at 20, 40, 80 and 120 DAS, respectively. This was followed by application of pendimethalin @ 1.0 kg ha^{-1} + HW (T_3) comparatively increased the K uptake of 2.37, 24.76, 48.55 and 77.33 kg ha^{-1} at 20, 40, 80 and 120 DAS, respectively. Application of cinmethylin @ 0.6 kg ha^{-1} + HW (T_7) and HW twice (T_2) were comparable with each other over unweeded control (T_1). Cinmethylin 0.5 kg ha^{-1} (T_4) and 0.6 kg ha^{-1} (T_6) without hand weeding comparable with respect to K uptake.

Growing of greengram (T_{14}) along with cotton progressively increased K uptake of 2.21, 22.83, 42.46 and 67.06 kg ha^{-1} at 20, 40, 80 and 120 DAS, respectively. This was closely followed by growing of cowpea (T_{12}) as smother crop. The unweeded control (T_1) recorded lower K uptake of 1.01, 14.24, 22.82 and 41.23 kg ha^{-1} at 20, 40, 80 and 120 DAS, respectively. Regarding allelopathic treatments, incorporation of parthenium @ 2 t ha^{-1} (T_{10}) and whole plant extract

Table 54. Effect of weed management practices on potassium uptake (kg ha^{-1}) of cotton during 1998-1999

Treatments	Potassium uptake (kg ha^{-1})			
	20 DAS	40 DAS	80 DAS	120 DAS
T_1	1.01	14.24	22.82	41.23
T_2	1.20	23.07	45.16	71.27
T_3	2.37	24.76	48.55	77.33
T_4	2.05	20.71	36.75	60.70
T_5	2.50	26.34	51.24	82.25
T_6	2.06	21.34	37.68	62.45
T_7	2.27	23.57	46.55	73.47
T_8	1.61	16.46	27.82	46.48
T_9	1.73	16.82	30.80	49.97
T_{10}	1.82	18.66	32.77	52.19
T_{11}	1.92	19.39	34.22	54.70
T_{12}	2.10	22.49	39.96	65.73
T_{13}	1.47	15.59	26.00	45.61
T_{14}	2.21	22.83	42.46	67.06
SEd	0.06	0.63	1.16	1.86
CD(P=0.05)	0.12	1.29	2.38	3.82

Table 55. Effect of weed management practices on potassium uptake ($kg\ ha^{-1}$) of cotton during 1999-2000

Treatments	Potassium uptake ($kg\ ha^{-1}$)			
	20 DAS	40 DAS	80 DAS	120 DAS
T_1	0.90	12.62	21.59	36.73
T_2	1.12	21.55	43.63	66.69
T_3	2.23	23.11	46.99	72.73
T_4	1.92	19.29	35.33	56.60
T_5	2.34	24.81	49.77	77.89
T_6	1.94	20.02	36.12	58.33
T_7	2.15	22.18	45.01	68.91
T_8	1.50	15.35	26.56	43.23
T_9	1.64	15.70	29.44	46.56
T_{10}	1.71	17.43	31.57	48.57
T_{11}	1.83	18.05	31.44	51.58
T_{12}	1.98	21.24	38.40	61.50
T_{13}	1.38	14.81	25.24	42.50
T_{14}	2.09	21.47	41.21	62.85
SEd	0.05	0.58	1.11	1.75
CD(P=0.05)	0.11	1.20	2.28	3.59

(10%) (T_{11}) spray combined with hand weeding at 40 DAS significantly increased over without hand weeding.

In the second crop, cinmethylin @ 0.5 kg ha^{-1} followed by hand weeding at 40 DAS (T_5) significantly improved the K uptake of 2.34, 24.81, 49.77 and 77.89 kg ha^{-1} 20, 40, 80 and 120 DAS, respectively. This was followed by pendimethalin @ 1.0 kg ha^{-1} followed by hand weeding at 40 DAS (T_3) registered higher K uptake of 2.23, 23.11, 46.99 and 72.73 kg ha^{-1} at 20, 40, 80 and 120 DAS, respectively. It was followed by cinmethylin @ 0.6 kg ha^{-1} + HW (T_7). Application of cinmethylin @ 0.5 kg ha^{-1} and 0.6 kg ha^{-1} without hand weeding both were on par with each other with respect to K uptake.

Greengram (T_{14}) as smother crop with cotton showed higher K uptake of 2.09, 21.47, 41.21 and 62.85 kg ha^{-1} at 20, 40, 80 and 120 DAS, respectively, which was closely followed by the growing of cowpea (T_{12}) as smother crop. Unweeded control (T_1) registered lowest K uptake of 0.90, 12.62, 21.59 and 36.73 kg ha^{-1} at 20, 40, 80 and 120 DAS, respectively. With respect to allelopathic treatments, incorporation of parthenium @ 2 t ha^{-1} (T_{10}) and whole plant extract (10%) spray (T_{11}) combined with hand weeding significantly improve the K uptake irrespective of the stages. In over all view, the K uptake of first crop was maximum as compared with second crop.

4.3.5. Economics and net monetary returns under various weed management practices

Data on cost of cultivation, net return and benefit-cost ratio under various weed management practices for the first and second crop of cotton were worked out and presented in Tables 56 and 57 (Fig. 22 and 23).

Table 56. **Economics of different weed management practices in cotton during 1998-1999**

Treatments	Total cost of cultivation (Rs. ha^{-1})	Seed cotton yield (Rs. ha^{-1})	Gross return (Rs. ha^{-1})	Net return (Rs. ha^{-1})	Benefit : cost ratio (BCR)
T_1	14288	754	16663	2375	1.17
T_2	16048	1651	36487	20439	2.27
T_3	16622	1764	38984	22362	2.35
T_4	15368	1569	34675	19307	2.26
T_5	16198	1878	41504	25306	2.56
T_6	15569	1595	35250	19681	2.26
T_7	16399	1688	37305	20906	2.27
T_8	15696	850	18785	3089	1.20
T_9	15067	948	20951	5884	1.39
T_{10}	16526	1137	25128	8602	1.52
T_{11}	15888	1266	27979	11453	1.69
T_{12}	15464	1615	35696	20232	2.31
T_{13}	15419	832	18387	2968	1.19
T_{14}	15494	1640	36244	20750	2.34

Table 57. Economics of different weed management practices in cotton during 1999-2000

Treatments	Total cost of cultivation (Rs. ha^{-1})	Seed cotton yield (Rs. ha^{-1})	Gross return (Rs. ha^{-1})	Net return (Rs. ha^{-1})	Benefit : cost ratio (BCR)
T_1	14088	678	14984	896	1.06
T_2	15828	1556	34388	18560	2.17
T_3	16402	1669	36885	20483	2.25
T_4	15148	1490	32929	17511	2.17
T_5	15978	1781	39360	23382	2.46
T_6	15349	1505	33261	17912	2.17
T_7	16179	1604	35448	19269	2.19
T_8	15476	775	17128	1652	1.11
T_9	14847	873	19293	4446	1.30
T_{10}	16306	1059	23404	7098	1.44
T_{11}	15668	1195	26410	10742	1.69
T_{12}	15244	1530	33813	18569	2.22
T_{13}	15199	763	16862	1663	1.11
T_{14}	15274	1548	34211	18937	2.24

Fig. 22. Effect of weed management methods on net return and benefit - cost ratio of cotton during 1998-1999

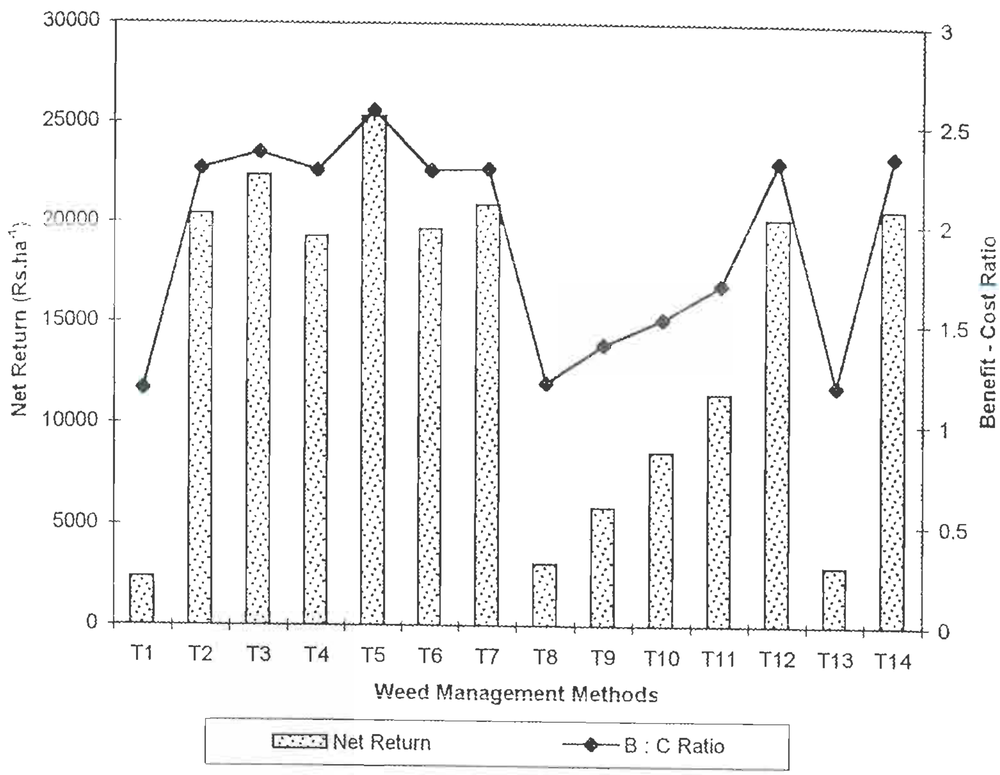
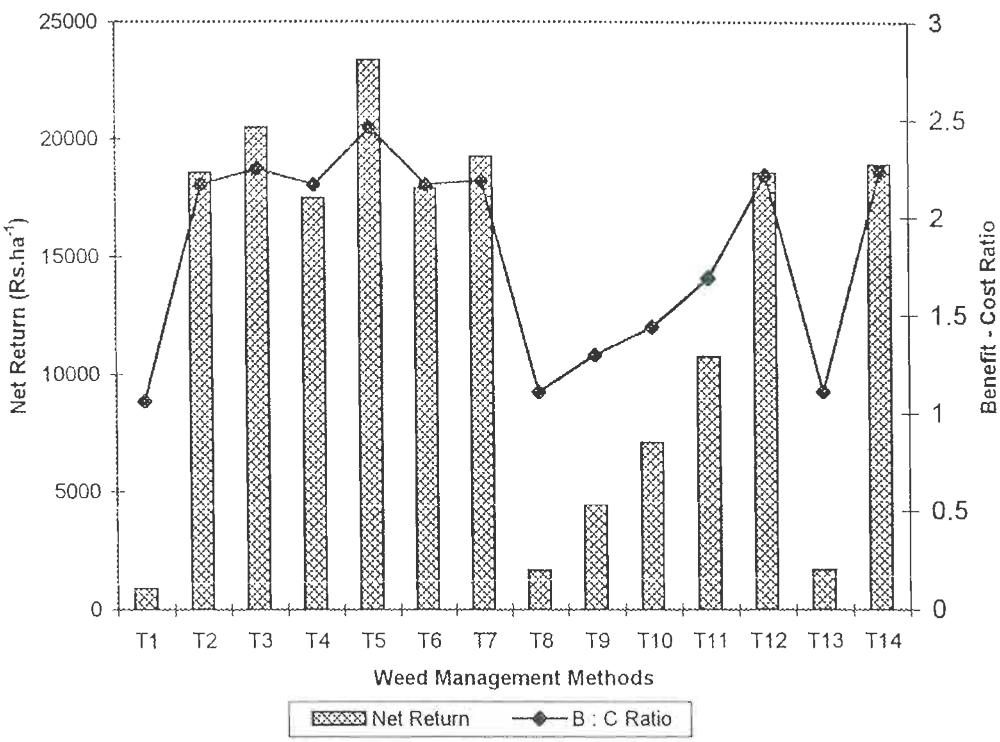


Fig.23. Effect of weed management methods on net return and benefit - cost ratio of cotton during 1999-2000



Adoption of different weed management practices such as cinmethylin, pendimethalin application, growing of smother crops (greengram and cowpea) and HW twice increased the net returns and benefit-cost ratio over unweeded control. In both the years highest net returns of Rs.25,306/- and Rs.23,382/- was obtained with application of cinmethylin @ 0.5 kg ha^{-1} followed by hand weeding at 40 DAS (T_5) with high benefit-cost ratio of 2.56 and 2.46. This was followed by pendimethalin @ 1.0 kg ha^{-1} + HW (T_3) received higher net returns of Rs.22,362/- and Rs.20,483/- in the first and second crop, respectively with the benefit-cost ratio of 2.35 and 2.25 in both the crops. Hand weeding twice (T_2), cinmethylin 0.5 kg ha^{-1} and 0.6 kg ha^{-1} (T_4 and T_6) were equal effect on net returns and benefit-cost ratio.

Growing of greengram (T_{14}) as smother crop with cotton upto 40 DAS recorded higher net return (Rs.20,750/- and Rs.18,937/-) and cost-benefit ratio of 2.34 and 2.24 in both the crops. This was followed by cowpea (T_{12}) as smother crop. In general, allelopathic treatments recorded lower net returns and benefit-cost ratio. The unweeded control (T_1) recorded lower benefit-cost ratio of 1.17 and 1.06.

4.3.6. Studies on microbial population

Microbial count was taken at 90 DAS and the data are presented in Table 58.

