BIOEFFICACY EVALUATION OF HALOSULFURON METHYL, CHLORIMURON ETHYL AND THEIR COMBINATION FOR WEED MANAGEMENT IN SUGARCANE AND ITS RESIDUAL EFFECT ON SUCCEEDING CROPS

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

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CERTIFICATE

This is to certify that the thesis entitled **BIOEFFICACY EVALUATION OF HALOSULFURON METHYL, CHLORIMURON ETHYL AND THEIR COMBINATION FOR WEED MANAGEMENT IN SUGARCANE AND ITS RESIDUAL EFFECT ON SUCCEEDING CROPS** submitted in part fulfillment of the requirements for the award of the degree of **DOCTOR OF PHILOSOPHY (AGRICULTURE)** in **AGRONOMY** to the Tamil Nadu Agricultural University, Coimbatore is a record of bonafide research work carried out by **Mrs. M. SUGANTHI** under my supervision and guidance and that no part of this thesis has been submitted for the award of any other degree, diploma, fellowship or other similar titles. However, part of the thesis work has been published in peer reviewed scientific journal of national / international repute (copy enclosed).

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[M. SUGANTHI]

Abstract

ABSTRACT

BIOEFFICACY EVALUATION OF HALOSULFURON METHYL, CHLORIMURON ETHYL AND THEIR COMBINATION FOR WEED MANAGEMENT IN SUGARCANE AND ITS RESIDUAL EFFECT ON SUCCEEDING CROPS

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Field experiments were conducted at Tamil Nadu Agricultural University, Coimbatore during main 2011-12 and late season 2012-13 to study the bioefficacy evaluation of halosulfuron methyl, halosulfuron methyl + chlorimuron ethyl and chlorimuron ethyl at different doses for control of weeds and on the selectivity, growth and yield of sugarcane and also their residual effect on succeeding crops.

The treatment consisted of test herbicides such as, halosulfuron methyl (45, 67.5, 90 and 135.5 g a.i. ha^{-1}), halosulfuron methyl + chlorimuron ethyl (45, 67.5, 90 and 135.5 g a.i. ha^{-1}) and chlorimuron ethyl (6, 9, 12 and 18 g a.i. ha^{-1}) along with registered formulation of atrazine 1.0 kg a.i. ha^{-1}, hand weeding on 30 DAP followed by earthing up on 60 DAP and unweeded control. There were totally fifteen treatments. The experiment was laid out in a randomised block design replicated thrice. The terminal residue of test herbicides in soil was estimated.

The weed flora of the experimental fields was dominated by broad leaved weeds in both main and late seasons. Major broad leaved weeds of the experimental fields were *Trianthema*

portulacastrum, Digera arvensis, Amaranthus viridis, Cleome gynandra, Partheneium hysterophorus and *Datura fastuosa.* Predominant grassy weeds found in the experimental site were *Dactyloctenium aegyptium, Echinochloa colonum, Setaria verticillata* and *Dinebra retroflexa. Cyperus rotundus* was the only dominant sedge weed observed in the experimental fields.

Among the herbicide treatments, halosulfuron methyl + chlorimuron ethyl at 135.5 g a.i. ha^{-1} markedly suppressed the weed growth. Halosulfuron methyl + chlorimuron ethyl at 90 g a.i. ha^{-1}, chlorimuron ethyl at 18 and 12 g a.i. ha^{-1}, atrazine at 1.0 kg a.i. ha^{-1}, hand weeding on 30 DAP were the next best treatments comparable with halosulfuron methyl + chlorimuron ethyl at 135.5 g a.i. ha^{-1}. Weed dry weight was also lower with halosulfuron methyl + chlorimuron ethyl at 135.5 g a.i. ha^{-1} followed by halosulfuron methyl + chlorimuron ethyl at 90 g a.i. ha^{-1}, chlorimuron ethyl at 18 and 12 g a.i. ha^{-1}, atrazine at 1.0 kg a.i. ha^{-1} and hand weeding on 30 DAP.

