CHEMICAL WEED MANAGEMENT IN SESAME
(*Sesamum indicum* L.)

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By

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CERTIFICATE

This is to certify that the thesis entitled **"CHEMICAL WEED MANAGEMENT IN SESAME (*Sesamum indicum* L.)"** submitted by **Mr. MRUTHUL T.,** in partial fulfillment of the requirement for the degree of **MASTER OF SCIENCE (AGRICULTURE)** in **AGRONOMY,** College of Agriculture, Raichur, University of Agricultural Sciences, Raichur, is a record of research work done by him during the period of his study in this University under my guidance and supervision and the thesis has not previously formed the basis for the award of any degree, diploma, associateship, fellowship or other similar titles.

RAICHUR
June, 2014

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Dedicated to

Beloved Parents and Teachers

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With ever regardful memories……

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Raichur

June, 2014 **(MRUTHUL, T.)**

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LIST OF ABBREVIATIONS

Abbreviation		Expansion
DAS	:	Days After Sowing
ha	:	hectare
g	:	gram
mg	:	miligram
kg	:	kilogram
q	:	quintal
ml	:	mililitre
dm	:	deci meter
mm	:	milimeter
cm	:	centimeter
m	:	meter
%	:	Per cent
BC	:	Benefit Cost ratio
NS	:	Non Significant
RH	:	Relative Humidity
S. Em.	:	Standard Error mean
C.D.	:	Critical Difference
Fig.	:	Figure

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INTRODUCTION

I. INTRODUCTION

Sesame (*Sesamum indicum* L.) is one of the important edible oilseed crop of India. It is recognized by various names like gingely, til, gergelim, simsim, biniseed *etc*. The crop has earned a poetic label "Queen of oilseeds" due to high quality poly-unsaturated stable fatty acids. Moreover, seed is a rich source of edible oil (48-55%) and protein (20-28%) consisting of both methionine and tryptophane, vitamin (Niacin) and minerals (Ca and P) as reported by Nagaraj, 1995. Sesame seeds have two compounds *viz*., sesamine and sesamolin. Sesame seed has pronounced antioxidant activity and thereby offer higher shelf life and is called as "seeds of immortality". Sesame oil has excellent nutritional, medicinal, cosmetic and cooking qualities. The sesame cake is used as organic manure as well as a good concentrate feed for livestock.

According to Watt (1893), cultivation of sesame has archeological evidences which dates back to Vedic to later Vedic period (1000-1600 B.C.). Vedic literature like Atharwaveda and Ashtadhayhi mention about cultivation and domestic utilization of sesame (Umarao Singh, 1958). Among the oilseed crops, sesame is the only crop having importance in religious rituals. Apart from these, sesame is a good catch crop and performs well in pure and mixed stand under residual soil moisture. Sesame is widely cultivated in tropical and sub-tropical parts of the world. India is the world's largest producer of sesame and stand first in both area and production but productivity is low. In India, it is cultivated over an area of 18 lakh ha with the production of 8.1 lakh tones with an average yield of 426 kg per ha. Whereas in Karnataka, it occupies an area of 0.67 lakh ha with a production of 0.31 lakh tones with a productivity of 500 kg per ha (Anon., 2012).

"A year's seeding is seven year's weeding" and thus Indian agriculture has been defined as a "confrontation with weeds". The welfare of mankind is highly dependent on farmer's ability to control the growth of weeds. Thus, it is necessary to concentrate more on weeding out the undesirables than for any other activity related to increasing agricultural production.

Weed infestation is the one of the major problem for low productivity of sesame which is sown during rainy season. Prevalence of high temperature with high relative humidity and frequent rainfall during the crop season coupled with slow plant growth

particularly during early growth stages favour luxuriant weed growth since seedling emergence and causes 50-75 per cent reduction in seed yield (Ghosh and Mukhopadhyay, 1980). Simultaneous emergence and rapid growth of weeds leads to weed competition for light, moisture, space and nutrients. The period from 15 to 30 DAS is the most critical period of crop weed competition in sesame (Venkatakrishnan and Gnanamurthy, 1998a). NPK efficiency may also be improved by adopting suitable weed management practices.

Though the conventional methods of weed control like hand weeding, hoeing *etc* are very much effective but due to high wages and non availability of labour during the critical weeding season and incessant protracted rains, use of herbicides could be more time saving, economical and efficient to check early crop weed competition. Herbicidal weed management is more favourable due to scarcity in availability of human labour during peak season (Kannan and Wahab, 1995).

By virtue of above points, a field experiment entitled "Chemical weed management in sesame (*Sesamum indicum* L.)" was conducted at Agricultural College Farm, Raichur with the following objectives.

1) To study the weed spectrum in sesame.
2) To evaluate the effect of herbicides on growth, yield and yield attributes and weed control efficiency in sesame and
3) To work out the economics of different weed management practices in sesame.

REVIEW OF LITERATURE

II. REVIEW OF LITERATURE

Weed infestation is one of the limiting factors in successful crop production**.** The weeds emerge simultaneously, grow vigorously with the crop and so compete for nutrients, space and solar radiation that cause reduction in seed yield. Weed competition is one of the major constraints for yield maximization in sesame. Hence, productivity of sesame largely depends on weed-free conditions, particularly in its early growth period. In this chapter, literature pertaining to weed flora in sesame, crop-weed competition and its effect on growth, yield and quality aspects, management of weeds through mechanical, chemical and integrated ways and the economics of weed control are presented.

2.1 Weed flora in sesame

Control of weeds is one of the major limiting factors in crop production. Knowledge about the nature of associated weeds / major weed flora is vital for planning and execution of weed management strategies for efficient production. The degree of damage caused by weeds is related to the type, species and density of weeds growing in a crop community.

Bansode and Shelke (1991) observed that *Brachiaria eruciformis, Cyperus rotundus* L., *Cynodon dactylon* (L.), *Commelina benghalensis* L., *Convolvulus arvensis* L., *Merremia emerginata* (Burn) Hall F., *Acalypha indica* L., *Euphorbia geniculata* and *Achyranthes aspera* L. were the major weeds during *kharif* season.

Sootrakar *et al*. (1995) revealed that the dominant weeds of experimental fields were *Echinochloa* spp., *Commelina benghalensis* L., *Digera arvensis, Phyllanthus niruri, Euphorbia* spp., *Cyperus rotundu*s L. and *Cynodon dactylon* (L.)

Balasubramanian *et al.* (1998) reported that *Echinochloa colonum* (L.) and *Trianthema portulacastrum* L. were the dominant weed species.

Venkatakrishnan and Gnanamurthy (1998a) found that *Boerhavia diffusa* (L.), *Amaranthus viridis* L. in broad leaf weeds, *Digitaria sanguinalis* (L.), *Dactyloctenium aegyptium* (L.) in grasses and *Cyperus rotundus* L. in sedges were the predominant weed flora of the experimental field.

Venkatakrishnan and Gnanamurthy (1998b) reported that *Cyperus rotundus* L. in sedges, *Dactyloctenium aegyptium* (L.), *Panicum repens* L. in grasses, *Boerhavia diffusa*

L., *Amaranthus viridis* L. and *Phyllanthus niruri* in broad leaf weeds were the major weed flora present in the experimental site.

Malam Singh Chandawat and Rathore (2004) found that the predominant weeds in crop field were *Amaranthus spinosus* L., *Cenchrus biflorus*, *Trianthema portulacastrum* L., *Tribulus terrestris* L., *Phyllanthus niruri, Cynodon dactylon* (L.), *Digera arvensis and Portulaca oleracea* L.

Sukhadia *et al*. (2004) observed that *Leucas aspera, Indigofera glandulosa, Phyllanthus niruri, Eluropus villosus, Dactyloctenium aegyptium* (L.), *Cynodon dactylon* (L.), *Echinochloa colonum* (L.), *Cyperus rotundus* L. were the major weeds in sesame.

Anil Kumar and Thakur (2005) revealed that the dominant weed flora of the experimental field included grassy weeds like *Panicum dichotomiflorum* (35%), *Echinochloa colonum* (25%), *E. crusgalli* (10%), *Cynodon dactylon* L. (10%) and sedges (15%) like *Cyperus iria* L. and *C. diformis*.

Mizan Amare (2011) indicated that the relative density of natural broadleaved weeds was about 90.2 per cent and that of grassy weeds was 9.8 per cent. Among broadleaved weeds *Ocimum basilicum* (L.) and *Corchorus trilocularis* were the most dominant which contributed to about 28.9 per cent of the total weed population.

Nisha Bhadauria *et al.* (2012a) revealed that among the weed flora, *Phyllanthus niruri, Commelina benghalensis* L., *Digera arvensis, Cyperus rotundus,* and *Echinochloa crusgalli* recorded the highest weed population.

Nisha Bhadauria *et al.* (2012b) found that experimental field was infested with *Digera arvensis* (33.67%), *Echinochloa crusgalli* (21.76%), *Cyperus rotundus* L. (17.6%), *Commelina benghalensis* L. (17.34%) and *Phyllanthus niruri* (9.91%).

Parvender Sheoran *et al*. (2012) revealed that the dominant weed flora in the field was *Cynodon dactylon* (L.) and *Eleusine aegyptiacum* in grassy weeds, while *Commelina benghalensis* L. and *Digera arvensis* were the main broadleaf weeds. In sedges *Cyperus rotundus* L. was the predominant weed.

2.2 Critical period for weed competition

Weeds present at different phenological stages of crop do not cause equal harm but only those weeds which are present at critical period are most damaging and hence it

is necessary to be aware of this critical period of crop from the point of weed competition to develop effective management strategy.

Kondap and Chandrashekhar Rao (1978) found that the critical period of weed competition in sesame was 15-30 days after sowing (DAS).

Subramanian and Sankaran (1978) reported that critical period of weed crop competition in sesame was between 15-30 DAS and yield reduction was up to 49 per cent.

Venkatakrishnan and Gnanamurthy (1998a) revealed that number of capsules per plant and seed yield of sesame were maximum in weed-free plot and were on par with weed-free period till 45, 60 and 75 DAS. The weed density and weed index were also minimum in these treatments. Hence, crop-weed competition from 15-30 DAS was found to be most critical.

Mizan Amare (2011) reported that critical period of weed control in sesame was found to be between 14 and 28 days after crop emergence with duration of 14 days.

2.3 Effect of weed competition on sesame

The degree of crop weed competition is determined by the weed species and their density, duration of infestation, associated crop in the field, growth habit of crop plants and environmental conditions. Weeds that grow with crop deplete considerable amount of costly fertilizer nutrients, limited moisture, light and space thereby giving poor growth and resulting in lower yield.

Ghosh and Mukhopadhyay (1980) revealed that 50-75 per cent reduction in seed yield was due to weed infestation and weeds removed 79.3 kg N, 11.5 kg P and 104.8 kg K ha^{-1}.

Shukla (1984) reported that unweeded sesame crop recorded 54 per cent lesser seed yield compared to weed free check.

Venkatakrishnan and Gnanamurthy (1998a) revealed that the weed-infested period until harvest, recorded the highest weed dry weight (608.3 kg ha^{-1}) at 80 DAS. The dry weight of weeds decreased with the increase in weed-free period. The dry weight of weeds was significantly higher in unweeded plot over other treatments at 80 DAS. The number of capsules per plant and seed yield of sesame was maximum in the increased

period of weed-free conditions and lowest in weed-infested situation until harvest (422 kg ha^{-1}) and yield loss of 64 per cent due to weed competition was recorded.

Narkhede *et al.* (2000) found that significantly lower seed yield (441 kg ha^{-1}) was obtained in unweeded control.

Baskaran and Solaimalai (2002) reported that significantly lower plant height, leaf area index, dry matter production and seed yield were obtained in unweeded control.

Dawale *et al.* (2009) revealed that significantly higher seed yield (805 kg ha^{-1}) was obtained in weed free check and all other herbicidal treatments recorded significantly higher seed yield over weedy check.

Nisha Bhadauria *et al.* (2012a) obtained significantly lower number of capsules per plant (20.3), number of seeds per capsules (41.8), test weight (2.25 g) and seed yield (410 kg ha^{-1}) in weedy check.

Nisha Bhadauria *et al.* (2012b) revealed that significantly lower total NPK uptake (34.4 kg N ha^{-1}, 13.8 kg P ha^{-1} ,43.3 kg K ha^{-1}) were recorded in unweeded control and significantly lower NPK depletion were observed in all herbicidal and manually weeded plots as compared to weedy check.

Parvender Sheoran *et al*. (2012) reported that significantly lower plant height, number of branches per plant, number of capsules per plant, seeds per capsules, test weight and seed yield were obtained in unweeded control.

2.4 Methods of weed control

2.4.1 Manual and cultural practices

It is the oldest method of controlling weeds. It is still a practical and efficient method of eliminating weeds in cropped and non-cropped lands. It is very effective against annual and biennial weeds.

Sootrakar *et al*. (1995) found that hand weeding thrice (25, 40 and 55 DAS) recorded significantly higher seed yield (766 kg ha^{-1}) and straw yield (154 kg ha^{-1}) with harvest index of 34.13 per cent followed by pre-plant incorporation of fluchloralin + one hand weeding at 25 DAS.

Chauhan and Gurjar (1998) reported that three hand weedings (20, 40, 60 DAS) and pre-planting application of 0.75 kg fluchloralin were on par with each other and recorded the highest seed yield, followed by two hand weedings (20 and 40 DAS).

Narkhede *et al*. (1999) revealed that cultural practices of two hand weedings and hoeings carried out at 20 and 30 days after sowing of sesame produced significantly higher grain yield (1239 kg ha^{-1}) and weed control efficiency (85.3%) than the rest of the integrated weed management practices and unweeded control.

Sukhadia *et al*. (2004) found that two interculture with weeding at 20 and 40 DAS recorded significantly higher seed yield (421 kg ha^{-1}) and was followed by interculture with weeding once (309 kg ha^{-1}).

Anil Kumar and Thakur (2005) reported that intercropping sesame with black gram reduced the weed density (53.3%) and weed dry matter accumulation (51.3%) over the sole sesame cropping.

Joseph *et al*. (2006) reported that sesame seed yield was significantly higher with hand weeding twice at 15 and 30 DAS, followed by hand weeding at 15 DAS + hand hoeing at 30 DAS and was statistically on par with the application of a single herbicide as pre-emergence followed by one hand weeding.

2.4.2 Chemical method

Inadequate weed management is one of the major causes for low yield in sesame. The conventional method of weed control through hand weeding is costly and unavailable at critical stages. If the cost of hand weeding is high, herbicide treatment becomes competitive and promising way to control weeds.

2.4.2.1 Pre-plant incorporation and pre-emergence application

With increasing labour cost and reduced availability and reduction in use of animal power in agriculture, chemical control of weeds is becoming popular these days and availability of variety of effective herbicides is also attracting growers in their use.

Ghosh and Mukhopadhyay (1980) found that pre-emergence application of fluchloralin @ 0.75 kg a.i. per ha was effective chemical method of weed control in sesame.

Balasubramanian *et al.* (1998) reported that pre-emergence application of fluchloralin @ 0.75 and 1.0 kg a.i. per ha effectively checked weeds with higher weed control efficiency and lowered the weed competition for nutrients.

Venkatakrishnan and Gnanamurthy (1998b) revealed that lower dose of alachlor @ 1.5 kg a.i. per ha was found to be an effective and economical herbicide for the control of weeds and obtaining higher seed yield and return per rupee invested in sesame. Weed control visual rating was also higher in alachlor @ 1.5 kg a.i. per ha without causing any phytotoxicity to sesame seedlings.

Singh *et al.* (2001) concluded that pre-plant application of fluchloralin @ 1.0 kg a.i. per ha followed by one manual weeding at three week after sowing (WAS) gave maximum seed yield (756 kg ha^{-1}) and net returns (`9600 ha^{-1}).

Malam Singh Chandwat and Rathore (2004) conducted experiment on herbicidal management of weeds in sesame and reported that pre plant incorporation of alachlor granules @ 2 kg a.i. per ha followed by weeding at 30 DAS proved to be the best weed control management tool providing maximum seed yield (713 kg ha^{-1}).

Anil Kumar and Thakur (2005) revealed that the highest seed yield (284 kg ha^{-1}) was obtained with alachlor @ 1.5 kg a.i. per ha plus one hand weeding which was on par with alachlor @ 1.5 kg a.i. per ha alone.

Gnanavel and Anbhazhagan (2006**)** revealed that pre-emergence application of oxyfluorfen @ 0.15 kg a.i. per ha with one hand weeding at 30 days after sowing was significantly superior in terms of weed control index (92.74%) and seed yield (920 kg ha^{-1}) compared to twice hand weedings or herbicide use alone.

Parvender Sheoran *et al.* (2012) reported that pre-emergence application of alachlor @ 1.5 kg a.i. per ha resulted in significantly higher yield (593 kg/ha) with 10.6 and 12.7 per cent yield superiority over pre emergence application of fluchloralin @ 1 kg a.i. per ha and trifluralin @ 1 kg a.i. per ha respectively. Integration of hand weeding with herbicide application irrespective of dose though resulted in higher seed yield, but the net income and BC ratio were lower when compared with sole application of the herbicide.

2.4.2.2 Post-emergence application

Dawale *et al.* (2009) opined that post-emergence application of quizalofop ethyl @ 40 g a.i. per ha + one hand weeding and one intercultivation at 40-45 DAS gave significantly higher seed yield (666 kg ha^{-1}).

Nisha Bhadauria *et al.* (2012a) reported that application of quizalofop-ethyl @ 0.05 kg a.i. per ha + one hand weeding (HW) proved to be the most effective method of weed control which also recorded lower weed population and dry weight followed by trifluralin @ 0.75 kg a.i. per ha + one HW and pendimethalin @ 0.75 kg a.i. per ha + one HW.

2.4.3 Integrated method

Hand weeding is commonly practiced by the farmers as an effective method of weed control but incessant rain, high wages and timely unavailability of labourers at weeding peaks are also some of the constraints. Therefore, integrated weed management (manual as well as chemical weeding) is most efficient and acceptable approach to combat with the weed control problems.

Baskaran and Solaimalai (2002) revealed that higher seed and stalk yields of sesame were obtained with alachlor @ 1.5 kg per ha as sand mix + hoeing at 30 DAS, which was on par with hand weeding twice. Pre-emergence application of either pendimethalin @ 0.75 kg per ha or fluchloralin @ 1.0 kg per ha as spray followed by hoeing at 30 DAS were on par with hand weeding twice.

Punia *et al.* (2001) reported that integration of either fluchloralin, pendimethalin and trifluralin @ 1.0 kg a.i. per ha with one hoeing at four weeks after sowing (WAS) were significantly better in terms of weed control efficiency and seed yield as compared to one hoeing at four weeks after sowing (WAS) or herbicides used alone.

Dungarwal *et al.* (2003) opined that integration of herbicides viz., fluchloralin, pendimethalin, trifluralin @ 1.0 kg a.i. per ha and alachlor @ 2 kg a.i. per ha with one hoeing at four weeks after sowing (WAS) was found to be more effective when assessed in terms of weed control efficiency and seed yield compared to their single application. Among the herbicides, pre-emergence application of alachlor at 2.0 kg a.i. per ha combined with one hoeing at four weeks after sowing (WAS) registered the highest weed control efficiency (WCE) which enhanced yield attributes leading to higher seed yield (530 kg ha^{-1}) and net returns (` 4275 ha^{-1}).

Nisha Bhadauria *et al.* (2012b) observed that application of trifluralin @ 0.75 kg a.i. per ha followed by one hand weeding at 30 DAS was found to be significantly

superior for seed yield (1127 kg ha^{-1}), uptake by plant (57.4 kg N ha^{-1}, 18.1 kg P ha^{-1}, 54.7 kg K ha^{-1}) and net returns (` 41,357 ha^{-1}).

2.5 Economics

The final choice of any weed control method depends to a greater extent on the cost of the herbicides and their relative efficiency. Although chemical weed control seems to be cheaper and effective, the overall economics of this practice does not justify its general adaptation by growers except in area where the labour is costly and scarce during peak period of farm operations.

Narkhede *et al*. (2000) revealed that cultural practice of two hand weedings and hoeing resulted in the highest gross monetary returns (` 26,519 ha^{-1}) and benefit cost ratio (6.64) than the rest of the integrated weed management practices and unweeded control.

Sukhadia *et al*. (2004) observed that among different treatments, two intercultures with weeding at 20 and 40 DAS recorded significantly higher net returns (`3,193 $ha^{-1}$) and followed by intercultures with weeding once (` 2,713 ha^{-1}) and butachlor @ 0.416 kg per ha + one inter cultivation (` 2,444 ha^{-1}).

Anil Kumar and Thakur (2005) revealed that application of alachlor @ 1.5 kg per ha + one hand weeding gave the highest net returns (` 12,984 $ha^{-1}$) followed by alachlor alone (` 11,727 ha^{-1}).

Joseph *et al*. (2006) reported that the highest gross returns (`13,298 $ha^{-1}$) and net returns (`6,261 ha^{-1}) were achieved from the treatment hand weeding twice at 15 and 30 DAS and this was followed by hand weeding at 15 DAS + hand hoeing at 30 DAS.

Nisha Bhadauria *et al.* (2012b) revealed that two-hand weeding at 20 and 40 DAS registered the highest net returns (` 42,391 $ha^{-1}$) and BC ratio (4.12) and among the herbicidal treatments, application of trifluralin @ 0.75 kg a.i. per ha followed by one hand weeding at 30 DAS recorded higher net income (` 41,357 ha^{-1}) and BC ratio (4.55).

Parvender Sheoran *et al.* (2012) reported that unweeded control plot recorded the lowest gross returns (` 9,000 $ha^{-1}$), net returns (` 1,770 ha^{-1}) and application of alachlor @ 1.5 kg a.i. per ha produced the highest net returns (` 4,990 ha^{-1}) and BC ratio (1.53).

2.6 Residual effect of weed control treatments on succeeding crops

Punia *et al*. (2011) revealed that chlorimuron and imazethapyr, irrespective of their dose and time of application, did not cause any injury to wheat, barley and chickpea planted as succeeding crop after harvest of clusterbean.

Mundra and Maliwal (2012) observed that herbicides applied in blackgram did not show any kind of phytotoxicity on any of the succeeding crops like wheat, mustard and chickpea. Post-emergence application of quizalofop-ethyl @ 37.5, 50.0 and 100.0 g a.i. ha^{-1} and pre-emergence application of pendimethalin @ 750 g a.i. ha^{-1} used in blackgram also did not show any residual effect on germination as well as seed / grain yield of these crops.

Sangeetha *et al*. (2012) reported that various dose of imazethapyr tested in soybean had no adverse residual effect on the growth of the succeeding crops. Yield of sunflower and pearl millet showed no distinct variation in succeeding crop due to different dose of imazethapyr.

MATERIAL AND METHODS

III. MATERIAL AND METHODS

The field experiment on chemical weed management in sesame (*Sesamum indicum* L.) was conducted during *kharif*, 2013 at Agricultural College farm, Raichur. The details of the materials used and the techniques adopted during the course of investigation are presented in this chapter.

3.1 Location

A field experiment was conducted under protective irrigation during *kharif*, 2013 at Agricultural College Farm, Raichur. Raichur is situated on 16^{o} $12^{'}$ North latitude, 77^{o} $20^{'}$ East longitude and at an elevation of 389 meters above mean sea level and is located in North Eastern Dry Zone of Karnataka.

3.2 Climatic conditions

The meteorological monthly data as recorded at meteorological observatory, Main Agricultural Research Station, Raichur, for the year 2013-14 and the mean data of climatic parameters like rainfall (mm), maximum and minimum temperatures (^{o}C) and relative humidity (%) are presented in Table 1 and depicted in Fig. 1.

3.3 Soil properties of experimental site

The soil of the experimental site was medium black with sandy loam texture. Composite soil sample was collected from experimental site before initiation of experiment. The soil was air-dried, powdered and allowed to pass through 2 mm sieve and was analyzed for physical and chemical properties. The values obtained along with the methods employed for their estimation are furnished in Table 2.

3.4 Previous crop in the experimental site

Pigeonpea was grown during *kharif*, 2012-13 in the experimental site with normal agronomic practices.

3.5 Experimental details

The details of the experiment are given below.

Table 2. Physical and chemical properties of soil in the experimental site

Particulars	Value obtained	Method adopted
I. Physical properties		
1. Particle size analysis		
a. Sand (%)	21.22	International pipette method (Piper, 1966)
b. Silt (%)	25.94	
c. Clay (%)	52.81	
2. Bulk density (mg m^{-3})	1.32	Core sampler method (Dastane, 1967)
II. Chemical analysis		
1. Soil pH (1:2.5)	8.21	pH meter (Piper, 1966)
2. Electrical conductivity (dS m^{-1})	0.357	Conductivity bridge (Jackson, 1967)
3. Organic carbon (%)	0.64	Wet oxidation method (Jackson, 1967)
4. Available nitrogen (kg ha^{-1})	223.25	Alkaline permanganate method (Subbaiah and Asija, 1956)
5. Available phosphorus (kg ha^{-1})	33.41	Olsen's method (Jackson, 1967)
6. Available potassium (kg ha^{-1})	195.30	Flame photometry method (Jackson, 1967)

Table 1. Mean monthly meteorological data for the year 2013-14 and mean of the last 82 years at Main Agricultural Research Station, Raichur

Month	Rainfall (mm)		Temperature (^{o}C)				Relative Humidity (%)	
			Maximum		Minimum			
	1931-2013	2013-2014	1931-2013	2013-2014	1931-2013	2013-2014	1931-2013	2013-2014
April	13	18	40	40	24	26	52	39
May	42	77	40	41	25	27	59	48
June	113	40	35	35	23	24	78	59
July	74	116	33	31	23	23	77	74
August	73	68	33	32	22	23	80	70
September	180	284	32	31	22	22	81	79
October	62	97	32	31	20	22	78	76
November	21	1	31	31	19	18	78	62
December	4	0	31	30	16	16	75	54
January	2	0	31	33	17	17	76	52
February	1	0	33	33	18	20	61	47
March	43	51	37	37	23	22	55	41
Total	**628**	**753**						

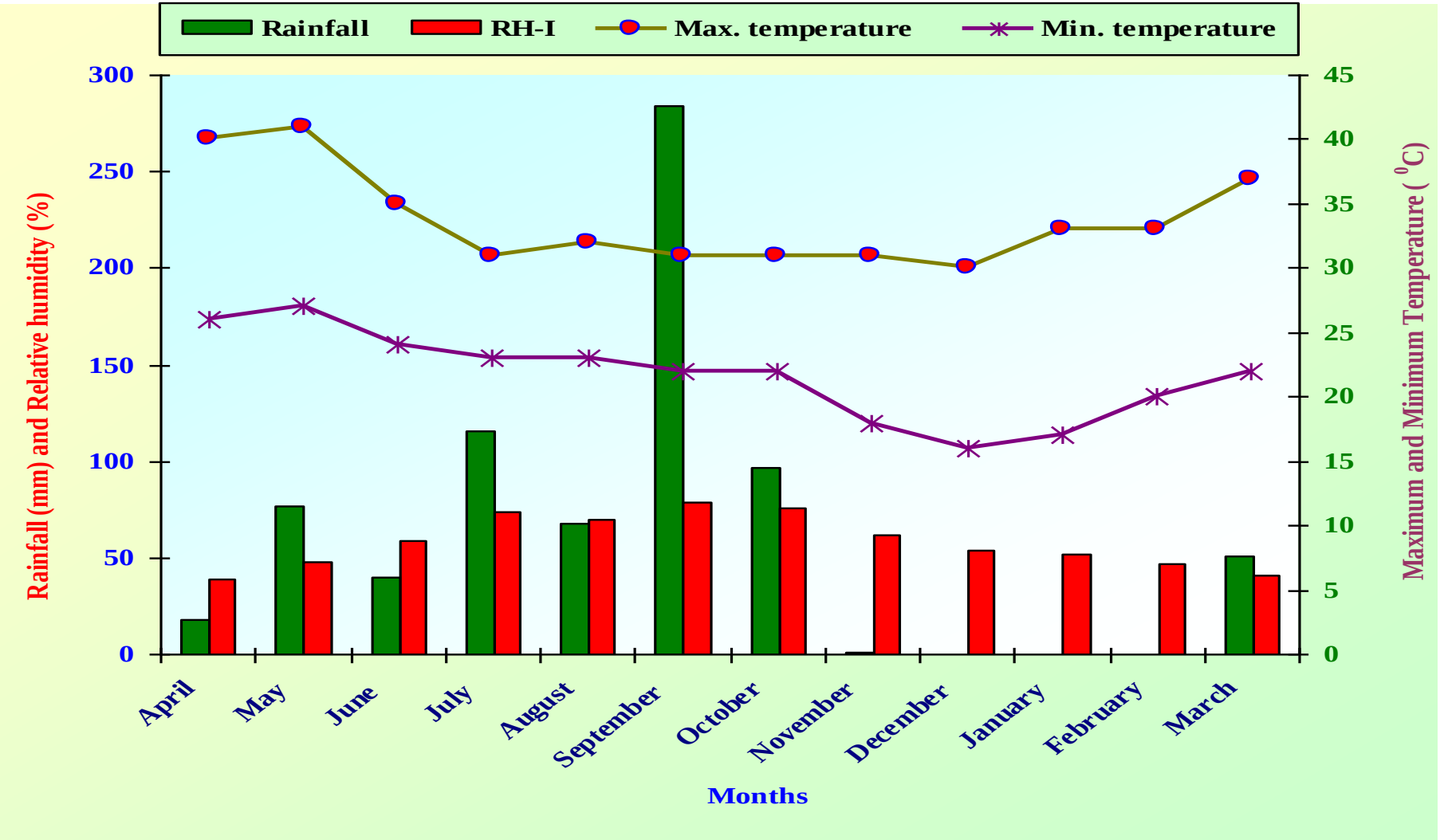

Fig. 1. Monthly meteorological data for the year 2013-14 at the Main Agricultural Research Station, Raichur

3.5.1 Treatment details

There were eight treatments, the details of which are given below.