4.3.6.1. Bacterial population (Table 58)

At 90 DAS, an increased bacterial count is observed in unweeded check (T_1), hand weeding twice (T_2) and cinmethylin 0.5 kg ha^{-1} + HW (T_5) in both the crops. The higher bacterial count in hand weeding twice (T_2) was on par with unweeded control (T_1), cinmethylin @ 0.5 kg ha^{-1} with and without hand weeding (T_4 and T_5). The bacterial count was lower in pendimethalin @ 1.0 kg ha^{-1} + HW

Table 58. Effect of weed management practices on population of soil bacteria (x 10^6/g), fungi (x 10^3/g) and actinomycetes (x 10^4/g) of oven dry soil on 90 DAS

	Treatments	First crop (1998-1999)			Second crop (1999-2000)		
		Bacteria	Fungi	Actino-mycetes	Bacteria	Fungi	Actino-mycetes
T_1	Unweeded Control	115.24 (2.07)	33.24 (1.55)	41.82 (1.64)	113.28 (2.06)	31.50 (1.53)	40.34 (1.63)
T_2	HW twice	117.32 (2.08)	34.38 (1.56)	42.84 (1.65)	114.32 (2.07)	32.42 (1.54)	41.21 (1.64)
T_3	Pendimethalin 1.0 kg ha^{-1}+ HW	101.48 (2.01)	28.24 (1.48)	39.28 (1.62)	101.22 (2.01)	27.52 (1.47)	37.19 (1.59)
T_4	Cinmethylin 0.5 kg ha^{-1}	112.48 (2.06)	31.50 (1.53)	41.24 (1.64)	108.82 (2.04)	29.24 (1.50)	39.56 (1.62)
T_5	Cinmethylin 0.5 kg ha^{-1} +HW	114.62 (2.07)	32.24 (1.54)	41.52 (1.64)	112.20 (2.06)	30.15 (1.51)	40.01 (1.62)
T_6	Cinmethylin 0.6 kg ha^{-1}	108.18 (2.04)	29.24 (1.50)	40.32 (1.63)	107.28 (2.04)	28.24 (1.48)	38.26 (1.61)
T_7	Cinmethylin 0.6 kg ha^{-1} + HW	110.32 (2.05)	29.98 (1.51)	40.98 (1.63)	109.25 (2.05)	28.58 (1.49)	38.21 (1.60)
	SEd	0.01	0.01	0.01	0.01	0.01	0.01
	CD(P=0.05)	0.02	0.01	0.02	0.02	0.01	0.02

(Figures in parenthesis indicate log (x + 2) transformed value)

(T_3), which was closely followed by cinmethylin @ 0.6 kg ha^{-1} with and without hand weeding (T_6 and T_7).

4.3.6.2. Fungal population (Table 58)

At 90 DAS, higher fungal count was observed in unweeded control (T_1) and hand weeding twice (T_2) in both the crops. Application of cinmethylin @ 0.5 kg ha^{-1} with and without hand weeding (T_4 and T_5) were on par with each other regarding fungal population. Application of cinmethylin @ 0.6 kg ha^{-1} with and without hand weeding (T_6 and T_7) were comparable with each other. The lowest fungal population was recorded in application of pendimethalin @ 1.0 kg ha^{-1} + HW (T_3) treatment in both the crops.

4.3.6.3. Actinomycetes population (Table 58)

At 90 DAS, the data on microbial count showed that the actinomycetes population was higher in hand weeding twice (T_2), unweeded control (T_1) and cinmethylin at 0.5 kg ha^{-1} + HW (T_5) application, whereas it was decreased with pendimethalin application in both the crops. HW twice (T_2) recorded significantly higher population which was on par with the unweeded control (T_1). Application of cinmethylin @ 0.5 kg ha^{-1} with and without hand weeding (T_4 and T_5) were on par with each other regarding to microbial count. The actinomycetes population was decreased with application of cinmethylin @ 0.6 kg ha^{-1} with and without hand weeding (T_6 and T_7). The lowest fungal population was observed in pendimethalin @ 1.0 kg ha^{-1} + HW (T_3) treatment in both the crops.

4.3.7. Residues of cinmethylin and pendimethalin (ppm) in cotton seed

Herbicide residues detected in the cotton seed were presented in Table 59a.

The cotton seed was taken from the kapas after ginning for the determination of residues of the herbicides in this experiment. Estimations

Table 59a. Residues of cinmethylin and pendimethalin (ppm) in cotton seed

	Treatments	Residues (ppm)	
		First crop (1998-1999)	Second crop (1999-2000)
H_1	Cinmethylin 0.5 kg ha^{-1}	0.06	0.06
H_2	Cinmethylin 0.5 kg ha^{-1}+HW	0.07	0.06
H_3	Cinmethylin 0.6 kg ha^{-1}	0.08	0.08
H_4	Cinmethylin 0.6 kg ha^{-1}+HW	0.09	0.09
H_5	Pendimethalin 1.0 kg ha^{-1} + HW	0.01	0.01

Cinmethylin : Maximum residue limit (ppm) = 0.1 (recommended for rice)

Pendimethalin : Maximum residue limit (ppm) = 0.1

Table 59b. Recovery percentage of cinmethylin in cotton seed

Quantity added (ppm)	Amount recovered (ppm)	Recovery percentage
1	0.82	82.00
2	1.63	81.50

Mean : 81.75

were carried out for both the herbicide doses *viz.*, cinmethylin @ 0.5 kg ha^{-1} and 0.6 kg ha^{-1} and pendimethalin at 1.0 kg ha^{-1}. The seed sample from the untreated plots were fortified with cinmethylin at known concentrations and determination was done using same methodology for working out recovery. The recovery percentage was 81.75 per cent by the present method (Table 59b).

Among the two levels of cinmethylin, lower level of cinmethylin 0.5 kg ha^{-1} + HW recorded the residue of 0.07 and 0.06 ppm in first and second crop, respectively, whereas the higher level of cinmethylin @ 0.6 kg ha^{-1} + HW registered the residue of 0.09 and 0.09 ppm in first and second crop, respectively. Application of higher dose of the herbicide left higher amount of residues in the cotton seed compared to lower dose. However, the residue levels were below the maximum residue limit of 0.1 ppm recommended for rice crop. Pendimethalin residue in cotton seed was found to be below the MRL.

4.3.8. Bio-assay studies on cucumber in post harvest cotton soil (Table 60)

The bio-assay study was carried out to assess the residual effect of herbicides on the succeeding crop. The residual effect of herbicides were assessed by estimating the germination percentage at 7 DAS, plant height and DMP of cucumber crop at 30 DAS.

The germination percentage of the cucumber crop indicated that there was no marked difference among the treatments, whereas plant height and DMP indicated that some difference among the herbicide treatments. The treatments like, hand weeding twice (T_2) and unweeded control (T_1) showed higher plant height as well as DMP of cucumber. Among the herbicides, cinmethylin @ 0.5 kg ha^{-1} + HW (T_5) recorded higher plant height and DMP. Pendimethalin @ 1.0 kg ha^{-1} + HW (T_3) recorded lower plant height and DMP.

Table 60. Bio-assay studies on cucumber in post harvest cotton soil

Treatments		Biometric observations		
		Germination (%)	Plant height at 30 DAS (cm)	DMP (g/plant) at 30 DAS
T_1	Unweeded control	90.00 (75.00)	22.42	1.66
T_2	Hand weeding twice	93.30 (77.71)	22.54	1.64
T_3	Pendimethalin 1.0 kg ha^{-1} + HW	80.00 (63.93)	21.00	1.36
T_4	Cinmethylin 0.5 kg ha^{-1}	86.67 (68.85)	21.98	1.34
T_5	Cinmethylin 0.5 kg ha^{-1} + HW	86.67 (68.85)	22.38	1.44
T_6	Cinmethylin 0.6 kg ha^{-1}	83.33 (66.15)	21.59	1.36
T_7	Cinmethylin 0.6 kg ha^{-1} + HW	83.33 (66.15)	22.01	1.40
	SEd	6.27	0.73	0.05
	CD (P=0.05)	NS	1.51	0.09

(Figures in parenthesis indicate Arc sine transformed value)

4.4. Residual effect of herbicides on cowpea, greengram, sorghum and soybean

4.4.1. Germination percentage (Table 61)

The germination percentage was recorded at 10 days after sowing. Cowpea, greengram, sorghum and soybean were sown as residual crops after the harvest of cotton which revealed that there was no significant difference in the germination of residue crops among the different herbicide treatments. About 90.10 to 93.24 per cent in cowpea, 88.43 to 91.24 per cent in greengram, 84.61 to 87.56 per cent in sorghum and 78.41 to 81.53 per cent in soybean were recorded.

Germination count of cowpea, greengram, sorghum and soybean following cotton were not markedly affected by the different weed management practices adopted for cotton.

4.4.2. Weed density in succeeding residue crops

4.4.2.1. Total weed population (Table 62)

Weed management practices adopted in the previous crop of cotton significantly reduced the total weed density in succeeding residual crops over unweeded control in both 15 and 30 DAS. Application of pendimethalin @ 1.0 kg ha^{-1} recorded lesser weed density of 12.24 and 14.59 m^{-2} at 15 and 30 DAS, respectively. This was followed by cinmethylin @ 0.6 kg ha^{-1} + HW (T_7) recorded lesser weed density of 12.82 and 15.01 at 15 and 30 DAS, respectively. This was closely followed by application @ 0.5 kg ha^{-1} + HW (T_5) (13.52 and 15.45 at 15 and 30 DAS, respectively). Unweeded control (T_1) registered higher weed density of 48.54 and 57.96 at 15 and 20 DAS, respectively.

Table 61. Effect of herbicide residues on germination percentage of cowpea, greengram, sorghum and soybean

	Treatments	Germination percentage			
		Cowpea	Green gram	Sorghum	Soybean
T_1	Unweeded control	92.37 (74.01)	91.24 (72.81)	87.56 (69.38)	81.38 (64.40)
T_2	Hand weeding twice	93.24 (75.02)	90.28 (71.87)	86.28 (68.28)	81.53 (64.52)
T_3	Pendimethalin 1.0 kg ha^{-1} + HW	90.10 (71.66)	88.43 (70.09)	84.61 (66.89)	78.73 (62.51)
T_4	Cinmethylin 0.5 kg ha^{-1}	91.92 (73.57)	88.94 (70.61)	85.54 (67.70)	79.82 (63.33)
T_5	Cinmethylin 0.5 kg ha^{-1} + HW	92.12 (73.78)	90.43 (71.95)	86.13 (68.19)	81.42 (64.47)
T_6	Cinmethylin 0.6 kg ha^{-1}	90.52 (72.05)	89.62 (71.19)	84.84 (67.05)	78.41 (62.31)
T_7	Cinmethylin 0.6 kg ha^{-1} + HW	90.92 (72.44)	89.49 (71.07)	84.72 (66.97)	81.01 (64.16)
	SEd	1.64	1.42	1.22	0.98
	CD (P=0.05)	NS	NS	NS	NS

(Figures in parenthesis indicate Arc sine transformed value)

Table 62. Total weed density (No. m^{-2}) and DMP (kg ha^{-1}) of weeds in residue crops

Treatments		Weed density (No.m^{-2})		Weed DMP (kg ha^{-1})	
		15 DAS	30 DAS	15 DAS	30 DAS
T_1	Unweeded control	48.54 (1.71)	57.96 (1.78)	121.35 (2.09)	197.06 (2.30)
T_2	Hand weeding twice	17.25 (1.29)	20.76 (1.36)	44.16 (1.67)	68.24 (1.85)
T_3	Pendimethalin 1.0 kg ha^{-1}+HW	12.24 (1.15)	14.59 (1.22)	33.02 (1.54)	38.24 (1.60)
T_4	Cinmethylin 0.5 kg ha^{-1}	15.58 (1.25)	16.58 (1.27)	36.61 (1.59)	47.25 (1.69)
T_5	Cinmethylin 0.5 kg ha^{-1}+HW	13.52 (1.19)	15.45 (1.24)	34.61 (1.57)	40.17 (1.66)
T_6	Cinmethylin 0.6 kg ha^{-1}	14.28 (1.21)	16.24 (1.26)	35.76 (1.58)	44.66 (1.67)
T_7	Cinmethylin 0.6 kg ha^{-1}+HW	12.82 (1.18)	15.01 (1.23)	33.72 (1.55)	39.65 (1.62)
	SEd	0.01	0.01	0.01	0.02
	CD (P=0.05)	0.02	0.02	0.03	0.04

(Figures in parenthesis indicate log (x + 2) transformed value)

4.4.2.2. Weed dry matter production (Table 62) (Fig. 24)

Different weed management practices in cotton had significant effect on the total weed DMP in the succeeding residue crops. Among different weed management practices followed, application of pendimethalin @ 1.0 kg ha^{-1} recorded lesser weed DMP of 33.02 and 38.24 m^{-2} at 15 and 30 DAS, respectively. This was followed by cinmethylin @ 0.6 kg ha^{-1} followed by hand weeding at 30 DAS (T_7) registering lower weed DMP of 33.72 and 39.65 kg ha^{-1} at 15 and 30 DAS, respectively, which was closely followed by cinmethylin @ 0.5 kg ha^{-1} + HW (T_5) registered weed DMP of 34.61 and 40.17 kg ha^{-1} 15 and 30 DAS, respectively. The unweeded control (T_1) recorded highest weed DMP of 121.35 and 197.06 at 15 and 30 DAS, respectively.

4.4.3. Plant height (cm) of succeeding residue crops (Table 63)

All the weed management practices adopted in cotton significantly increased the plant height of succeeding residue crops at 30 DAS over unweeded control (T_1). Among the weed management practices followed cinmethylin @ 0.5 kg ha^{-1} + HW (T_5) registered higher plant height of 29.87 cm of cowpea, 25.97 cm of greengram, 57.28 cm of sorghum and 30.48 cm of soybean at 30 DAS, which was followed by cinmethylin @ 0.5 kg ha^{-1} (T_4) without hand weeding. Application of cinmethylin @ 0.6 kg ha^{-1} followed by hand weeding at 40 DAS (T_7) and pendimethalin @ 1.0 kg ha^{-1} followed by hand weeding at 40 DAS (T_3) were on par with each other regarding plant height of residue crops. The lowest plant height of 24.10 cm of cowpea, 22.62 cm of greengram, 46.28 cm of sorghum and 25.48 cm of soybean were recorded in unweeded control (T_1) at 30 DAS.