Visual phytotoxicity was not noticed for the test herbicides even at higher doses. Early post emergence application of halosulfuron methyl + chlorimuron ethyl at 135.5 g a.i. ha^{-1}, halosulfuron methyl + chlorimuron ethyl at 90 g a.i. ha^{-1}, chlorimuron ethyl at 18 and 12 g a.i. ha^{-1}, atrazine at 1.0 kg a.i. ha^{-1}, hand weeding on 30 DAP enhanced the growth components like plant height, tiller production, leaf area and plant dry matter production. The yield components like cane length, individual weight, internode length, number of internodes and cane girth were also higher with the test herbicides at higher doses during both the seasons of study, through reduced weed growth, restricted nutrient depletion by weeds and increased nutrient uptake by the crop.

The cane and sugar yields were higher with halosulfuron methyl + chlorimuron ethyl at 135.5 g a.i. ha^{-1} followed by halosulfuron methyl + chlorimuron ethyl at 90 g a.i. ha^{-1}, chlorimuron ethyl at 18 and 12 g a.i. ha^{-1}, atrazine at 1.0 kg a.i. ha^{-1}, hand weeding on 30 DAP followed by earthing up on 60 DAP in both the years of study. The test herbicides at lower doses recorded significantly lesser cane and sugar yields. Unweeded control recorded the least cane yield. Lower doses of test herbicides did not hold promise for weed management in sugarcane. Subleathal doses might be less effective for the control of weed species occurred in the field.

Weed management practices did not have any significant influence on the quality characters like brix, sucrose percent, purity coefficient and commercial cane sugar percent during both the year of study. The test herbicides at higher doses showed a detrimental effect on soil bacteria, fungi and actinomycetes and reduced the microbial population in herbicide treated plots at 1, 15, 30 and 60 DAHS. Microbial density started to recover slowly after 60 days of their application.

Halosulfuron methyl + chlorimuron ethyl at 135.5 and 90 g a.i. ha^{-1}applied plots recorded lower density of total weeds at a depth of 0-15 cm and 15-30 cm and this was comparable with chlorimuron ethyl at 18 and 12 g a.i. ha^{-1}, atrazine at 1.0 kg a.i. ha^{-1}, hand weeding on 30 DAP in both the years of study. Succeeding crops like pearl millet and sunflower sown immediately after the harvest of sugarcane were not affected by the residue of test herbicides even at higher doses.

Considering the economic indices, highest B:C ratio and net income were realised with early post emergence application of halosulfuron methyl + chlorimuron ethyl at 135.5 g a.i. ha^{-1}. This was comparable with halosulfuron methyl + chlorimuron ethyl at 90 g a.i. ha^{-1}, chlorimuron ethyl at 18 and 12 g a.i. ha^{-1}, atrazine at 1.0 kg a.i. ha^{-1}, hand weeding on 30 DAP in both the years of study. The B:C ratio was less with test herbicides at lower doses and unweeded control. The terminal residues of halosulfuron methyl, chlorimuron ethyl in soil samples were below the maximum residual limit.

From the results, it could be concluded that in sugarcane, the weeds could be effectively and economically managed by early post emergence application of halosulfuron methyl + chlorimuron ethyl at 135.5 and 90 g a.i. ha^{-1} at 2-3 leaf stage of weed followed by partial earthing up at 60 DAP. Chlorimuron ethyl at 18 and 12 g a.i. ha^{-1}, atrazine at 1.0 kg a.i. ha^{-1}, hand weeding on 30 DAP are also comparable with herbicide combination of halosulfuron methyl + chlorimuron ethyl at 135.5 and 90 g a.i. ha^{-1}.

Thus, early post emergence application of halosulfuron methyl + chlorimuron ethyl at 90 g a.i. ha^{-1} is found to be the alternative as early post emergence herbicide combination to achieve effective control of sedges and broad leaved weeds besides realizing higher yields and economic returns in sugarcane.