T_1: Unweeded Check

T_2: Weed Free Check (Hand weeding (HW) at 15 DAS + Inter-cultivation (IC) at 30 and 45 DAS).

T_3: Recommended practice (Alachlor 50 EC @ 0.75 kg a.i. ha^{-1} as pre-emergence (PRE) application + Hand weeding (HW) at 30 DAS + Inter-cultivation (IC) at 45 DAS)

T_4: Pendimethalin 30 EC @ 1 kg a.i. ha^{-1} as pre-emergence (PRE) application + Hand weeding (HW) at 30 DAS + Inter-cultivation (IC) at 45 DAS.

T_5: Pendimethalin 38.7 CS @ 1 kg a.i. ha^{-1} as pre-emergence (PRE) application + Hand weeding (HW) at 30 DAS + Inter-cultivation (IC) at 45 DAS.

T_6: Butachlor 50 EC @ 1 kg a.i. ha^{-1}as pre-emergence (PRE) application + Hand weeding (HW) at 30 DAS + Inter-cultivation (IC) at 45 DAS.

T_7: Quizalofop ethyl 5 EC @ 40 g a.i. ha^{-1} as post emergence (POE) application at 20 DAS + Inter-cultivation (IC) at 45 DAS.

T_8: Imazethapyr 10 SL @ 75 g a.i. ha^{-1} as post emergence (POE) application at 20 DAS + Inter-cultivation (IC) at 45 DAS.

3.5.2 Plot size:

Gross plot : 5.4 m x 4.5 m
Net plot : 4.2 m x 3.6 m

3.5.3 Spacing

Inter row : 30 cm

Intra row : 15 cm

3.5.4 Description of the variety and herbicides used

Characters	DS-1
Progeny	Cross between Gulbarga local x J-68-135
Branching	Shy branching
Seed colour	White
Duration	90 days
Yield	500 to 600 kg ha^{-1}
Special characters	Tolerant to bacterial leaf blight and powdery mildew
Capsule position	More capsules on main stem with capsules at each node

3.5.5 Herbicides

Sl. No.	Common name	Chemical name	Mode of action	Reference
1.	Alachlor 50 EC	2-chloro-2, 6-diethyl-N-(methoxy methyl)-acetanilide	Cell division inhibitors	Das, T. K., 2011
2.	Butachlor 50 EC	2-chloro-2, 6-diethyl-N-(butoxy methyl)-acetanilide	Cell division inhibitors	Das, T. K., 2011
3.	Pendimethalin 30 EC	2,6-Dinitro-N-(1-ethylpropyl) 3,4 xylindine	Inhibition of microtubule formation	Bryson *et al*., 2007
4.	Pendimethalin 38.7 CS	2,6-Dinitro-N-(1-ethylpropyl) 3,4 xylindine	Inhibition of microtubule formation	Bryson *et al*., 2007
5.	Quizalofop ethyl 5 EC	Ethyl-2 [4[(6-chloro-2-quinoxalinyl-oxy] phenoxy] propionate	Inhibition of fatty acid biosynthesis	Bhattacharya *et al*., 2004
6.	Immazethapyr 10 SL	2-[4, 5-dihydro-4-methyl 4-(1-methylethyl)-5 oxo1H-imidazol-2-yl]-5-ethyl-3-pyridinecarboxylic acid.	Acetolactate synthase inhibitors	Shaner *et al*.,1984

3.5.6 Design and layout

The experiment was laid out in Randomized Block Design (RBD) with eight treatments replicated thrice.

3.6 Cultural operations

3.6.1 Land preparation

The land was ploughed once with mould board plough and then harrowed twice to bring the soil into fine tilth. Then experiment was laid out as per the plan. Small bunds were raised around each plot. Lines were marked both ways as per the treatments.

LEGEND

Treatment details

T_1: Unweeded Check

T_2: Weed Free Check (Hand weeding (HW) at 15 DAS + Inter-cultivation (IC) at 30 and 45 DAS).

T_3: Recommended practice (Alachlor 50 EC @ 0.75 kg a.i. ha^{-1} as pre-emergence (PRE) application + Hand weeding (HW) at 30 DAS + Inter-cultivation (IC) at 45 DAS)

T_4: Pendimethalin 30 EC @ 1 kg a.i. ha^{-1} as pre-emergence (PRE) application + Hand weeding (HW) at 30 DAS + Inter-cultivation (IC) at 45 DAS.

T_5: Pendimethalin 38.7 CS @ 1 kg a.i. ha^{-1} as pre-emergence (PRE) application + Hand weeding (HW) at 30 DAS + Inter-cultivation (IC) at 45 DAS.

T_6: Butachlor 50 EC @ 1 kg a.i. ha^{-1} as pre-emergence (PRE) application + Hand weeding (HW) at 30 DAS + Inter-cultivation (IC) at 45 DAS.

T_7: Quizalofop ethyl 5 EC @ 40 g a.i. ha^{-1} as post emergence (POE) application at 20 DAS + Inter-cultivation (IC) at 45 DAS.

T_8: Imazethapyr 10 SL @ 75 g a.i. ha^{-1} as post emergence (POE) application at 20 DAS + Inter-cultivation (IC) at 45 DAS.

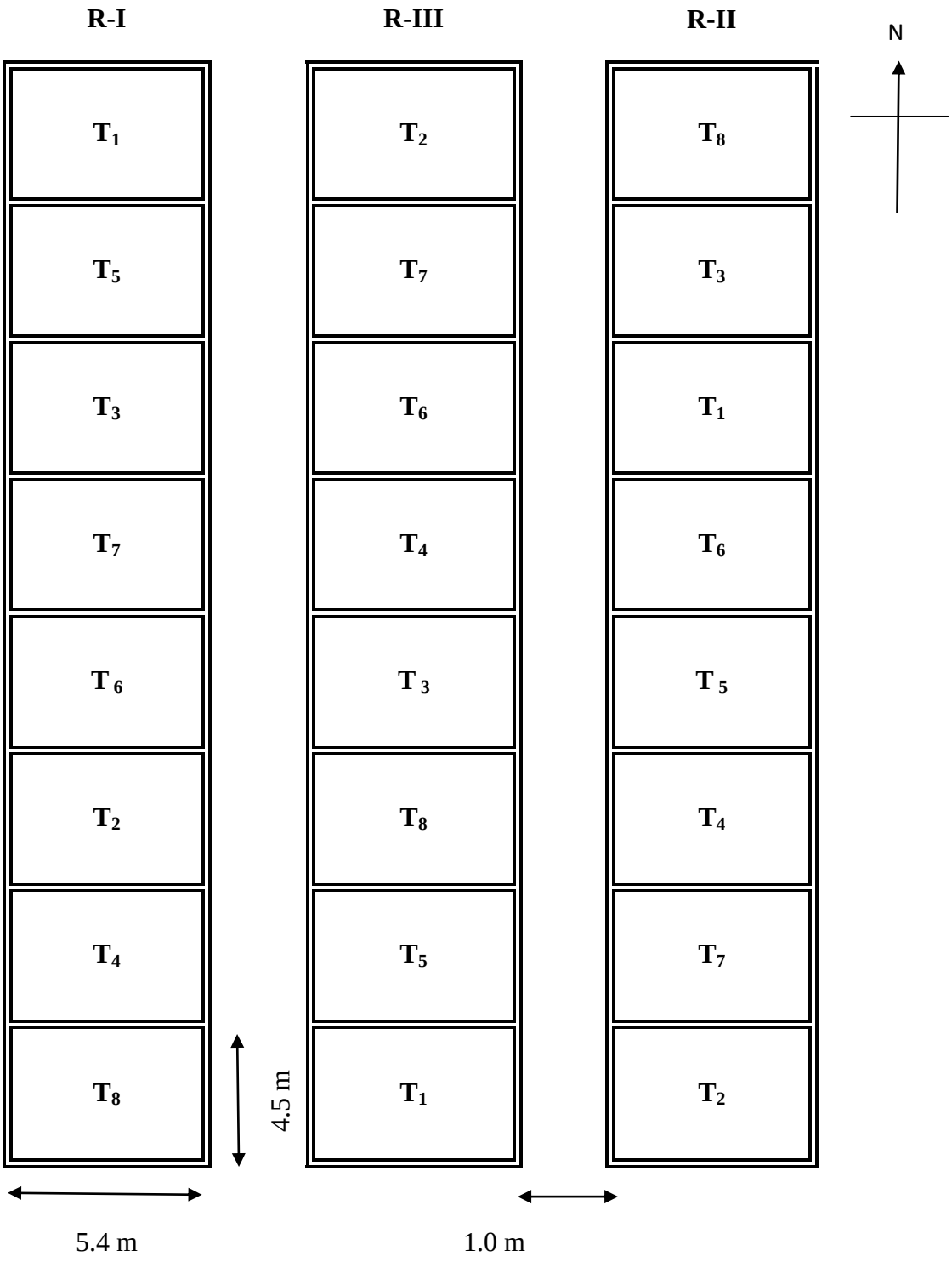

Fig. 2. Plan of layout of the experimental site

3.6.2 Fertilizer application

The entire quantity of recommended dose of fertilizer (50:25:25 kg N: P_2O_5: K_2O ha^{-1}) was applied as basal dose at the time of sowing in the form of Urea, DAP and Muriate of potash and FYM @ 6 tones ha^{-1} was applied 2 weeks before sowing. The fertilizer mixture was applied 7 cm deep in the seed line and mixed thoroughly with the soil.

3.6.3 Seeds and sowing

Shallow furrows were opened at 30 cm apart with the help of a marker. The seeds mixed with sand in 1:4 proportion were hand sown uniformily on 3-06-2013 in the furrows and was covered with moist soil immediately after sowing . Before sowing, the seeds were treated with carbendazim @ 3 g per kg.

3.6.4 Gap filling and thinning

Gap filling was undertaken one week after sowing to maintain optimum plant population. Thinning was attended 15 days after sowing (DAS) to retain only one healthy seedling at each spot.

3.6.5 After care

To control leaf eating caterpiller, Chloropyriphos (2 ml $litre^{-1}$) was sprayed at 20 days after sowing (DAS). To control viral diseases, Confidor (0.2 ml $litre^{-1}$) and Acephate (1 g $litre^{-1}$) were sprayed at 30 days after sowing (DAS). For controlling white flies, Triazophos (1.5 ml $litre^{-1}$) was sprayed at 60 days after sowing (DAS).

3.6.6 Harvesting and threshing

First, all the border plants were harvested and then the net plot area as per the treatment was harvested in each plot by cutting the plants close to the ground. After harvesting, the plants were bundled and allowed for sun drying. After complete sun drying, the crop was threshed by beating with wooden sticks. The seeds were winnowed, cleaned and seed weight per net plot was recorded.

3.7 Recording of experimental data

3.7.1 Observations on weeds

3.7.1.1 Weed flora

Weed species observed in net plots were identified and are listed in Table 3.

3.7.1.2 Weed count

Weeds were counted at 20, 40, 60 DAS and at harvest. Monocot and dicot weeds present within 0.5 m x 0.5 m random quadrant in each net plot were counted separately and expressed as number of weeds per m^2.

3.7.1.3 Dry weight of weeds

Weed dry weight was recorded at 20, 40, 60 DAS and at harvest. Weeds in 0.5 m x 0.5 m quadrant in each net plot were cut close to the ground level and were dried at 70^o C to a constant weight and weight was recorded. Based on this data, dry weight of weeds per m^2 and per hectare were worked out and expressed in g m^{-2} and kg ha^{-1} respectively.

3.7.1.4 Weed control efficiency

Weed control efficiency (WCE) was calculated by the following method.

$$WCE\ (\%) = \frac{WCC - WCT}{WCC} \times 100$$

Where,

WCC = Dry weight of weeds in unweeded control plot

WCT = Dry weight of weeds in treated plot

3.7.1.5 Weed index

Weed index was calculated by following the method of Gill and Vijayakumar (1966).

$$Weed\ index\ (\%) = \frac{X - Y}{X} \times 100$$

Where,

X = Seed yield in weed free check plot (kg ha^{-1})

Y = Seed yield in treated plot (kg ha^{-1})

3.7.2 Crop Phytotoxicity

Phytotoxicity effects were assessed using the criteria developed by Rao (1986). The injury ratings were based on the scale i.e. 0 = no injury and 10 = complete kill.

Effect	Rating	Weed	Crop description
None	0	No control	No injury, normal
Slight	1	Very poor control	Slight stunting, injury or discoloration
	2	Poor control	Some stand loss, stunting or Discoloration
	3	Poor to deficient control	Injury more pronounced but not persistent
Moderate	4	Deficient control	Moderate injury, recovery possible
	5	Deficient to moderate control	Injury more persistent, recovery doubtful
	6	Moderate control	Near severe injury, no recovery possible
Severe	7	Satisfactory control	Severe injury, stand loss
	8	Good control	Almost destroyed, a few plants Surviving
	9	Good to excellent control	Very few plants alive
Complete	10	Complete control	Complete destruction

Crop phytotoxicity due to pre-emergence herbicides was recorded at 10, 13, 16 and 19 DAS. Whereas, crop phytotoxicity due to post-emergence herbicides was recorded at 23, 26, 29 and 32 DAS.

3.8 Observation on growth components

Five plants were tagged at random in net plot area for recording various observations on growth parameters at 30, 60 DAS and at harvest.

3.8.1 Plant height

Plant height from ground level up to the growing tip of the plant was recorded from five tagged plants and the mean plant height was worked out and expressed in centimeters.

3.8.2 Number of branches per plant

The number of branches arising from the main stem were counted and the mean was taken as number of branches per plant.

3.8.3 Leaf area per plant

The leaf area per plant was worked out by disc method on dry weight basis as per the procedure suggested by Vivekanandan *et al.* (1972).

$$LA = \frac{Wa \times A}{Wd}$$

Where,

LA = Leaf area (cm^2)

Wa = Oven dry weight of all leaves (inclusive of 10 disc weight)

Wd = Oven dry weight of 10 discs

A = Area of the 10 discs (cm^2)

3.8.4 Leaf area index (LAI)

Leaf area index (LAI) was worked out by dividing the leaf area per plant by land area occupied by the plant (Sestak *et al.*, 1971)

$$LAI = \frac{A}{P}$$

Where,

A = Leaf area per plant (cm^2)

P = Land area occupied by the plant (cm^2)

3.8.5 Dry matter production and its accumulation in different plant parts

Plant samples for dry matter studies were collected at 30, 60 DAS and at harvest. At each sampling, five plants were uprooted at random in each treatment and partitioned into leaf, stem and reproductive parts. These samples were oven dried at

70^{o}C in hot air oven for 72 hours till a constant weight. The dry weights of different plant parts were recorded. The total dry matter production per plant was obtained with the summation of dry weight of all plant parts and was expressed on per plant basis (g plant^{-1}).

3.9 Observation on yield components and yield

The plants selected for growth studies were utilized for recording the observations on the following yield components.

3.9.1 Number of capsules per plant

The capsules from five tagged plants were counted and the mean number of capsules per plant were calculated.

3.9.2 Number of seeds per capsule

Total number of seeds from the five randomly selected capsules were counted and the mean was worked out and expressed as number of seeds per capsule.

3.9.3 Seed weight per capsule

Five capsules were selected randomly from the plants in the net plot area at harvest and mean seed weight per capsule was worked out after separating the seeds from the capsules and expressed in grams per capsule.

3.9.4 Test weight (1000-seed weight)

From the seed yield of each net plot, 1000 seeds were randomly counted and weight was recorded. This weight was taken as 1000 seed weight and expressed in grams.

3.9.5 Seed yield per hectare

Seed yield of the net plot was recorded after hand threshing and air-drying. After recording the seed yield of net plot area, seed yield per ha was worked out and expressed in kg ha^{-1}.

3.9.6 Stalk yield per hectare

The plants from the net plot area after threshing were dried and weight was recorded. Stalk yield per ha was worked out and expressed as kg ha^{-1}.

3.9.7 Harvest index (HI)

Harvest index was estimated as per the formula suggested by Donald (1962).

$$HI = \frac{\text{Economic yield (kg ha}^{-1})}{\text{Biological yield (kg ha}^{-1})}$$

3.10 Quality parameters

3.10.1 Oil content (%)

Fifteen grams of dried seeds of sesame drawn from the net plot of each treatment were used for estimation of oil content by Nuclear Magnetic Resonance (NMR) method and expressed in percentage.

3.10.2 Oil yield (kg ha^{-1})

Oil yield was calculated by multiplying the oil per cent with seed yield as follows.

$$\text{Seed oil yield (kg/ha)} = \frac{\text{Seed oil content (\%) x Seed yield (kg/ha)}}{100}$$

3.11 Chemical analysis of plant samples

3.11.1 Uptake of N, P and K by sesame and weeds

Nitrogen, phosphorus and potassium contents in composite plant samples of sesame and of weeds at harvest were estimated by modified micro-kjeldhal method, Vanadomolybdate yellow colour method and flame photometer method, respectively as outlined by Jackson (1967). Nutrient uptake was calculated by using the following formula.

$$\text{Uptake (kg ha}^{-1}) = \frac{\text{Nutrient concentration (\%) x Biomass (kg ha}^{-1})}{100}$$

3.11.2 Chlorophyll content of sesame leaves

The chlorophyll content of green leaves of each of five tagged plants was recorded at 30 and 60 DAS. For this estimation, chlorophyll meter (Model, SPAD-502) was used and values were obtained.

3.12 Chemical analysis of soil

3.12.1 Soil organic carbon and available NPK

Initial organic carbon content of finally ground soil sample was determined by Walkely and Black's wet oxidation method by Jackson (1967) and expressed in percentage. In addition, available nitrogen was determined by modified alkaline permanganate method as described by Subbaiah and Asija (1956) using Kjeldhal instrument. Available phosphorus was determined by Olsen's method as outlined by Jackson (1967) using spectrophotometer. Available potassium was extracted with neutral normal ammonium acetate and the content was estimated by flame photometer (Jackson, 1967).

3.13 Economics

The costs of the following items were considered for working out the cost of cultivation of sesame.

1. Labour charges
2. Seeds
3. Fertilizers
4. Plant protection chemicals
5. Miscellaneous (land rent, marketing charges *etc*.)

The prices of the input prevailed during experimentation were considered for working out the cost of cultivation. Gross returns (Rs. ha^{-1}) were calculated using the sesame yield and the market price of the produce at the time of marketing. The labour wages, cost of inputs and outputs are furnished in Appendix I.

3.13.1 Net returns

The net returns per hectare were calculated by deducting the cost of cultivation per hectare from gross returns per hectare.

3.13.2 Benefit cost ratio

The Benefit cost ratio was worked out as follows.

$$\text{Benefit cost ratio} = \frac{\text{Gross returns (₹ ha}^{-1})}{\text{Cost of cultivation (₹ ha}^{-1})}$$

3.14 Residual effect of weed control treatments on succeeding crops

After the harvest of sesame, residual effect of treatments was studied by raising succeeding crop chickpea.

3.14.1 Observations on chickpea

3.14.1.1 Germination count

Germinated seeds were counted at 10 and 20 DAS.

3.14.1.2 Crop phytotoxicity

Crop phytotoxicity was recorded at 7 and 15 DAS.

3.14.1.3 Seed yield per hectare

Seed yield of the net plot was recorded after threshing and air-drying. After recording the seed yield of net plot area, seed yield per ha was worked out and expressed in kg ha^{-1}.

3.15 Statistical analysis

The analysis and interpretation of data were done using the Fisher's method of analysis of variance technique as described by Panse and Sukhatme (1967). The level of significance used in "F" and "t" test was p=0.05. Critical difference values were calculated whenever the "F" test was significant.

3.16 Transformation

Data on weed count and weed dry weight showed high degree of variation. A linear relationship between the means and variance was observed and therefore, the data on weed count was subjected to $(X+1)^{1/2}$ transformation, while the data on weed dry weight was subjected to log (X+2) transformation to derive analysis of variance valid as suggested by Bartlett (1947)

EXPERIMENTAL RESULTS

IV. EXPERIMENTAL RESULTS

The results of the experiment conducted on chemical weed management in sesame (*Sesamum indicum* L.) during *kharif,* 2013 at the Agricultural College farm, Raichur are presented below.

4.1 Observation on weeds

4.1.1 Weed flora (Cf Table 3)

The important monocotyledonous weeds observed in the experiment were *Agropyron repens* (L.)., *Cyperus rotundus* L., *Cynodon dactylon* (L.) Pers, *Dinebra retroflexa*. While, common dicotyledonous weed observed were *Abutilon indicum* (L.) Sweet, *Acalypha indica*, *Ageratum conyzoides* L., *Commelina benghalensis* L., *Cyanotis dactylon* L., *Mervemia emarginata* (L.) Cufod., *Parthenium hysterophorus* L., *Phyllauthus maderaspetensis*, *Portulaca oleraceae*, *Tribulus terrestris* L., *Xanthium strumarium* L.

4.1.2 Weed density

Observations recorded on weed population at different stages of crop growth are presented in table 4, 5 and 6.

4.1.2.1 Monocot weed density per m^2 (Cf Table 4)

The number of monocot weeds per m^2 differed significantly due to weed control treatments at all stages of crop growth.

At 20 DAS, the lowest monocot weed count (2.77/m^2) in sesame was recorded in recommended practice (T_3) and was followed by butachlor 50 EC @ 1 kg a.i. ha^{-1} as PRE application + HW at 30 DAS + IC at 45 DAS (T_6) which were on par with each other and recorded significantly lower weed population over unweeded check (T_1) and rest of the treatments *viz*., pendimethalin 38.7 CS @ 1 kg a.i. ha^{-1} as PRE application + HW at 30 DAS + IC at 45 DAS (T_5), pendimethalin 30 EC @ 1 kg a.i. ha^{-1} as PRE application + HW at 30 DAS + IC at 45 DAS (T_4), imazethapyr 10 SL @ 75 g a.i. ha^{-1} as POE application at 20 DAS + IC at 45 DAS (T_8) and quizalofop ethyl 5 EC @ 40 g a.i. ha^{-1} as POE application at 20 DAS + IC at 45 DAS (T_7). The highest weed density (4.93/m^2) was noticed in unweeded check (T_1) and was followed by quizalofop ethyl 5 EC @ 40 g a.i. ha^{-1} as POE application at 20 DAS + IC at 45 DAS (4.58/m^2).

Table 3. Weed flora observed in the experimental site

Scientific name of weed species	Family
Monocots	
Agropyron repens (L.) Beauv.	Poaceae
Cyperus rotundus L.	Cyperaceae
Cynodon dactylon (L.) Pers	Poaceae
Dinebra retroflexa (Vahl.)	Poaceae
Echinochloa colonum (L.) Link	Poaceae
Echinochloa crusgalli (L.) Beauv	Poaceae
Dicots	
Abutilon indicum (L.) Sweet	Malvaceae
Ageratum conyzoides L.	Asteraceae
Calotropis gigantea R. Br.	Asclepidaceae
Commelina benghalensis L.	Commelinaceae
Cyanotis cucullata (Roth)R.R. &K.	Commelinaceae
Digera arvensis Forsk	Amaranthaceae
Celosia argentea L.	Amaranthaceae
Merremia emarginata (L.) Cufod	Convolvulaceae
Parthenium hysterophorus L.	Asteraceae
Xanthium strumarium L.	Asteraceae

LEGEND (Plate 1)

1. Common name: Bermuda grass

   Scientific name: *Cynodon dactylon* (L.)Pers.
   Family : Poaceae

2. Common name: Congress grass

   Scientific name: *Parthenium hysterophorus* L.
   Family : Asteraceae

3. Common name: Cyanotis

   Scientific name: *Cyanotis tuberose*

   Family : Commelinaceae

4. Common name: Garden spurge

   Scientific name: *Ephorbia hirta* L.

   Family : Euphorbiaceae

Table 4. Monocot weed density per m^2 in sesame at different stages of crop growth as influenced by weed control treatments

Tr. No.	Treatment	Monocot weeds density m^{-2}			
		20 DAS	40 DAS	60 DAS	At harvest
T_1	Unweeded check	4.93 (23.33)	5.19 (26.00)	5.41 (28.33)	7.68 (58.00)
T_2	Weed free check (HW at 15 DAS + IC at 30 and 45 DAS)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)
T_3	Recommended practice (Alachlor 50 EC @ 0.75 kg a.i. ha^{-1}as PRE application + HW at 30 DAS + IC at 45 DAS)	2.77 (6.67)	2.63 (6.00)	2.99 (8.00)	4.51 (19.33)
T_4	Pendimethalin 30 EC @ 1 kg a.i. ha^{-1} as PRE application + HW at 30 DAS + IC at 45 DAS	3.65 (12.33)	3.51 (11.33)	3.60 (12.00)	6.06 (35.67)
T_5	Pendimethalin 38.7 CS @ 1 kg a.i. ha^{-1} as PRE application + HW at 30 DAS + IC at 45 DAS	3.51 (11.33)	3.40 (10.67)	3.46 (11.00)	5.72 (31.67)
T_6	Butachlor 50 EC @ 1 kg a.i. ha^{-1}as PRE application + HW at 30 DAS + IC at 45 DAS	3.06 (8.33)	2.99 (8.00)	3.36 (10.33)	5.10 (25.00)
T_7	Quizalofop ethyl 5 EC @ 40 g a.i. ha^{-1} as POE application at 20 DAS + IC at 45 DAS	4.58 (20.00)	2.37 (4.67)	2.64 (6.00)	3.87 (14.00)
T_8	Imazethapyr 10 SL @ 75 g a.i. ha^{-1} as POE application at 20 DAS + IC at 45 DAS	3.87 (14.00)	3.45 (11.00)	3.60 (12.00)	5.74 (32.00)
	S.Em.±	0.15	0.18	0.16	0.15
	C.D. at 5%	0.46	0.54	0.48	0.44

EC : Emulsifiable Concentrate CS : Capsular Suspension SL : Soluble Liquid HW: Hand Weeding IC: Intercultivation
DAS : Days After Sowing PRE : Pre-emergence POE : Post-emergence

*Figures in parentheses indicate original values
Total weed count (x) data were transformed to $(x+1)^{1/2}$

At 40 DAS, quizalofop ethyl 5 EC @ 40 g a.i. ha^{-1} as POE application at 20 DAS + IC at 45 DAS (T_7) recorded the lowest monocot weed density (2.37/m^2) while, recommended practice (alachlor 50 EC @ 0.75 kg a.i. ha^{-1} as PRE application + HW at 30 DAS + IC at 45 DAS) was on par with it. Other treatments were intermediate in their effects. Significantly higher monocot weed density (5.19/m^2) was registered in unweeded check (T_1) and was followed by pendimathalin 30 EC @ 1 kg a.i. ha^{-1} as PRE application + HW at 30 DAS + IC at 45 DAS (T_4).