Table 63. Plant height (cm) of residue crops at 30 DAS as influenced by weed management practices

Treatments	Plant height (cm)			
	Cowpea	Greengram	Sorghum	Soybean
T_1 Unweeded control	24.10	22.62	46.28	25.48
T_2 Hand weeding twice	28.24	24.28	48.28	27.42
T_3 Pendimethalin 1.0 kg ha^{-1}+HW	27.02	25.30	52.94	28.92
T_4 Cinmethylin 0.5 kg ha^{-1}	28.24	24.74	56.79	30.23
T_5 Cinmethylin 0.5 kg ha^{-1}+HW	29.87	25.97	57.28	30.48
T_6 Cinmethylin 0.6 kg ha^{-1}	27.26	23.76	53.98	28.96
T_7 Cinmethylin 0.6 kg ha^{-1}+HW	27.97	24.47	54.45	29.02
SEd	0.57	0.47	1.03	0.56
CD (P=0.05)	1.17	0.98	2.12	1.15

Table 64. **DMP of residue crops at 30 DAS as influenced by weed management practices (kg ha^{-1})**

Treatments	Crop DMP (kg ha^{-1})			
	Cowpea	Greengram	Sorghum	Soybean
T_1 Unweeded control	158	140	578	160
T_2 Hand weeding twice	220	219	794	192
T_3 Pendimethalin 1.0 kg ha^{-1}+HW	242	227	892	268
T_4 Cinmethylin 0.5 kg ha^{-1}	252	239	874	248
T_5 Cinmethylin 0.5 kg ha^{-1}+HW	265	245	950	295
T_6 Cinmethylin 0.6 kg ha^{-1}	248	228	780	272
T_7 Cinmethylin 0.6 kg ha^{-1}+HW	254	235	850	280
SEd	7.06	6.87	24.05	7.69
CD (P=0.05)	14.52	14.12	49.45	15.81

Fig.24. Residual effect of herbicide treatments on dry matter production of weeds in residue crops

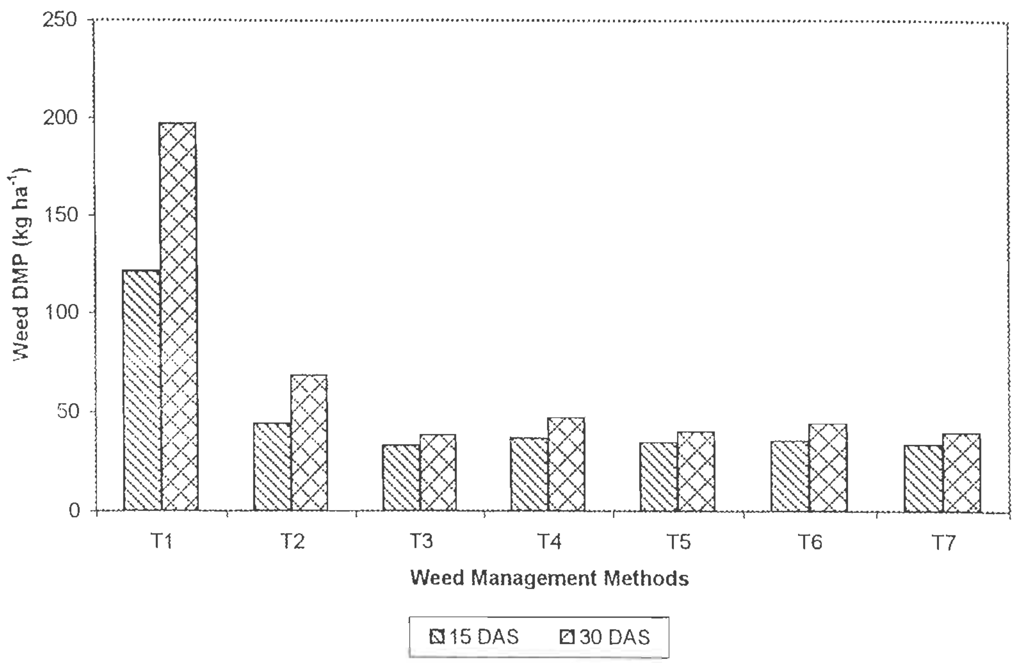
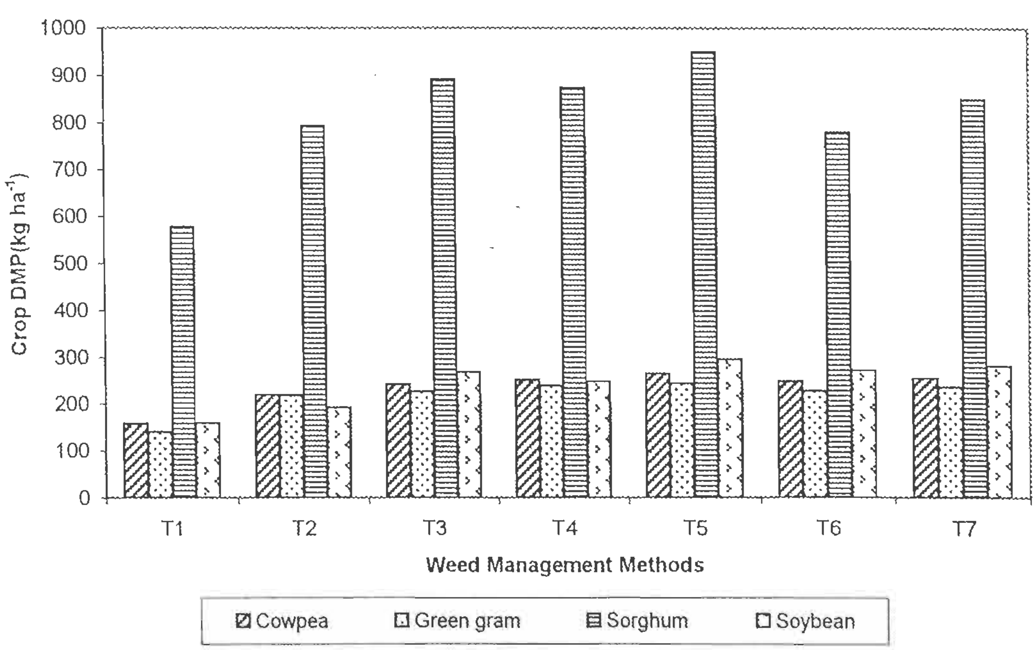


Fig. 25. Residual effect of herbicide treatments on dry matter production of residual crops on 30 DAS



4.4.4. Dry matter production (DMP) (Table 64) (Fig. 25)

DMP of succeeding residue crops was significantly improved by the weed management practices adopted in cotton crop. Cinmethylin applied to cotton crop @ 0.5 kg ha^{-1} + HW (T_5) registered markedly higher DMP of 265 kg ha^{-1} of cowpea, 245 kg ha^{-1} of greengram, 950 kg ha^{-1} of sorghum and 295 kg ha^{-1} of soybean at 30 DAS, which is followed by application of cinmethylin @ 0.6 kg ha^{-1} + HW (T_7) higher crop DMP (254 kg ha^{-1} for cowpea, 235 kg ha^{-1} for greengram, 850 kg ha^{-1} for sorghum and 280 kg ha^{-1} of soybean at 30 DAS) which was on par with pendimethalin @ 1.0 kg ha^{-1} + HW (T_3). The lowest crop DMP of 158 kg ha^{-1} of cowpea, 140 kg ha^{-1} of greengram, 578 kg ha^{-1} of sorghum and 160 kg ha^{-1} of soybean were recorded in unweeded control (T_1) at 30 DAS.

DISCUSSION

CHAPTER V
DISCUSSION

Field experiments were conducted at Agricultural College and Research Institute, Tamil Nadu Agricultural University, Coimbatore from August 1998 to January 2000 with the aim to develop efficient weed management practices for irrigated cotton and to study the residual effect of herbicide applied to cotton on the succeeding pulses and cereal crops. The results obtained from the experiments are discussed in this chapter.

The weather parameters prevailed during winter season of 1998 and 1999 were normal and condusive for the normal growth and development of cotton crop. During winter season, due to frequent rains, there was luxurious growth of weeds which competed with the growth of cotton. Different species of weeds in the experimental field were identified which have been in association with cotton. The effect of weed management treatments on different weed species is discussed.

5.1. Preliminary trial results

A preliminary experiment was conducted with pre-emergence herbicide like cinmethylin with 3 doses *viz.*, 0.4, 0.6 and 0.8 kg ha^{-1} along with control to assess its suitability to cotton under irrigated condition. Application of cinmethylin @ 0.4 kg ha^{-1} did not cause any phytotoxicity to cotton. However, cinmethylin @ 0.6 and 0.8 kg ha^{-1} have caused some phytotoxic effect (ratings of light to moderate injury). During initial stages these exhibit some phytotoxicity on cotton at 7 and 15 DAS. Application of cinmethylin at 0.56 to 0.84 kg ha^{-1} did not show significant crop injury and provided excellent control of annual grasses (Russell *et al.*, 1991). Bozarth *et al.* (1984) stated that peanut and cotton were highly tolerant to cinmethylin. The suitability of above herbicide at 0.4-0.6 kg ha^{-1} resulted in good to excellent weed control as ascertained through visual and control ratings in terms of reduction in weed density, which effectively controlled grasses, some sedges and few broad leaved weeds at 15 and 30 DAS. Application of cinmethylin @ 2.05 and 4.1 litres ha^{-1} was poor against broad leaved weeds (Liu *et al.,* 1990). Application of cinmethylin @ 1.68 kg ha^{-1} provided excellent control of grasses (Russell *et al.,* 1991).

The weed control efficiency of this herbicide ranged from 66.94 to 90.32 per cent. This might be due to effective control of weeds from seed germination itself. Cinmethylin showed greater activity against grasses and sedges than against broad leaved weeds and its herbicidal activity results from the disruption of meristematic development in the growing points of roots and shoots of susceptible species (Anonymous, 1988).

Regarding plant height, application of cinmethylin @ 0.6 kg ha^{-1} recorded taller plants (26.72 cm) than 0.4 kg ha^{-1} (24.38 cm) and 0.8 kg ha^{-1} (23.85 cm) in 30 DAS. This might be due to lower dose of herbicide did not control weeds effectively, whereas higher dose of herbicide gave excellent control of weeds, which causes phytotoxicity to cotton plant. Therefore a dose in between these two levels of cinmethylin *viz.,* 0.5 kg ha^{-1} would be safer to cotton plant as well as weed control.

5.2. Studies on weeds

5.2.1. Weed spectrum

The results of the present study revealed that the broad leaved weeds population was dominant over grasses and sedges in cotton. This might be due to the smothering effect of broad leaved weeds on grasses. Among the weed flora of the experimental field, the grasses and sedges occupied the second and third position. Among the broad leaved weeds in the experimental field, *Digera arvensis* and *Trianthema portulacastrum* were dominant weed flora in both the crops at 20, 40, 80 and 120 DAS. This might be due to their inherent capacity for attaining a faster growth rate by expanding its leaf area within shorter time span. The greater leaf area would have intercepted high incoming solar radiation in between the slow growing seedlings of cotton. This should have promoted the effective utilization of available resources which lead to their dominance over other weed species. Among the weed groups the broad leaved weeds occupied 44.43 to 45.31 and 47.15 to 50.06 per cent at 20 and 40 DAS, respectively in both the crops. The grasses occupied second position in weed groups of 41.32 to 43.21 and 37.16 to 39.89 per cent at 20 and 40 DAS, respectively in both the crops. Among the grasses in the experimental field, the dominant species are *Dactyloctenium aegyptium, Echinochloa colonum, Chloris barbata* and *Cynodon dactylon*. Among the perennial weeds, *Cyperus rotundus* was the only sedge weed observed. This sedge weed constituted about 12.36 to 13.33 and 12.78 to 12.96 per cent at 20 and 40 DAS, respectively in both the crops. Balasubramanian (1985) has reported that similar association of dicots like *Digera arvensis, Trianthema portulacastrum* and moncots like *Dactyloctenium aegyptium, Echinochloa colonum* and *Cyperus rotundus* were dominant weeds in sandy loam soil of Coimbatore. The predominance of above species among the broad leaved weed confirms with the earlier reports of Chander *et al.* (1994).

5.2.2. Population of major weed groups

5.2.2.1. Broad leaved weeds

Among the broad leaved weeds, weed species such as *Digera arvensis* and *Trianthema portulacastrum* were effectively controlled by the pendimethalin @ 1.0 kg ha^{-1} followed by hand weeding at 40 DAS. This effective weed control might be due to longer persistence and more residue activity of pendimethalin on the emerging seedlings of broad leaved weeds. Balasubramanian (1992) found that pre-emergence application of pendimethalin @ 1.25 to 3.0 kg ha^{-1} controlled most of broad leaved and grass weeds. Akhtar *et al.* (1986) reported that application of pendimethalin @ 1.50 kg ha^{-1} was most effective in controlling broad leaved weeds in cotton when compared to hand weeding and unweeded control.

The broad leaved weeds were suppressed by cinmethylin @ 0.6 as well as 0.5 kg ha^{-1} followed by hand weeding at 40 DAS. This might be due to its persistence for long time under aerobic conditions. Tomlin (1999) has found that half life period of cinmethylin ranges from 23 to 75 days depending on soil texture. In clay soil it persist still more time. Wilson (1989) also concluded that application of cinmethylin @ 0.1 to 1.6 kg ha^{-1} resulted in good control of grasses and controlled few annual broad leaved weeds in tropical legumes. Similar findings were also reported by Russell *et al.* (1990).

The density of broad leaved weeds such as *Digera arvensis* and *Trianthema portulacastrum* were reduced by growing of smother intercropping systems *viz.*, cotton + greengram and cotton + cowpea upto 40 DAS. This might be due to the smothering efficiency of intercrops and lesser light availability for weed growth. Under intercropping situation the pulses grow vigourously during the early stages and cover the soil with their canopy resulting in reduced weed growth (Balasubramanian *et al.*, 1992).

5.2.2.2. Grasses

The population of grasses such as *Dactyloctenium aegyptium, Echinochloa colonum* and *Chloris barbata* were most effectively controlled by the pre-emergence application of cinmethylin @ 0.6 and 0.5 kg ha^{-1} followed by hand weeding at 40 DAS. Cinmethylin, being a grass herbicide it controlled all grasses effectively irrespective of the stages whereas in case of *Cynodon dactylon* which is less effective. This might be due to the increased weed control efficiency with the increasing doses of cinmethylin. Forney *et al.* (1985) also reported that pre-emergence application of cinmethylin gave excellent control of most of annual grasses in soybean. The application of pendimethalin @ 1.0 kg ha^{-1} followed by hand weeding at 40 DAS effectively controlled the grasses population. This could be due to longer residual effect of pendimethalin. Chandler (1984) found that dinitroaniline herbicides controlled most of the annual weeds. Regarding smother crops, in cotton growing of greengram and cowpea have partially controlled grasses upto 40 DAS as compared to other allelopathic treatments. The population of grasses were markedly reduced at 80 DAS in all treatment plots. This was due to the earthing up given to all the plots at 45 DAS.

5.2.2.3. Sedges

Application of cinmethylin @ 0.6 and 0.5 kg ha^{-1} followed by hand weeding at 40 DAS effectively controlled *Cyperus rotundus* throughout the crop period. Tomlin (1999) also found that cinmethylin was effective against *Echinochloa* spp. and *Cyperus difformis* in transplanted rice. Application of pendimethalin @ 1.0 kg ha^{-1} followed by hand weeding at 40 DAS partially controlled *Cyperus rotundus* but it was less effective when compared to cinmethylin. However, the *Cyperus rotundus* population was markedly decreased after 80 and 120 DAS in all treatments. This might be due to hand weeding given at 40 DAS and earthing up operation at 45 DAS. Growing of smother crops such as greengram and cowpea did not have much effect on *Cyperus rotundus* population.