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ACRONYMS AND ABBREVIATIONS USED

%	-	Percentage	LAI	-	Leaf area index
^0C	-	Degree Celsius	l ha^{-1}	-	Litre per hectare
^0N	-	Degree North	m^{-2}	-	Per square metre
^0E	-	Degree East	Max.	-	Maximum
‘000 ha^{-1}	-	Thousands per hectare	Min.	-	Minimum
µg g^{-1}	-	Microgram per gram	Max. Temp.	-	Maximum temperature
a.i	-	Active ingredient	Min. Temp.	-	Minimum temperature
AD	-	Absolute density	N	-	Nitrogen
B:C	-	Benefit cost Ratio	NMC	-	Number of millable cane
BLW	-	Broad leaved weeds	No. m^2	-	Number per meter square
cal $cm^{-2}day^{-1}$	-	Calories per centimeter square per day	NS	-	Not significant
CD	-	Critical difference	P	-	Phosphorus
CGR	-	Crop growth rate	P_2O_5	-	Diphosphorus Pentoxide
RGR	-	Relative growth rate	PE	-	Pre-emergence
CFU	-	Colony forming unit	pH	-	Negative logritham of hydrogen ion
CCS	-	Commercial cane sugar	EPOE	-	Early Post emergence
cm	-	Centimetre	ppm	-	parts per million
DAHS	-	Days after herbicide spray	dSm^{-1}	-	Decisiemen per meter
DAP	-	Days after planting	EC	-	Emulsifiable concentrate

DAS	-	Days after sowing	RBD	-	Randomized Block Design
DMP	-	Dry matter production	EPA	-	Environmental Protection Act
et al.,	-	Co-workers	RD	-	Relative density
Fig.	-	Figure	RH	-	Relative humidity
GA_3	-	Gibbrelic Acid	Rs.	-	Rupees
g g^{-1} day^{-1}	-	gram per gram per day	RF	-	Rainfall
g l^{-1}	-	Gram per litre	SEd	-	Standard error of deviation
g m^{-2} day^{-1}	-	gram per square metre per day	sp.	-	Species
ha	-	Hectare	Sq.	-	Square
ha^{-1}	-	Per hectare	U.S.A.	-	United States of America
HW	-	Hand weeding	viz.,	-	Namely
K	-	Potassium	WCE	-	Weed control efficiency
K_2O	-	Di potassium oxide	WI	-	Weed index
kg ha^{-1}	-	Kilograms per hectare	wt	-	weight

Introduction

CHAPTER I

INTRODUCTION

Sugarcane (*Saccharum officinarum.* L.) crop occupies an important position in Indian agriculture. It is the most important and celebrated crop cultivated widely in India since time immemorial (Lal *et al*., 2006). It is the second largest organized cane based agro industry in the country next to textile. It employs over 40 million cane growers and about 3.5 lakh skilled and unskilled workers. Sugarcane is grown in not less than 105 countries and presently it covers a total acreage of about 19 million hectares for a world production of approximately 1.3 billion tonnes of cane and 127 million tonnes of sugar. Today, India maintains the second position, next to Brazil in terms of production (Shrivastava *et al*., 2011).

In India, sugarcane is grown in about 4.5 million hactare with an average productivity of 68 tonnes ha^{-1}. The average sugar production in the country is in the range of 18-20 million tonnes while the present annual requirement of sugar is about 23 million tonnes. Our country shares about 13.25 per cent of the World and 41.1 per cent of Asian sugar production. The estimated requirement of sugar by 2025 is 32.5 million tonnes for which cane production should be around 455 million tonnes with 11 per cent sugar recovery. Among the states, Uttar Pradesh ranks first in area (45 per cent) and Maharashtra ranks first in sugar production and Tamil Nadu ranks first in productivity (Nair, 2011).

In Tamil Nadu, sugarcane is cultivated in an area of 3.22 lakh hactare with a production of 30.03 million tonnes and productivity of 105 tonnes ha^{-1}. Among the sugarcane growing states of the country, Tamil Nadu occupies fifth and third place in total sugarcane area and production, respectively. It is an important commercial crop of the state and contributes around 10 per cent of the total sugar production of the country (Anon, 2009a). The reasons for low yield of sugarcane includes improper land preparation, conventional planting methods, less than recommended seed rate, heavy weed infestation, shortage of irrigation water, imbalanced fertilizer application, less support price, lack of coordination between growers and mill owners, natural calamities, delayed harvesting, pests and disease incidence, poor management of ratoon crop and salinity. Among the various factors limiting cane production, weed infestation is one of the major biotic constraints in sugarcane production (Malik and Gurmani, 2005).