At 60 DAS, the lowest monocot weed density (2.64/m^2) was recorded in quizalofop ethyl 5 EC @ 40 g a.i. ha^{-1} as POE application at 20 DAS + IC at 45 DAS (T_7) and was followed by recommended practice (T_3) which were on par with each other. The highest moncot weed density (5.41/m^2) was recorded in unweeded check (T_1) and was followed by pendimethalin 30 EC @ 1 kg a.i. ha^{-1} as PRE application + HW at 30 DAS + IC at 45 DAS (T_4).

At harvest, the lowest monocot weed density (3.87/m^2) was recorded in quizalofop ethyl 5 EC @ 40 g a.i. ha^{-1} as POE application at 20 DAS + IC at 45 DAS (T_7) and was followed by recommended practice (T_3). The highest monocot weed density (7.68/m^2) was recorded in unweeded check (T_1) and was followed by pendimethalin 30 EC @ 1 kg a.i. ha^{-1} as PRE application + HW at 30 DAS + IC at 45 DAS (T_4) which were significantly different from each other.

4.1.2.2 Dicot weed density per m^2 (Cf Table 5)

The dicot weed population at different stages of the crop differed significantly due to weed control treatments.

At 20 DAS, the lowest dicot weed density (3.42/m^2) was recorded in recommended practice *i.e.*, alachlor 50 EC @ 0.75 kg a.i. ha^{-1} as PRE application + HW at 30 DAS + IC at 45 DAS (T_3) and was followed by butachlor 50 EC @ 1 kg a.i. ha^{-1} as PRE application + HW at 30 DAS + IC at 45 DAS (T_6), pendimethalin 38.7 CS @1 kg a.i. ha^{-1} as PRE application + HW at 30 DAS + IC at 45 DAS (T_5) and pendimethalin 30 EC @ 1 kg a.i. ha^{-1} as PRE application + HW at 30 DAS + IC at 45 DAS (T_4) which were on par with each other and significantly differed from unweeded control (T_1). The highest dicot weed density (5.72/m^2) was observed in unweeded check (T_1) and was followed by quizalofop ethyl 5 EC @ 40 g a.i. ha^{-1} as POE application at 20 DAS + IC at 45 DAS (T_7).

At 40 DAS, the lowest dicot weed count (2.50/m^2) was recorded in recommended practice (T_3) and was followed by imazethapyr 10 SL @ 75 g a.i. ha^{-1} as POE application at 20 DAS + IC at 45 DAS (T_8), butachlor 50 EC @ 1 kg a.i. ha^{-1} as PRE application + HW at 30 DAS + IC at 45 DAS (T_6) and pendimathalin 38.7 CS @ 1 kg a.i. ha^{-1} as PRE application + HW at 30 DAS + IC at 45 DAS (T_5) which were on par with each other. The highest dicot weed density (6.90/m^2) was observed in unweeded check (T_1) and was followed by quizalofop ethyl 5 EC @ 40 g a.i. ha^{-1} as POE application at 20 DAS + IC at 45 DAS (T_7).

At 60 DAS the lowest (3.16/m^2) dicot weed density was recorded in recommended practice (T_3) and was followed by imazethapyr 10 SL @ 75 g a.i. ha^{-1} as POE application at 20 DAS + IC at 45 DAS (T_8) which were on par with each other. The treatments *viz*., butachlor 50 EC @ 1 kg a.i. ha^{-1} as PRE application + HW at 30 DAS + IC at 45 DAS (T_6) and pendimethalin 38.7 CS @ 1 kg a.i. ha^{-1} as PRE application + HW at 30 DAS + IC at 45 DAS (T_5) were in increasing order of their dicot weed density and on par with each other. The highest (7.26/m^2) dicot weed density was recorded in unweeded check (T_1) and was followed by quizalofop ethyl 5 EC @ 40 g a.i. ha^{-1} as POE application at 20 DAS + IC at 45 DAS (T_7) which significantly differed from each other.

At harvest, the lowest (4.83/m^2) dicot weed density was recorded in recommended practice (T_3) and was followed by imazethapyr 10 SL @ 75 g a.i. ha^{-1} as POE application at 20 DAS + IC at 45 DAS (T_8) and butachlor 50 EC @ 1 kg a.i. ha^{-1} as PRE application + HW at 30 DAS + IC at 45 DAS ($T_{6)}$ which were on par with each other and significantly different from other treatments. The highest dicot weed density (8.06/m^2) was observed in unweeded check (T_1) and was followed by pendimethalin 30 EC @ 1 kg a.i. ha^{-1} as PRE application + HW at 30 DAS + IC at 45 DAS (T_4), Quizalofop ethyl 5 EC @ 40 g a.i. ha^{-1} as POE application at 20 DAS + IC at 45 DAS (T_7) and pendimethalin 38.7 CS @ 1 kg a.i. ha^{-1} as PRE application + HW at 30 DAS + IC at 45 DAS (T_5) which were on par with each other.

4.1.2.3 Total weed density per m^2 (Cf Table 6)

The total weed density differed significantly among the treatments at all the stages of crop growth.

At 20 DAS, the lowest (4.28/m^2) total weed density was recorded in recommended practice *i.e.,* alachlor 50 EC @ 0.75 kg a.i. ha^{-1} as PRE application + HW

Table 5. Dicots weed density per m^2 in sesame at different stages of crop growth as influenced by weed control treatments

Tr. No.	Treatment	Dicot weeds density m^{-2}			
		20 DAS	40 DAS	60 DAS	At harvest
T_1	Unweeded check	5.72 (31.67)	6.90 (46.67)	7.26 (51.67)	8.06 (64.00)
T_2	Weed free check (HW at 15 DAS + IC at 30 and 45 DAS)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)
T_3	Recommended practice (Alachlor 50 EC @ 0.75 kg a.i. ha^{-1}as PRE application + HW at 30 DAS + IC at 45 DAS)	3.42 (10.67)	2.50 (5.33)	3.16 (9.00)	4.83 (22.33)
T_4	Pendimethalin 30 EC @ 1 kg a.i. ha^{-1} as PRE application + HW at 30 DAS + IC at 45 DAS	3.74 (13.00)	3.32 (10.00)	4.00 (15.00)	5.72 (31.67)
T_5	Pendimethalin 38.7 CS @ 1 kg a.i. ha^{-1} as PRE application + HW at 30 DAS + IC at 45 DAS	3.70 (12.67)	2.99 (8.00)	3.79 (13.33)	5.60 (30.33)
T_6	Butachlor 50 EC @ 1 kg a.i. ha^{-1}as PRE application + HW at 30 DAS + IC at 45 DAS	3.56 (11.67)	2.93 (7.67)	3.64 (12.33)	5.03 (24.33)
T_7	Quizalofop ethyl 5 EC @ 40 g a.i. ha^{-1} as POE application at 20 DAS + IC at 45 DAS	5.26 (26.67)	3.42 (10.67)	4.16 (16.33)	5.63 (30.67)
T_8	Imazethapyr 10 SL @ 75 g a.i. ha^{-1} as POE application at 20 DAS + IC at 45 DAS	4.28 (17.33)	2.76 (6.67)	3.46 (11.00)	4.86 (22.67)
	S.Em.±	0.19	0.17	0.13	0.14
	C.D. at 5%	0.58	0.50	0.40	0.41

EC : Emulsifiable Concentrate CS : Capsular Suspension SL : Soluble Liquid HW: Hand Weeding IC: Intercultivation
DAS : Days After Sowing PRE : Pre-emergence POE : Post-emergence

*Figures in parentheses indicate original values
Total weed count (x) data were transformed to $(x+1)^{1/2}$

at 30 DAS + IC at 45 DAS (T_3) and was followed by butachlor 50 EC @ 1 kg a.i. ha^{-1} as PRE application + HW at 30 DAS + IC at 45 DAS (T_6) which were on par with each other and significantly different from unweeded check (T_1). The highest (7.48/m^2) total weed count was observed in unweeded check (T_1) and was followed by quizalofop ethyl 5 EC 40 g a.i. ha^{-1} as POE application at 20 DAS + IC at 45 DAS (T_7) which were on par with each other.

At 40 DAS, the lowest (3.56/m^2) total weed density was recorded in recommended practice (T_3) and was followed by quizalofop ethyl 5 EC @ 40 g a.i. ha^{-1} as POE application at 20 DAS + IC at 45 DAS (T_7) which were on par with each other. The treatments *viz*., butachlor 50 EC @ 1 kg a.i. ha^{-1} as PRE application + HW at 30 DAS + IC at 45 DAS (T_6), imazethapyr 10 SL @ 75 g a.i. ha^{-1} as POE application at 20 DAS + IC at 45 DAS (T_8) and pendimethalin 38.7 CS @ 1 kg a.i. ha^{-1} as PRE application + HW at 30 DAS + IC at 45 DAS (T_5) were in increasing order of their total weed density per m^2 and were on par with each other. The highest total weed density (8.58/m^2) was recorded in unweeded check (T_1) and was followed by pendimethalin 30 EC @ 1 kg a.i. ha^{-1} as PRE application + HW at 30 DAS + IC at 45 DAS (T_4) which were significantly different from each other.

At 60 DAS, application of alachlor 50 EC @ 0.75 kg a.i. ha^{-1} as PRE application + HW at 30 DAS + IC at 45 DAS (T_3) recorded the lowest (4.24/m^2) total weed density and was followed by quizalofop ethyl 5 EC @ 40 g a.i. ha^{-1} as POE application at 20 DAS + IC at 45 DAS (T_7) which were on par with each other. The treatments *viz*., butachlor @ 1 kg a.i. ha^{-1} as PRE application + HW at 30 DAS + IC at 45 DAS (T_6), imazethapyr 10 SL @ 75 g a.i. ha^{-1} as POE application at 20 DAS + IC at 45 DAS (T_8), pendimethalin 38.7 CS @ 1 kg a.i. ha^{-1} as PRE application + HW at 30 DAS + IC at 45 DAS (T_5) and pendimethalin 30 EC @ 1 kg a.i. ha^{-1} as PRE application + HW at 30 DAS + IC at 45 DAS (T_4) were in ascending order of total weed density per m^2 and were on par with each other. The highest (9.00/m^2) was recorded in unweeded check (T_1) and was followed by pendimethalin 30 EC @ 1 kg a.i. ha^{-1} as PRE application + HW at 30 DAS + IC at 45 DAS (T_4) which were significantly different from each other.

At harvest, the lowest (6.53/m^2) total weed density was noticed in recommended practice (T_3) and was followed by quizalofop ethyl 5 EC @ 40 g a.i. ha^{-1} as POE application at 20 DAS + IC at 45 DAS (T_7) which were on par with each other. The treatments *viz*., butachlor 50 EC @ 1 kg a.i. ha^{-1} as PRE application + HW at 30 DAS +

Table 6. Total weed density per m^2 in sesame at different stages of crop growth as influenced by weed control treatments

Tr. No.	Treatment	Total weed density m^2			
		20 DAS	40 DAS	60 DAS	At harvest
T_1	Unweeded check	7.48 (55.00)	8.58 (72.67)	9.00 (80.00)	11.09 (122.00)
T_2	Weed free check (HW at 15 DAS + IC at 30 and 45 DAS)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)
T_3	Recommended practice (Alachlor 50 EC @ 0.75 kg a.i. ha^{-1}as PRE application + HW at 30 DAS + IC at 45 DAS)	4.28 (17.34)	3.56 (11.33)	4.24 (17.00)	6.53 (41.66)
T_4	Pendimethalin 30 EC @ 1 kg a.i. ha^{-1} as PRE application + HW at 30 DAS + IC at 45 DAS	5.13 (25.33)	4.73 (21.33)	5.29 (27.00)	8.31 (67.34)
T_5	Pendimethalin 38.7 CS @ 1 kg a.i. ha^{-1} as PRE application + HW at 30 DAS + IC at 45 DAS	5.00 (24.00)	4.43 (18.67)	5.03 (24.33)	7.94 (62.00)
T_6	Butachlor 50 EC @ 1 kg a.i. ha^{-1}as PRE application + HW at 30 DAS + IC at 45 DAS	4.55 (20.00)	4.08 (15.67)	4.87 (22.66)	7.09 (49.33)
T_7	Quizalofop ethyl 5 EC @ 40 g a.i. ha^{-1} as POE application at 20 DAS + IC at 45 DAS	6.90 (46.67)	4.04 (15.34)	4.83 (22.33)	6.78 (44.67)
T_8	Imazethapyr 10 SL @ 75 g a.i. ha^{-1} as POE application at 20 DAS + IC at 45 DAS	5.69 (31.33)	4.32 (17.67)	4.90 (23.00)	7.46 (54.67)
	S.Em.±	0.21	0.16	0.20	0.11
	C.D. at 5%	0.65	0.48	0.62	0.34

EC : Emulsifiable Concentrate CS : Capsular Suspension SL : Soluble Liquid HW: Hand Weeding IC: Intercultivation
DAS : Days After Sowing PRE : Pre-emergence POE : Post-emergence

*Figures in parentheses indicate original values
Total weed count (x) data were transformed to $(x+1)^{1/2}$

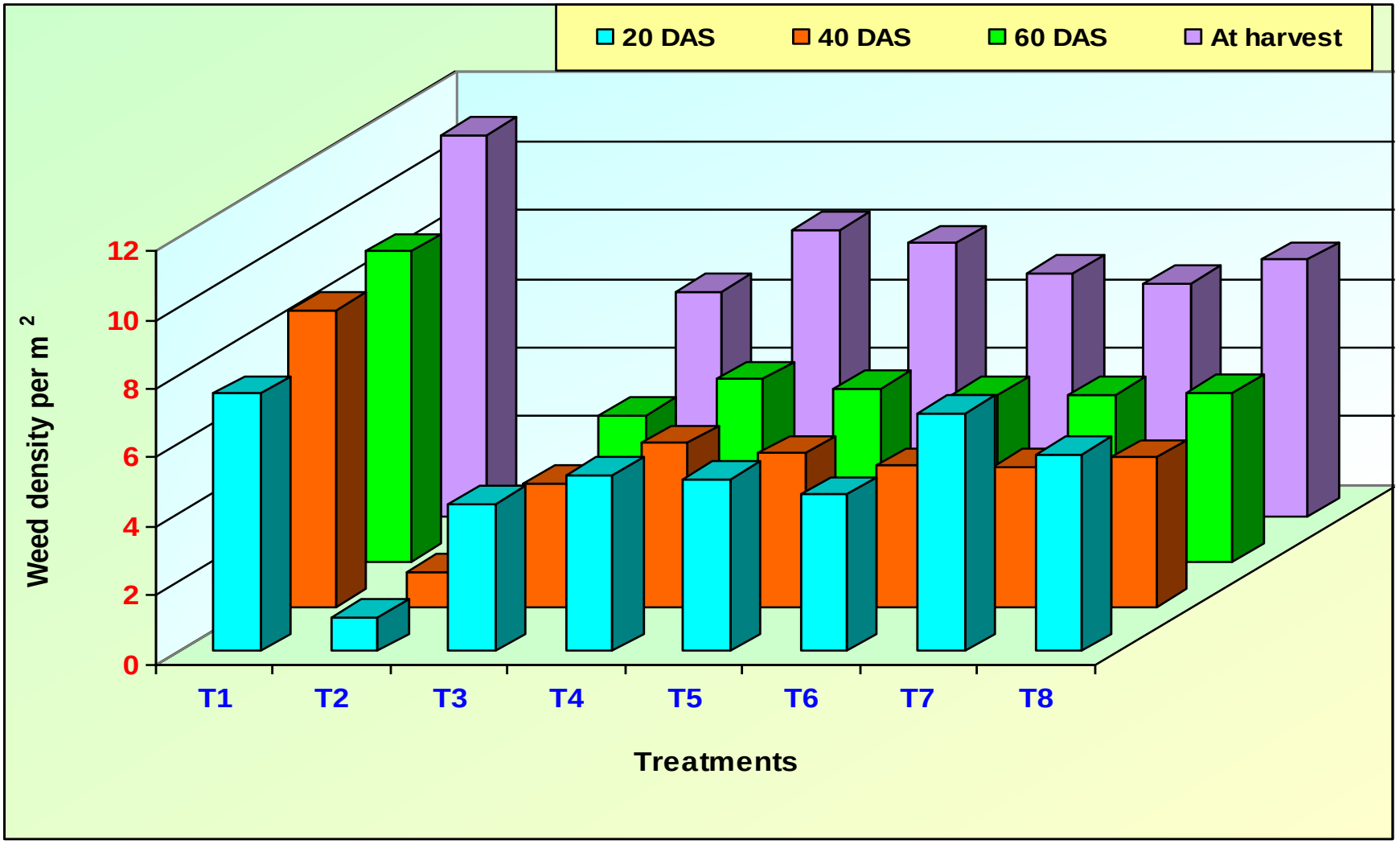

Fig. 3. Total weed density per m^2 in sesame as influenced by weed control treatments

IC at 45 DAS (T_6) and imazethapyr 10 SL @ 75 g a.i. ha^{-1} as POE application + at 20 DAS + IC at 45 DAS (T_8) were in ascending order of total weed count and on par with each other. The highest (11.09/m^2) total weed count was recorded in unweeded check (T_1) and was followed by pendimethalin 30 EC @ 1 kg a.i. ha^{-1} as PRE application + HW at 30 DAS + IC at 45 DAS (T_4) which were significantly different from each other.

4.1.3 Total dry weight of weed (g/m^2) (Cf Table 7)

The total dry weight of weeds significantly varied due to different weed control treatments at all the growth stages of crop.

At 20 DAS, recommended practice *i.e.*, alachlor 50 EC @ 0.75 kg a.i. ha^{-1} as PRE application + HW at 30 DAS + IC at 45 DAS (T_3) recorded the lowest (0.73 g/m^2) total weed dry matter among all the other treatments. The treatments *viz*., butachlor 50 EC @ 1 kg a.i. ha^{-1} as PRE application + HW at 30 DAS + IC at 45 DAS (T_6) and pendimethalin 38.7 CS @ 1 kg a.i. ha^{-1} as PRE application + HW at 30 DAS + IC at 45 DAS (T_5) were on par with each other. The highest (1.04 g/m^2) total weed dry matter was obtained in unweeded control (T_1) and was followed by quizalofop ethyl 5 EC @ 40 g a.i. ha^{-1} as POE application at 20 DAS + IC at 45 DAS (T_7) which were on par with each other.

At 40 DAS, the lowest (0.63 g/m^2) total weed dry matter was recorded in recommended practice (T_3) and was followed by quizalofop ethyl 5 EC @ 40 g a.i. ha^{-1} as POE application at 20 DAS + IC at 45 DAS (T_7) which were on par with each other. The treatments *viz*., butachlor 50 EC @ 1 kg a.i. ha^{-1} as PRE application + HW at 30 DAS + IC at 45 DAS (T_6), imazethapyr 10 SL @ 75 g a.i. ha^{-1} as POE application at 20 DAS + IC at 45 DAS (T_8) and pendimethalin 38.7 CS @ 1 kg a.i. ha^{-1} as PRE application + HW at 30 DAS + IC at 45 DAS (T_5) were in ascending order of total dry weight of weed and on par with each other. The highest (1.75 g/m^2) total weed dry matter was recorded in unweeded check (T_1) and was followed by pendimathalin 30 EC @ 1 kg a.i. ha^{-1} as PRE application + HW at 30 DAS + IC at 45 DAS (T_4).

At 60 DAS, recommended practice (T_3) recorded the lowest (0.85 g/m^2) total weed dry weight and was followed by quizalofop ethyl 5 EC @ 40 g a.i. ha^{-1} as POE application at 20 DAS + IC at 45 DAS (T_7) which were on par with each other. The treatments *viz*., butachlor 50 EC @ 1 kg a.i. ha^{-1} as PRE application + HW at 30 DAS + IC at 45 DAS (T_6), imazethapyr 10 SL @ 75 g a.i. ha^{-1} as POE application at 20 DAS + IC at 45 DAS (T_8) were in ascending order at total weed dry weight and on par with each

Table 7. Total dry weight of weeds in sesame at different stages of crop growth as influenced by weed control treatments

Tr. No.	Treatment	Total dry weight of weeds (g/m^2)			
		20 DAS	40 DAS	60 DAS	At harvest
T_1	Unweeded check	1.04 (9.07)	1.75 (53.67)	1.93 (83.19)	2.38 (238.87)
T_2	Weed free check (HW at 15 DAS + IC at 30 and 45 DAS)	0.30 (0.00)	0.30 (0.00)	0.30 (0.00)	0.30 (0.00)
T_3	Recommended practice (Alachlor 50 EC @ 0.75 kg a.i. ha^{-1}as PRE application + HW at 30 DAS + IC at 45 DAS)	0.73 (3.40)	0.63 (2.23)	0.85 (5.03)	1.80 (61.53)
T_4	Pendimethalin 30 EC @ 1 kg a.i. ha^{-1} as PRE application + HW at 30 DAS + IC at 45 DAS	0.92 (6.33)	0.91 (6.1)	1.30 (17.87)	2.00 (97.37)
T_5	Pendimethalin 38.7 CS @ 1 kg a.i. ha^{-1} as PRE application + HW at 30 DAS + IC at 45 DAS	0.89 (5.77)	0.89 (5.73)	1.23 (14.80)	1.98 (93.85)
T_6	Butachlor 50 EC @ 1 kg a.i. ha^{-1}as PRE application + HW at 30 DAS + IC at 45 DAS	0.85 (5.10)	0.83 (4.73)	1.06 (9.47)	1.93 (83.36)
T_7	Quizalofop ethyl 5 EC @ 40 g a.i. ha^{-1} as POE application at 20 DAS + IC at 45 DAS	1.00 (8.10)	0.72 (3.23)	0.93 (6.47)	1.84 (69.67)
T_8	Imazethapyr 10 SL @ 75 g a.i. ha^{-1} as POE application at 20 DAS + IC at 45 DAS	1.01 (8.27)	0.85 (5.1)	1.08 (10.10)	1.94 (85.10)
	S.Em.±	0.02	0.03	0.03	0.01
	C.D. at 5%	0.06	0.09	0.09	0.04

EC : Emulsifiable Concentrate CS : Capsular Suspension SL : Soluble Liquid HW: Hand Weeding IC: Intercultivation
DAS : Days After Sowing PRE : Pre-emergence POE : Post-emergence

*Figures in parentheses indicate original values
Total weed count (x) data were transformed to log (x+2)

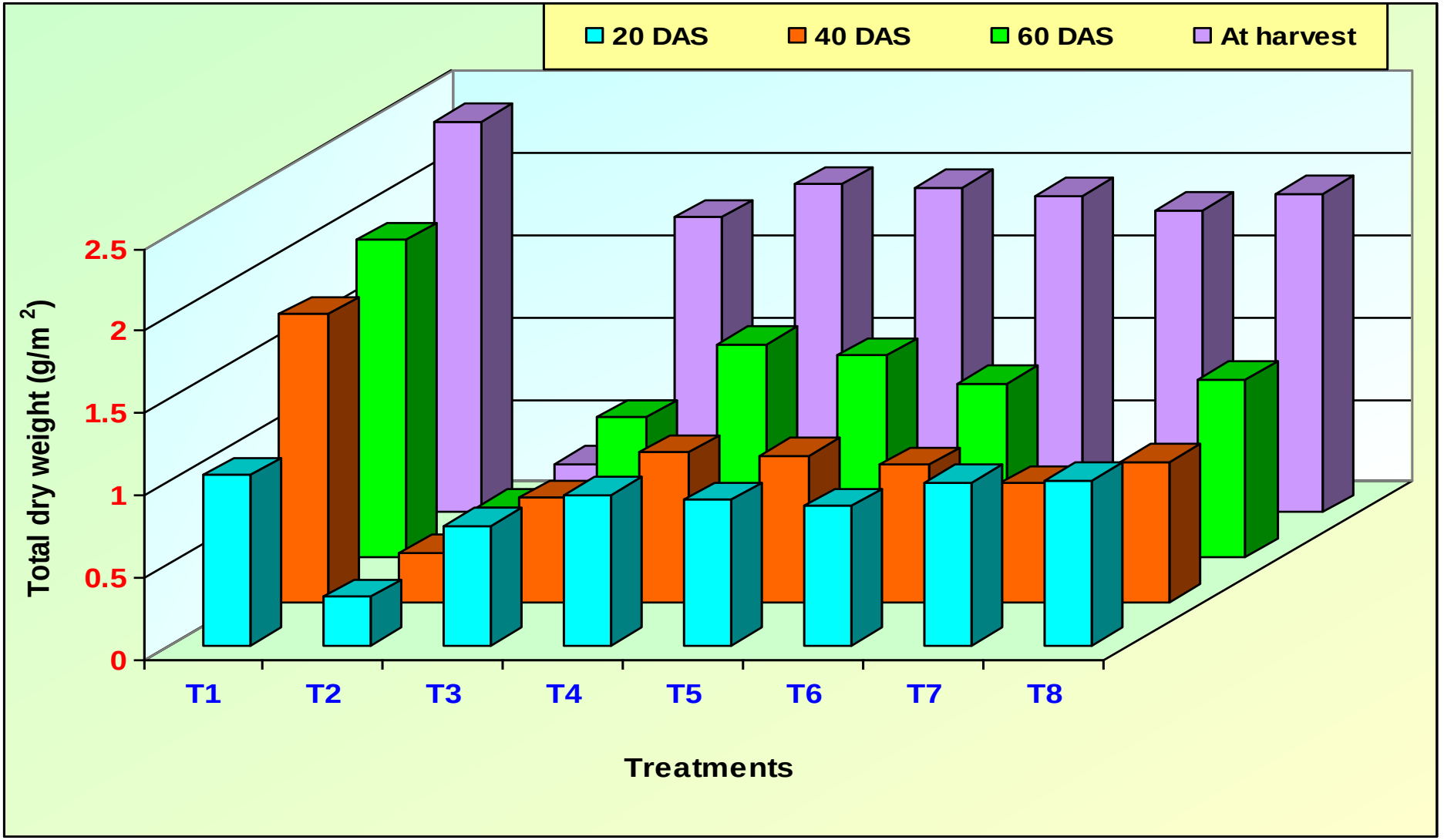

Fig. 4. Total dry weight of weeds (g/ m^2) in sesame at different stages of crop growth as influenced by weed control treatments

other. The highest (1.93 g/m^2) total weed dry weight per m^2 was noticed in unweeded check (T_1) and was followed by pendimethalin 30 EC @ 1 kg a.i. ha^{-1} as PRE application + HW at 30 DAS + IC at 45 DAS (T_4) which significantly differed from each other.

At harvest, the lowest (1.80 g/m^2) total weed dry weight was recorded in recommended practice (T_3) and was followed by quizalofop ethyl 5 EC @ 40 g a.i. ha^{-1} as POE application at 20 DAS + IC at 45 DAS (T_7) which were on par with each other. The highest (2.38 g/m^2) total weed dry weight was observed in unweeded check (T_1) and was followed by pendimethalin 30 EC @ 1 kg a.i. ha^{-1} as PRE application + HW at 30 DAS + IC at 45 DAS (T_4).