5.2.3. Weed population

In both the crops, the total weed population (grasses, sedges and broad leaved weeds) increased upto 40 DAS, then there was declining trend. Similar results were recorded by Balasubramanian (1992) who found that the hand weeding and earthing up were given at 40 and 45 DAS, respectively in all the plots and cotton itself had some smothering effect at later stages. This could be attributed to the completion of life cycle of early germinated weeds and reduced germination of weeds at later stages of the crop (80 and 120 DAS).

In general, chemical weed management reduced the population of all the weeds at all the stages of crop growth as compared to weedy check. Application of cinmethylin @ 0.6 and 0.5 kg ha^{-1} followed by hand weeding at 40 DAS most effectively controlled the weed population (esp. grasses and sedges) in both the crops. This might be due to the fact that cinmethylin is highly effective against grasses, sedges and suppression activities on broad leaved weeds. In legume crops, similar report was recorded by Wilson (1989) who found that application of cinmethylin @ 0.1 to 1.6 kg ha^{-1} resulted in good control of grasses and broad leaved weeds. The higher dose of cinmethylin @ 0.6 kg ha^{-1} affected the plant growth because of injury to cotton plants at higher dose of cinmethylin. Russell *et al.* (1991) also observed similar injury on soybean, snap bean, cotton and cucumber.

The results of present study indicated that pendimethalin @ 1.0 kg ha^{-1} followed by hand weeding at 40 DAS registered lesser weed population as compared with hand weeding twice and unweeded control. Pendimethalin reduced the density of weed species, particularly grass weeds and broad leaved weeds which are annual in nature. It is primarily a grass weed killer besides killing some dicots and few sedges. It mainly enters into the grasses through the coleoptile and shoot of the seedling below the ground. Thus, the grasses were effectively checked with this herbicide. Generally, integrated weed control could result in a broad spectrum weed control especially when herbicides were applied as pre-emergence. This study indicates that broad spectrum weed control was achieved due to combination of herbicide, pendimethalin as pre-emergence with one hand weeding at 40 DAS. Similar result was also reported by Ramamoorthy (1994) who reported that pendimethalin was effective against grasses and broad leaved weeds.

Growing of cotton with smother crops such as greengram and cowpea upto 40 DAS significantly controlled the grasses as well as broad leaved weeds. After 45 DAS the earthing up was given all treatment plots, which leads to weed free environment throughout crop growth (80 and 120 DAS). This might be due to initial rapid growth and development of good canopy cover of greengram and cowpea probably suppresses the broad leaved weeds in cotton. This finding was in line with reports of Balasubramanian (1985) who found that cowpea and lab-lab in cotton as smother intercrops effectively suppressed the weeds during the critical period of crop-weed competition. Similar results were also reported by Purushothaman (1991). Among the allelopathic treatments, parthenium whole plant extract (10%) spray and parthenium incorporation @ 2 t ha^{-1} followed by hand weeding at 40 DAS considerably decreased the total weed population irrespective of the stages. Parthenium biomass incorporation and whole plant extract might have released some allelochemicals such as sesquiterpene, lactones, alkaloids, parthenin, kaemferol, P-coumaric acid and caffeic acid which might be the reason for control of weed population at earlier stages. Arunachalam (1997) found that parthenium whole plant extract suppresses *Cyperus* population at 40 DAS under field conditions and Umapathy *et al.* (1998) reported that parthenium incorporation @ 5 t ha^{-1} effectively controlled *Trianthema portulacastrum* and *Cyperus rotundus* in blackgram.

Comparison of relative density values of grasses, sedges and broad leaved weeds at 20 and 40 DAS revealed that broad leaved weeds dominated over grasses and sedges at both the stages. In cinmethylin applied treatment, the broad leaved weeds dominated over sedges and grasses. This relative density indicates that cinmethylin effectively controlled grasses and some sedges. Application of pendimethalin effectively controlled grasses and broad leaved weeds than sedges. The relative density of sedges and grasses were dominated than broad leaved weeds in pendimethalin applied treatment. With advancement in growth of crop the relative density values of grasses and sedges showed decline whereas broad leaved weeds increased. The relative density of broad leaved weeds was lower with cotton + greengram and cotton + cowpea as smother cropping systems. Dominance of broad leaved weeds in the early stages was due to their faster growth and deep root system which enabled them to tap the soil moisture as reported by Sankaran and De Datta (1984).

With the advancement of crop duration, the growth and development of grasses as well as sedges were decreased whereas broad leaved weeds were increased including herbicide treated plots like cinmethylin (relative density of weeds at 80 and 120 DAS). But relative density of grasses and sedges were less irrespective of all the stages of the crop. The treatments which received hand weeding twice and pendimethalin @ 1.0 kg ha^{-1} + HW at 40 DAS have registered higher sedges followed by broad leaved weeds and grasses. The reason might be that during hand weeding operation top portion of weed and growth from the side shoots were left behind in the soil. The results are in line with the earlier reports by Ramamoorthy (1985). After removal of smother crops at 40 DAS the relative density values of the broad leaved weeds has dominated over grasses and sedges. This might be due to the fact that ground intercepted much of incident light and regeneration of broad leaved weeds may occur.

5.2.4. Dry matter production of weeds

The dry matter production of weeds was higher in unweeded control throughout the cropping period. The dry weight of grasses, sedges and broad leaved weeds as well as total weeds were drastically lowered due to different weed management practices. Further, the dry matter production of weeds showed an increasing trend from germination to the end of critical period of crop-weed competition (upto 40 to 60 DAS) and it decline thereafter. It might be due to the completion of life cycle by the early germinated weed at this period.

The dry matter showed a decreasing trend with increasing rate of cinmethylin. Application of cinmethylin @ 0.6 and 0.5 kg ha^{-1} followed by hand weeding at 40 DAS effectively reduced the weed dry matter production. This might be due to effective control of grasses, sedges and few broad leaved weeds by the herbicide irrespective of the stages. This finding is in accordance with the results of Venkata Ramana *et al.*(1992) who found that cinmethylin @ 0.08 kg ha^{-1} alone and cinmethylin + 2,4-DEE (0.08 and 0.4 kg ha^{-1}) reduced total dry weight of weeds in transplanted rice.

Pre-emergence application of pendimethalin also registered lower weed biomass as a result of inhibition of weed seed germination by herbicidal action and reduction of weed density. Application of pendimethalin @ 1.0 kg ha^{-1} + HW at 40 DAS effectively controlled weed dry matter production due to control of annual broad leaved weeds and grasses. Application of pendimethalin @ 1.5 kg ha^{-1} as pre-plant incorporation reduced weed DMP effectively (Panwar *et al.,* 1995). Similarly Angirs *et al.* (1991) also found that pre-emergence application of pendimethalin at 1.50 kg ha^{-1} and oxyflourfen at 0.20 kg ha^{-1} most effectively reduced the dry matter of weeds in flax crop.

The dry matter of grasses, broad leaved weeds as well as total weeds were significantly reduced by growing of smother intercrops. The reduction was higher in cotton + greengram and cotton + cowpea smother intercrops at 20 and 40 DAS in both the cotton crops. This might be due to the smothering efficiency of intercrops through canopy cover and high population pressure which lead to a reduction in the density of weeds. This finding is in accordance with the results of Balasubramanian (1985) who found that inclusion of quick growing pulses as smother intercrops effectively suppressed the growth of weeds and weed biomass accumulation. Similar results were described by Velayutham (1996) who reported that the weed dry weight was reduced due to cotton + cowpea intercropping than cotton + soybean intercropping system.

Regarding allelopathic treatments, parthenium incorporation and whole plant extract spray (10%) considerably reduced the dry weight of sedges and broad leaved weeds. This might be due to the presence of allelochemicals such as parthenin, caffeic acid, P-coumaric acid, ferulic acid, vanillic acid and anisic acid in parthenium reduced the weed population. Parthenium reduced dry weight of seedlings of *Cassia tora, Cassia occidentalis* and *Cassia sophera* (Rahman and Acharia, 1998). Parthenium incorporation @ 5 t ha^{-1} effectively controlled the sedges and broad leaved weeds in black gram as recently reported by Umapathy *et al.* (1998). Aqueous leachates of parthenium was found to be inhibitory to the *Ageratum gengeticus* seedlings (Asha Gupta and Gupta, 1996).

While comparing the relative dry weight values, the DMP of broad leaved weeds to total weeds was higher (30.12 to 75.6 per cent) than grasses (10.89 to 42.25 per cent) and sedges (9.63 to 41.43 per cent). In earlier experiments, dominance of broad leaved weeds over grasses and sedges has been reported by Alwar Arunachalam (1993) and (Velayutham, 1996). The herbicides respond differently among relative dry weight. The pre-emergence application of cinmethylin @ 0.6 and 0.5 kg ha^{-1} followed by hand weeding at 40 DAS reduced the relative dry weight values of grasses and sedges. While pendimethalin @ 1.0 kg ha^{-1} + HW at 40 DAS reduced relative dry weight of grasses as well as broad leaved weeds. This might be due to the herbicides which are having different mode of action and selectivity.

Growing of weed smother crops, the relative dry weight of weeds were more or less equally distributed at 20 and 40 DAS. This might be due to suppression of grasses, sedges and broad leaved weeds effectively by smother crops of greengram and cowpea. This finding is in accordance with the results of Solaiappan *et al.* (1994).

The summed dominance ratio of broad leaved weeds at 20 as well as 40 DAS was much higher in cinmethylin treated plots than the pendimethalin treated plots. This indicated that the application of cinmethylin @ 0.6 and 0.5 kg ha^{-1} followed by hand weeding at 40 DAS effectively controlled the grasses and sedge weeds, whereas pendimethalin @ 1.0 kg ha^{-1} followed by hand weeding at 40 DAS effectively controlled broad leaved weeds. This was supported by the observations on greater selectivity of cinmethylin against grasses, sedges and some broad leaved weeds in peanut (Russell *et al.,* 1991). The pendimethalin was effective against broad leaved weeds (Ahuja and Yaduraj, 1992).

The summed dominance ratio of broad leaved weeds at 20 and 40 DAS were lesser by growing of smother crops *viz.,* greengram and cowpea along with cotton. Whereas grasses and sedges were occupied major summed dominance ratio. This might be due to greengram and cowpea which offer the great competition with broad leaved weeds. This finding was in line with Velayutham (1996) who reported that sole crop of cotton due to wider interspace, greater light availability and slow growth of cotton, the broad leaved weeds were dominated, whereas when intercrops like cowpea and soybean were raised in the interspace, the growth of *Trianthema portulacastrum* was affected due to lesser availability of space and light and greater competition from the vigorous growth of the intercropped pulses. The summed dominance ratio of sedge was lower irrespective of all the stages of parthenium incorporation and whole plant extract spray whereas the broad leaved weeds were dominated. This might be due to allelochemical present in the parthenium, which inhibit the sedge weed population.

This was in accordance with Arunachalam (1997) who found that parthenium whole plant extract suppressed *Cyperus* population at 40 DAS at field conditions.

5.2.5. Weed control efficiency

In both the crops, weed control efficiency (WCE), which indicates the comparative magnitude of reduction in weed dry matter by weed control treatments, was highly influenced by different treatments. The weed control efficiency was higher in application of cinmethylin @ 0.6 kg ha^{-1} and 0.5 kg ha^{-1} followed by hand weeding at 40 DAS irrespective of the stages of crop growth (20, 40, 80 and 120 DAS). This might be due to efficient control of grasses, sedges and few broad leaved weeds followed by hand weeding at 40 DAS, which effectively controlled left over weeds and thereby reduction of weed dry matter throughout the crop period. Similar finding was reported in rice by Govinda Singh and Gupta (1992) who found that application of cinmethylin @ 0.08 kg ha^{-1} reduced the weed dry matter and thereby increased the WCE in rice.

The results of the present study indicated that application of pendimethalin @ 1.0 kg ha^{-1} followed by hand weeding at 40 DAS produced higher WCE throughout the crop period which is comparable to the conventional weeding i.e. hand weeding twice. This integrated weed management practice gave the broad spectrum weed control as a result of longer persistency in the soil profile. Nevertheless, manual weeding is usually rendered difficult especially during the monsoon seasons due to intermittent rains and consequently the moisture content of the soil would be too high for mechanical manipulation. Hence, application of pendimethalin at 1.00 kg ha^{-1} followed by hand weeding at 40 DAS is quite suitable to overcome the weed problem in cotton. A similar finding was reported by Balasubramanian (1992) who found that the weed control efficiency was comparatively higher with the application of pendimethalin @ 1.00 kg ha^{-1} as compared to 0.50 and 0.75 kg ha^{-1}.

Growing of greengram and cowpea as smother crops along with cotton comparatively increased the WCE in both the crops. This might be due to vigorous growth of smother crops during early stages and cover the soil with their canopy resulted in reduced weed growth. Similar result was observed by Muruganandam (1984) who described that cotton + greengram system resulted higher WCE. Among the allelopathic treatments, parthenium incorporation and whole plant extract spray with hand weeding at 40 DAS recorded higher WCE. This might be due to inhibition of weed seed germination by allelochemicals of parthenium and integration of hand weeding at 40 DAS increased the WCE. This finding is in accordance with the results of Kanchan (1975) who reported that the presence of inhibitors in root, leaf, inflorescence and fruits of matured plant of parthenium shows inhibition of coleoptile growth and dry matter accumulation of weeds.

5.2.6. Weed index

The extent of yield reduction due to weed competition was assessed through weed index. Application of cinmethylin @ 0.5 kg ha^{-1} followed by hand weeding at 40 DAS recorded minimum weed competition and maximum seed cotton yield and it was considered as the maximum possible yield under the study situation i.e. 100 per cent yield. This might be due to reduction in population and DMP of weeds which led to higher seed cotton yield. This was followed by application of pendimethalin @ 1.0 kg ha^{-1} followed by hand weeding at 40 DAS which recorded lowest weed index of 5.66 and 6.24 per cent in first and second crop, respectively.

The higher dose of cinmethylin @ 0.6 kg ha^{-1} followed by hand weeding at 40 DAS recorded higher weed index of 10.09 and 9.89 per cent in first and second crop, respectively. This might be due to higher dose of cinmethylin which affected the growth, development and yield parameters of plants thereby reduced the seed cotton yield, which was confirmed by the preliminary experiment. Growing of greengram and cowpea as smother intercrops with cotton reduced the weed index to the tune of 12.58 and 12.99 per cent for greengram and 14.00 and 14.07 per cent for cowpea in first and second crop, respectively. This might be due to the weed free condition created by this treatment and thereby increased the seed cotton yield. The allelopathic treatments were recorded higher weed index. This might be due to higher density and DMP of weeds resulting in reduced plant growth parameters, yield parameters and thereby decreased the seed cotton yield.