The weeds germinate before the crop and become good competitor for the sugarcane crop. Because of wider spacing (60 to 90 cm row distance), slow germination at initial growth, heavy fertilization and frequent irrigations in sugarcane, weeds pose serious threat. The extent of loss in cane yield caused by weeds is from 10 per cent to total crop failure depending upon composition and diversity of weeds (Srivasatva and Chauhan, 2002).

Due to weed infestation, the yield loss in sugarcane was reported to be 40 to 60 per cent (Khan *et al*., 2004a). It also causes more economic loss in sugarcane than all the other pests put together. It reduces tonnage in the field, sucrose recovery in the mills and ratoon crop lifecycle (Kathiresan *et al.*, 2004). Weeds compete throughout the life cycle of main crop, but, it is more sensitive to presence of weeds at a specific period during its life cycle. It is known as critical period of weed-crop competition. The critical period of crop-weed competition has been recorded to be 60-120 days after planting in spring cane and 150 days in autumn cane (Singh *et al*., 2011). Therefore, it is imperative that the crop is to be provided with weed free environment during the critical period for enhanced productivity.

Weed management is an essential agronomic intervention in sugarcane production. Hoeing not only controls the emergence of weeds, but also, improves physical condition of soil which facilitates profuse cane root development and soil aeration. However, factors like inclement weather and non availability of labour for timely weeding may cause undue delay in weeding operations and thus resulting in yield losses. Hence, early control of weeds could be achieved through the use of herbicides.

A relatively weed free environment during early stages of crop growth can be better ensured by the use of pre-emergence herbicides that control weeds right at germination itself. Chemical weed control is time saving and easier. Serrated leaf margin in sugarcane makes hand weeding and other cultural and mechanical methods more difficult. Weed management through herbicides is also economical and can be adopted in a situation where scarcity of agricultural labour exists. Weed management through herbicides will be of great help in crop production in the present context of energy shortage and reducing the loss of non-renewable costly inputs applied under intensive agriculture.

Due to variation in selectivity of the herbicides, some of the weeds are not controlled and becoming more competitive. Usage of herbicides also influence the species composition of the weed seed bank and may increase or decrease it, depending on the chemicals used (Ball, 1992).

While applying herbicides, it is important to consider the herbicide dose. However, leathal dose may cause build up of herbicide residue in the soil and it leads to loss of herbicide selectivity. Leathal dose may be toxic to plants by way of inhibiting the photosynthesis and nitrogen metabolism.

When herbicides are applied, most of the spray solution contacts the soil and affect soil microorganisms that are important while fixing the dose of the chemical. It is important for sustainable agriculture, recycling of plant nutrients and maintenance of soil structure (Rosana *et al.*, 2007). In economic point of view, chemical weeding is inevitable. It is also necessary to consider the cost of chemical while using the herbicides. Considering these aspects, there is a need for time to time selection of more efficient herbicide and it's effective optimum dose, that offers selective and economical control right from the beginning, giving the crop an advantage of a good head start and competitive superiority over weeds.

The over dependence and over use of one single herbicide or herbicides having the same mode of action may result in the development of resistance in weeds and build up residue in the soil by long term continuous annual use of the same herbicide. Residual toxicity of herbicides on the succeeding crops is the main constraint in the use of chemical weed control (Grichar *et al*., 2003). An ideal herbicide should provide the required period of weed control and then should be degraded into innocuous products. However, sometimes herbicides persist in the soil beyond harvest and cause residual effect on subsequent crops. Besides, some quantity are also taken by crop plants and accumulated in the crop produce as residues.

Currently for sugarcane, the triazine group of herbicides are being used for weed control as pre emergence herbicides. The herbicides belonging to this group like atrazine are effective against certain grasses and broad leaved weeds and not effective against sedges. The pre emergence herbicides are soil active herbicides which are used against germinating weeds and the late emerged weeds are left uncontrolled. In this context, there is need to evaluate new formulation of herbicides which are selective in sugarcane for broad spectrum control and also for application as early post emergence herbicide.

Keeping these views in mind, field experiments were taken up to evaluate the new early post emergence herbicides halosulfuron methyl and chlorimuron ethyl and their combination along with atrazine herbicide for weed management in sugarcane with the following objectives.