4.1.4 Weed control efficiency (Cf Table 8)

The results showed that the highest weed control efficiency (74.24%) was recorded in recommended practice *i.e.*, alachlor 50 EC @ 0.75 kg a.i. ha^{-1} as PRE application + HW at 30 DAS + IC at 45 DAS (T_3) and was followed by quizalofop ethyl 5 EC @ 40 g a.i. ha^{-1} as POE application at 20 DAS + IC at 45 DAS (70.83%) which were significantly different from each other. The lowest (59.23%) weed control efficiency was recorded in pendimethalin 30 EC @ 1 kg a.i. ha^{-1} as PRE application + HW at 30 DAS + IC at 45 DAS (T_4) and was followed by pendimethalin 38.7 CS @ 1 kg a.i. ha^{-1} as PRE application + HW at 30 DAS + IC at 45 DAS (T_5) which were on par with each other.

4.1.5 Weed index (Cf Table 8)

The results showed that the lowest weed index (16.89%) was recorded in recommended practe *i.e.*, alachlor 50 EC @ 0.75 kg a.i. ha^{-1} as PRE application + HW at 30 DAS + IC at 45 DAS (T_3) and was followed by quizalufop ethyl 5 EC @ 40 g a.i. ha^{-1} as POE application at 20 DAS + IC at 45 DAS (T_7) which were on par with each other. The next best treatments which were having weed index value in ascending order were butachlor 50 EC @ 1 kg a.i. ha^{-1} as PRE application + HW at 30 DAS + IC at 45 DAS (T_6), pendimethalin 38.7 CS @ 1 kg a.i. ha^{-1} as PRE application + HW at 30 DAS + IC at 45 DAS (T_5) and pendimethalin 30 EC @ 1 kg a.i. ha^{-1} as PRE application + HW at 30 DAS + IC at 45 DAS (T_4). The highest (85.11%) weed index was observed in imazethapyr 10 SL @ 75 g a.i. ha^{-1} as POE application at 30 DAS + IC at 45 DAS (T_8) and was followed by unweeded check (T_1).

Table 8. Weed control efficiency and weed index in sesame as influenced by weed control treatments

Tr. No.	Treatment	Weed control efficiency (%)	Weed index (%)
T_1	Unweeded check	0.00	68.95
T_2	Weed free check (HW at 15 DAS + IC at 30 and 45 DAS)	100.00	0.00
T_3	Recommended practice (Alachlor 50 EC @ 0.75 kg a.i. ha^{-1}as PRE application + HW at 30 DAS + IC at 45 DAS)	74.24	16.89
T_4	Pendimethalin 30 EC @ 1 kg a.i. ha^{-1} as PRE application + HW at 30 DAS + IC at 45 DAS	59.23	52.71
T_5	Pendimethalin 38.7 CS @ 1 kg a.i. ha^{-1} as PRE application + HW at 30 DAS + IC at 45 DAS	60.70	51.78
T_6	Butachlor 50 EC @ 1 kg a.i. ha^{-1}as PRE application + HW at 30 DAS + IC at 45 DAS	60.91	36.20
T_7	Quizalofop ethyl 5 EC @ 40 g a.i. ha^{-1} as POE application at 20 DAS + IC at 45 DAS	70.83	28.95
T_8	Imazethapyr 10 SL @ 75 g a.i. ha^{-1} as POE application at 20 DAS + IC at 45 DAS	64.26	85.11
	S.Em.±	1.02	4.12
	C.D. at 5%	3.08	12.50

EC : Emulsifiable Concentrate CS : Capsular Suspension SL : Soluble Liquid HW: Hand Weeding IC: Intercultivation
DAS : Days After Sowing PRE : Pre-emergence POE : Post-emergence

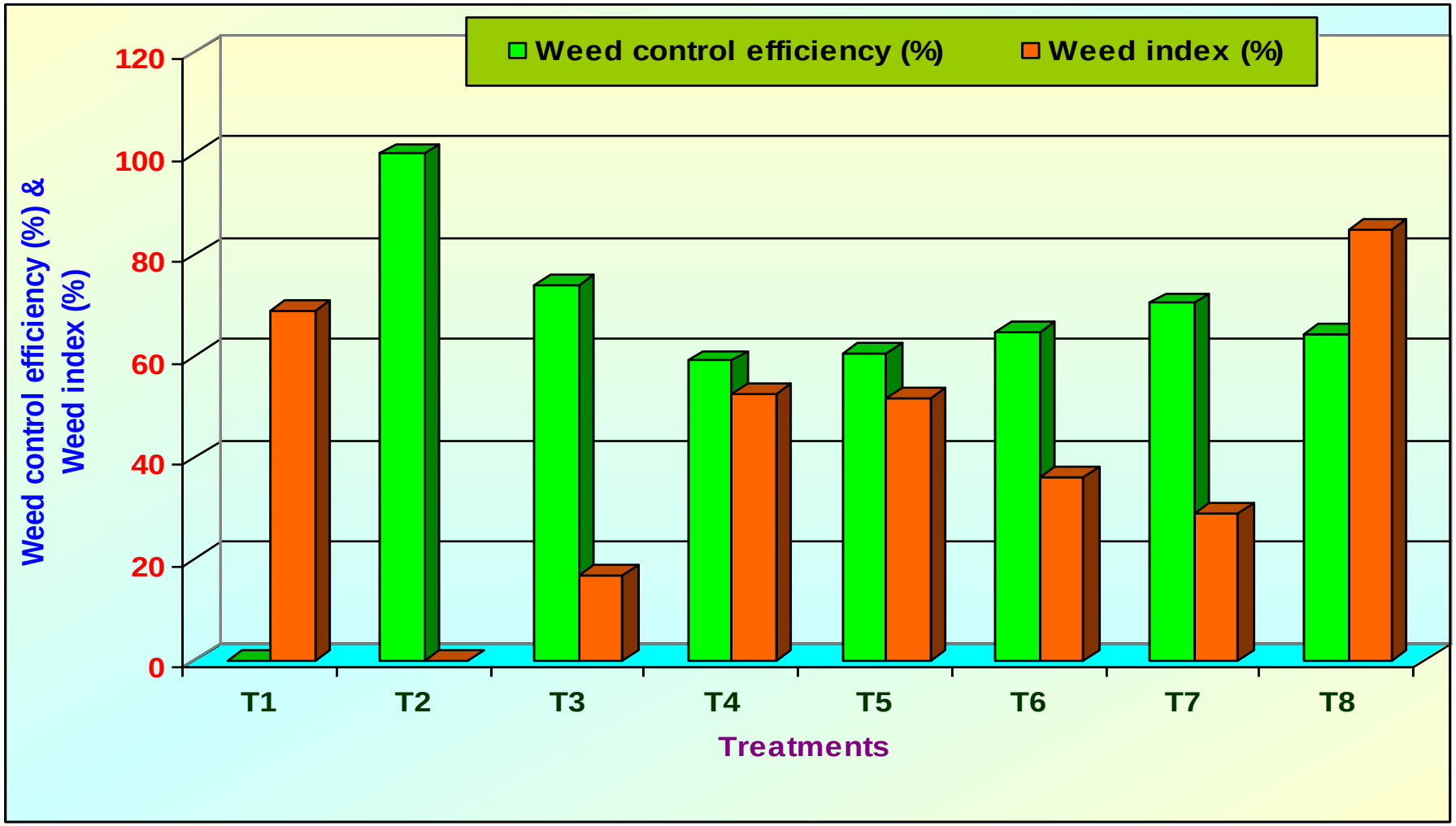

Fig. 5. Weed control efficiency and weed index in sesame as influenced by weed control treatments

4.2 Observations on sesame

4.2.1 Crop phytotoxicity due to pre-emergence herbicides (Cf Table 9)

At 10 DAS, pendimethalin 38.7 CS @ 1 kg a.i. ha^{-1} as PRE application + HW at 30 DAS + IC at 45 DAS (T_5) recorded higher phytotoxicity rating (1.67) and was followed by pendimethalin 30 EC @ 1 kg a.i. ha^{-1} as PRE application + HW at 30 DAS + IC at 45 DAS (1.33). The similar trend was observed during 13 to 19 DAS with reduced crop phytotoxicity ratings. The crop phytotoxicity was reduced progressively during 10 to 19 DAS.

4.2.1.1 Crop phytotoxicity due to post-emergence herbicides (Cf Table 10)

Among the post emergent herbicides, application of quizalofop ethyl 5 EC @ 40 g a.i. ha^{-1} did not have any phytotoxic symptoms on sesame but severe crop phytotoxic symptoms were recorded due to the spray of imazethapyr 10 SL @ 75 g a.i. ha^{-1} as POE application + IC at 45 DAS (T_8) which recorded higher phytotoxicity rating (6.00) and progressively increased and reached crop phytotoxicity rating of 8.00 at 32 DAS.

4.2.2 Growth parameters of sesame

4.2.2.1 Plant height of sesame (Cf Table 11)

Plant height differed significantly due to weed control treatments at all the growth stages of the crop.

At 30 DAS, significantly higher (15.97 cm) plant height was recorded in weed free check (T_2). Next best treatments were recommended practice *i.e.*, alachlor 50 EC @ 0.75 kg a.i. ha^{-1} as PRE application + HW at 30 DAS + IC at 45 DAS (T_3), quizalofop ethyl 5 EC @ 40 g a.i. ha^{-1} as POE application at 20 DAS + IC at 45 DAS (T_7), butachlor 50 EC @ 1 kg a.i. ha^{-1} as PRE application + HW at 30 DAS + IC at 45 DAS (T_6) and pendimethalin 38.7 CS @ 1 kg a.i. ha^{-1} as PRE application + HW at 30 DAS + IC at 45 DAS (T_5) which were on par with each other and significantly different from rest of the treatments. Significantly lower plant height (5.36 cm) was recorded in imazethapyr 10 SL @ 75 g a.i. ha^{-1} as POE application at 20 DAS + IC at 45 DAS (T_8) followed by unweeded check (7.40 cm).

Table 9. Crop phytotoxicity due to pre-emergence herbicides in sesame as influenced by weed control treatment

Tr. No.	Treatment	Crop phytotoxicity			
		10 DAS	13 DAS	16 DAS	19 DAS
T_1	Unweeded check	-	-	-	-
T_2	Weed free check (HW at 15 DAS + IC at 30 and 45 DAS)	-	-	-	-
T_3	Recommended practice (Alachlor 50 EC @ 0.75 kg a.i. ha^{-1}as PRE application + HW at 30 DAS + IC at 45 DAS)	0.00	0.00	0.00	0.00
T_4	Pendimethalin 30 EC @ 1 kg a.i. ha^{-1} as PRE application + HW at 30 DAS + IC at 45 DAS	1.33	1.33	0.5	0.33
T_5	Pendimethalin 38.7 CS @ 1 kg a.i. ha^{-1} as PRE application + HW at 30 DAS + IC at 45 DAS	1.67	1.67	1.00	0.67
T_6	Butachlor 50 EC @ 1 kg a.i. ha^{-1}as PRE application + HW at 30 DAS + IC at 45 DAS	0.00	0.00	0.00	0.00
T_7	Quizalofop ethyl 5 EC @ 40 g a.i. ha^{-1} as POE application at 20 DAS + IC at 45 DAS	-	-	-	-
T_8	Imazethapyr 10 SL @ 75 g a.i. ha^{-1} as POE application at 20 DAS + IC at 45 DAS	-	-	-	-

EC : Emulsifiable Concentrate CS : Capsular Suspension SL : Soluble Liquid HW: Hand Weeding IC: Intercultivation
DAS : Days After Sowing PRE : Pre-emergence POE : Post-emergence

Table 10. Crop phytotoxicity due to post-emergence herbicides in sesame as influenced by weed control treatments

Tr. No.	Treatment	Crop phytotoxicity			
		23 DAS	26 DAS	29 DAS	32 DAS
T_1	Unweeded check	-	-	-	-
T_2	Weed free check (HW at 15 DAS + IC at 30 and 45 DAS)	-	-	-	-
T_3	Recommended practice (Alachlor 50 EC @ 0.75 kg a.i. ha^{-1}as PRE application + HW at 30 DAS + IC at 45 DAS)	-	-	-	-
T_4	Pendimethalin 30 EC @ 1 kg a.i. ha^{-1} as PRE application + HW at 30 DAS + IC at 45 DAS	-	-	-	-
T_5	Pendimethalin 38.7 CS @ 1 kg a.i. ha^{-1} as PRE application + HW at 30 DAS + IC at 45 DAS	-	-	-	-
T_6	Butachlor 50 EC @ 1 kg a.i. ha^{-1}as PRE application + HW at 30 DAS + IC at 45 DAS	-	-	-	-
T_7	Quizalofop ethyl 5 EC @ 40 g a.i. ha^{-1} as POE application at 20 DAS + IC at 45 DAS	0.00	0.00	0.00	0.00
T_8	Imazethapyr 10 SL @ 75 g a.i. ha^{-1} as POE application at 20 DAS + IC at 45 DAS	6.00	7.00	8.00	8.00

EC : Emulsifiable Concentrate CS : Capsular Suspension SL : Soluble Liquid HW: Hand Weeding IC: Intercultivation
DAS : Days After Sowing PRE : Pre-emergence POE : Post-emergence

Table 11. Plant height of sesame at different growth stages as influenced by weed control treatments

Tr. No.	Treatment	Plant height (cm)		
		30 DAS	60 DAS	At harvest
T_1	Unweeded check	7.40	61.64	85.04
T_2	Weed free check (HW at 15 DAS + IC at 30 and 45 DAS)	15.97	119.84	146.33
T_3	Recommended practice (Alachlor 50 EC @ 0.75 kg a.i. ha^{-1}as PRE application + HW at 30 DAS + IC at 45 DAS)	14.08	110.00	137.28
T_4	Pendimethalin 30 EC @ 1 kg a.i. ha^{-1} as PRE application + HW at 30 DAS + IC at 45 DAS	10.33	74.57	122.87
T_5	Pendimethalin 38.7 CS @ 1 kg a.i. ha^{-1} as PRE application + HW at 30 DAS + IC at 45 DAS	13.23	78.58	123.10
T_6	Butachlor 50 EC @ 1 kg a.i. ha^{-1}as PRE application + HW at 30 DAS + IC at 45 DAS	13.57	98.09	133.08
T_7	Quizalofop ethyl 5 EC @ 40 g a.i. ha^{-1} as POE application at 20 DAS + IC at 45 DAS	13.82	104.00	134.96
T_8	Imazethapyr 10 SL @ 75 g a.i. ha^{-1} as POE application at 20 DAS + IC at 45 DAS	5.36	29.40	64.23
	S.Em.±	0.61	2.25	1.38
	C.D. at 5%	1.85	6.83	4.19

EC : Emulsifiable Concentrate CS : Capsular Suspension SL : Soluble Liquid HW: Hand Weeding IC: Intercultivation
DAS : Days After Sowing PRE : Pre-emergence POE : Post-emergence

At 60 DAS, significantly higher (119.84 cm) plant height was recorded in weed free check (T_2) when compared to other treatments. The treatments *viz*., recommended practice (alachlor 50 EC @ 0.75 kg a.i. ha^{-1} as PRE application + HW at 30 DAS + IC at 45 DAS) and quizalofop ethyl 5 EC @ 40 g a.i. ha^{-1} as POE application at 20 DAS + IC at 45 DAS (T_7) which were on par with each other. The significantly lower plant height (29.40 cm) was recorded in imazethapyr 10 SL @ 75 g a.i. ha^{-1} as POE application at 20 DAS + IC at 45 DAS (29.40 cm) followed by unweeded check (61.64 cm).

At harvest, significantly higher (146.33) plant height was recorded in weed free check (T_2). Next best treatments were recommended practice *i.e*., alachlor 50 EC @ 0.75 kg a.i. ha^{-1} as PRE application + HW at 30 DAS + IC at 45 DAS (T_3), quizalofop ethyl 5 EC @ 40 g a.i. ha^{-1} as POE application at 20 DAS + IC at 45 DAS (T_7), butachlor 50 EC @ 1 kg a.i. ha^{-1} as PRE application + HW at 30 DAS + IC at 45 DAS (T_6) which were on par with each other. The lowest plant height (64.23 cm) was recorded in imazethapyr 10 SL 75 g a.i. ha^{-1} as POE application at 20 DAS + IC at 45 DAS followed by unweeded check (85.04 cm).

4.2.2.2 Number of branches (Cf Table 12)

Number of branches differed significantly due to different weed control treatments at all stages of crop growth.

At 60 DAS, the highest number of branches $plant^{-1}$ (2.93) were recorded in weed free check (T_2) and was followed by recommended practice (alachlor 50 EC @ 0.75 kg a.i. ha^{-1} as PRE application + HW at 30 DAS + IC at 45 DAS (T_3), quizalofop ethyl @ 40 g a.i. ha^{-1} as POE application at 20 DAS + IC at 45 DAS (T_7) which differed significantly. Butachlor 50 EC @ 1 kg a.i. ha^{-1} as PRE application + HW at 30 DAS + IC at 45 DAS (T_6), pendimethalin 38.7 CS @ 1 kg a.i. ha^{-1} as PRE application + HW at 30 DAS + IC at 45 DAS (T_5) and pendimethalin 30 EC @ 1 kg a.i. ha^{-1} as PRE application + HW at 30 DAS + IC at 45 DAS (T_4) were in descending order of number of branches per plant and on par with each other. Imazethapyr 10 SL @ 75 g a.i. ha^{-1} as POE application at 20 DAS + IC at 45 DAS registered significantly the lowest number of branches plant (1.00) and followed by unweeded check (1.63).

At harvest, imazethapyr 10 SL @ 75 g a.i. ha^{-1} as POE application at 20 DAS + IC at 45 DAS resulted in significantly lower number of branches $plant^{-1}$ (2.07) followed by unweeded check (2.53). The significantly higher number of branches $plant^{-1}$ (3.27)

Table 12. Number of branches of sesame at different growth stages as influenced by weed control treatments

Tr. No.	Treatment	Number of branches plant^{-1}	
		60 DAS	At harvest
T_1	Unweeded check	1.63	2.53
T_2	Weed free check (HW at 15 DAS + IC at 30 and 45 DAS)	2.93	3.27
T_3	Recommended practice (Alachlor 50 EC @ 0.75 kg a.i. ha^{-1}as PRE application + HW at 30 DAS + IC at 45 DAS)	2.73	3.20
T_4	Pendimethalin 30 EC @ 1 kg a.i. ha^{-1} as PRE application + HW at 30 DAS + IC at 45 DAS	1.80	2.80
T_5	Pendimethalin 38.7 CS @ 1 kg a.i. ha^{-1} as PRE application + HW at 30 DAS + IC at 45 DAS	1.93	2.80
T_6	Butachlor 50 EC @ 1 kg a.i. ha^{-1}as PRE application + HW at 30 DAS + IC at 45 DAS	2.27	2.93
T_7	Quizalofop ethyl 5 EC @ 40 g a.i. ha^{-1} as POE application at 20 DAS + IC at 45 DAS	2.67	3.20
T_8	Imazethapyr 10 SL @ 75 g a.i. ha^{-1} as POE application at 20 DAS + IC at 45 DAS	1.00	2.07
	S.Em.±	0.26	0.09
	C.D. at 5%	0.80	0.26

EC : Emulsifiable Concentrate CS : Capsular Suspension SL : Soluble Liquid HW: Hand Weeding IC: Intercultivation
DAS : Days After Sowing PRE : Pre-emergence POE : Post-emergence

were recorded in weed free check (T_2) followed by recommended practice *i.e.,* alachlor 50 EC @ 0.75 kg a.i. ha^{-1} as PRE application + HW at 30 DAS + IC at 45 DAS (T_3) and quizalofop ethyl 5 EC @ 40 g a.i. ha^{-1} as POE application at 20 DAS + IC at 45 DAS (T_7) which were on par with each other. The treatments viz., butachlor 50 EC @ 1 kg a.i. ha^{-1} as PRE application + HW at 30 DAS + IC at 45 DAS (T_6), pendimethalin 38.7 CS @ 1 kg a.i. ha^{-1} as PRE application + HW at 30 DAS + IC at 45 DAS (T_3) and pendimethalin 30 EC @ 1 kg a.i. ha^{-1} as PRE application + HW at 30 DAS + IC at 45 DAS (T_4) were on par with each other and significantly superior over unweeded check (T_1).

4.2.2.3 Leaf area (Cf Table 13)

Leaf area of sesame increased with advancement in age and reached peak by 60 DAS thereafter started declining towards maturity.

At 30 DAS, the highest leaf area (241.17 cm^2 $plant^{-1}$) was recorded in weed free check (T_2) and was followed by recommended practice (alachlor 50 EC @ 0.75 kg a.i.ha^{-1} as PRE application + HW at 30 DAS + IC at 45 DAS), quizalofop ethyl 5 EC @ 40 g a.i. ha^{-1} as POE application at 20 DAS + IC at 45 DAS (T_7) and butachlor 50 EC @ 1 kg a.i. ha^{-1} as PRE application + HW at 30 DAS + IC at 45 DAS (T_6) which were on par with each other. Pendimethalin 38.7 CS @ 1 kg a.i. ha^{-1} as PRE application + HW at 30 DAS + IC at 45 DAS (T_5) and pendimethalin 30 EC @ 1 kg a.i. ha^{-1} as PRE application + HW at 30 DAS + IC at 45 DAS (T_4) were next in order of leaf area and on par with each other. The lowest leaf area (117.40 cm^2 $plant^{-1}$) was recorded in imazethapyr 10 SL @ 75 g a.i. ha^{-1} as POE application at 20 DAS + IC at 45 DAS followed by unweeded check (183.33 cm^2 $plant^{-1}$).

At 60 DAS, weed free check continued to maintain its superiority recording the highest leaf area (791.13 cm^2 $plant^{-1}$) and was on par with rest of the treatment except imazethayr 10 SL @ 75 g a.i. ha^{-1} as POE application at 20 DAS + IC at 45 DAS and unweeded check (T_1). Significantly lower leaf area (507.60 cm^2 $plant^{-1}$) was recorded in imazethapyr 10 SL @ 75 g. a.i. ha^{-1} as POE application at 20 DAS + IC at 45 DAS (T_8) followed by unweeded check (T_1).

At harvest, significantly higher leaf area (256 cm^2 $plant^{-1}$) was observed in weed free check (T_2) which was on par with rest of the treatments except unweeded check (T_1) and imazethapyr 10 SL @ 75 g a.i. ha^{-1} as POE application at 20 DAS + IC at 45 DAS (T_8) produced significantly lower leaf area (147.53 cm^2 $plant^{-1}$).

Table 13. Leaf area of sesame at different growth stages as influenced by weed control treatments

Tr. No.	Treatment	Leaf area (cm^2 $plant^{-1}$)		
		30 DAS	60 DAS	At harvest
T_1	Unweeded check	183.33	652.07	188.33
T_2	Weed free check (HW at 15 DAS + IC at 30 and 45 DAS)	241.17	791.13	256.00
T_3	Recommended practice (Alachlor 50 EC @ 0.75 kg a.i. ha^{-1}as PRE application + HW at 30 DAS + IC at 45 DAS)	228.43	769.37	245.50
T_4	Pendimethalin 30 EC @ 1 kg a.i. ha^{-1} as PRE application + HW at 30 DAS + IC at 45 DAS	216.53	755.27	237.87
T_5	Pendimethalin 38.7 CS @ 1 kg a.i. ha^{-1} as PRE application + HW at 30 DAS + IC at 45 DAS	217.53	757.63	238.53
T_6	Butachlor 50 EC @ 1 kg a.i. ha^{-1}as PRE application + HW at 30 DAS + IC at 45 DAS	223.93	761.60	241.87
T_7	Quizalofop ethyl 5 EC @ 40 g a.i. ha^{-1} as POE application at 20 DAS + IC at 45 DAS	225.07	763.57	243.20
T_8	Imazethapyr 10 SL @ 75 g a.i. ha^{-1} as POE application at 20 DAS + IC at 45 DAS	117.40	507.60	147.53
	S.Em.±	7.29	16.25	11.69
	C.D. at 5%	22.11	49.28	35.45

EC : Emulsifiable Concentrate CS : Capsular Suspension SL : Soluble Liquid HW: Hand Weeding IC: Intercultivation
DAS : Days After Sowing PRE : Pre-emergence POE : Post-emergence

4.2.2.4 Leaf area index (LAI) (Cf Table 14)

The results indicate that leaf area index differed significantly due to weed control treatments at all the stages of crop growth.

At 30 DAS, significantly lower leaf area index (0.26) was recorded in imazethapyr 10 SL @ 75 g a.i. ha^{-1} as POE application at 20 DAS + IC at 45 DAS (T_8) followed by unweeded check (T_1). Significantly higher leaf area index (0.53) was recorded in weed free check and was on par with rest of the treatment except unweeded check (T_1) and imazethapyr 10 SL @ 75 g a.i. ha^{-1} as POE application at 20 DAS + IC at 45 DAS (T_8).

At 60 DAS and at harvest, significantly superior leaf area index (1.75 and 0.56, respectively) were observed in weed free check (T_2) and was on par with rest of the treatments except unweeded check (T_1) and imazethapyr 10 SL @ 75 g a.i. ha^{-1} as POE application at 20 DAS + IC at 45 DAS (T_8) which recorded significantly lower leaf area index (1.12 and 0.33) at 60 DAS and at harvest, respectively.

4.2.2.5 Dry matter accumulation in leaves (Cf Table 15)

The dry matter accumulation in leaves of sesame differed significantly due to weed control treatment at all the stages of crop growth.

At 30 DAS, significantly higher dry matter accumulation in leaves (2.26 g $plant^{-1}$) was noticed in weed free check (HW at 15 DAS + IC at 30 and 45 DAS). Next best treatments were recommended practice (T_3), quizalofop ethyl 5 EC @ 40 g a.i. ha^{-1} as POE application + IC at 45 DAS (T_7) and butachlor 50 EC @ 1 kg a.i. ha^{-1} as PRE application + HW at 30 DAS + IC at 45 DAS (T_6) which were on par with each other. The treatments *viz.*, pendimethalin 38.7 CS @ 1 kg a.i. ha^{-1} as PRE application + HW at 30 DAS + IC at 45 DAS (T_5) and pendimethalin 30 EC @ 1 kg a.i. ha^{-1} as PRE application + HW at 30 DAS + IC at 45 DAS (T_4) were in descending order of dry matter accumulation in leaves and on par with each other. The lowest dry matter accumulation in leaves (0.46 g $plant^{-1}$) was with imazethapyr 10 SL @ 75 g a.i. ha^{-1} as POE application at 20 DAS + IC at 45 DAS (T_8) followed by unweeded check (T_1).