5.2.7. Nutrient removal by weeds

Slow growth of cotton at initial stages permitted the weeds to compete for nutrients. Herbicides application saved nutrients loss appreciably by decreasing the nutrient (nitrogen, phosphorus and potassium) depletion by weeds in the all stages of crop growth compared to unweeded control.

The nutrients (NPK) uptake of weeds was greatly reduced by application of cinmethylin @ 0.6 kg ha^{-1} followed by hand weeding at 40 DAS. The nutrient content was reduced by the above treatment to the tune of 88.03, 89.60, 91.36 and 94.0 per cent and 89.38, 88.89, 91.39 and 93.87 per cent of nitrogen, 96.78, 95.72, 96.08 and 95.18 per cent and 96.85, 95.69, 95.32 and 95.49 per cent of phosphorus and 90.50, 90.60, 91.72 and 91.56 per cent and 90.25, 90.83, 91.66 and 91.23 per cent of potassium at 20, 40, 80 and 120 DAS in first and second crop, respectively over unweeded control. This was followed by application of cinmethylin @ 0.5 kg ha^{-1} followed by hand weeding at 40 DAS. Hence, the NPK depletion by weeds in these treatments had a direct relationship with the quantum of weed dry matter produced. The weeds removed 5 to 6 times of N, 5 to 12 times of P and 2 to 5 times of K under upland cotton (Jain *et al.,* 1981).

The results of the present study revealed that loss of nutrients (NPK) through weeds could be checked considerably by application of pendimethalin @

1.0 kg ha^{-1} followed by hand weeding at 40 DAS. This might be due to the weed free environment created by the herbicide thereby reduced the weed DMP. This finding was in line with the reports of Chander *et al.* (1994) who described that application of pendimethalin @ 1.25 kg ha^{-1} followed by hand weeding reduced the nutrient removal by weeds which was comparable with hand weeding twice. The final estimate of nutrient depletion by weeds at 80 and 120 DAS was reduced in the supplemental hand weeding at 40 DAS. Such positive effect was due to lower population and dry weight of weeds resulting from effective control.

Growing of greengram and cowpea as smother intercrops effectively reduced NPK removal by weeds in both the crops. This might be due to lesser weed population and lower weed DMP. This study was in conformity with Singh *et al.* (1983) who stated that the population, growth and uptake of nutrients by weeds were significantly lowered by intercropping of cotton with cowpea and greengram. Mohamed Ali *et al.* (1987) stated that the removal of nutrient by weeds was significantly lower in intercropping systems with greengram than with onion as intercrop in cotton.

Spraying of parthenium whole plant extract followed by hand weeding at 40 DAS considerably reduced the NPK removal by weeds throughout the crop period. This might be due to considerable reduction of weed population and DMP. At all the stages, weeds removed more quantities of NPK in unweeded control. This was due to markedly higher DMP by the weeds. The results of the present study are in accordance with the findings of Nadanassababady (1999).

5.3. Studies on cotton

5.3.1. Germination

Different weed management treatments, did not influence the germination of cotton. However, cinmethylin at higher rates (0.6 kg ha^{-1}) caused some phytotoxicity in cotton plants. The crop plants showed phytotoxic symptoms only after some time (10 DAS). Pendimethalin also showed some phytotoxicity in initial stages. This might be due to the lethal effect of herbicide on crop plants only after they are reaching higher rates of transpiration. These results are in conformity with the findings of Caverly (1976) who reported that symptoms of herbicide damage may not show up until a certain rate of transpiration is reached in crop plants, which may take several weeks. Gupta (1984) described that sub-optimal rate of herbicides improve their selectivity to crops, whereas their over rates are most likely to reduce selectivity and cause crop injury. This finding was in accordance with Russell *et al.* (1991) who found that cotton injury was greater at 14 and 28 DAS under drench irrigation over other irrigation regimes at highest level of 0.6 and 0.9 kg ha^{-1} of cinmethylin.

5.3.2. Effect of weed management treatments on crop growth characters

Plant height, the important growth parameter is mainly governed by the factors such as light, space, water and nutrients. It is evident from the results that weed competition due to higher weed population and biomass in unweeded plots suppressed the growth of cotton at all stages.

Among the weed management treatments, the plant height was higher in cinmethylin @ 0.5 kg ha^{-1} followed by hand weeding at 40 DAS. This treatment was closely followed by application of pendimethalin @ 1.0 kg ha^{-1} + HW at 40 DAS. This might be due to better weed control and utilization of resources such as light, space, water and nutrients for their growth. This observation was in accordance with the findings of Balasubramanian (1985) who found that application of fluchloralin 1.00 kg ha^{-1} + hand weeding significantly increased the plant height due to the higher WCE, reduced population density and dry matter production of weeds which resulted in better crop growth.

Growing of smother crops such as greengram and cowpea upto 40 DAS improved the plant height of cotton. This might be due to optimum availability of resources for the crop growth on account of reduced weed competition. Unweeded control reduced the plant height. This might be due to higher weed population and dry matter throughout the crop period. Stiff weed competition, reduced the nutrient uptake by crop and ultimately reduced the growth of crop as evidenced from the lowest plant height in unweeded control (Balasubramanian, 1985).

Leaf Area Index (LAI) is the important growth parameter which decides the dry matter production and yield of crop. The weed free situation throughout crop period recorded highest LAI at all the stages. Application of cinmethylin @ 0.5 kg ha^{-1} followed by hand weeding at 40 DAS recorded higher LAI. This might be due to increased weed control efficiency and reduced weed density by this treatment. This was followed by pendimethalin @ 1.0 kg ha^{-1} + HW at 40 DAS recorded higher LAI. This might be due to better control of broad leaved weeds such as *Digera arvensis* and *Trianthema portulacastrum* as well as grasses like *Dactyloctenium aegyptium* from the initial phases of growth. Application of cinmethylin @ 0.6 kg ha^{-1} followed by hand weeding at 40 DAS reduced the LAI. This might be due to the initial phytotoxicity exhibited in the form of chlorosis, reduced plant vigour, reduced number of leaves and growth is suppressed.

Growing of greengram and cowpea as smother crops recorded higher LAI in both the crops. This might be due to effective suppression of broad leaved weeds by the treatments. LAI reduced in hand weeding twice at later stages. This might be due to the increased weed competition at later stages of the crop growth. Integrating herbicides and hand weeding gave higher LAI of crops. Lowest LAI was recorded in unweeded control. This might be due to reduced number of leaves which resulted by severe weed competition (Muruganandam, 1984).

5.3.2.1. Dry matter production of crop

The increase in plant height and LAI by the adoption of different weed management practices naturally resulted in higher DMP of cotton. The increase in DMP due to different weed management practices over unweeded check at 20 DAS ranged from 37 to 77 kg ha^{-1}. The initial period of crop-weed competition was 4 to 6 weeks after sowing. Application of cinmethylin @ 0.5 kg ha^{-1} followed by hand weeding at 40 DAS and pendimethalin @ 1.0 kg ha^{-1} followed by hand weeding at 40 DAS recorded higher DMP over other herbicide treatments. This might be due to the higher plant height, LAI and better growth that were observed in the early stages of crop growth due to efficient weed control obtained in these treatments.

Growing of greengram and cowpea as smother crop significantly improved the crop DMP through effective reduction in dry matter production and nutrient uptake of weeds thereby facilitating more availability and uptake of nutrients by the crop. This promoted better crop growth with increased canopy development and production of more number of bolls which has reflected on dry matter accumulation. In unweeded control, lowest crop DMP was recorded due to the severe competition exerted by weeds at all the stages of crop growth. Similar finding of decrease in DMP of cotton by increased weed population under ineffective weed control situation was reported by Singh (1983).

5.3.2.2. Nutrient uptake of crop

The uptake of major nutrients by the crop being a function of crop DMP, nutrient availability and nutrient concentration of the plants. Due to the effective control of weeds by the different weed management practices adopted, it eliminated the competition for nutrients by weeds. As a result, higher nutrient uptake was recorded with weed management practices.

Application of cinmethylin @ 0.5 kg ha^{-1} followed by hand weeding at 40 DAS recorded higher NPK uptake by cotton irrespective of all the stages (20, 40, 80 and 120 DAS). This was due to the competition free environment prevailed throughout the crop period and effective control of dry matter accumulation of weeds is favoured the crop to utilize maximum amount of nitrogen, phosphorus and potassium. Chander *et al.* (1994) stated that minimum weed competition throughout the crop period that facilitated higher DMP and nutrients (NPK) uptake by the crop.

Application of pendimethalin @ 1.0 kg ha^{-1} followed by hand weeding at 40 DAS recorded higher NPK uptake by crop irrespective of all the stages (20, 40, 80 and 120 DAS). This effective suppression of weeds might have increased the nutrient availability and uptake by the crop. The higher dose of cinmethylin (0.6 kg ha^{-1} + HW at 40 DAS) has reduced the crop growth, cleared the way for fast growth of weeds and increased dry weight of weeds. Because the higher dose also not effective in controlling the late emerged weeds, it increased dry weight of weeds and decreased the DMP of crop thereby reduced NPK uptake by the crop.

Growing of greengram and cowpea as smother intercrops considerably increased the NPK uptake by the crop irrespective of all the stages. This might be due to increased weed control efficiency and least DMP accumulation of weeds. The allelopathic treatments showed least uptake of nutrients (NPK) irrespective of all the stages. The unweeded control recorded lesser uptake of nutrients. This might be due to increased crop-weed competition from early stage itself and it continuous upto harvest.

5.3.3. Effect of weed management treatments on yield parameters of cotton

Number of monopodial branches, number of sympodial branches, number of bolls plant $^{-1}$ and boll weight are the major yield contributors which decides the yield of seed cotton.

Number of sympodial branches plant $^{-1}$ was more with the application of cinmethylin @ 0.5 kg ha^{-1} followed by hand weeding at 40 DAS recorded 49.4 and 50.88 per cent higher over unweeded control in both the crops. This was followed by pendimethalin @ 1.0 kg ha^{-1} + HW at 40 DAS (46.5 and 48.0 per cent higher over unweeded control in both the crops). Better weed control, higher plant height and dry matter accumulation might have favoured more number of sympodial branches plant^{-1}. Higher dose of cinmethylin @ 0.6 kg ha^{-1} followed by hand weeding at 40 DAS, which exhibited marginal toxicity did not affect the yield contributing character. This might be due to regaining of normal growth by the surviving plants at later stages of its growth. Growing of greengram and cowpea as smother intercrops recorded higher sympodial branches plant^{-1} (42.47 and 44.58 per cent by greengram and 42.14 and 44.06 per cent by cowpea were recorded over unweeded control in both first and second crop, respectively). This might be due to reduced weed growth and increased plant height in these treatments. Severe infestation of weeds in unweeded check resulted in lowest number of sympodial branches plant^{-1}. Reduced number of branches under higher weed density was reported in chillies (AICRPWC, 1997).

The number of bolls plant^{-1} was the important yield contributing character. Application of cinmethylin @ 0.5 kg ha^{-1} followed by hand weeding at 40 DAS recorded higher number of bolls plant^{-1} (55.03 and 57.93 per cent in the first and second crop, respectively over unweeded control). This was closely followed by pendimethalin @ 1.0 kg ha^{-1} followed by hand weeding at 40 DAS (45.45 and

48.64 per cent in the first and second crop, respectively over unweeded control). This might be due to the reduction in crop-weed competition by the treatments which enhanced early flowering, more number of flowers and formation of more number of bolls. This finding was accordance with the reports of Nehra *et al.* (1988) who described that weed free condition produced 45 per cent more bolls than unweeded control. Application of cinmethylin @ 0.6 kg ha^{-1} followed by hand weeding at 40 DAS recorded less number of bolls $plant^{-1}$ compared to lower dose of 0.5 kg ha^{-1} + HW at 40 DAS. This might be due to suppression of plant due to herbicide effect as seen in tables 44 and 45. Greengram and cowpea as smother intercrops recorded higher number of bolls $plant^{-1}$ of 43.98 and 47.49 per cent by greengram, 42.09 and 45.63 per cent by cowpea in first and second crop, respectively over unweeded control. This might be due to reduced weed competition and thereby increased number of bolls $plant^{-1}$.

Similarly, Pagar *et al.* (1995) recorded more number of bolls in weed free situation. The number of bolls was minimum under unweeded control. Decrease in the number of bolls due to severe crop-weed competition under unweeded control deprive the major sources like nutrients, moisture, light and space was reported by Virk *et al.* (1982).

The weight of bolls produced by cinmethylin @ .0.5 kg ha^{-1} followed by hand weeding at 40 DAS recorded 0.66 and 0.68 gram was more over unweeded control. This was followed by pendimethalin @ 1.0 kg ha^{-1} + HW at 40 DAS (0.62 and 0.68 grams more over unweeded control). This could be explained by the source and sink relationship. The season long weed control resulted in better crop growth and enhanced source capacity (leaf area) which might have resulted in increased photosynthesis, and translocation of more photosynthates to sink resulting in increased boll weight. Hand weeding twice recorded higher boll weight than at higher dose of cinmethylin @ 0.6 kg ha^{-1} + HW at 40 DAS.

Growing of smother crops (greengram and cowpea) along with cotton resulted in increased the boll weight. This might be due to fact that reduction in weed competition enables the plant to develop large sized well matured bolls. Unweeded control recorded lesser boll weight. This was due to severe competition exerted by unchecked weeds for space, light and nutrient throughout the crop period.

5.3.4. Effect of weed management treatments on seed cotton yield

Under irrigated upland conditions, crop and weed seeds germinate simultaneously. Slow growth in early stage and wider spacing, make the cotton crop succumb to weeds. Higher photosynthetic efficiency of plants directly related to higher yield. Competition for light between cotton crop and weeds caused by natural shading which reduced the net photosynthesis. This might result in greater reduction in growth and yield of cotton as observed in unweeded control plots as well as in treatments where weeds were not effectively controlled.