At 60 DAS, significantly higher dry matter accumulation in leaves (7.92 g $plant^{-1}$) was recorded in weed free check (HW at 15 DAS + IC at 30 and 45 DAS). Next best treatments were recommended practice (T_3) and quizalofop ethyl 5 EC @ 40 g a.i. ha^{-1} as

Table 14. Leaf area index of sesame at different growth stages as influenced by weed control treatments

Tr. No.	Treatment	Leaf area index		
		30 DAS	60 DAS	At harvest
T_1	Unweeded check	0.40	1.43	0.41
T_2	Weed free check (HW at 15 DAS + IC at 30 and 45 DAS)	0.53	1.75	0.56
T_3	Recommended practice (Alachlor 50 EC @ 0.75 kg a.i. ha^{-1}as PRE application + HW at 30 DAS + IC at 45 DAS)	0.50	1.70	0.54
T_4	Pendimethalin 30 EC @ 1 kg a.i. ha^{-1} as PRE application + HW at 30 DAS + IC at 45 DAS	0.48	1.67	0.53
T_5	Pendimethalin 38.7 CS @ 1 kg a.i. ha^{-1} as PRE application + HW at 30 DAS + IC at 45 DAS	0.48	1.68	0.53
T_6	Butachlor 50 EC @ 1 kg a.i. ha^{-1}as PRE application + HW at 30 DAS + IC at 45 DAS	0.50	1.69	0.53
T_7	Quizalofop ethyl 5 EC @ 40 g a.i. ha^{-1} as POE application at 20 DAS + IC at 45 DAS	0.50	1.69	0.53
T_8	Imazethapyr 10 SL @ 75 g a.i. ha^{-1} as POE application at 20 DAS + IC at 45 DAS	0.26	1.12	0.33
	S.Em.±	0.02	0.05	0.03
	C.D. at 5%	0.05	0.17	0.08

EC : Emulsifiable Concentrate CS : Capsular Suspension SL : Soluble Liquid HW: Hand Weeding IC: Intercultivation
DAS : Days After Sowing PRE : Pre-emergence POE : Post-emergence

Table 15. Dry matter accumulation in leaves of sesame as influenced by weed control treatments

Tr. No.	Treatment	Dry matter accumulation in leaves (g plant^{-1})		
		30 DAS	60 DAS	At harvest
T_1	Unweeded check	0.70	3.17	1.47
T_2	Weed free check (HW at 15 DAS + IC at 30 and 45 DAS)	2.26	7.92	4.74
T_3	Recommended practice (Alachlor 50 EC @ 0.75 kg a.i. ha^{-1}as PRE application + HW at 30 DAS + IC at 45 DAS)	1.69	6.10	3.71
T_4	Pendimethalin 30 EC @ 1 kg a.i. ha^{-1} as PRE application + HW at 30 DAS + IC at 45 DAS	1.21	5.15	2.91
T_5	Pendimethalin 38.7 CS @ 1 kg a.i. ha^{-1} as PRE application + HW at 30 DAS + IC at 45 DAS	1.27	5.18	2.97
T_6	Butachlor 50 EC @ 1 kg a.i. ha^{-1}as PRE application + HW at 30 DAS + IC at 45 DAS	1.41	5.43	3.20
T_7	Quizalofop ethyl 5 EC @ 40 g a.i. ha^{-1} as POE application at 20 DAS + IC at 45 DAS	1.50	5.63	3.23
T_8	Imazethapyr 10 SL @ 75 g a.i. ha^{-1} as POE application at 20 DAS + IC at 45 DAS	0.46	1.87	0.83
	S.Em.±	0.11	0.20	0.12
	C.D. at 5%	0.34	0.61	0.36

EC : Emulsifiable Concentrate CS : Capsular Suspension SL : Soluble Liquid HW: Hand Weeding IC: Intercultivation
DAS : Days After Sowing PRE : Pre-emergence POE : Post-emergence

POE application + IC at 45 DAS (T_7) which were on par with each other. The treatments *viz.,* butachlor 50 EC @ 1 kg a.i. ha^{-1} as PRE application + HW at 30 DAS + IC at 45 DAS (T_6), pendimethalin 38.7 CS @ 1 kg a.i. ha^{-1} as PRE application + HW at 30 DAS + IC at 45 DAS (T_5), pendimethalin 30 EC @ 1 kg a.i. ha^{-1} as PRE application + HW at 30 DAS + IC at 45 DAS (T_4) were in descending order of dry matter accumulation in leaves and on par with each other. The lowest dry matter accumulation in leaves (1.87 g $plant^{-1}$) was recorded in imazethapyr 10 SL @ 70 g a.i. ha^{-1} as POE application @ 20 DAS + IC at 45 DAS (T_8) followed by unweeded check (T_1).

At harvest, imazethapyr 10 SL @ 70 g a.i. ha^{-1} as POE application at 20 DAS + IC at 45 DAS (T_8) resulted in significantly lower (0.83 g $plant^{-1}$) dry matter accumulation in leaves followed by unweeded check (1.47 g $plant^{-1}$). Significantly higher dry matter accumulation in leaves (4.74 g $plant^{-1}$) was observed in weed free check (T_2). The next best treatments were recommended practice (T_3) and quizalofop ethyl 5 EC @ 40 g a.i. ha^{-1} as POE application at 20 DAS + IC at 45 DAS which were on par with each other. The treatments viz., butachlor 50 EC @ 1 kg a.i. ha^{-1} as PRE application + HW at 30 DAS + IC at 45 DAS (T_6), pendimethalin 38.7 CS @ 1 kg a.i. ha^{-1} as PRE application + HW at 30 DAS + IC at 45 DAS (T_5), pendimethalin 30 EC @ 1 kg a.i. ha^{-1} as PRE application + HW at 30 DAS + IC at 45 DAS (T_4) were in descending order of dry matter accumulation in leaves and on par with each other.

4.2.2.6 Dry matter accumulation in stem (Cf Table 16)

The dry matter accumulation in stem of sesame differed significantly due to weed control treatments at all stages of crop growth.

At 30 and 60 DAS, weed free check (T_2) recorded significantly higher dry matter accumulation in stem (0.65 and 8.46 g $plant^{-1}$, respectively). Treatments *viz*., recommended practice (T_3), quizalofop ethyl 5 EC @ 40 g a.i. ha^{-1} as POE application at 20 DAS + IC at 45 DAS (T_7), butachlor 50 EC @ 1 kg a.i. ha^{-1} as PRE application + HW at 30 DAS + IC at 45 DAS (T_6), pendimethalin 38.7 CS @ 1 kg a.i. ha^{-1} as PRE application + HW at 30 DAS + IC at 45 DAS (T_5) and pendimethalin 30 EC @ 1 kg a.i. ha^{-1} as PRE application + HW at 30 DAS + IC at 45 DAS (T_4) were in next order and on par with each other. Significantly lower dry matter accumulation in stem (0.07 and 2.93 g $plant^{-1}$) was noticed in imazethapyr 10 SL @ 75 g a.i. ha^{-1} as POE application at 20 DAS + IC at 45 DAS (T_8) followed by unweeded check (T_1) at 30 and 60 DAS.

Table 16. Dry matter accumulation in stem of sesame as influenced by weed control treatments

Tr. No.	Treatment	Dry matter accumulation in stem (g plant^{-1})		
		30 DAS	60 DAS	At harvest
T_1	Unweeded check	0.24	4.87	8.33
T_2	Weed free check (HW at 15 DAS + IC at 30 and 45 DAS)	0.65	8.46	12.73
T_3	Recommended practice (Alachlor 50 EC @ 0.75 kg a.i. ha^{-1}as PRE application + HW at 30 DAS + IC at 45 DAS)	0.38	8.17	12.48
T_4	Pendimethalin 30 EC @ 1 kg a.i. ha^{-1} as PRE application + HW at 30 DAS + IC at 45 DAS	0.27	7.77	11.71
T_5	Pendimethalin 38.7 CS @ 1 kg a.i. ha^{-1} as PRE application + HW at 30 DAS + IC at 45 DAS	0.30	7.86	12.00
T_6	Butachlor 50 EC @ 1 kg a.i. ha^{-1}as PRE application + HW at 30 DAS + IC at 45 DAS	0.32	7.96	12.31
T_7	Quizalofop ethyl 5 EC @ 40 g a.i. ha^{-1} as POE application at 20 DAS + IC at 45 DAS	0.34	8.07	12.40
T_8	Imazethapyr 10 SL @ 75 g a.i. ha^{-1} as POE application at 20 DAS + IC at 45 DAS	0.07	2.93	5.47
	S.Em.±	0.06	0.20	0.22
	C.D. at 5%	0.19	0.62	0.68

EC : Emulsifiable Concentrate CS : Capsular Suspension SL : Soluble Liquid HW: Hand Weeding IC: Intercultivation
DAS : Days After Sowing PRE : Pre-emergence POE : Post-emergence

At harvest, weed free check resulted is significantly higher dry matter accumulation is stem (12.73 g plant $^{-1}$) followed by recommended practice (alachlor 50 EC @ 0.75 kg a.i. ha^{-1} as PRE application + HW at 30 DAS + IC at 45 DAS), quizalofop ethyl 5 EC @ 40 g a.i. ha^{-1} as POE application at 20 DAS + IC at 45 DAS (T_7), butachlor 50 EC @ 1 kg a.i. ha^{-1} as PRE application + HW at 30 DAS + IC at 45 DAS (T_6) and pendimethalin 38.7 CS @ 1 kg a. i. ha^{-1} as PRE application + HW at 30 DAS + IC at 45 DAS (T_5) which were on par with each other. The lowest dry matter accumulation in stem (5.47 g plant^{-1}) was recorded in imazethapyr 10 SL @ 75 g a.i. ha^{-1} as POE application at 20 DAS + IC at 45 DAS followed by unweeded check.

4.2.2.7 Dry matter accumulation in reproductive parts (Cf Table 17)

The dry matter accumulation in the reproductive parts of sesame differed significantly due to weed control treatments at all the growth stages of crop.

At 60 DAS, significantly higher dry matter accumulation in reproductive parts (8.10 g plant^{-1}) was recorded is weed free check (T_2). The next best treatments were recommended practice (T_3) and quizalofop ethyl 5 EC @ 40 g a.i. ha^{-1} as POE application at 20 DAS + IC at 45 DAS (T_7) which were on par with each other. The treatments viz., butachlor 50 EC @ 1 kg a.i. ha^{-1} as PRE application + HW at 30 DAS + IC at 45 DAS (T_6), pendimethalin 38.7 CS @ 1 kg a. i. ha^{-1} as PRE application + HW at 30 DAS + IC at 45 DAS (T_5) and pendimethalin 30 EC @ 1 kg a.i. ha^{-1} as PRE application + HW at 30 DAS + IC at 45 DAS (T_4) were in descending order of dry matter accumulation in reproductive parts and on par with each other. Significantly lower dry matter accumulation in reproductive parts (2.20 g plant^{-1}) was produced by imazethapyr 10 SL @ 75 g a.i. as POE application at 20 DAS + IC at 45 DAS (T_8) followed by unweeded check (T_1).

At harvest, the lowest dry matter accumulation in reproductive parts (3.32 g plant $^{-1}$) was noticed in imazethapyr 10 SL @ 75 g a.i. as POE application at 20 DAS + IC at 45 DAS (T_8) followed by unweeded check (T_1). Significantly higher dry matter accumulation in reproductive parts (12.48 g plant^{-1}) was recorded in weed free check (T_2). The treatments viz., recommended practice (T_3) and quizalofop ethyl 5 EC @ 40 g a.i. ha^{-1} as POE application at 20 DAS + IC at 45 DAS (T_7) were on par with each other. Butachlor 50 EC @ 1 kg a.i. ha^{-1} as PRE application + HW at 30 DAS + IC at 45 DAS (T_6) and pendimethalin 38.7 CS @ 1 kg a.i. ha^{-1} as PRE application + HW at 30 DAS +

Table 17. Dry matter accumulation in reproductive parts of sesame as influenced by weed control treatments

Tr. No.	Treatment	Dry matter accumulation in reproductive parts (g plant^{-1})	
		60 DAS	At harvest
T_1	Unweeded check	4.33	6.44
T_2	Weed free check (HW at 15 DAS + IC at 30 and 45 DAS)	8.10	12.48
T_3	Recommended practice (Alachlor 50 EC @ 0.75 kg a.i. ha^{-1}as PRE application + HW at 30 DAS + IC at 45 DAS)	7.03	10.61
T_4	Pendimethalin 30 EC @ 1 kg a.i. ha^{-1} as PRE application + HW at 30 DAS + IC at 45 DAS	5.70	8.25
T_5	Pendimethalin 38.7 CS @ 1 kg a.i. ha^{-1} as PRE application + HW at 30 DAS + IC at 45 DAS	5.97	8.72
T_6	Butachlor 50 EC @ 1 kg a.i. ha^{-1}as PRE application + HW at 30 DAS + IC at 45 DAS	6.37	9.61
T_7	Quizalofop ethyl 5 EC @ 40 g a.i. ha^{-1} as POE application at 20 DAS + IC at 45 DAS	6.40	9.82
T_8	Imazethapyr 10 SL @ 75 g a.i. ha^{-1} as POE application at 20 DAS + IC at 45 DAS	2.20	3.32
	S.Em.±	0.25	0.28
	C.D. at 5%	0.75	0.85

EC : Emulsifiable Concentrate CS : Capsular Suspension SL : Soluble Liquid HW: Hand Weeding IC: Intercultivation
DAS : Days After Sowing PRE : Pre-emergence POE : Post-emergence

IC at 45 DAS (T_5) were next in order and on par with each other and significantly superior over unweeded control (T_1).

4.2.2.8 Dry matter production (Cf Table 18)

Weed control treatments differed significantly with respect to dry matter production per plant at all the growth stages.

At 30 DAS, significantly higher dry matter production (2.91 g plant^{-1}) was recorded in weed free check (T_2) when compared to other treatments. The next best treatments were recommended practice (alachlor 50 EC @ 0.75 kg a.i. ha^{-1} as PRE application + HW at 30 DAS + IC at 45 DAS), quizalofop ethyl 5 EC @ 40 g a.i. ha^{-1} as POE application at 20 DAS + IC at 45 DAS (T_7) and butachlor 50 EC @ 1 kg a.i. ha^{-1} as PRE application + HW at 30 DAS + IC at 45 DAS (T_6) were on par with each other. The lowest dry matter production (0.53 g plant^{-1}) was produced in imazethapyr 10 SL @ 75 g a.i. ha^{-1} as POE application at 20 DAS + IC at 45 DAS (T_8) followed by unweeded check (0.94 g plant^{-1}).

At 60 DAS and at harvest, imazethapyr 10 SL @ 75 g a.i. ha^{-1} as POE application at 20 DAS + IC at 45 DAS (T_8) recorded the lowest (7.00 and 9.62 g plant^{-1}, respectively) dry matter production followed by unweeded check (T_1). The highest dry matter production (24.47 and 29.95 g plant^{-1}) was noticed in weed free check (T_2) and was followed by recommended practice (alachlor 50 EC @ 0.75 kg a.i. ha^{-1} as PRE application + HW at 30 DAS + IC at 45 DAS).

4.2.2.9 Chlorophyll content (Cf Table 19)

Chlorophyll content decreased with advancement in age of sesame and differed significantly due to weed control treatments.

At 30 DAS, significantly higher chlorophyll content (45.69) was noticed in weed free check (T_2) and was followed by recommended practice (T_3) and quizalofop ethyl 5 EC @ 40 g a.i. ha^{-1} as POE application at 20 DAS + IC at 45 DAS (T_7) which were on par with each other. The lowest chlorophyll content (24.83) was recorded in imazethypyr 10 SL @ 75 g a.i. ha^{-1} as POE application at 20 DAS + IC at 45 DAS (T_8) and was followed by unweeded check (T_1).

At 60 DAS, the lowest chlorophyll content (14.33) was observed in imazethapyr 10 SL @ 75 g a.i. ha^{-1} as POE application at 20 DAS + IC at 45 DAS (T_8) and was

Table 18. Dry matter production of sesame at different growth stages as influenced by weed control treatments

Tr. No.	Treatment	Dry matter production(g plant^{-1})		
		30 DAS	60 DAS	At harvest
T_1	Unweeded check	0.94	12.37	16.24
T_2	Weed free check (HW at 15 DAS + IC at 30 and 45 DAS)	2.91	24.47	29.95
T_3	Recommended practice (Alachlor 50 EC @ 0.75 kg a.i. ha^{-1}as PRE application + HW at 30 DAS + IC at 45 DAS)	2.07	21.30	26.80
T_4	Pendimethalin 30 EC @ 1 kg a.i. ha^{-1} as PRE application + HW at 30 DAS + IC at 45 DAS	1.48	18.62	22.87
T_5	Pendimethalin 38.7 CS @ 1 kg a.i. ha^{-1} as PRE application + HW at 30 DAS + IC at 45 DAS	1.57	19.01	23.68
T_6	Butachlor 50 EC @ 1 kg a.i. ha^{-1}as PRE application + HW at 30 DAS + IC at 45 DAS	1.73	19.76	25.13
T_7	Quizalofop ethyl 5 EC @ 40 g a.i. ha^{-1} as POE application at 20 DAS + IC at 45 DAS	1.84	20.10	25.45
T_8	Imazethapyr 10 SL @ 75 g a.i. ha^{-1} as POE application at 20 DAS + IC at 45 DAS	0.53	7.00	9.62
	S.Em.±	0.16	0.4	0.46
	C.D. at 5%	0.48	1.20	1.41

EC : Emulsifiable Concentrate CS : Capsular Suspension SL : Soluble Liquid HW: Hand Weeding IC: Intercultivation
DAS : Days After Sowing PRE : Pre-emergence POE : Post-emergence

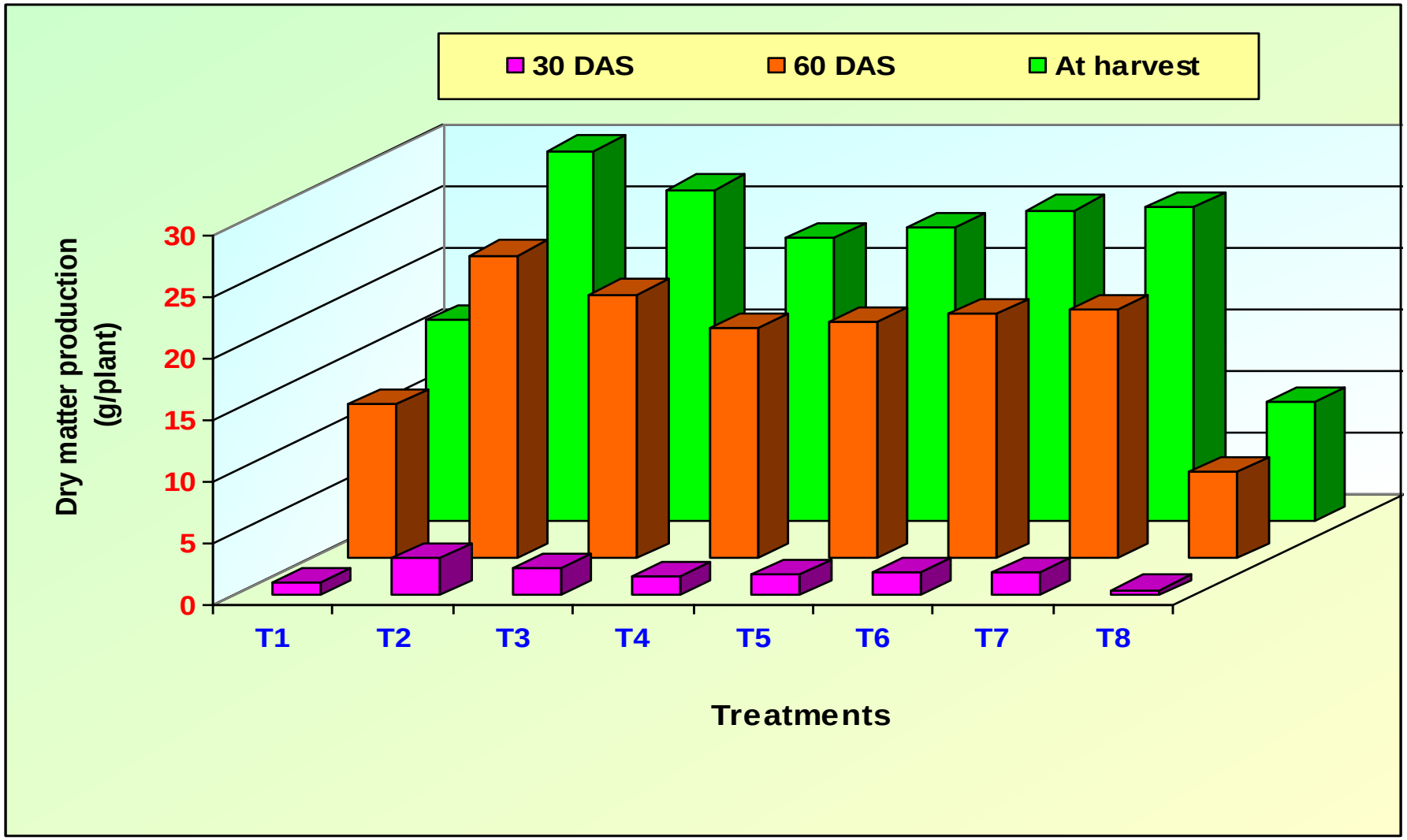

Fig. 6. Dry matter production (g/plant) of sesame at different growth stages as influenced by weed control treatments

Table 19. Chlorophyll content of sesame at 30 and 60 DAS as influenced by weed control treatments

Tr. No.	Treatment	Chlorophyll content (SPAD meter values)	
		30 DAS	60 DAS
T_1	Unweeded check	32.20	16.37
T_2	Weed free check (HW at 15 DAS + IC at 30 and 45 DAS)	45.69	27.83
T_3	Recommended practice (Alachlor 50 EC @ 0.75 kg a.i. ha^{-1}as PRE application + HW at 30 DAS + IC at 45 DAS)	44.10	25.95
T_4	Pendimethalin 30 EC @ 1 kg a.i. ha^{-1} as PRE application + HW at 30 DAS + IC at 45 DAS	37.85	19.77
T_5	Pendimethalin 38.7 CS @ 1 kg a.i. ha^{-1} as PRE application + HW at 30 DAS + IC at 45 DAS	39.40	20.67
T_6	Butachlor 50 EC @ 1 kg a.i. ha^{-1}as PRE application + HW at 30 DAS + IC at 45 DAS	40.33	21.52
T_7	Quizalofop ethyl 5 EC @ 40 g a.i. ha^{-1} as POE application at 20 DAS + IC at 45 DAS	41.96	23.84
T_8	Imazethapyr 10 SL @ 75 g a.i. ha^{-1} as POE application at 20 DAS + IC at 45 DAS	24.83	14.33
	S.Em.±	1.50	0.68
	C.D. at 5%	4.56	2.07

EC : Emulsifiable Concentrate CS : Capsular Suspension SL : Soluble Liquid HW: Hand Weeding IC: Intercultivation
DAS : Days After Sowing PRE : Pre-emergence POE : Post-emergence

followed by unweeded check (T_1). The highest chlorophyll content (27.83) was recorded in weed free check (T_2) and was followed by recommended practice (25.95) which were on par with each other.

4.3 Yield parameters of sesame

4.3.1 Number of capsules per plant (Cf Table 20)

The number of capsules plant^{-1} differed significantly due to weed control treatments. Significantly higher (31.67) number of capsules plant^{-1} were obtained in weed free check (T_2). The treatments *viz*., recommended practice (T_3) and quizalofop ethyl 5 EC @ 40 g a.i. ha^{-1} as POE application at 20 DAS + IC at 45 DAS (T_7) were in descending order with respect to number of capsules plant^{-1} and on par with each other. The next best treatments were butachlor 50 EC @ 1 kg a.i. ha^{-1} as PRE application + HW at 30 DAS + IC at 45 DAS (T_6) and pendimethalin 38.7 CS @ 1 kg a.i. ha^{-1} as PRE application + HW at 30 DAS + IC at 45 DAS (T_5) which were significantly different from each other. Significantly lower number of capsules plant^{-1} (13.73) were observed in imazethapyr 10 SL @ 75 g a.i. ha^{-1} as POE application at 20 DAS + IC at 45 DAS followed by unweeded check (T_1).

4.3.2 Number of seeds per capsule (Cf Table 20)

The variation in number of seeds capsule^{-1} due to weed control treatment was significant. The highest number of seeds capsule^{-1} (38.33) were noticed in weed free check (T_2). The next best treatments were recommended practice (T_3) and quizalofop ethyl 5 EC @ 40 g a.i. ha^{-1} as POE application at 20 DAS + IC at 45 DAS (T_7) which were on par with each other. The treatments receiving butachlor 50 EC @ 1 kg a.i. ha^{-1} as PRE application + HW at 30 DAS + IC at 45 DAS (T_6), pendimethalin 38.7 CS @ 1 kg a.i. ha^{-1} as PRE application + HW at 30 DAS + IC at 45 DAS (T_5) and pendimethalin 30 EC @ 1 kg a.i. ha^{-1} as PRE application + HW at 30 DAS + IC at 45 DAS (T_4) were in descending order with respect to number of seeds capsule^{-1} and on par with each other. On the other hand, significantly lower (19.00) number of seeds capsule^{-1} were recorded in imazethapyr 10 SL @ 75 g a.i. ha^{-1} as POE application at 20 DAS + IC at 45 DAS (T_8) followed by unweeded check (T_1).

4.3.3 Seed weight per capsule (Cf Table 20)

The influence of weed control treatments on seed weight capsule^{-1} was significant. Significantly higher seed weight capsule^{-1} (0.17 g) was recorded in weed free check (T_2)

Table 20. Number of capsules plant^{-1}, number of seeds capsule^{-1}, seed weight capsule^{-1} and 1000-seed weight in sesame as influenced by weed control treatments

Tr. No.	Treatment	Number of capsules per plant	Number of seeds per capsule	Seed weight per capsule (g)	Thousand seed weight (g)
T_1	Unweeded check	18.00	23.00	0.11	2.17
T_2	Weed free check (HW at 15 DAS + IC at 30 and 45 DAS)	31.67	38.33	0.17	2.38
T_3	Recommended practice (Alachlor 50 EC @ 0.75 kg a.i. ha^{-1}as PRE application + HW at 30 DAS + IC at 45 DAS)	29.00	34.33	0.14	2.33
T_4	Pendimethalin 30 EC @ 1 kg a.i. ha^{-1} as PRE application + HW at 30 DAS + IC at 45 DAS	21.67	26.67	0.12	2.25
T_5	Pendimethalin 38.7 CS @ 1 kg a.i. ha^{-1} as PRE application + HW at 30 DAS + IC at 45 DAS	22.67	27.33	0.12	2.26
T_6	Butachlor 50 EC @ 1 kg a.i. ha^{-1}as PRE application + HW at 30 DAS + IC at 45 DAS	25.67	29.00	0.13	2.27
T_7	Quizalofop ethyl 5 EC @ 40 g a.i. ha^{-1} as POE application at 20 DAS + IC at 45 DAS	27.00	31.33	0.13	2.30
T_8	Imazethapyr 10 SL @ 75 g a.i. ha^{-1} as POE application at 20 DAS + IC at 45 DAS	13.73	19.00	0.10	1.93
	S.Em.±	0.88	1.20	0.01	NS
	C.D. at 5%	2.68	3.64	0.02	NS

EC : Emulsifiable Concentrate CS : Capsular Suspension SL : Soluble Liquid HW: Hand Weeding IC: Intercultivation
DAS : Days After Sowing PRE : Pre-emergence POE : Post-emergence

when compared to other treatments. The treatments *viz.,* recommended practice (T_3) quizolofop ethyl 5 EC @ 40 g a.i. ha^{-1} as POE application at 20 DAS + IC at 45 DAS (T_7), butachlor 50 EC @ 1 kg a.i. ha^{-1} as PRE application + HW at 30 DAS + IC at 45 DAS (T_6), pendimethalin 38.7 CS @ 1 kg a.i. ha^{-1} as PRE application + HW at 30 DAS + IC at 45 DAS (T_5) and pendimethalin 30 EC @ 1 kg a.i. ha^{-1} as PRE application + HW at 30 DAS + IC at 45 DAS (T_4) were on par with each other. The lowest seed weight $capsule^{-1}$(0.10 g) were observed in imazethapyr 10 SL @ 75 g a.i. ha^{-1} as POE application at 20 DAS + IC at 45 DAS (T_8) and was followed by unweeded check (T_1).

4.3.4 Thousand seed weight (Cf Table 20)

No significant differences were observed in test weight due to weed control treatments.

4.3.5 Seed yield per hectare (Cf Table 21)

The significant effect of weed control treatments were reflected on seed yield of sesame. Significantly higher seed yield $hectare^{-1}$ (588 kg ha^{-1}) was recorded in weed free check (T_2). The next best treatments were recommended practice (T_3) and quizalofop ethyl 5 EC @ 40 g a.i. ha^{-1} as POE application at 20 DAS + IC at 45 DAS (T_7) which were on par with each other. Whereas significantly lower seed yield (86 kg ha^{-1}) was noticed in imazethapyr 10 SL @ 75 g a.i. ha^{-1} as POE application at 20 DAS + IC at 45 DAS (T_8) and was followed by unweeded check (T_1).