Application of cinmethylin @ 0.5 kg ha^{-1} followed by hand weeding at 40 DAS recorded higher seed cotton yield of 60 and 62 per cent in the first and second crop, respectively over unweeded control. The increased seed cotton yield might be attributed to the effective control of predominant weeds like *Dactyloctenium aegyptium*, *Echinochloa colonum* and *Chloris barbata* among grasses, *Cyperus rotundus* and few broad leaved weeds resulting in lesser competition of weeds for the crop growth factors. This facilitated the crop to utilize more moisture, nutrients, and solar radiation by which the plant height, leaf area index, dry matter and nutrient uptake were promoted in cotton crop. This enhanced the yield attributes like number of bolls and its weight. All these factors collectively contributed for higher seed cotton yield. These results are in accordance with the findings of Forney *et al.* (1985) in soybean who found that pre-emergence application of cinmethylin @ 0.2 to 0.7 kg $acre^{-1}$ gave excellent control of most of annual grasses and thereby increased the soybean yield in USA. Application of pendimethalin @ 1.0 kg ha^{-1} followed by hand weeding at 40 DAS (57 and 59 per cent increased seed cotton yield in first and second crop, respectively over unweeded control) and cinmethylin @ 0.6 kg ha^{-1} followed by hand weeding at 40 DAS (55 and 57 per cent increased seed cotton yield in first and second crop, respectively over unweeded control) were comparable. Application of pendimethalin increased the seed cotton yield, might be due to the effective control of predominant weeds like *Trianthema portulacastrum, Digera arvensis* among the broad leaved weeds and *Dactyloctenium aegyptium* among grasses resulting in lesser weed competition throughout the crop period. Similar finding was reported by Akthar *et al.* (1986) who reported that pendimethalin @ 1.5 kg ha^{-1} was the most effective treatment in controlling broad leaved weeds and it increased the seed cotton yield by 31 and 12 per cent over the unweeded control and hand weeding, respectively.

Hand weeding twice registered lower seed cotton yield as compared to best treatment (12.09 and 12.63 per cent in first and second crop, respectively). This might be due to poor control of monocots and dicots at later stages of crop growth. This treatment was comparable with the growing of greengram and cowpea as smother crops along with cotton. The growing of smother crops like greengram and cowpea have recorded higher seed cotton yield of 54 and 56 per cent by greengram and 53 and 56 per cent by cowpea over unweeded control in first and second crop, respectively. This might be due to high weed control efficiency, lower dry matter accumulation of weeds and lesser nutrients removal by weeds as compared to unweeded control. This result was in accordance with the reports of Balasubramanian (1985) who found that the highest seed cotton yield under cotton + blackgam system was due to higher smothering efficiency as a result of higher number of sympodial branches $plant^{-1}$ and highest number of bolls $plant^{-1}$ over pure crop, consequently as a cumulative effect produced highest seed cotton yield. The allelopathic treatments such as parthenium incorporation and whole plant extract spray were integrated with hand weeding recorded higher seed cotton yield as compared to unweeded control.

5.3.5. Effect of weed management treatments on quality parameters of cotton

Among the quality parameters of cotton, ginning percentage, seed index and lint index were did not influence by different weed control treatments. The fibre fineness ranged from 3.06 to 3.85 micronaire and 3.02 to 3.72 micronaire and mean fibre length ranged from 29.83 to 31.40 cm and 29.57 to 31.19 cm in first and second crop, respectively. Use of herbicides in cotton had no adverse effect on the quality of fibre. In fact it improved the quality by providing weed free environment which is in accordance with the findings of Muruganandam (1984). Waugh et al. (1992) reported that application of fluchloralin at 2 lit. ha^{-1} + one hand weeding at 60 DAS improved the quality characters viz., ginning percentage and fibre length in cotton. The data on span length, maturity co-efficient and uniformity ratio were not significantly influenced by varying weed competition level with different weed control treatments. Application of cinmethylin @ 0.5 kg ha^{-1} followed by hand weeding at 40 DAS increased the bundle strength of 6.6 and 6.0 per cent in first and second crop, respectively over unweeded control.

5.3.6. Economics of different weed management treatments

Among the different weed management practices, cinmethylin @ 0.5 kg ha^{-1} followed by hand weeding at 40 DAS recorded higher net return of Rs.25,306/- and Rs.23,382/- and benefit-cost ratio of 2.56 and 2.46 in first and second crop, respectively. This might be due to higher seed cotton yield obtained by effective control of weeds in this treatments resulted in higher returns and benefit-cost ratio. Hussain *et al.* (1989) stated that higher net returns was recorded due to the application of herbicides in cotton. This was followed by the adoption of pendimethalin @ 1.0 kg ha^{-1} + HW at 40 DAS recorded the net return of Rs.22,362/- and Rs.20,483/- and benefit-cost ratio of 2.35 and 2.25 in the first and second crop, respectively. This was attributed to reduction of weed competition and thereby leading to better growth and yield of crop. This finding was in line with reports of Wilcut *et al.* (1988) who found that higher net profit in cotton with use of herbicides *viz.,* pendimethalin and fluometuron. As compared with total cost of cultivation, application of pendimethalin recorded higher cost of cultivation of Rs.16,622/- and Rs.16,402/- in first and second crop, respectively. This might be due to higher herbicide cost and hand weeding at 40 DAS consumed more labour and thereby total cost of cultivation was increased. The higher dose of cinmethylin @ 0.6 kg ha^{-1} followed by hand weeding at 40 DAS recorded lesser net return of Rs.4,400/- and Rs.4,113/- and benefit-cost ratio of 0.29 and 0.27 in first and second crop, respectively, over cinmethylin @ 0.5 kg ha^{-1} + HW at 40 DAS. This might due to higher dose of cinmethylin caused stunted growth, increased the cost of cultivation and consequently reduced the benefit-cost ratio.

Growing of greengram and cowpea as smother crops along with cotton increased net return (Rs.18,375/- and Rs.18,041/- by greengram, Rs.17,857/- and Rs.17,673/- by cowpea in first and second crop, respectively) and benefit-cost ratio (1.17 and 1.14 by greengram, 1.18 and 1.16 by cowpea in first and second crop, respectively) over unweeded control. These treatments were comparable with application of pendimethalin @ 1.0 kg ha^{-1} followed by hand weeding at 40 DAS with regard to benefit-cost ratio. This might be due to the fact that growing of smother crops did not involve any additional cost like hand weeding and herbicide application. Hand weeding twice registered lesser benefit-cost ratio as compared with other treatments due to high labour consuming for two hand weeding. The unweeded control registered lower net return of Rs.2,375/- and Rs.896/- and benefit cost ratio of 1.17 and 1.06 in the first and second crop, respectively. With respect to allelopathic treatments, parthenium incorporation and whole plant extract spray did not have much effect on gross return and benefit-cost ratio.

5.3.7.Effect of weed management practices on soil microbial population

Cinmethylin application, hand weeding twice and unweeded control exhibited higher population of fungi, bacteria and actinomycetes as compared to pendimethalin. The lower microbial population in pendimethalin treatment might be due to longer persistence of pendimethalin in the soil than cinmethylin as evidenced through the higher values of residues in soil even after 150 days after sowing. Youssef *et al.* (1987) described that population of fungi, bacteria and actinomycetes were significantly higher in the rhizosphere of cotton treated with herbicides.

Under application of cinmethylin @ 0.5 kg ha^{-1} followed by hand weeding at 40 DAS, hand weeding twice and unweeded control, the microbial population of bacteria, fungi and actinomycetes were comparable each other at 90 days after herbicide application. This might be due to application of cinmethylin is relatively short lived in nature and its half life period considerably very less. This finding was in accordance with the reports that cinmethylin is relatively short-lived compound in the environment and its primary route of soil degradation of the parent material occurs, by liberation of carbondioxide indicating extensive metabolism (Anonymous, 1988).

5.3.8. Herbicide residues in cotton seed

The residue analysis of cinmethylin and pendimethalin was carried out in the cotton seed after lint was removed from the seed cotton. Among the two herbicides, cinmethylin residue was detected in both lower and higher dose of herbicide in cotton seed but it was below the maximum residue limit. Cinmethylin was relatively short lived in nature and this compound was quickly metabolized by microbial breakdown. This finding was in line with Tomlin (1999) who found that cinmethylin was relatively short lived compound in environment under aerobic conditions, the half-life ranges from 23 to 75 days depending upon soil texture. Application of pendimethalin @ 1.0 kg ha^{-1} to cotton detected below the maximum residue limit (0.01 ppm) in cotton seed. This study was in accordance with the reports of Jayakumar *et al.* (1992) In cotton seed, residue of the herbicides were below maximum limit (Anonymous, 1985).

5.3.9. Bio-assay studies

The bio-assay study was conducted on cucumber in polyethylene bags with post harvest cotton soil which indicated that the biometric observations (germination percentage, plant height and DMP) made on cucumber resulted that the applied herbicide did not affect the succeeding sensitive crop. As the cotton crop occupied the field for more than five months, the herbicide applied at normal rate did not have significant residues in field by the end of cropping period. This might be due to half life of cinmethylin which ranges from 23 to 75 days only, it did not leave much residue in soil. This finding was conformity with the reports of Tomlin (1999). Application of pendimethalin @ 1.0 kg ha^{-1} registered lesser plant height and DMP as compared to cinmethylin. This might be due to longer persistence of herbicide but did not affect the succeeding crops. Jayakumar *et al.* (1988) reported that cucumber plant was not influenced by soil treated with pendimethalin.

5.4. Effect of herbicide treatments to cotton on germination and growth of succeeding crops

5.4.1. Studies on weeds

5.4.1.1. Weed population

The effect of weed management through herbicides checked regeneration of weeds in the succeeding residual crops also. The reduced weed density in plots treated with herbicides in cotton during previous season was more due to the reduced availability of seeds of weeds rather than any persistent residual effect of herbicides. This similar result was earlier reported by Moody (1983) who observed that plots received best weed control treatments in the preceding season recorded lower weed density in the succeeding crop. The unweeded control in the previous crop resulted in significantly higher weed population in the succeeding crops of cowpea, greengram, sorghum and soybean. This might be due to the initiation of fresh life cycle by weeds from the seeds added by the unweeded control plot in the previous crop. This was in accordance with the results obtained by Burnside (1978) who reported that adequate weed control during the entire crop rotation is very important, since allowing heavy stand of weeds to produce seeds which affect the subsequent crop production potential.

5.4.1.2. Weed dry matter production

The pre-emergence application of cinmethylin and pendimethalin to cotton crop significantly influenced the DMP of weeds in the succeeding residue crops. Pendimethalin @ 1.0 kg ha^{-1} + HW at 40 DAS and cinmethylin @ 0.6 and 0.5 kg ha^{-1} followed by hand weeding at 40 DAS recorded lesser weed DMP as compared to unweeded control and hand weeding twice. The drastic reduction in the weed dry matter could be attributed to the residual effect of herbicide in the succeeding season, after the harvest of cotton. This is in accordance with the results of Ramamoorthy and Ali (1988) who stated that in the succeeding crops of cowpea and greengram, reduction in weed population and weed DMP was reported with residues of pendimethalin which was applied at 1.25 kg ha^{-1} in upland rice. Among the treatments, unweeded control plot recorded maximum weed DMP. This might be due to the addition of weed seeds and increased weed persistence in this plot, due to the non-adoption of weed control measures throughout the growth period of the previous crop.

5.4.2. Studies on residual crops

5.4.2.1. Germination percentage

The germination percentage of the residual crops such as cowpea, greengram, sorghum and soybean were not affected due to application of cinmethylin and pendimethalin to previous crop. This clearly indicated that there was no residual toxic effect of different herbicides used for cotton crop on the following residual crops.

5.4.2.2. Growth characters

Plant height of residual crops such as cowpea, greengram, sorghum and soybean were significantly influenced due to use of different herbicides treated in the previous crop of cotton. The plant height of residual crops were higher at 0.5 kg ha^{-1} + HW at 40 DAS of cinmethylin treated plots in the previous crop of cotton. This might be due to cinmethylin is a short lived compound and microbial breakdown under aerobic conditions. This is in accordance with the reports of Anonymous (1988) who reported that application of cinmethylin to rice crop, will not persist in the soil beyond the season. Therefore, cinmethylin was not available for uptake in the following crop season. Plant height of residual crops were reduced by pendimethalin @ 1.0 kg ha^{-1} followed by hand weeding at 40 DAS in the previous crop of cotton. This was due to the presence of pendimethalin residues in soil, even after the cotton crop.

The DMP of residual crops were markedly influenced due to different herbicides treated in the previous crop of cotton. The DMP of residual crops were more in cinmethylin @ 0.5 kg ha^{-1} + HW at 40 DAS, due to its application in the previous crop of cotton. This might be due to higher germination and plant height of residual crops which contributed higher accumulation of crop dry matter. The DMP of residual crops was reduced by pendimethalin @ 1.0 kg ha^{-1} followed by hand weeding at 40 DAS, due to its application in the previous crop of cotton.

The reduced dry matter of residual crops was mainly due to the residual effect of pendimethalin which resulted in weaker growth of residual crops throughout their growth period. Residues from soil samples collected four months after pendimethalin application (0.84 kg ha^{-1}) reduced the growth of japanese millet (*Echinochola crusgalli*) and grain sorghum by 24 to 49 per cent (Miller and Carter, 1980). The reduced DMP of residual crops noticed in unweeded control, was mainly due to aggressive growth and development of weeds in the plot left unweeded in the previous crop of cotton.

SUMMARY AND CONCLUSION

CHAPTER VI

SUMMARY AND CONCLUSION

Field experiments were carried out at Agricultural College and Research Institute, Tamil Nadu Agricultural University, Coimbatore from August 1998 to January 2000 to develop efficient weed management practices for irrigated cotton (MCU 5) and to study the residual effect of herbicides applied to cotton on succeeding cowpea, greengram, sorghum and soybean crops and herbicide residues in the cotton seed. A brief summary of the results obtained and conclusions drawn are presented in this chapter.

The field experiments were laid out in a randomized block design with three replications. The treatments consisted of two doses of cinmethylin @ 0.5 and 0.6 kg ha^{-1} with and without hand weeding at 40 DAS. The different doses of cinmethylin were compared with the recommended herbicide pendimethalin @ 1.0 kg ha^{-1} + HW at 40 DAS, allelopathic treatments such as parthenium incorporation @ 2 t ha^{-1} and whole plant extract spray (10%) with and without hand weeding at 40 DAS, growing of cowpea, pearl millet and greengram as smother intercrops in cotton upto 40 DAS, hand weeding twice (20 and 40 DAS) and unweeded control (weedy check). The residual effect of cinmethylin and pendimethalin on crops were studied in field as well as polybag experiments. In the field experiment, the carry over effect of cinmethylin and pendimethalin were studied by growing of cowpea, greengram, sorghum and soybean crops upto 30 DAS and in polybag experiment, the residue effect of cinmethylin and pendimethalin were studied by growing of susceptible crop like cucumber upto 30 DAS.

The weed flora of the experimental field included sedges, grasses and broad leaved weeds. Among this, broad leaved weeds were more dominant followed by grasses and sedges. The relative density values of broad leaved weeds was higher ranging from 12.85 to 76.22 per cent at 120 DAS.

The weed species observed consisted of 13 species, of these five were grasses, one sedge and seven broad leaved weeds. The predominant weeds were *Dactyloctenium aegyptium, Echinochloa colonum, Chloris barbata* and *Cynodon dactylon* among grasses, *Cyperus rotundus* among sedges and *Digera arvensis, Trianthema portulacastrum* among broad leaved weeds. Broad leaved weeds of *Parthenium hysterophorus, Flaveria australasica, Commelina benghalensis, Phyllanthus maderaspatensis* and *Amaranthus viridis* were also present in the experimental field.

Pre-emergence application of cinmethylin @ 0.6 kg ha^{-1} followed by hand weeding at 40 DAS gave excellent control of grasses such as *Dactyloctenium aegyptium, Echinochloa colonum* and *Chloris barbata*, sedges and some broad leaved weeds. This was closely followed by cinmethylin @ 0.5 kg ha^{-1} + HW at 40 DAS. The pre-emergence application of pendimethalin 1.0 kg ha^{-1} + HW at 40 DAS effectively controlled broad leaved weeds and grasses. Manual weeding twice and herbicide with one hand weeding at 40 DAS were effective in controlling *Cyperus rotundus*. While herbicides alone were not effective, growing of greengram and cowpea as a smother crops effectively checked grasses, sedges and broad leaved weeds in early stages and was economically viable than other chemical methods.

The relative density values of grasses, sedges and broad leaved weeds at 20 and 40 DAS revealed that broad leaved weeds have dominated over grasses and sedges. In application of cinmethylin (0.6 and 0.5 kg ha^{-1} + HW at 40 DAS), the broad leaved weeds dominated over sedges and grasses, whereas in pendimethalin applied (1.0 kg ha^{-1} + HW at 40 DAS) plot the sedges and grasses were dominated over broad leaved weeds. The relative density of broad leaved weeds was lower with cotton + greengram and cotton + cowpea.

The total dry matter production of weeds reduced by the pre-emergence application of cinmethylin @ 0.6 and 0.5 kg ha^{-1} + HW at 40 DAS. The application of cinmethylin @ 0.6 kg ha^{-1} + HW at 40 DAS effectively reduced weed DMP of grasses and sedges at all the stages. This was closely followed by cinmethylin @ 0.5 kg ha^{-1} + HW at 40 DAS. The pre-emergence application of pendimethalin @ 1.0 kg ha^{-1} + HW at 40 DAS effectively reduced DMP of broad leaved weeds and grasses. Growing of smother crop such as greengram reduced DMP of grasses, sedges and broad leaved weeds. This was closely followed by cowpea as smother crop.

While comparison of the relative dry weight values, application of cinmethylin @ 0.6 and 0.5 kg ha^{-1} followed by hand weeding at 40 DAS reduced the relative dry weight of grasses and sedges over broad leaved weeds. Application of pendimethalin @ 1.0 kg ha^{-1} + HW at 40 DAS reduced the relative dry weight of grasses as well as broad leaved weeds. Regarding weed smother crops, the relative dry weight of weeds are more or less equally distributed at 20 and 40 DAS.

The summed dominance ratio of broad leaved weeds at 20 as well as 40 DAS was much higher in cinmethylin treated plots. This indicates that the application of cinmethylin @ 0.6 and 0.5 kg ha^{-1} + HW at 40 DAS effectively controlled the grasses and sedges over broad leaved weeds, whereas pendimethalin @ 1.0 kg ha^{-1} followed by hand weeding at 40 DAS effectively controlled broad leaved weeds, and grasses over sedges. The summed dominance ratio of broad leaved weeds at 20 and 40 DAS was lesser in growing of smother crops such as greengram and cowpea along with cotton whereas grasses and sedges have occupied major summed dominance ratio over broad leaved weeds.

Regarding weed control efficiency, cinmethylin @ 0.6 and 0.5 kg ha^{-1} followed by hand weeding at 40 DAS showed highest value of WCE irrespective of all the stages (20,40,80 and 120 DAS). This was followed by pendimethalin @ 1.0 kg ha^{-1} + HW at 40 DAS. Growing of cotton + greengram as smother intercropping recorded higher WCE and it was followed by cowpea as smother crop with cotton.

Application of cinmethylin @ 0.5 kg ha^{-1} followed by hand weeding at 40 DAS recorded minimum weed competition and maximum seed cotton yield which was considered as the maximum possible yield under the study situation i.e. 100 per cent yield. This was followed by application of pendimethalin @ 1.0 kg ha^{-1} followed by hand weeding at 40 DAS recorded lowest weed index. Growing of greengram and cowpea as smother intercrops with cotton reduced the weed index.

The depletion of nutrients by weeds varied due to different weed management practices. The depletion of nutrients was lower at early stages and higher at later stages. The nutrient uptake was greatly reduced by application of cinmethylin @ 0.6 kg ha^{-1} followed by hand weeding at 40 DAS. This was comparable with the application of cinmethylin @ 0.5 kg ha^{-1} followed by hand weeding at 40 DAS recording lesser removal of nutrients. Growing of smother intercrops such as greengram and cowpea in cotton effectively reduced nutrient removal by weeds. The above treatments limited the nutrient depletion by weeds and thereby increased the nutrient availability to crop.

Significant improvements in plant growth characters like plant height, LAI and DMP were obtained with application of cinmethylin @ 0.5 kg ha^{-1} followed by hand weeding at 40 DAS. Application of cinmethylin @ 0.6 kg ha^{-1} + HW at 40 DAS reduced the plant growth characters initially. Similarly, application of pendimethalin @ 1.0 kg ha^{-1} + HW at 40 DAS recorded higher plant height, LAI, and DMP. Growing of greengram and cowpea as smother intercrop significantly improved the plant growth characters *viz.,* plant height, LAI and DMP. The increase in plant height and LAI by the adoption of different weed management practices naturally resulted in higher DMP of cotton.

Application of cinmethylin @ 0.5 kg ha^{-1} followed by hand weeding at 40 DAS recorded higher NPK uptake by cotton at all stages (20, 40, 80 and 120 DAS). This was followed by application of pendimethalin @ 1.0 kg ha^{-1} + HW at 40 DAS. The higher dose of cinmethylin @ 0.6 kg ha^{-1} + HW reduced the crop growth, cleared the way for fast growth of weeds and increased the dry weight of weeds thereby decreased the DMP of crop and reduced the NPK uptake by the crop. Growing of greengram and cowpea as smother intercrop considerably increased the NPK uptake by the cotton at all the stages.

The yield attributing characters *viz.*, number of sympodial branches $plant^{-1}$, number of bolls $plant^{-1}$, boll weight showed significant differences. Application of cinmethylin @ 0.5 kg ha^{-1} followed by hand weeding at 40 DAS registered higher sympodial branches $plant^{-1}$, number of bolls $plant^{-1}$ and boll weight. This was followed by application of pendimethalin @ 1.0 kg ha^{-1} + HW at 40 DAS. Growing of greengram and cowpea as smother intercrops recorded higher number of sympodial branches $plant^{-1}$, number of bolls $plant^{-1}$ and boll weight. With regard to allelopathic treatments, parthenium incorporation and whole plant extract spray integrated with hand weeding at 40 DAS recorded higher number of sympodial branches $plant^{-1}$, number of bolls $plant^{-1}$ and boll weight than the treatments without hand weeding.

The pre-emergence application of cinmethylin @ 0.5 kg ha^{-1} followed by hand weeding at 40 DAS recorded higher seed cotton yield as compared to other treatments. It was followed by application of pendimethalin @ 1.0 kg ha^{-1}, cinmethylin 0.6 kg ha^{-1} with a supplemental hand weeding at 40 DAS and hand weeding given at 20 and 40 DAS. This facilitated the crop to utilize more moisture, nutrients and solar radiation by which the plant height, LAI, DMP and nutrient uptake were increased. All these factors collectively contributed for higher seed cotton yield. Growing of greengram and cowpea along with cotton as smother intercrops recorded higher seed cotton yield over allelopathic treatments and unweeded control. The allelopathic treatments such as parthenium incorporation and whole plant extract spray with and without hand weeding recorded lesser seed cotton yield as compared to herbicide treatments and growing of smother crops for weed suppression.

Among the quality parameters of cotton, ginning percentage, seed index and lint index were not influenced by different weed control treatments. Among different weed management treatments, pendimethalin @ 1.0 kg ha^{-1} recorded marginally higher fibre fineness than the other treatments. The quality parameters *viz.*, mean fibre length, span length, maturity co-efficient, uniformity ratio did not differ significantly with regard to application of cinmethylin, pendimethalin, growing of smother crops and allelopathic treatments. Application of cinmethylin @ 0.5 kg ha^{-1} + HW at 40 DAS recorded slightly higher bundle strength as compared to other treatments.

Among the different weed management practices, cinmethylin @ 0.5 kg ha^{-1} followed by hand weeding at 40 DAS recorded higher net return of Rs.25,306/- and Rs.23,382/- and benefit-cost ratio of 2.56 and 2.46 in first and second crop, respectively. This was followed by pendimethalin @ 1.0 kg ha^{-1} followed by hand weeding at 40 DAS recorded the net return of Rs.22,362/- and Rs.20,483/- and benefit-cost ratio of 2.35 and 2.25 in the first and second crop, respectively. The higher dose of cinmethylin @ 0.6 kg ha^{-1} followed by hand weeding at 40 DAS recorded lesser net return of Rs.4,400/- and Rs.4,113/- and benefit-cost ratio of

0.29 and 0.27 in the first and second crop, respectively over cinmethylin @ 0.5 kg ha^{-1} + HW at 40 DAS. Growing of greengram and cowpea as smother crops along with cotton upto 40 DAS increased net return and benefit-cost ratio over unweeded control. These treatments were comparable with application of pendimethalin @ 1.0 kg ha^{-1} followed by hand weeding at 40 DAS with regard to benefit-cost ratio. Hand weeding twice registered lesser benefit-cost ratio as compared with the other treatments due to high labour consumption for two hand weeding. Parthenium incorporation and whole plant extract spray did not have much effect on gross return and benefit-cost ratio.

Regarding soil microbial population, application of cinmethylin, hand weeding twice and unweeded control exhibited higher population of bacteria, fungi and actinomycetes as compared to pendimethalin. In application of cinmethylin @ 0.5 kg ha^{-1} with and without hand weeding at 40 DAS, hand weeding twice and unweeded control, the microbial population of bacteria, fungi and actinomycetes were comparable with each other at 90 days after herbicide application. The higher microbial population in cinmethylin treated plot was due to relatively short lived nature of cinmethylin whereas pendimethalin recorded lesser microbial population due to longer its persistence in the soil than cinmethylin.

The determination of herbicide residue in cotton seed due to application of cinmethylin and pendimethalin revealed that they are well below the maximum residue limit (MRL). The cinmethylin residue was detected in both lower and higher dose of herbicide in cotton seed but it was below the MRL. Cinmethylin was relatively short lived in nature and this compound was quickly metabolized by microbial breakdown. Application of pendimethalin @ 1.0 kg ha^{-1} + HW at 40 DAS to cotton detected below the MRL in cotton seed. From the above studies it can be concluded that cotton being a long duration crop, the herbicide residue could not persist in the soil beyond the season.

The bio-assay study indicated that the biometric observations of germination percentage, plant height and DMP made on cucumber resulted that the applied herbicide did not affect the succeeding sensitive crop. As the cotton crop occupied the field for more than five months, the herbicide applied at normal rate did not have any significant residues in field by the end of cropping period. The half life of cinmethylin ranges from 23 to 75 days only, it did not leave much residue in soil.

The effect of weed management through herbicides checked regeneration of weeds in the succeeding residual crops also. The total weed population was reduced in plots treated with herbicides during previous season was more due to the reduced availability of seeds of weeds rather than any persistent residual effect of herbicides. The unweeded control in the previous crop resulted in higher weed population in the succeeding crops of cowpea, greengram, sorghum and soybean.

The pre-emergence application of cinmethylin and pendimethalin to cotton crop influenced the DMP of weeds in the succeeding crops. Application of pendimethalin @ 1.0 kg ha^{-1} + HW at 40 DAS, cinmethylin @ 0.6 and 0.5 kg ha^{-1} followed by hand weeding at 40 DAS recorded lesser weed DMP as compared to unweeded control and hand weeding twice. Unweeded control plot recorded maximum weed dry weight due to the addition of weed seeds and increased weed persistence in this plot due to non-adoption of weed control measures throughout the growth period of the previous crop.

The germination percentage of the residual crops such as cowpea, greengram, sorghum and soybean were not affected due to application of cinmethylin and pendimethalin to previous crop. This indicates that there was no residual toxic effect of different herbicides used for cotton crop on the following residual crops. However, the germination percentage of succeeding residue crops was marginally reduced by pendimethalin treated @ 1.0 kg ha^{-1} followed by hand weeding at 40 DAS in the previous crop of cotton.

Plant height and dry matter production of residual crops such as cowpea, greengram, sorghum and soybean were influenced by the use of different herbicides in the previous crop of cotton. The plant height and DMP of residual crops were higher in cinmethylin at 0.5 kg ha^{-1} + HW at 40 DAS in the previous crop of cotton. Application of pendimethalin @ 1.0 kg ha^{-1} followed by hand weeding at 40 DAS to the previous crop of cotton reduced the plant height and DMP of residual crops, due to the residual effect of pendimethalin which resulted in weaker growth of residual crops throughout their crop growth. The DMP of residual crop was reduced in unweeded control due to aggressive growth and development of weeds in the plots left unchecked in the previous crop of cotton.

Following conclusions are drawn from the present study based on the above results.

Taking into consideration of weed control efficiency, crop growth and development, nutrient uptake by crops, seed cotton yield and economic returns, it is concluded that, among the weed management methods, pre-emergence application of cinmethylin @ 0.5 kg ha^{-1} integrated with a late hand weeding at 40 DAS gave the effective control of weeds resulting in the highest seed cotton yield and it can be recommended as most efficient and economical method of weed management practice for irrigated cotton under garden land conditions. The next best treatment was the recommended herbicide, pendimethalin @ 1.0 kg ha^{-1} + HW at 40 DAS. This was comparable with cinmethylin @ 0.6 kg ha^{-1} + HW at 40 DAS. These treatments were followed by growing of greengram and cowpea as weed smother intercrops with cotton upto 40 DAS which checked the weed growth markedly. As a result higher seed cotton yield, net return and benefit-cost ratio were obtained. However, this is comparable with pendimethalin @ 1.0 kg ha^{-1} + HW at 40 DAS. Hence, this is an efficient and economic method of non-chemical weed management practice for irrigated cotton, but next only to cinmethylin @ 0.5 kg ha^{-1} + HW.