4.3.6 Stalk yield per hectare (Cf Table 21)

The stalk yield differed significantly among the treatments due to weed control treatments. The highest (2520 kg ha^{-1}) stalk yield was recorded in weed free check (T_2). The next best treatments were recommended practice (T_3) and quizalofop ethyl 5 EC @ 40 g a.i. ha^{-1} as POE application at 20 DAS + IC at 45 DAS which were on par with each other. The lowest stalk yield $hectare^{-1}$ (713 kg ha^{-1}) was recorded in imazethapyr 10 SL @ 75 g a.i. ha^{-1} as POE application at 20 DAS + IC at 45 DAS (T_8) and was followed by unweeded check (T_1).

4.3.7 Harvest index (Cf Table 21)

Weed control treatments influenced the harvest index significantly. Significantly higher harvest index (0.19) was recorded in weed free check (T_2). The treatments *viz.,* recommended practice (T_3), quizalofop ethyl 5 EC @ 40 g a.i. as POE application 20

Table 21. Seed yield, stalk yield and harvest index of sesame as influenced by weed control treatments

Tr. No.	Treatment	Seed yield (kg ha^{-1})	Stalk yield (kg ha^{-1})	Harvest index
T_1	Unweeded check	180	1267	0.12
T_2	Weed free check (HW at 15 DAS + IC at 30 and 45 DAS)	588	2520	0.19
T_3	Recommended practice (Alachlor 50 EC @ 0.75 kg a.i. ha^{-1}as PRE application + HW at 30 DAS + IC at 45 DAS)	480	2356	0.16
T_4	Pendimethalin 30 EC @ 1 kg a.i. ha^{-1} as PRE application + HW at 30 DAS + IC at 45 DAS	273	1683	0.14
T_5	Pendimethalin 38.7 CS @ 1 kg a.i. ha^{-1} as PRE application + HW at 30 DAS + IC at 45 DAS	283	1750	0.14
T_6	Butachlor 50 EC @ 1 kg a.i. ha^{-1}as PRE application + HW at 30 DAS + IC at 45 DAS	367	2100	0.15
T_7	Quizalofop ethyl 5 EC @ 40 g a.i. ha^{-1} as POE application at 20 DAS + IC at 45 DAS	410	2239	0.15
T_8	Imazethapyr 10 SL @ 75 g a.i. ha^{-1} as POE application at 20 DAS + IC at 45 DAS	86	713	0.10
	S.Em.±	25	48	0.01
	C.D. at 5%	75	145	0.02

EC : Emulsifiable Concentrate CS : Capsular Suspension SL : Soluble Liquid HW: Hand Weeding IC: Intercultivation
DAS : Days After Sowing PRE : Pre-emergence POE : Post-emergence

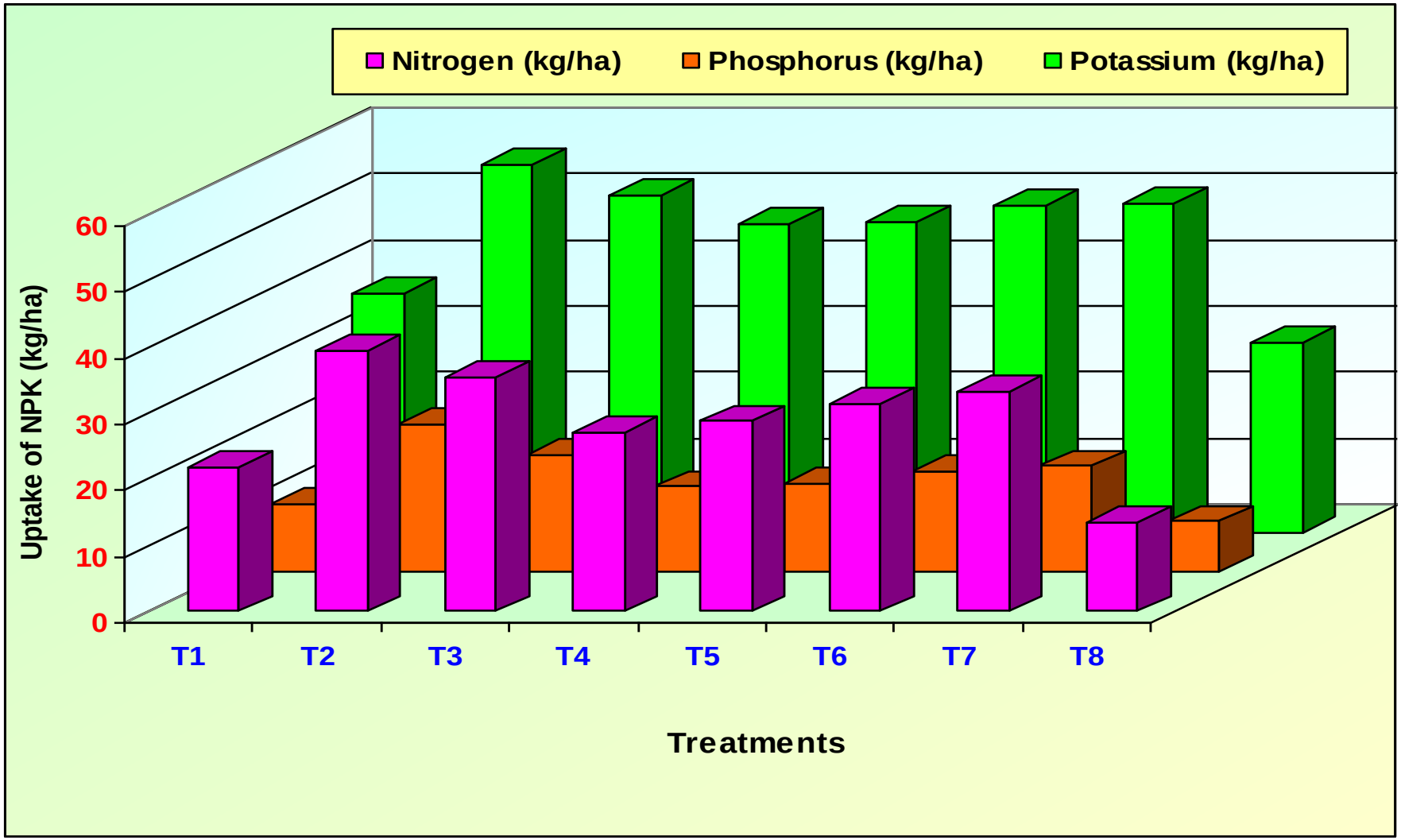

Fig. 8. Uptake of nitrogen, phosphorus and potassium by crop in sesame as influenced by weed control treatments

DAS + IC at 45 DAS (T_7), butachlor 50 EC @ 1 kg a.i. ha^{-1} as PRE application + HW at 30 DAS + IC at 45 DAS (T_6), pendimethalin 38.7 CS @ 1 kg a.i. ha^{-1} as PRE application + HW at 30 DAS + IC at 45 DAS (T_5), and pendimethalin 30 EC @ 1 kg a.i. ha^{-1} as PRE application + HW at 30 DAS + IC at 45 DAS (T_4) were in descending order and on par with each other. On the other hand, the lowest harvest index (0.10) was recorded in imazethapyr 10 SL @ 75 g a.i. ha^{-1} as POE application at 20 DAS + IC at 45 DAS and was followed by unweeded check (T_1).

4.4 Quality parameters of sesame

4.4.1 Oil content (Cf Table 22)

Oil content did not differ significantly due to weed control practices.

4.4.2 Oil yield (Cf Table 22)

The influence of weed control treatments on oil yield was significant. The highest oil yield (282.67 kg ha^{-1}) was noticed in weed free check (T_2). The next best treatments were recommended practice (T_3) and quizalofop ethyl 5 EC @ 40 g a.i. ha^{-1} as POE application at 20 DAS + IC at 45 DAS (T_7) which were on par with each other. On the other hand, the lowest oil yield (40.95 kg a.i. ha^{-1}) was recorded in imazethapyr 10 SL @ 75 g a.i. ha^{-1} as POE application at 20 DAS +IC at 45 DAS (T_8) and was followed by unweeded check (T_1).

4.5 Uptake of nutrients

4.5.1 Uptake of N, P and K by sesame (Cf Table 23)

Uptake of nitrogen by sesame differed significantly due to weed control treatments. The highest nitrogen uptake (39.33 kg ha^{-1}) was noticed in weed free check (T_2). The next best treatments were recommended practice (T_3) and quizalofop ethyl 5 EC @ 40 g a.i. ha^{-1} as POE application at 20 DAS + IC at 45 DAS (T_7) which were on par with each other. The lowest nitrogen uptake (13.33 kg ha^{-1}) was recorded in imazethapyr 10 SL @ 75 g a.i. ha^{-1} as POE application at 20 DAS + IC at 45 DAS (T_8) and was followed by unweeded check (T_1).

Weed control treatments had significant influence on phosphorus uptake. Significantly lower phosphorus uptake (7.67 kg ha^{-1}) was observed in imazethapyr 10 SL @ 75 g a.i. ha^{-1} as POE application at 20 DAS + IC at 45 DAS (T_8) and was followed by

Table 22. Oil content and oil yield of sesame as influenced by weed control treatments

Tr. No.	Treatment	Oil content (%)	Oil yield (kg ha^{-1})
T_1	Unweeded check	47.47	85.27
T_2	Weed free check (HW at 15 DAS + IC at 30 and 45 DAS)	48.07	282.67
T_3	Recommended practice (Alachlor 50 EC @ 0.75 kg a.i. ha^{-1}as PRE application + HW at 30 DAS + IC at 45 DAS)	47.97	230.28
T_4	Pendimethalin 30 EC @ 1 kg a.i. ha^{-1} as PRE application + HW at 30 DAS + IC at 45 DAS	47.27	129.17
T_5	Pendimethalin 38.7 CS @ 1 kg a.i. ha^{-1} as PRE application + HW at 30 DAS + IC at 45 DAS	47.50	134.50
T_6	Butachlor 50 EC @ 1 kg a.i. ha^{-1}as PRE application + HW at 30 DAS + IC at 45 DAS	47.63	174.72
T_7	Quizalofop ethyl 5 EC @ 40 g a.i. ha^{-1} as POE application at 20 DAS + IC at 45 DAS	47.93	196.66
T_8	Imazethapyr 10 SL @ 75 g a.i. ha^{-1} as POE application at 20 DAS + IC at 45 DAS	47.40	40.95
	S.Em.±	NS	12.08
	C.D. at 5%	NS	36.64

EC : Emulsifiable Concentrate CS : Capsular Suspension SL : Soluble Liquid HW: Hand Weeding IC: Intercultivation
DAS : Days After Sowing PRE : Pre-emergence POE : Post-emergence NS : Non significant

Table 23. Uptake of nitrogen, phosphorus and potassium by sesame as influenced by weed control treatments

Tr. No.	Treatment	Nitrogen (kg ha^{-1})	Phosphorus (kg ha^{-1})	Potassium (kg ha^{-1})
T_1	Unweeded check	21.67	10.33	36.00
T_2	Weed free check (HW at 15 DAS + IC at 30 and 45 DAS)	39.33	22.33	55.40
T_3	Recommended practice (Alachlor 50 EC @ 0.75 kg a.i. ha^{-1}as PRE application + HW at 30 DAS + IC at 45 DAS)	35.33	17.70	50.87
T_4	Pendimethalin 30 EC @ 1 kg a.i. ha^{-1} as PRE application + HW at 30 DAS + IC at 45 DAS	27.00	12.87	46.55
T_5	Pendimethalin 38.7 CS @ 1 kg a.i. ha^{-1} as PRE application + HW at 30 DAS + IC at 45 DAS	28.66	13.37	46.87
T_6	Butachlor 50 EC @ 1 kg a.i. ha^{-1}as PRE application + HW at 30 DAS + IC at 45 DAS	31.30	15.17	49.33
T_7	Quizalofop ethyl 5 EC @ 40 g a.i. ha^{-1} as POE application at 20 DAS + IC at 45 DAS	33.26	16.00	49.73
T_8	Imazethapyr 10 SL @ 75 g a.i. ha^{-1} as POE application at 20 DAS + IC at 45 DAS	13.33	7.67	28.67
	S.Em.±	0.83	0.51	0.73
	C.D. at 5%	2.51	1.55	2.21

EC : Emulsifiable Concentrate CS : Capsular Suspension SL : Soluble Liquid HW: Hand Weeding IC: Intercultivation
DAS : Days After Sowing PRE : Pre-emergence POE : Post-emergence

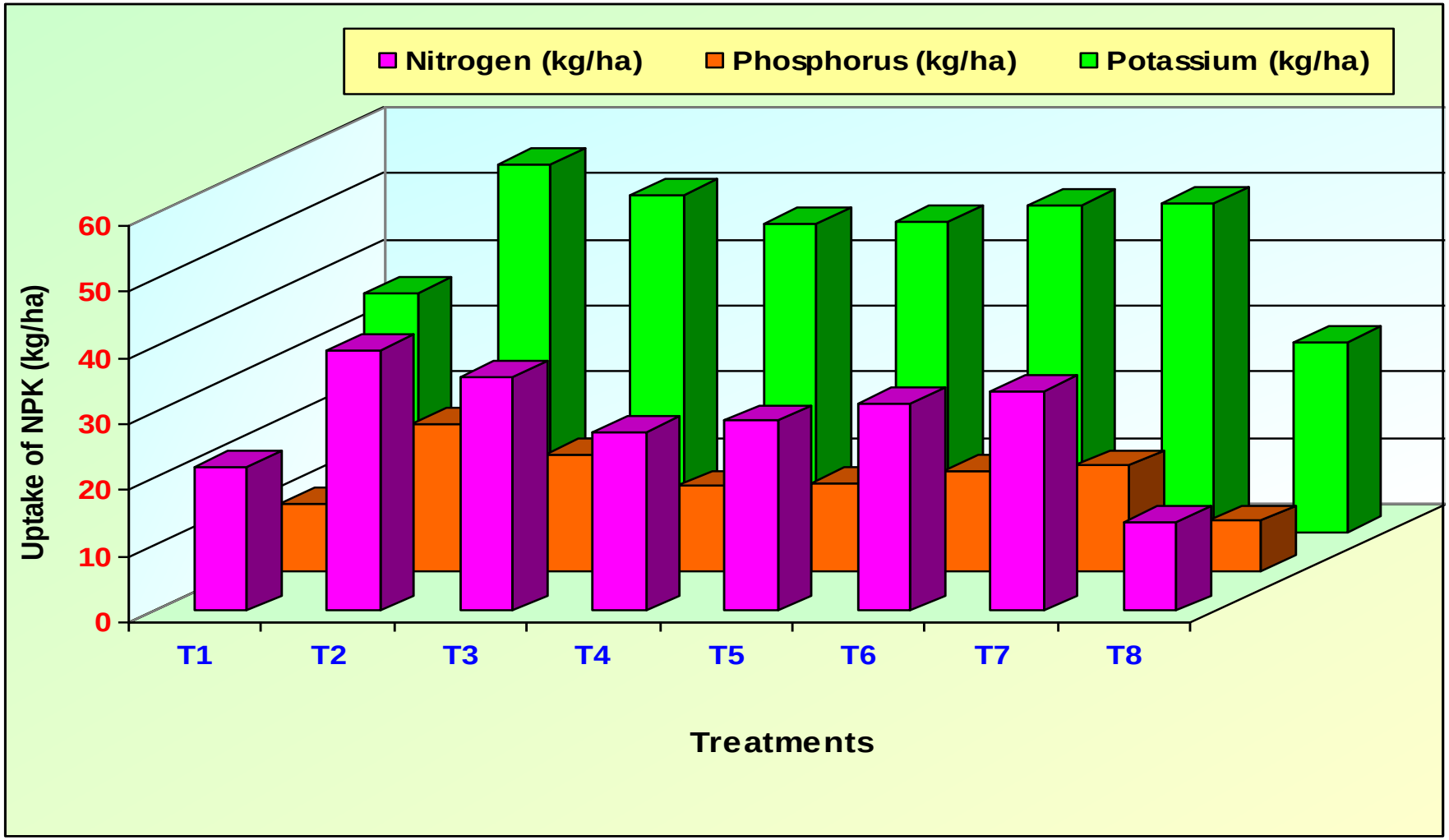

Fig. 8. Uptake of nitrogen, phosphorus and potassium by crop in sesame as influenced by weed control treatments

unweeded check (T_1). The highest phosphorus uptake (22.33 kg ha^{-1}) was noticed in weed free check (T_2) and was followed by recommended practice (alachlor 50 EC @ 0.75 kg a.i. ha^{-1} as PRE application + HW at 30 DAS + IC at 45 DAS) and quizalofop ethyl 5 EC @ 40 g a.i. ha^{-1} as POE application at 20 DAS + IC at 45 DAS (T_7).

Uptake of potassium differed significantly due to weed control treatments. The highest (55.40 kg ha^{-1}) potassium uptake was recorded in weed free check (T_2). The next best treatments were recommended practice (T_3) and quizalofop ethyl 5 EC @ 40 g a.i. ha^{-1} as POE application at 20 DAS + IC at 45 DAS (T_7) which were on par with each other. The lowest (28.67 kg ha^{-1}) potassium uptake by crop was recorded in imazethapyr 10 SL @ 75 g a.i. ha^{-1} as POE at 20 DAS + IC at 45 DAS (T_8) and was followed by unweeded check (T_1).

4.5.2 Uptake of N, P and K by weeds (Cf Table 24)

Recommended practice *i.e.*, alachlor 50 EC @ 0.75 kg a.i. ha^{-1} as PRE application + HW at 30 DAS + IC at 45 DAS (T_3) recorded significantly lower (7.23 kg ha^{-1}) nitrogen depletion by weeds which was followed by quizalofop ethyl 5 EC @ 40 g a.i. ha^{-1} as POE application at 20 DAS + IC at 45 DAS (T_7), butachlor 50 EC @ 1 kg a.i. ha^{-1} as PRE application + HW at 30 DAS + IC at 45 DAS (T_6) and imazethapyr 10 SL @ 75 g a.i. ha^{-1} as POE application at 20 DAS + IC at DAS (T_8) which in turn were on par with each other. Unweeded check (T_1) recorded significantly higher (35.00 kg ha^{-1}) nitrogen depletion by weeds.

Phosphorus depletion by weeds was also significant. The lowest phosphorus depletion (1.80 kg ha^{-1}) was noticed is recommended practice (T_3) and was followed by quizalofop ethyl 5 EC @ 40 g a.i. ha^{-1} as POE application at 20 DAS + IC at 45 DAS (T_7) and butachlor 50 EC @ 1 kg a.i. ha^{-1} as PRE application + HW at 30 DAS + IC at 45 DAS (T_6) which were on par with each other and significantly different from unweeded control (T_1). On the other hand, the highest (5.90 kg ha^{-1}) phosphorus depletion was recorded in unweeded check (T_1) and was significantly inferior to rest of the weed management practices.

Potassium uptake by weeds was higher (32.67 kg ha^{-1}) in unweeded check (T_1) and was the lowest (6.17 Kg ha^{-1}) in recommended practice (T_3) and was followed by quizalofop ethyl 5 EC @ 40 g a.i. ha^{-1} as POE application at 20 DAS +IC at 45 DAS (T_7) which were on par with each other.

Table 24. Uptake of nitrogen, phosphorus and potassium by weeds in sesame as influenced by weed control treatments

Tr. No.	Treatment	Nitrogen (kg ha^{-1})	Phosphorus (kg ha^{-1})	Potassium (kg ha^{-1})
T_1	Unweeded check	35.00	5.90	32.67
T_2	Weed free check (HW at 15 DAS + IC at 30 and 45 DAS)	0.00	0.00	0.00
T_3	Recommended practice (Alachlor 50 EC @ 0.75 kg a.i. ha^{-1}as PRE application + HW at 30 DAS + IC at 45 DAS)	7.23	1.80	6.17
T_4	Pendimethalin 30 EC @ 1 kg a.i. ha^{-1} as PRE application + HW at 30 DAS + IC at 45 DAS	10.57	2.70	9.57
T_5	Pendimethalin 38.7 CS @ 1 kg a.i. ha^{-1} as PRE application + HW at 30 DAS + IC at 45 DAS	10.48	2.50	9.23
T_6	Butachlor 50 EC @ 1 kg a.i. ha^{-1}as PRE application + HW at 30 DAS + IC at 45 DAS	8.23	2.30	8.17
T_7	Quizalofop ethyl 5 EC @ 40 g a.i. ha^{-1} as POE application at 20 DAS + IC at 45 DAS	8.17	2.23	7.83
T_8	Imazethapyr 10 SL @ 75 g a.i. ha^{-1} as POE application at 20 DAS + IC at 45 DAS	8.35	2.36	8.43
	S.Em.±	0.45	0.17	0.65
	C.D. at 5%	1.37	0.52	1.97

EC : Emulsifiable Concentrate CS : Capsular Suspension SL : Soluble Liquid HW: Hand Weeding IC: Intercultivation
DAS : Days After Sowing PRE : Pre-emergence POE : Post-emergence

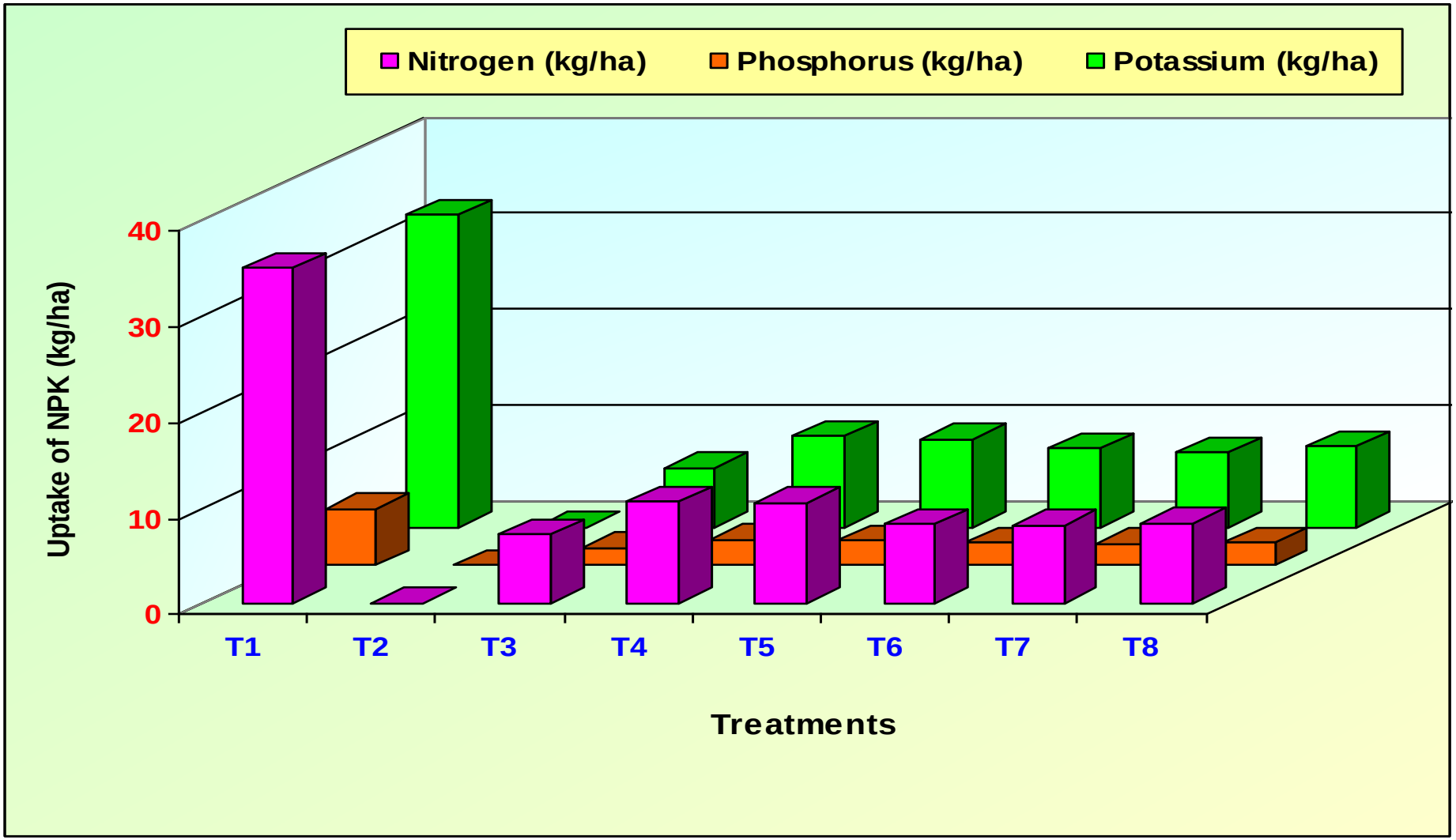

Fig. 9. Uptake of nitrogen, phosphorus and potassium by weeds in sesame as influenced by weed control treatments

4.6 Economics

4.6.1 Cost of cultivation (Cf Table 25)

The highest cost of cultivation (₹28,937 ha^{-1}) was recorded in pendinethalin 38.7 CS @ 1 kg a.i. ha^{-1} as PRE application + HW at 30 DAS + IC at 45 DAS (T_5) and the lowest was recorded in unweeded check (₹19,548 ha^{-1}). All other treatments *viz*., pendimthalin 30 EC @ 1 kg a.i. ha^{-1} as PRE application + HW at 30 DAS + IC at 45 DAS (T_4), butachlor 50 EC @ 1 kg a.i. ha^{-1} as PRE application + HW at 30 DAS + IC at 45 DAS (T_6), recommended practice (T_3), weed free check (T_2), imazethapyr 10 SL @ 75 g a.i. ha^{-1} as POE application at 20 DAS + IC at 45 DAS (T_8) and quizalofop ethyl 5 EC @ 40 g a.i. ha^{-1} as POE application at 20 DAS + IC at 45 DAS (T_7) were in descending order of their cost of cultivation.

4.6.2 Gross returns (Cf Table 25)

Weed control treatments exerted significant difference on the gross returns. Weed free check (T_2) recorded significantly higher gross returns (₹ 70,600 ha^{-1}) among all other treatments. The next best treatments which were having gross returns in descending order were recommended practice (T_3), quizalofop ethyl 5 EC @ 40 g a.i. ha^{-1} as POE application at 20 DAS + IC at 45 DAS (T_7), butachlor 50 EC @ 1 kg a.i. ha^{-1} as PRE application + HW at 30 DAS + IC at 45 DAS (T_6), pendimethalin 38.7 CS @ 1 kg a.i. ha^{-1} as PRE application + HW at 30 DAS + IC at 45 DAS (T_5) and pendimethalin 30 EC @ 1 kg a.i. ha^{-1} as PRE application + HW at 30 DAS + IC at 45 DAS (T_4). The lowest (₹ 10,360 ha^{-1}) gross returns was recorded in imazethapyr 10 SL @ 75 g a.i. ha^{-1} as POE application at 20 DAS + IC at 45 DAS (T_8) and was followed by unweeded check (₹21,560 ha^{-1}) which were significantly different from each other.

4.6.3 Net returns (Cf Table 25)

Weed control treatments exerted significant difference on net returns. Significantly higher net returns (₹ 42,982 ha^{-1}) was recorded in weed free check (T_2). The next best treatments were recommended practice *i.e*., alachlor 50 E @ 0.75 kg a.i. ha^{-1} as PRE application + HW at 30 DAS + IC at 45 DAS (T_3) and quizalofop ethyl 5 EC @ 40 g a.i. ha^{-1} as POE application at 20 DAS + IC at 45 DAS (T_7) which were on par with each other and significantly different from other treatments. Significantly lower (₹ -11,816 ha^{-1}) net returns was recorded in imazethapyr 10 SL @ 75 g a.i. ha^{-1} as POE application at 20 DAS + IC at 45 DAS (T_8) and was followed by unweeded check (T_1).