The herbicides left very negligible amount of residue in cotton seed, which was below the maximum residue limit (MRL) and so did not have any adverse effect on the succeeding crops like cowpea, greengram, sorghum and soybean.

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PLATES

Plate 1. General view of the experimental field.

Plate 2. Application of cinmethylin @ 0.5 kg ha^{-1} + HW at 40 DAS.

Plate 3. Application of cinmethylin @ 0.6 kg ha^{-1}+ HW at 40 DAS.

Plate 4. Application of pendimethalin @ 1.0 kg ha^{-1} + HW at 40 DAS.

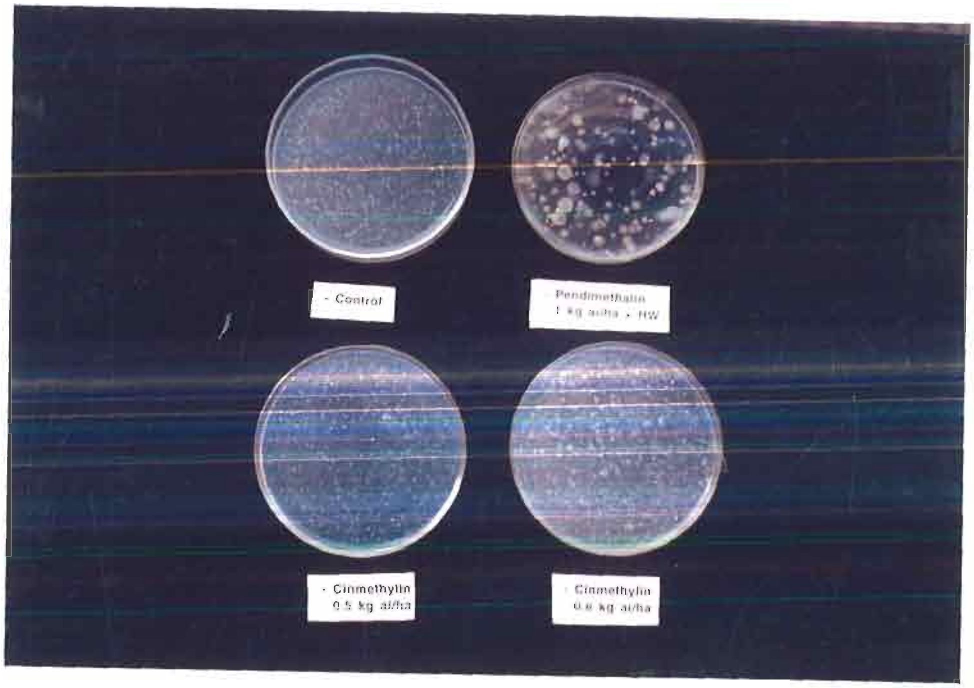


Plate 5. Effect of herbicide treatments on bacterial population.

Plate 6. Effect of herbicide treatments on fungal population.

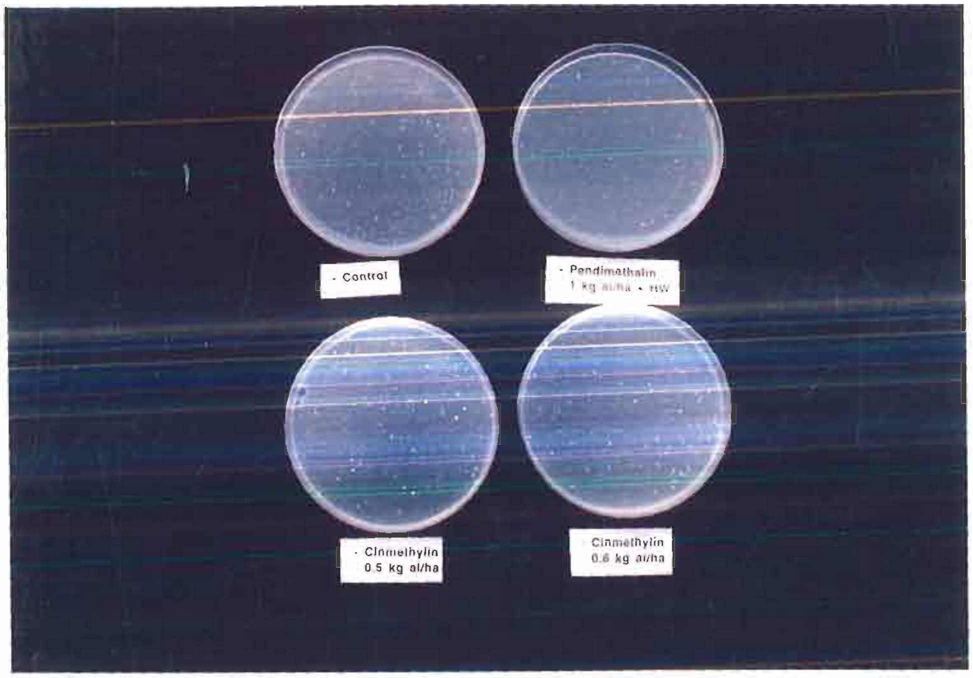


Plate 7. Effect of herbicide treatments on actinomycetes population.

Plate 8. Bio-assay study of cucumber.

APPENDICES

APPENDIX-I

Weekly meteorological data for cropping season

(August 1998 - February 1999)

Standard week	Month and Date	Mean temperature(°C)		Mean relative humidity (%)		Rainfall (mm)	Rainy days	Solar Radiation cal/cm^2 day^{-1}
		Maximum	Minimum	07.22 hrs	14.22 hrs			
34	Aug 20-26	30.9	22.9	84	58	8.1	1	286.3
35	Aug.27-Sep.2	31.9	21.9	83	54	54.0	1	371.0
36	Sep.3-9	30.8	23.0	88	64	40.6	1	334.3
37	Sep.10-16	30.8	23.4	74	52	2.0	-	389.0
38	Sep.17-23	32.2	22.1	79	48	-	-	416.8
39	Sep.24-30	29.4	22.3	90	71	73.9	2	281.9
40	Oct.1-7	31.5	22.8	86	56	2.0	1	353.1
41	Oct.8-14	30.3	23.4	83	64	5.0	1	347.6
42	Oct.15-21	30.6	21.5	77	51	-	-	440.0
43	Oct.22-28	32.0	21.5	88	52	8.0	-	368.0
44	Oct.29-Nov.4	29.9	21.8	91	68	103.3	3	295.7
45	Nov.5-11	28.4	22.4	91	64	213.4	4	347.7
46	Nov.12-18	31.0	19.7	88	53	2.0	-	434.5
47	Nov.19-25	31.2	20.8	87	55	-	-	418.8
48	Nov.26-Dec.2	30.2	19.6	90	53	39.6	1	373.4
49	Dec.3-9	28.4	21.0	88	56	-	-	344.6
50	Dec.10-16	26.0	21.2	92	82	122.0	5	208.4
51	Dec.17-23	28.4	19.1	91	55	-	-	428.1
52	Dec.24-31	28.3	18.4	90	52	-	-	387.0
1	Jan.1-7	29.2	17.3	90	46	-	-	458.9
2	Jan.8-14	29.9	19.2	89	46	-	-	419.7
3	Jan.15-21	29.3	17.9	88	44	-	-	418.9
4	Jan.22-28	29.9	14.2	89	33	-	-	458.3
5	Jan.29-Feb.4	31.7	17.2	89	40	-	-	464.2
6	Feb.5-11	32.0	21.6	88	45	3.0	1	412.3

APPENDIX-II

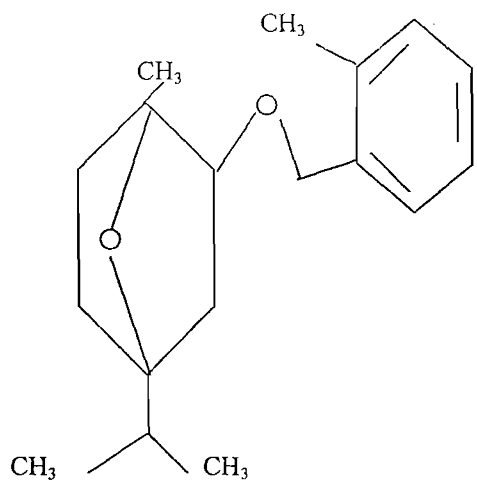
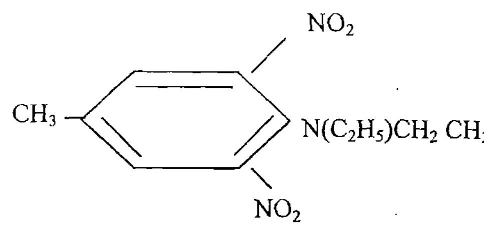
Weekly meteorological data for cropping season

(August 1999 - January 2000)

Standard week	Month and Date	Mean temperature(°C)		Mean relative humidity (%)		Rainfall (mm)	Rainy days	Sunshine hrs.
		Maximum	Minimum	07.22 hrs	14.22 hrs			
32	Aug.6-12	31.2	23.1	81	55	3.0	1	4.8
33	Aug.13-19	32.7	22.3	87	50	0.2	-	8.2
34	Aug. 20-26	32.0	21.8	88	52	18.7	-	5.6
35	Aug.27-Sep.2	32.2	21.9	85	46	-	-	7.2
36	Sep.3-9	32.3	22.3	78	43	-	-	7.9
37	Sep.10-16	33.0	21.4	83	43	-	-	9.3
38	Sep.17-23	33.7	22.4	89	50	-	-	8.0
39	Sep.24-30	33.5	22.9	91	46	28.0	3	6.1
40	Oct.1-7	29.9	22.5	94	68	72.3	4	3.9
41	Oct.8-14	30.9	22.3	93	60	31.9	3	7.7
42	Oct.15-21	29.5	21.9	95	74	155.4	6	3.4
43	Oct.22-28	29.8	22.5	94	65	44.5	3	5.5
44	Oct.29-Nov.4	30.2	20.2	94	64	2.0	-	6.9
45	Nov.5-11	29.9	19.8	91	51	64.2	2	8.0
46	Nov.12-18	29.7	18.4	88	47	-	-	9.9
47	Nov.19-25	27.4	21.0	93	71	35.0	3	3.5
48	Nov.26-Dec.2	28.4	21.0	91	63	6.4	1	6.3
49	Dec.3-9	28.3	19.1	91	59	-	-	5.6
50	Dec.10-16	26.2	19.3	91	62	3.0	1	6.1
51	Dec.17-23	27.9	18.3	88	57	10.0	1	5.2
52	Dec.24-31	26.8	19.3	90	54	8.8	1	7.6
1	Jan.1-7	28.3	19.9	87	52	-	-	5.7
2	Jan.8-14	28.1	20.5	87	62	2.0	-	2.9
3	Jan.15-21	30.5	18.1	91	39	-	-	9.2
4	Jan.22-28	31.6	16.9	90	35	-	-	9.5
5	Jan.29-Feb.4	31.0	18.3	89	40	-	-	6.7

APPENDIX III

Details of herbicides used

S. No	Properties	Cinmethylin	Pendimethalin
1.	Chemical name	(1RS, 2SR, 4SR) - 1,4 - epoxy-p- menth-2-yl-2-methyl benzyl ether (IUPAC)	N-(1-ethyl propyl) – 3,4 – dimethyl – 2,6 dinitroaniline
2.	Chemical family	Cineole	Dinitroaniline
3.	Chemical structure		
4.	Molecular formula	$C_{18} H_{26} O_2$	$C_{13}\ H_{19}\ N_3O_4$
5.	Common name	Cinmethylin	Pendimethalin
6.	Trade name and formulation	Argold 10 % EC	Stomp 30 % EC
7.	Manufacturer	Cyanamid (India) Ltd	Cyanamid (India) Ltd.
8.	Physical state	Liquid	Orange-yellow liquid
9.	Boiling point	313°C at 760 mm Hg	Decomposes on distillation
10.	Stability	Thermally stable upto 145°C. Hydrolytically stable from pH 3 to pH 11 at 25°C. Light catalyzed decomposition occurs in the presence of air	Very stable in storage. Stable to acids and alkalis slowly decomposed by light

Continued .....

S. No.	Properties	Cinmethylin	Pendimethalin
11.	Solubility	In water, 63 mg/l at 20°C and miscible with a organic solvents	In water at 20°C, 0.3 mg/l. Readily soluble in benzene, slightly soluble in petroleum ether and petrol.
12.	Density	1.014 g/ml at 20°C	-
13.	Corrosiveness	-	Non-corrosive
14.	Specific gravity	-	1.19 at 25°C
15.	Vapour pressure	-	4 Mpa at 25°C
16.	Molecular weight	274.4	281.31
17.	Analysis of residue	By HPLC	By GLC with ECD
18.	Mode of action	Selective herbicide, absorbed through the shoots and roots of germinating or emerging weeds. Herbicide activity results from the disruption of meristematic development in the growing points of roots and shoots of susceptible species.	Absorbed by the roots and leaves. Inhibits cell division and cell elongation. Affected plants die shortly after germination or following emergence from the soil.
19.	Uses	Control of weeds of rice, including *Echinochloa* spp., *Monochoria vaginalis* and *Cyperus difformis*	Control of most annual grasses and man broad leaved weeds in cereals and cotton.

APPENDIX IV

Details of the medium used for microbial study

1. **Nutrient agar medium (Allen, 1953)**

Glucose	-	5.0 g
Peptone	-	5.0 g
Beef extract	-	3.0 g
Nacl	-	5.0 g
Agar	-	15 g
Distilled water	-	1000 ml
pH	-	6.8 - 7.2

2. **Martin's rose bengal agar medium (Martin, 1950)**

Dextrose	:	10.0 g
Peptone	:	5.0 g
KH_2PO_4	:	1.0 g
$MgSO_4 . 7H_2O$	:	0.5 g
Rose bengal	:	0.035 g
Agar	:	20g
Streptomycin sulphate	:	0.03 g
Distilled water	:	1000 ml

3. **Kenknight's agar medium (Allen, 1953)**

Glucose	:	1.0 g
KH_2PO_4	:	0.1 g
Sodium nitrate	:	0.1 g
Potassium chloride	:	0.1 g
$MgSO_4 . 7H_2O$	:	0.1g
Agar	:	15.0 g
Distilled water	:	1000 ml