Table 25. Cost of cultivation , gross returns, net returns and benefit cost ratio of sesame as influenced weed control treatments

Tr. No.	Treatment	Cost of cultivation(` ha^{-1})	Gross returns (` ha^{-1})	Net returns (` ha^{-1})	BC ratio
T_1	Unweeded check	19,548	21,560	2,012	1.10
T_2	Weed free check (HW at 15 DAS + IC at 30 and 45 DAS)	27,618	70,600	42,982	2.56
T_3	Recommended practice (Alachlor 50 EC @ 0.75 kg a.i. ha^{-1}as PRE application + HW at 30 DAS + IC at 45 DAS)	28,118	57,600	29,482	2.05
T_4	Pendimethalin 30 EC @ 1 kg a.i. ha^{-1} as PRE application + HW at 30 DAS + IC at 45 DAS	28,755	32,800	4,045	1.14
T_5	Pendimethalin 38.7 CS @ 1 kg a.i. ha^{-1} as PRE application + HW at 30 DAS + IC at 45 DAS	28,937	34,000	5,063	1.17
T_6	Butachlor 50 EC @ 1 kg a.i. ha^{-1}as PRE application + HW at 30 DAS + IC at 45 DAS	28,194	44,000	15,806	1.56
T_7	Quizalofop ethyl 5 EC @ 40 g a.i. ha^{-1} as POE application at 20 DAS + IC at 45 DAS	21,868	49,200	27,332	2.25
T_8	Imazethapyr 10 SL @ 75 g a.i. ha^{-1} as POE application at 20 DAS + IC at 45 DAS	22,176	10,360	-11,816	0.47
	S.Em.±	-	2952	2952	0.10
	C.D. at 5%	-	8956	8956	0.33

EC : Emulsifiable Concentrate CS : Capsular Suspension SL : Soluble Liquid HW: Hand Weeding IC: Intercultivation
DAS : Days After Sowing PRE : Pre-emergence POE : Post-emergence

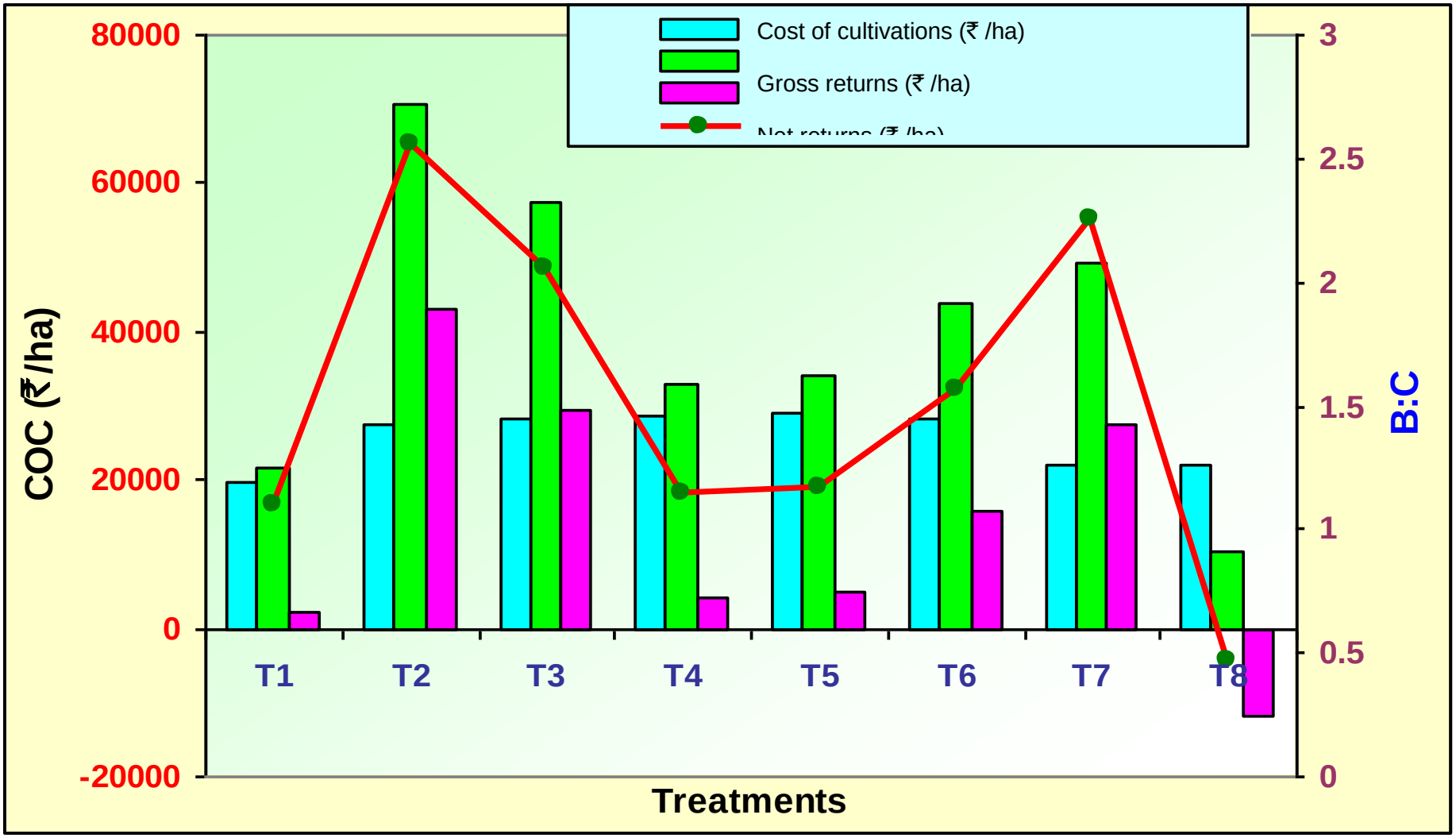

Fig. 10. Cost of cultivation, gross returns, net returns and benefit cost ratio of sesame as influenced weed control treatments

4.6.4 Benefit cost ratio (Cf Table 25)

Weed control treatments exerted significant differences on BC ratio. Weed free check (T_2) recorded significantly higher BC ratio (2.56) and was followed by quizalofop ethyl 5 EC @ 40 g a.i. ha^{-1} as POE application at 20 DAS + IC at 45 DAS (T_7) which were on par with each other. The treatments *viz*., quizalofop ethyl 5 EC @ 40 g a.i. ha^{-1} as POE application at 20 DAS + IC at 45 DAS (T_7) and recommended practice *i.e*., alachlor 50 EC @ 0.75 kg a.i. ha^{-1} as PRE application + HW at 30 DAS + IC at 45 DAS (T_3) were in decreasing order of their BC ratios and on par with each other. The lowest BC ratio (0.47) was recorded in imazathapyr 10 SL @ 75 g a.i. ha^{-1} as POE application at 20 DAS + IC at 45 DAS (T_8) and was followed by unweeded check (1.10) which were significantly different from each other.

4.7 Residual effect of weed control treatments on succeeding chickpea

4.7.1 Germination count (Cf Table 26)

Germination count did not differ significantly due to residual effect of herbicides imposed on sesame during *kharif* season.

4.7.2 Crop phytotoxicity (Cf Table 27)

Chickpea did not show any visual phytotoxicity symptoms due to residual effect of herbicides which were imposed on sesame during *kharif* season.

4.7.3 Seed yield (Cf Table 28)

Seed yield of chickpea did not differ significantly due to residual effect of herbicides imposed on sesame during *kharif* season.

Table 26. Residual effect of weed control treatments imposed during *kharif* on germination count of chickpea

Tr. No.	Treatment	Germination count (%)	
		10 DAS	20 DAS
T_1	Unweeded check	86.45	89.80
T_2	Weed free check (HW at 15 DAS + IC at 30 and 45 DAS)	87.21	90.58
T_3	Recommended practice (Alachlor 50 EC @ 0.75 kg a.i. ha^{-1}as PRE application + HW at 30 DAS + IC at 45 DAS)	87.32	88.24
T_4	Pendimethalin 30 EC @ 1 kg a.i. ha^{-1} as PRE application + HW at 30 DAS + IC at 45 DAS	86.56	88.10
T_5	Pendimethalin 38.7 CS @ 1 kg a.i. ha^{-1} as PRE application + HW at 30 DAS + IC at 45 DAS	87.30	89.12
T_6	Butachlor 50 EC @ 1 kg a.i. ha^{-1}as PRE application + HW at 30 DAS + IC at 45 DAS	86.14	88.00
T_7	Quizalofop ethyl 5 EC @ 40 g a.i. ha^{-1} as POE application at 20 DAS + IC at 45 DAS	87.78	91.23
T_8	Imazethapyr 10 SL @ 75 g a.i. ha^{-1} as POE application at 20 DAS + IC at 45 DAS	86.56	88.50
	S.Em.±	NS	NS
	C.D. at 5%	NS	NS

EC : Emulsifiable Concentrate CS : Capsular Suspension SL : Soluble Liquid HW: Hand Weeding IC: Intercultivation
DAS : Days after sowing PRE : Pre-emergence POE : Post-emergence NS : Non significant

Table 27. Crop phytotoxicity effects of herbicides imposed during *kharif* on the succeeding crop (chickpea after sesame)

Tr. No.	Treatments	Crop phytotoxic Symptoms											
		Epinasty		Hyponasty		Wilting		Necrotic symptoms		Yellowing		Stunted growth	
		7 DAS	15 DAS	7 DAS	15 DAS	7 DAS	15 DAS	7 DAS	15 DAS	7 DAS	15 DAS	7 DAS	15 DAS
T_1	Unweeded check	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
T_2	Weed free check (HW at 15 DAS + IC at 30 and 45 DAS)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
T_3	Recommended practice (Alachlor 50 EC @ 0.75 kg a.i. ha^{-1}as PRE application + HW at 30 DAS + IC at 45 DAS)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
T_4	Pendimethalin 30 EC @ 1 kg a.i. ha^{-1} as PRE application + HW at 30 DAS + IC at 45 DAS	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
T_5	Pendimethalin 38.7 CS @ 1 kg a.i. ha^{-1} as PRE application + HW at 30 DAS + IC at 45 DAS	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
T_6	Butachlor 50 EC @ 1 kg a.i. ha^{-1}as PRE application + HW at 30 DAS + IC at 45 DAS	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
T_7	Quizalofop ethyl 5 EC @ 40 g a.i. ha^{-1} as POE application at 20 DAS + IC at 45 DAS	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
T_8	Imazethapyr 10 SL @ 75 g a.i. ha^{-1} as POE application at 20 DAS + IC at 45 DAS	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	S.Em±	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	C.D. at 5%	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

EC : Emulsifiable Concentrate CS : Capsular Suspension SL : Soluble Liquid HW: Hand Weeding IC: Intercultivation
DAS : Days After Sowing PRE : Pre-emergence POE : Post-emergence NA : Not Applicable

Table 28. Residual effect of weed control treatments imposed during *kharif* on seed yield of chickpea

Tr. No.	Treatment	Seed yield (kg/ha)
T_1	Unweeded check	867
T_2	Weed free check (HW at 15 DAS + IC at 30 and 45 DAS)	870
T_3	Recommended practice (Alachlor 50 EC @ 0.75 kg a.i. ha^{-1}as PRE application + HW at 30 DAS + IC at 45 DAS)	862
T_4	Pendimethalin 30 EC @ 1 kg a.i. ha^{-1} as PRE application + HW at 30 DAS + IC at 45 DAS	865
T_5	Pendimethalin 38.7 CS @ 1 kg a.i. ha^{-1} as PRE application + HW at 30 DAS + IC at 45 DAS	867
T_6	Butachlor 50 EC @ 1 kg a.i. ha^{-1}as PRE application + HW at 30 DAS + IC at 45 DAS	860
T_7	Quizalofop ethyl 5 EC @ 40 g a.i. ha^{-1} as POE application at 20 DAS + IC at 45 DAS	872
T_8	Imazethapyr 10 SL @ 75 g a.i. ha^{-1} as POE application at 20 DAS + IC at 45 DAS	863
	S.Em.±	NS
	C.D. at 5%	NS

EC : Emulsifiable Concentrate CS : Capsular Suspension SL : Soluble Liquid HW: Hand Weeding IC: Intercultivation
DAS : Days After Sowing PRE : Pre-emergence POE : Post-emergence NS : Non significant

DISCUSSION

V. DISCUSSION

The results of the field experiment conducted on chemical weed management in sesame (*Sesamum indicum* L.) during *kharif*, 2013 at the Agricultural College Farm, Raichur are discussed in this chapter.

5.1 Effect of weed control treatments on weed growth

5.1.1 Weed density

The number of monocot, dicot and total weed density at all the stages (20, 40, 60 DAS and at harvest) differed significantly with lower weed density in herbicide treatments compared to unweeded control (Table 4, 5 and 6). Similar results were reported by Joseph *et al.* (2006) where weed free check recorded minimum weed density throughtout the crop season. Similar findings was also obtained by Punia *et al.* (2001).

At 20 DAS, the treatments which received alachlor @ 0.75 kg a.i. ha^{-1} as PRE application + HW at 30 DAS + IC at 45 DAS (T_3), butachlor 50 EC @ 1 kg a.i. ha^{-1} as PRE application + HW at 30 DAS + IC at 45 DAS (T_6), pendimethalin 38.7 CS @ 1 kg a.i. ha^{-1} as PRE application + HW at 30 DAS + IC at 45 DAS (T_5), pendimethalin 30 EC @ 1 kg a.i. ha^{-1} as PRE application + HW at 30 DAS + IC at 45 DAS (T_4) and weed free check (T_2) recorded the lowest number of monocots, dicots and total weed density than unweeded check (T_1), quizalofop ethyl 5 EC @ 40 g a.i. ha^{-1} as POE application at 20 DAS + IC at 45 DAS (T_7) and imazethapyr 10 SL @ 75 g a.i. ha^{-1} as POE application at 20 DAS + IC at 45 DAS (T_8). This might be due to the prevention of germination of weed seeds which also controlled the growth of germinated weed seeds. The results corroborate findings of Sukhadia *et al.* (2004).

The highest weed density was recorded in unweeded check (T_1) and the treatments which received post-emergence spray of quizalofop 5 EC @ 40 g a.i. ha^{-1} (T_7) and imazethapyr 10 SL @ 75 a.i. ha^{-1} (T_8) may be because the weeds were allowed to grow upto 20 DAS.

At 40 DAS, the treatments which received alachlor 50 EC @ 0.75 kg a.i. ha^{-1} as PRE application + HW at 30 DAS + IC at 45 DAS (T_3), pendimethalin 30 EC @ 1 kg a.i. ha^{-1} as PRE application + HW at 30 DAS + IC at 45 DAS (T_4), pendimethalin 38.7 CS @ 1 kg a.i. ha^{-1} as PRE application + HW at 30 DAS + IC at 45 DAS (T_5) and butachlor 50

EC @ 1 kg a.i. ha^{-1} as PRE application + HW at 30 DAS + IC at 45 DAS (T_6) showed decrease in total weed population from 20 to 40 DAS. This may be attributed to the imposition of weed control treatments at 30 DAS. Treatments which received quizalofop ethyl 5 EC @ 40 g a.i. ha^{-1} as POE application at 20 DAS + IC at 45 DAS (T_7) and imazethapyr 10 SL @ 75 g a.i. ha^{-1} as POE application at 20 DAS + IC at 45 DS (T_8) recorded slight decrease in total weed density because of the treatment imposition at 20 DAS.

At 60 DAS, there was slight increase in the total weed count from 40 to 60 DAS in all weed control treatment except weed free check.

At harvest, there was also increase in the total weed count from 60 DAS. This clearly indicates that there was continuous emergence of weeds.

5.1.2 Weed dry weight

At 20 DAS, the treatments which received alachlor 50 EC @ 0.75 kg a.i. ha^{-1} as PRE application + HW at 30 DAS + IC at 45 DAS (T_3), butachlor 50 EC @ 1 kg a.i. ha^{-1} as PRE application + HW at 30 DAS + IC at 45 DAS (T_6), pendimethalin 38.7 CS @ 1 kg a.i. ha^{-1} as PRE application + HW at 30 + IC at 45 DAS (T_5) and pendimethalin 30 EC @ 1 kg a.i. ha^{-1} as PRE application + HW at 30 DAS + IC at 45 DAS (T_4) recorded lower weed dry weight which was mainly due to lower weed population (Table 7). Similar results was obtained by Malam Singh Chandawat and Rathore (2004).

At 40 and 60 DAS, the lowest weed dry weight was recorded in recommended practice (T_3) and was followed by quizalofop ethyl 5 EC @ 40 g a.i. ha^{-1} as POE application at 20 DAS + IC at 45 DAS (T_7) which were on par with each other. It might be due to the lower number of weed population in these treatments and hence, could been attributed for reduced weed dry weight. This result is in conformity with the findings of Joseph *et al.* (2006).

At harvest, there was an increase in weed dry weight in all the treatments because of the continuous emergence of weeds during this period. Similar results was reported by Malam Singh Chandawat and Rathore (2004).

5.1.3 Weed control efficiency and weed index

The highest weed control efficiency of 74.16 per cent was recorded in recommended practice *i.e.*, alachlor 50 EC @ 0.75 kg a.i. ha^{-1} as PRE application + HW

at 30 DAS + IC at 45 DAS (T_3) followed by quizalofop ethyl 5 EC @ 40 g a.i. ha^{-1} as POE application at 20 DAS + IC at 45 DAS (Table 8). The higher weed control efficiency is attributed to lower dry weight of weeds. This might be due to the combination of both cultural and chemical methods which was found to be more effective in suppressing the weed density as well as weed dry matter. Similar results were obtained by Joseph *et al.* (2006) and Rao and Narayana Rao (1992).

Weed index is directly related to the reduction in yield due to weed population and weed dry weight. The highest weed index (85.11%) was recorded under imazethapyr 10 SL @ 75 g a.i. ha^{-1} as POE application at 20 DAS + IC at 45 DAS (T_8) because of the severe phytotoxicity of this herbicide to sesame. James Grichar *et al.* (2001) reported that acifluorfen, imazethapyr, imazapic and 2,4-DB reduced sesame yield when compared with the untreated check. The lower weed index was recorded under treatments which received the application of herbicides combined with cultural practices *viz.,* alachlor @ 0.75 kg a.i. ha^{-1} as PRE application + HW at 30 DAS + IC at 45 DAS (T_3) and quizalofop ethyl 5 EC @ 40 g a.i. ha^{-1} as POE application at 20 DAS + IC at 45 DAS (T_7 and Table 8).

5.2 Crop phytotoxicity

5.2.1 Crop phytotoxicity due to pre-emergence herbicides

The toxicity rating recorded on crop from 10 to 19 DAS revealed that pendimethalin 38.7 CS @ 1 kg ha^{-1} and pendimethalin 30 EC @ 1 kg ha^{-1} herbicides showed slight stunting/ discolouration up to 16 DAS and later on the sesame plants grew normally. The herbicides *viz.,* alachlor 0.75 kg a.i. ha^{-1} and butachlor 1 kg a.i. ha^{-1} did not cause any injury to sesame (Table 9). The results are in conformity with the findings of Venkatakrishnan and Gnanamurthy (1998b) and Vishnu Shukla (1984).

5.2.2 Crop phytotoxicity due to post-emergence herbicides

Application of quizalofop ethyl 5 EC @ 40 g a.i. ha^{-1} did not have any phytotoxic symptoms on sesame but severe crop phytotoxic symptoms were recorded due to the spray of imazethapyr 10 SL @ 75 g a.i. ha^{-1} as POE at 20 DAS (T_8 and Table 10). This result is in close vicinity with the findings of James Grichar *et al.* (2001).

5.3 Effect of weed control treatments on growth parameters, yield components and seed yield of sesame

The plant height differed significantly among the treatments at all the stages of the crop growth. The plant height was maximum (15.97 cm at 30 DAS, 119.84 cm at 60 DAS, 146.33 cm at harvest under weed free check (T_2 and Table 11) and was followed by alachlor @ 0.75 kg a.i. ha^{-1} as PRE application + HW at 30 DAS + IC at 45 DAS (T_3) and quizalofop ethyl 5 EC @ 40 g a.i. ha^{-1} as POE application at 20 DAS + IC at 45 DAS (T_7). Similar results was reported by Parvender Sheoran *et al.* (2012). Imazethapyr 10 SL @ 75 g a.i. ha^{-1} as POE application at 20 DAS + IC at 45 DAS (T_8) recorded the lowest plant height (5.36 cm at 30 DAS, 29.40 cm at 60 DAS and 64.23 cm at harvest) followed by unweeded check (T_1) due to phytotoxic effect on the crop. James Grichar *et al.* (2001) reported that acifluorfen, imazapic, imazethapyr and the high rate of pyridate caused ≥ 65% sesame injury and ≥ 50% sesame stunting when compared with the unweeded check. It might have led to the reduction of plant height.

The increased plant height caused higher number of branches per plant at 60 DAS and at harvest of crop and was significantly different due to weed control treatments. At 60 DAS and at harvest, imazethapyr 10 SL @ 75 g a.i. ha^{-1} as POE application at 20 DAS + IC at 45 DAS (T_8) recorded the lowest (1.00 and 2.07) number of branches per plant (Table 12). The significant reduction in number of branches per plant was mainly due to phytotoxic effect of herbicide. Unweeded check (T_1) recorded next lowest number of branches at 60 DAS and at harvest (2.00 and 2.53) and was mainly attributed to severe weed competition. The results are in line with the findings of Sootrakar *et al.* (1995). The highest number of branches at 60 DAS and at harvest (2.93 and 3.27, respectively) were recorded in weed free check and was followed by alachlor 50 EC @ 0.75 kg a.i. ha^{-1} as PRE application + HW at 30 DAS + IC at 45 DAS (T_3) and quizalofop ethyl 5 EC @ 40 g a.i. ha^{-1} as POE application at 20 DAS + IC at 45 DAS (T_7).

Leaf area and leaf area index of weed free check (T_2) was significantly higher than other weed control treatments at all the stages of crop growth (Table 13 and 14). Significantly higher leaf area at harvest (256.00 cm^2/plant) was recorded in weed free check (T_2) and was followed by alachlor 50 EC @ 0.75 kg a.i. ha^{-1} as PRE application + HW at 30 DAS + IC at 45 DAS (T_3) and leaf area index also followed the same trend. The results are in conformity with the findings of Baskaran and Solaimalai (2002). The lowest leaf area and leaf area index (147.53 cm^2/plant and 0.33) was recorded in

imazethapyr 10 SL @ 75 g a.i. ha^{-1} as POE application at 20 DAS + IC at 45 DAS (T_8) due to phytotoxic effect on crop.

The dry matter production of sesame was the lowest in imazethapyr 10 SL @ 75 g a.i. ha^{-1} as POE application at 20 DAS + IC at 45 DAS (T_8) at 30, 60 DAS and at harvest (0.37, 7.00 and 9.62 g, respectively) due to phytotoxic effect of the herbicide (Table 18). Unweeded check (T_1) recorded the next lowest dry matter production at all the growth stages due to the severe weed competition. The highest dry matter production per plant (2.91 g at 30 DAS, 24.48 g at 60 DAS and 29.95 g at harvest) was recorded in weed free check (T_2) and was followed by recommended practice (T_3). Similar results were reported by Basakaran and Solaimalai (2002).

Weed free check recorded significantly higher number of capsules per plant, number of seeds per capsule and seed weight per capsule (31.67, 38.33 and 0.17, respectively) than rest of the treatments (Table 20). This might be due to the lower weed density, weed dry weight and higher weed control efficiency which ultimately resulted in better crop growth. These results are in conformity with the findings of Nisha Bhadauria *et al.* (2012). The next best treatments were alachlor 50 EC @ 0.75 kg a.i. ha^{-1} as PRE application + HW at 30 DAS + IC at 45 DAS (T_3) and quizalofop ethyl 5 EC @ 40 g a.i. ha^{-1} as POE application at 20 DAS + IC at 45 DS (T_7). This might be due to timely and effective control of weeds by herbicides coupled with cultural methods resulted in better availability of soil moisture and nutrients. Similar results were obtained by Parvender Sheoran *et al.* (2012) and Nisha Bhadauria *et al.* (2012a). The significantly lower number of capsules per plant, number of seeds per capsule and seed weight per capsule (13.73, 19.00 and 0.11 g, respectively) was recorded in imazethapr 10 SL @ 75 g a.i. ha^{-1} as POE application at 20 DAS + IC at 45 DAS (T_8) due to phytotoxic effect on crop.

The highest seed yield, stalk yield and harvest index (588.00 kg, 2520.06 kg and 0.19, respectively) were recorded in weed free check (T_2 and Table 21) and was followed by alachlor 50 EC @ 0.75 kg a.i. ha^{-1} as PRE application + HW at 30 DAS + IC at 45 DAS (T_3) and quizalofop ethyl 5 EC @ 40 g a.i. ha^{-1} as POE application at 20 DAS + IC at 45 DAS (T_7). This might be due the application of herbicide and cultural practices resulting in reduced crop weed competition and creating good environment for better growth of plant which gave higher yield of sesame. Similar results were reported by Parvender Sheoran *et al.* (2012) and Nisha Bhadauria *et al.* (2012a). The lowest seed yield (86.00 kg ha^{-1}) was recorded in imazethapyr 10 SL @ 75 g a.i. ha^{-1} as POE

Plate 3. General view of experimental plot at 60 DAS

Plate 4. Field view of unweeded control at 60 DAS

Plate 5. Field view of weed free check at 60 DAS

Plate 6. Field view of alachlor 50 EC @ 0.75 kg a.i. ha^{-1}as PRE application + HW at 30 DAS + IC at 45 DAS

Plate 7. Field view of quizalofop ethyl 5 EC @ 40 g a.i. ha^{-1} as post emergence (POE) application at 20 DAS + Inter-cultivation (IC) at 45 DAS

Plate 8. Field view of Imazethapyr 10 SL @ 75 g a.i. ha^{-1} as post emergence (POE) application at 20 DAS + Inter-cultivation (IC) at 45 DAS.

application at 20 DAS + IC at 45 DAS (T_8) due severe phytotoxic effect on the crop. James Grichar *et al.* (2001) revealed that imazapic, imazethapyr, 2,4-DB and pyridate reduced sesame yield by 26-87 per cent when compared with the untreated check. Unweeded check (T_1) recorded the next lowest (179.67 kg ha^{-1}) seed yield due to severe weed competition with sesame which resulted in stunted growth and lower yield. This result was also reported by Narkhede *et al.* (2000).

Oil content (%) did not differ significantly due to weed control treatments. Similar result was obtained by Chauhan and Gurjar (1998). On the other hand, oil yield differed significantly due to weed control treatments (Table 22). The highest (282.67 kg ha^{-1}) oil yield was recorded in weed free check (T_2) and was followed by recommended practice (T_3) and quizalofop ethyl 5 EC @ 40 g a.i. ha^{-1} as POE application at 20 DAS + IC at 45 DAS (T_8). This might be due to the lower weed crop competition, which shifted the balance in favour of crop in the utilization of nutrients, moisture, light and space.

Chlorophyll content at 30 and 60 DAS differed significantly due to weed management practices (Table 19). The highest chlorophyll content at 30 and 60 DAS (45.69 and 27.83 SPAD meter values) were obtained in weed free check (T_2) and was followed by recommended practice (T_3) and quizalofop ethyl 5 EC @ 40 g a.i. ha^{-1} as POE application at 20 DAS + IC at 45 DAS (T_7). This might be due to lower weed competition during critical period of the crop growth stages, which might have provided the better availability of soil moisture and nutrients for crop growth.

The lowest (24.83 and 14.35 SPAD meter values) chlorophyll content at 30 and 60 DAS were recorded in imzethapyr 10 SL @ 75 g a.i. ha^{-1} as POE application at 20 DAS + IC at 45 DAS (T_8) due to phytotoxic effect on sesame.

5.4 Uptake of nitrogen, phosphorus and potassium by crop and weeds

Weed free check (T_2) recorded significantly higher uptake of nutrients (39.33, 22.33 and 55.40 kg N, P_2O_5 and K_2O ha^{-1}, respectively) over all other treatments and was followed by recommended practice *i.e.,* alachlor 50 EC @ 0.75 kg a.i. ha^{-1} as PRE application + HW at 30 DAS + IC at 45 DAS (T_3) and quizalofop ethyl 5 EC @ 40 g a.i. ha^{-1} as POE application at 20 DAS + IC at 45 DAS (T_7). Nisha Bhadauria *et al.* (2012b) also reported significantly higher NPK uptake by herbicidal and manual weeded treatments as compared to weedy check. The lowest (13.33, 7.67 and 28.67 kg N, P_2O_5 and K_2O ha^{-1}, respectively) nutrient uptake by crop was observed in imazethapyr 10 SL

@ 75 g a.i. ha^{-1} as POE application at 20 DAS + IC at 45 DAS (T_8) due to phytotoxic effect on crop (Table 23).

Unweeded check (T_1) recorded significantly higher (35.00, 5.96 and 32.67 kg N, P_2O_5 and K_2O ha^{-1}, respectively) uptake of nutrients by weeds over all other treatments (Table 24). This might be due to the profused growth of weeds during the crop growth. Similar findings were reported for nitrogen removal by weeds (Singh *et al.*, 2001) and for NPK uptake in weeds in sesame (Nisha Bhadauria *et al.*, 2012b). Among the herbicidal treatments, the lowest (7.23, 1.80 and 6.17 kg N, P_2O_5, K_2O ha^{-1}, respectively) nutrient removal by weeds was found to be in recommended practice (T_3) and was followed by quizalofop ethyl 5 EC @ 40 g a.i. ha^{-1} as POE application at 20 DAS + IC at 45 DAS (T_7). This might be due to lower weed population and dry weight of weeds during the crop growth period.

5.5 Economics

Significantly higher net returns (`42,982 ha^{-1}) was recorded in weed free check (T_2 and Table 25) and was followed by recommended practice *i.e.*, alachlor 50 EC @ 0.75 kg a.i. ha^{-1} as PRE application + HW at 30 DAS + IC at 45 DAS (T_3) and quizalofop ethyl 5 EC @ 40 g a.i. ha^{-1} as POE application at 20 DAS + IC at 45 DAS (T_7). Joseph *et al.* (2006) reported that application of pre or post emergence herbicide followed by cultural practices recorded higher net returns of sesame. On the other hand, significantly lower net returns (`-11,816 $ha^{-1}$) was recorded in imazethapyr 10 SL @ 75 g a.i. $ha^{-1}$ as POE application at 20 DAS + IC at 45 DAS ($T_8$) due to phytotoxicity of the chemical which led to lower seed yield of sesame. The next lowest (`2,012 ha^{-1}) net returns was recorded in unweeded check (T_1). This might be due severe crop weed competition as reflected in seed yield (180 kg ha^{-1}). This result was also reported by Anil Kumar and Thakur (2005).

The highest BC ratio (2.56) was obtained from weed free check (T_2) and was followed by quizalofop ethyl 5 EC @ 40 g a.i. ha^{-1} as POE application at 20 DAS + IC at 45 DAS (T_7). The treatments like quizalofop ethyl 5 EC @ 40 g a.i. ha^{-1} as POE application at 20 DAS + IC at 45 DAS (T_7) and recommended practice (T_3) were on par with each other. Similar results were also reported by Nisha Bhadauria *et al.* (2012a) and Parvender Sheoran *et al.* (2012). The lowest BC ratio (0.47) was obtained with imazethapyr 10 SL @ 75 g a.i. ha^{-1} as POE application at 20 DAS + IC at 45 DAS (T_8) due to phytotoxic effect on crop and was followed by unweeded check (T_1).

5.6 Residual effect of weed control treatments on succeeding chickpea

Germination count, crop phytotoxicity ratings and seed yield of chickpea did not differ significantly due to residual effect of herbicides imposed on sesame during *kharif* season (Table 26, 27 and 28). Mundra and Maliwal (2012) revealed that herbicides applied in blackgram did not show any kind of phytotoxicity on any succeeding crops, *viz.*, wheat, mustard and chickpea. Post-emergence application of quizalofop ethyl 37.5, 50.0 and 100 g a.i. ha^{-1} and pre-emergence application of pendimethalin 750 g a.i. ha^{-1} used in blackgram also did not show any residual effect on germination as well as seed yield of these crops. Sangeetha *et al.* (2012) reported that the residues of imazethapyr at different doses did not have influence on the germination, growth and yield of sunflower and pearl millet. These results were also reported by Punia *et al.* (2011).

5.7 Practical application of the findings

Based on the results obtained from the present investigation, the following weed management practices for North Eastern Dry Zone (Zone-2) of Karnataka are indicated.

1. Effective control of weeds and increased seed yield of sesame can be obtained with the application of pre or post emergence herbicides combined with cultural practices.
2. Application of quizalofop ethyl 5 EC @ 40 g a.i. ha^{-1} as POE application at 20 DAS + IC at 45 DAS (T_7) can be used as a alternative weed control method to recommended practice (alachlor 50 EC @ 0.75 kg a.i. ha^{-1} as PRE application + HW at 30 DAS + IC at 45 DAS).

5.8 Future line of work

1. Physiological studies on phytotoxicity of imazethapyr on sesame.
2. To study the effect of herbicides on biological and chemical properties of the soil.

SUMMARY AND CONCLUSIONS

VI. SUMMARY AND CONCLUSIONS

Field experiment was conducted on chemical weed management in sesame (*Sesamum indicum* L.) during *kharif* 2013 at the Agricultural College Farm, Raichur. The relevant findings of this investigation are summarized below.

6.1 Weeds

The total weed count differed significantly among the treatments at all the stages of crop growth. At 20 DAS, the lowest total weed density in sesame was recorded in alachlor 50 EC @ 0.75 kg a.i. ha^{-1} as PRE application + HW at 30 DAS + IC at 45 DAS (T_3), butachlor 50 EC @ 1 kg a.i. ha^{-1} as PRE application + HW at 30 DAS + IC at 45 DAS (T_6), pendimethalin 38.7 CS @ 1 kg a.i. ha^{-1} as PRE application + HW at 30 DAS + IC at 45 DAS (T_5) and pendimethalin 30 EC @ 1 kg a.i. ha^{-1} as PRE application + HW at 30 DAS + IC at 45 DAS (T_4). At 40 DAS, the lowest weed density in sesame was recorded in recommended practice (T_3), quizalofop ethyl 5 EC @ 40 g a.i. ha^{-1} as POE application at 20 DAS + IC at 45 DAS (T_7), butachlor 50 EC @ 1 kg a.i. ha^{-1} as PRE application + HW at 30 DAS + IC at 45 DAS (T_6), imazethapyr 10 SL @ 75 g a.i. ha^{-1} as POE application at 20 DAS + IC at 45 DAS (T_8), pendimethalin 38.7 CS @ 1 kg a.i. ha^{-1} as PRE application + HW at 30 DAS + IC at 45 DAS (T_5) and pendimethalin 30 EC @ 1 kg a.i. ha^{-1} + HW at 30 DAS + IC at 45 DAS (T_4) than unweeded control. The similar trend in total weed density was followed at 60 DAS and at harvest.

The total dry weight of weeds was significantly higher in unweeded check (T_1) over other treatments. At 20 DAS, application of alachlor 50 EC @ 0.75 kg a.i. ha^{-1} as PRE application + HW at 30 DAS + IC at 45 DAS (T_3) recorded the lowest (0.73 g/m^2) total dry weight of weeds and was followed by butachlor 50 EC @ 1 kg a.i. ha^{-1} as PRE application + HW at 30 DAS + IC at 45 DAS (T_6) and at 40, 60 DAS and at harvest. Application of alachlor 50 EC @ 0.75 kg a.i. ha^{-1} as PRE application + HW at 30 DAS + IC at 45 DAS (T_3) recorded the lowest (0.63, 0.85 and 1.80 g/m^2 respectively) total dry weight of weeds and was followed by quizalofop ethyl 5 EC @ 40 g a.i. ha^{-1} as POE application at 20 DAS + IC at 45 DAS (T_7) at 40 and 60 DAS and at harvest respectively.

The highest weed control efficiency (74.16%) was recorded in recommended practice (T_3) and was followed by quizalofop ethyl 5 EC @ 40 g a.i. ha^{-1} as POE

application at 20 DAS + IC at 45 DAS (70.57%). Significantly lower weed control efficiency (59.17%) was recorded in pendimethalin 30 EC @ 1 kg a.i. ha^{-1} as PRE application + HW at 30 DAS + IC at 45 DAS (T_4) and was followed by pendimethalin 38.7 CS @ 1 kg a.i. ha^{-1} as PRE application + HW at 30 DAS + IC at 45 DAS (T_5).

Weed index was significantly lower (16.89%) in treatments which received alachlor 50 EC @ 0.75 kg a.i. ha^{-1} as PRE application + HW at 30 DAS + IC at 45 DAS (T_3) and was followed by quizalofop ethyl 5 EC @ 40 g a.i. ha^{-1} as POE application at 20 DAS + IC at 45 DAS (T_7), butachlor 50 EC @ 1 kg a.i. ha^{-1} as PRE application + HW at 30 DAS + IC at 45 DAS (T_6), pendimethalin 38.7 CS @ 1 kg a.i. ha^{-1} as PRE application + HW at 30 DAS + IC at 45 DAS (T_5) and pendimethalin 30 EC @ 1 kg a.i. ha^{-1} as PRE application + HW at 30 DAS + IC at 45 DAS (T_4). The highest weed index (85.11%) was observed in imazethapyr 10 SL @ 75 g a.i. ha^{-1} as POE application at 20 DAS + IC at 45 DAS (T_8) and was followed by unweeded check (T_1).

6.2 Crop phytotoxicity due to weed control practices

Among the pre-emergence herbicides, application of pendimethalin 38.7 CS @ 1 kg ha^{-1} and pendimethalin 30 EC @ 1 kg ha^{-1} showed slight stunting / discolouration up to 16 DAS and later on the same plants grew normally and other herbicides like alachlor 0.75 kg a.i. ha^{-1} and butachlor 1 kg a.i. ha^{-1} did not cause any injury to sesame.

Among the post-emergence herbicides, application of imazethapyr 10 SL @ 75 g a.i. ha^{-1} as POE at 20 DAS (T_6) recorded severe crop phytotoxicity symptoms but quizalofop ethyl 5 EC @ 40 g a.i. ha^{-1} (T_7) did not have any phytotoxic symptoms on sesame.

6.3 Growth parameters, yield components and seed yield of sesame

Significant differences in growth parameters were also recorded due to weed control treatments. At 30 DAS, plant height, leaf area, leaf area index and dry matter production were significantly higher in weed free check (T_2) and was followed by alachlor 50 EC @ 0.75 kg a.i. ha^{-1} as PRE application + HW at 30 DAS + IC at 45 DAS (T_3) and butachlor 50 EC @ 1 kg a.i. ha^{-1} as PRE application + HW at 30 DAS + IC at 45 DAS (T_6) than unweeded control (T_1). At 60 DAS and at harvest, weed free check (T_2) recorded significantly higher leaf area, leaf area index and dry matter production and was followed by recommended practice (alachlor 50 EC @ 0.75 kg a.i. ha^{-1} as PRE

application + HW at 30 DAS + IC at 45 DAS) and quizalofop ethyl 5 EC @ 40 g a.i. ha^{-1} as POE application at 20 DAS + IC at 45 DAS (T_7). The lowest growth parameters were recorded in imazethapyr 10 SL @ 75 g a.i. ha^{-1} as POE application at 20 DAS + IC at 45 DAS (T_8) and was followed by unweeded check (T_1).

Significant differences were also observed in yield components such as number of capsules per plant, number of seeds per capsule, seed weight per capsule, seed yield, stalk yield and harvest index except 1000 seed weight. All these yield components were significantly higher in weed free check (T_2) and was followed by alachlor 50 EC @ 0.75 kg a.i. ha^{-1} as PRE application + HW at 30 DAS + IC at 45 DAS (T_3) and quizalofop ethyl 5 EC @ 40 g a.i. ha^{-1} as POE application at 20 DAS + IC at 45 DAS (T_7). Significantly lower yield components were recorded in imazethapyr 10 SL @ 75 g a.i. ha^{-1} as POE application at 20 DAS + IC at 45 DAS (T_8) and was followed by unweeded control.

Seed yield per hectare differed significantly due to weed control treatments. Significantly higher seed yield (588 kg ha^{-1}) was recorded in weed free check (T_2) and was followed by recommended practice (T_3) and quizalofop ethyl 5 EC @ 40 g a.i. ha^{-1} as POE application at 20 DAS + IC at 45 DAS (T_6). The lowest (86 kg ha^{-1}) seed yield was observed in imazethapyr 10 SL @ 75 g a.i. ha^{-1} as POE application at 20 DAS + IC at 45 DAS (T_6) and was followed by unweeded control (T_1).

6.4 Economics

Significantly higher net returns (`42,982 $ha^{-1}$) was recorded in weed free check ($T_2$) and was followed by recommended practice *i.e.,* alachlor 50 EC @ 0.75 kg a.i. $ha^{-1}$ as PRE application + HW at 30 DAS ($T_3$) and quizalofop ethyl 5 EC @ 40 a.i. $ha^{-1}$ as POE application at 20 DAS + IC at 45 DAS ($T_7$). The lowest (`-11,816 ha^{-1}) net returns was recorded in imazethapyr 10 SL @ 75 g a.i. ha^{-1} as POE application at 20 DAS + IC at 45 DAS (T_8) and was followed by unweeded check (T_1). Similar trend was also followed for gross returns.

The highest BC ratio (2.56) was recorded in weed free check (T_2) and was followed by quizalofop ethyl 5 EC @ 40 g a.i. ha^{-1} as POE application at 20 DAS + IC at 45 DAS (T_7) which were on par with each other. The treatment quizalofop ethyl 5 EC @

40 g a.i. ha^{-1} as POE application at 20 DAS + IC at 45 DAS (T_7) was on par with recommended practice (T_3).

6.5 Residual effect of weed control treatments on succeeding chickpea

Germination count, crop phytotoxicity ratings and seed yield of chickpea did not differ significantly due to residual effect of herbicides imposed on sesame during *kharif* season.

From the result of this agronomic investigation, the conclusions are as follows.

1. Recommended practice *i.e.*, alachlor 50 EC @ 0.75 kg a.i. ha^{-1} as PRE application + HW at 30 DAS + IC at 45 DAS (T_3) and quizalofop ethyl 5 EC @ 40 g a.i. ha^{-1} as POE application at 20 DAS + IC at 45 DAS (T_7) were found to be more effective in controlling weeds.

2. Application of imazethapyr 10 SL @ 75 g a.i. ha^{-1} as POE application at 20 DAS caused phytotoxicity on sesame.

3. Among the herbicidal treatments, highest BC ratio (2.25) was recorded in quizalofop ethyl 5 EC @ 40 g a.i. ha^{-1} as POE application at 20 DAS + IC at 45 DAS and was followed by recommended practice (T_3) which were on par with each other.

4. Herbicides applied in sesame did not show any kind of phytotoxicity on succeeding chickpea.

REFERENCES

VII. REFERENCES

Anil kumar and Thakur, K. S., 2005, Effects of sowing method and weed control practices on production potential of sesame based intercropping system under rainfed condition. *Indian J. Weed Sci.*, 35 (3 & 4): 236-238.

Anonymous, 2012, Ministry of Agriculture, Govt. of India. www.indiastat.com.

Balasubramanian, R. P., Jayapaul and Mark Devasagayam, M., 1998, Efficacy of herbicides on weed control, productivity and economics of sesame. *Sesame and Safflower Newslett*., 13: 80-83.

Bansode, B. U. and Shelke, D. K., 1991, Integrated weed management in sesamum. *J. Maharashtra Agric. Univ.*, 16(2): 275.

Bartlett, M. S., 1947, Some examples of statistical methods of research in agriculture and applied biology. *Biometrics*, 3:1-2.

Baskaran, R. and Solaimalai, A., 2002, Growth and yield of rice fallow sesame as influenced by weed management practices. *Sesame and Safflower Newslett.*, 17**:** 42-45.

Bhattacharya, S. P., Mondal, L., Pal Debes and Saha, M., 2004, Bio- efficacy of Targa super (Quizalofop-ethyl 5% EC) in controlling weeds of Jute. *Pestology*, 28(4): 32-33.

Bryson, C. T., Kogerlll, C. H. and Byrd, J. D., 2007, Effects of temperature and exposure period to heat on cogongrass (*Imperata cylindrica*). *Weed Tech.*, 21: 141-144.

Chauhan, D. V. S. and Gurjar, B. S., 1998, Mechanical and chemical weed control in sesame *(Sesamum indicum* L.). *Indian J. Agron.*, 43(3): 480-483.

Das, T. K., 2011, *Weed science basics and applications*, Jain brothers publications, New Delhi, India. pp. 405.

Dastane, N. G., 1967, *A Practical Manual for Water Use Research*. Navabharath Prakashan Publication, Poona, India. pp. 5-6.

Dawale, J. S., Zalate, P. Y., Padmani, D. R. and Nikam, D. R., 2009, Effect of weed management practices on yield, yield attributing characters and oil content of sesame *(Sesamum indicum* L.). *Bioinfolet*, 6(4): 331-333.

Donald, C. M., 1962, In search of yield. *J. Aust. Inst. Agric. Sci.*, 28: 171- 178.

Dungarwal, H. S., Chaplot, P. C. and Nagda, B. L., 2003, Integrated weed management in sesame (*Sesamum indicum* L.). *Indian J. Weed Sci.*, 35 (3 & 4): 236-238.

Ghosh, D. C. and Mukhopadhyay, S. K., 1980, Weeds and weed control in sesame. *Pesticides*, 14(11): 24-29.

Gill, V. S. and Vijayakumar, 1966, Weed index: A new method for reporting weed control trials. *Indian J. Agron.*, 14: 96-98.

Gnanavel, I. and Anbhazhagan, R., 2006, Integrated weed management in sesame *(Sesamum indicum* L.). *Agric. Sci. Digest*, 23(1): 67-68.

Jackson, M. L., 1967, *Soil Chemical Analysis.* Prentice Hall of India Pvt. Ltd., New Delhi, PP. 498.

James Grichar, David Sestak, Kevin Brewer, Brent Besler, Charles Stichler and Dudley Smith, 2001, Sesame (*Sesamum indicum* L.) tolerance with various post-emergence herbicides, *Crop Prot*., 20: 685-689.

Joseph, M., Sridhar, P., Hemalatha, M. and Bhaskaran, R., 2006, Integrated weed management in irrigated sesame. *Sesame and Safflower Newslett.*, 21: 51-53.

Kanan, K. and Wahab, K., 1995, Economics of nitrogen and weed management in sesame. *Madras Agric. J.*, 82(2): 154:155.

Kondap, S., M. and Chandrashekhar Rao, 1978, Abstract of papers ISWS/TNAU weed science conference, Coimbatore.

Malam Singh Chandawat, I. and Rathore, M. S., 2004, Herbicidal management of weeds in sesame (*Sesamum indicum* L.). *J. Oilseeds Res.*, 21(1): 95-97.

Mizan Amare, 2011, Estimation of critical period for weed control in sesame (*Sesamum indicum* L.). *Ethiopian J.Appl.Sci.Technol*., 2(1): 59-66.

Mundra, S. L. and Maliwal P. L., 2012, Influence of quizalofop-ethyl on narrow-leaved weeds in blackgram and its residual effect on succeeding crops. *Indian J. Weed Sci.,* 44(4): 231-234.

Nagaraj, 1995, Quality of oilseeds, Directorate of Oilseeds, Hyderabad, India.

Narkhede, T. N., Wadile, S. C., Attarde, D. R. and Suryawanshi, R. T., 2000, Integrated weed management in sesame under rainfed condition. *Indian J. Agric. Res.,* 34(4): 247-250.

Narkhede, T. N., Wadile, S. C., Shinde, Y. M. and Attarde, D. R., 1999, Integrated weed management in sesame under rainfed condition. *Sesame and Safflower Newslett*., 14: 50-54.

Nisha Bhadauria, Asha Arora and Yadav, K. S., 2012b, Effect of weed management practices on seed yield and nutrient uptake in sesame. *Indian J. Weed Sci.,* 44(2): 129–131.

Nisha Bhadauria, Yadav, K. S., Rajput, R. L. and Singh, V. B., 2012a, Integrated weed management in sesame. *Indian J. Weed Sci.*, 44(4): 235–237.

Panse, V. G. and Sukhatme, P. V., 1967, *Statistical Methods for Agricultural Workers*, Indian Council of Agricultural Research, New Delhi.

Parvender Sheoran, Virender Shardana, Sher Singh, Pushp Sharma and Atwal, A. K., 2012, Evaluation of pre-emergence herbicides for weed management in sesame (*Sesamum indicum* L.) under semi arid subtropical conditions. *J. Oilseeds Res.,* 29(1): 53-57.

Piper, C. S., 1966, Soil and Plant Analysis. Academic Press, New York, pp. 236.

Punia, S. S., Mayank Raj, Ashok Yadav and Malik, R. K., 2001, Bioefficacy of dinitroaniline herbicides against weeds in sesame (*Sesamum indicum* L.). *Indian J. Weed Sci.,* 33 (3 & 4): 143-146.

Punia, S. S., Samunder Singh and Dharambir Yadav, 2011, Bioefficacy of imazethapyr and chlorimuron-ethyl in clusterbean and their residual effect on succeeding rabi crops. *Indian J. Weed Sci.,* 43 (1 & 2): 48-53.

Rao, V. S., 1986, *Principles of Weed Science*, Oxfords and IBH Publishing Co., Private Limited, New Delhi, pp. 450.

Rao, K. N. and Narayana Rao, N. K., 1992, Control of weeds with herbicides in gingelly (*Sesamum indicum* L.). Proceedings of the Vth Biennial Conference. Indian Society of Weed Science, Hariyana Agricultural University, Hissar, pp.709.

Sangeetha, C., Chinnusamy, C. and Prabhakaran, N. K., 2012, Efficacy of imazethapyr on productivity of soybean and its residual effect of succeeding crops. *Indian J. Weed Sci.*, 44(2):135-138.

Sestak, Z., Catsky, T. and Saris, P. G., 1971, Plant synthesis production manual of the methods. Dr. Junk, N. V. N. V. Publications. *The Hague*, pp. 343- 382.

Shaner, D. L., Anderson, P. C. and Stidham, M. A., 1984, Imidazolinones: potent inhibitors of acethydroxyacid synthase. *Plant Physiol*., 76: 545-546.

Shukla, V., 1984, Chemical weed control in sesame. *Pesticides*, 18(3): 13-14.

Singh, P. K., Om Prakash and Singh, B. P., 2001, Studies on the effect of nitrogen fertilization and weed control techniques on weed suppression, yield and nutrient uptake in sesame (*Sesamum indicum* L.). *Indian J. Weed Sci.*, 33 (3&4): 143-146.

Sootrakar, B. P., Namdeo, K. N. and Khare, L. J., 1995, Effect of weed control on productivity of sesame (*Sesamum indicum* L.). *Indian J. Agron*., 40(3): 454-458.

Subbaiah, B. Y. and Asija, G. L., 1956, A rapid procedure for the estimation of available nitrogen in soils. *Curr. Sci.*, 25: 259- 260.

Subramanian, A. and Sankaran, S., 1978, Effect of herbicides on nutrient removal by weeds in sesame and its impact on seed production. All India Weed Science Conference, Abstract No.42.

Sukhadia, N. M., Ramani, B. B., Mathukia, R. K. and Khanpara, V. D., 2004. Integrated weed management in *Kharif* sesame. *Indian J. Weed Sci.*, 36 (3 & 4): 239-242.

Umarao Singh, 1958, Plants in ancient India. *The Botanica*, Delhi University, 9: 43-45.

Venkatakrishnan, A. S. and Gnanamurthy, P., 1998a, Influence of varying period of crop weed competition in sesame. *Indian J. Weed Sci.*, 30 (3 & 4): 143-146.

Venkatakrishnan, A. S. and Gnanamurthy, P., 1998b, A preliminary evaluation of herbicides on the control of weeds in irrigated sesame. *Sesame and Safflower Newslett.*, 13: 77-79.

Vishnu Shukla, 1984, Chemical weed control in sesame. *Pesticides*, 13-14.

Vivekanandan, A. S., Gunasena, H. P. M. and Sivananyagam, T., 1972, Statistical evaluation of accuracy of three techniques used in estimation of leaf area of crop plants. *Indian J. Agric. Sci.*, 42: 857- 860.

Watt, G., 1893, Dictionary of economic products of India, Government of India, Central printing office, Culcutta.

APPENDIX

APPENDIX – I

Price of inputs and outputs (as per the prevailing market prices) during 2013-2014

Sl. No.	Particulars	Unit	Price (Rs.)
A.	**Input**		
I.	Seed	1 kg	120
II.	Fertilizer		
	1) Urea	kg	5.50
	2) DAP	kg	23
	3) Muriate of potash	kg	7.50
III.	Labour		
	1) Men	Day	236
	2) Women	Day	236
	3) Bullock pair	Day	500
IV	Plant protection chemicals		
	1) Chlorphyriphos	1 litre	384
	2) Confidor	1 litre	2800
	3) Acephate	250 g	125
	4)Triazophos	500 ml	240
V	Herbicides		
	1) Alachlor 50 EC	1 litre	400
	2) Butachlor 50 EC	500 ml	169
	3) Pendimethalin 30 EC	1 litre	375
	4) Pendimethalin 38.7 CS	1 litre	550
	5) Quizalofop ethyl 5EC	500 ml	700
	6) Imazethapyr 10 SL	1 litre	1905
B.	**Output**		
I	Seed (sesame)	q	12000

CHEMICAL WEED MANAGEMENT IN SESAME (*Sesamum indicum* L.)

MRUTHUL, T. **2014** **Dr. A.S. HALEPYATI**
MAJOR ADVISOR

ABSTRACT

The field experiment was conducted at College of Agriculture Farm, Raichur on medium black soil during *kharif*, 2013 to study chemical weed management in sesame (*Sesamum indicum* L.). The experiment was laid out in Randomized Block Design (RBD) with eight treatments and three replications. Pre-emergent application of alachlor 50 EC @ 0.75 kg a.i. ha^{-1}+ HW at 30 DAS + IC at 45 DAS recorded significantly lower weed population (6.53/m^2), weed dry weight (1.80 g/m^2) and higher weed control efficiency (74.24%) at harvest compared to other treatments. Severe crop phytotoxic symptoms were recorded due to the spray of imazethapyr 10 SL @ 75 g a.i. ha^{-1} as POE at 20 DAS. Among the herbicidal treatments, alachlor 50 EC @ 0.75 kg a.i. ha^{-1}as PRE application + HW at 30 DAS + IC at 45 DAS recorded significantly higher yield components *viz*., number of capsules per plant (29.00), number of seeds per capsule (34.33), seed weight per capsule (0.14 g) and seed yield (480 kg ha^{-1}) when compared to all other treatments but it was on par with quizalofop ethyl 5 EC @ 40 g a.i. ha^{-1} as POE application at 20 DAS + IC at 45 DAS. Weed free check recorded significantly higher uptake of nutrients (39.33, 22.33 and 55.40 NPK kg ha^{-1}) and was followed by pre-emergence application of alachlor 50 EC @ 0.75 kg a.i. ha^{-1} + HW at 30 DAS + IC at 45 DAS. Germination count, crop phytotoxicity ratings and seed yield of chickpea did not differ significantly due to residual effect of herbicides imposed on sesame during *kharif* season.

Weed free check recorded significantly higher net returns (₹42,982 ha^{-1}) followed by recommended practice *i.e.*, alachlor 50 EC @ 0.75 kg a.i. ha^{-1} as PRE application + HW at 30 DAS + IC at 45 DAS (₹29,482) and quizalofop ethyl 5 EC @ 40 g a.i. ha^{-1} as POE application at 20 DAS + IC at 45 DAS (₹27,332). The highest BC ratio (2.56) was obtained from weed free check followed by quizalofop ethyl 5 EC @ 40 g a.i. ha^{-1} as POE application at 20 DAS + IC at 45 DAS (2.25).