- To evaluate the bio efficacy and phytotoxicity of halosulfuron methyl, chlorimuron ethyl and their combination in sugarcane,
- To study the effect of weed management practices on growth, development and productivity of sugarcane,
- To study the weed seed bank as influenced by weed management practices,
- To evaluate the economics of different weed control practices and
- To assess the residual effect of herbicide on the succeeding crops like sunflower and pearlmillet.

Review of Literature

CHAPTER II

REVIEW OF LITERATURE

Sugarcane is the most adaptable plant under sub-tropical and tropical conditions. In tropical agriculture weeds are the major threat in crop production which affects the crop yields considerably (Baloch *et al*., 2002; Malik and Gurmani, 2005). Among the C_4 group of plants, sugarcane (*Saccharum officinarum* L.) is one of the most efficient crops. Converting efficiency of solar radiation into photosynthates is relatively higher in sugarcane than any other crops evolved. In India, sugarcane is one among the leading commodities in trade. There is a wide yield gap in productivity between the tropical and sub tropical regions of the country. The average productivity in tropics is around 80 t ha^{-1}, where in the sub tropics it is around 50 t ha^{-1}. Many sugarcane workers have reported that there is a wide yield gap between the actually harvested and estimated potential and the gap is estimated to be around 20.3 per cent (Singh *et al*., 2009 and Nair, 2011).

Crops and weeds have similar requirements for growth and development. Competition begins when crop and weeds are grown in close proximity to one another and supply of necessary growth factor falls below the demands of the both. Sugarcane crop, being of long duration, takes more time to cover the space between the rows and slow initial growth habit leads to more acute weed problem. The yield loss due to weed infestation was estimated as around 75 per cent (Singh and Moolani, 1975; Shafi *et al*., 1994). Kadam *et al*. (2011) reported that the reduction in cane yield due to weeds ranged from 40 to 60 per cent.

In Tamil Nadu due to weed infestation, the yield loss in cane crop was also estimated to be between 40 and 60 per cent (Kathiresan *et al*., 2004) which resulted in more economic loss in sugarcane than all other pests put together. It reduces tonnage in the field, sucrose recovery in the mills and shortened ratoon crop lifecycle. However, the yield loss depends upon the weed intensity and stage of the infestation. A brief review of literature on weed flora, critical period of crop-weed competition, their competitive effect on growth, yield and nutrient uptake of sugarcane as well as on different methods of weed control and herbicide residues in the soil and crop produce are presented here under.

2.1. Weed flora of sugarcane

Identifying and understanding of weed community associated with sugarcane crop is essential for the successful weed control programme. Weed flora differ widely in their diversity depending upon environmental and soil factors and hence, the information on the type of weed spectrum occurrence in sugarcane fields is necessary for the formulation of effective and appropriate management practices. He also reported that, the weed population in sugarcane field was composed of 41 per cent broad-leaved weeds, 36 per cent grasses and 23 per cent sedges (Drost *et al*., 1983).

In spite of the wide variation around two hundred weed species have been reported to infest the sugarcane fields, the number of species that constitute the major portion of the weed flora causing economic concern to the grower was usually lesser than ten species (Moody and Drost, 1983). However, in India, about 63 weed species belonging to 29 families were found to occur in sugarcane (Jeyaraman *et al*., 2002). The type and number of weed species vary from country to country due to varied climatic, edaphic and biotic factors. Losses up to 40 per cent of cane yield were reported by different types of weed population. Johnson grass and tall perennial grasses decreased cane yield by 36 per cent and sugar yield by 31 per cent compared to weed-free sugarcane fields (El-Shafai *et al*., 2010).

Broad leaved weeds accounted for 62 per cent and the remaining 38 per cent was of monocot weeds. Among the weed species, *Panicum repens, Cynodon dactylon, Imperata cylindrica, Ipomea hardwichia* and *Cyperus rotundus* are perennial weeds which are propagated by the vegetative organs, even though they produce sterile seeds. Such species adapt themselves in both the lowland and upland conditions (Halmie *et al*., 1994). *Cynodon dactylon, Phalaris arundinacea, Cyperus esculentus, Phyllanthus tenellus, Cyperus rotundus, Digitaria horizontalisi, Portulaca oleracea, Alternanthera sessilis, Solanum nigrum* and *Mimosa pudica* were the major weed species observed in sugarcane fields of Mauritius islands (Samoo and Barbe, 1998).

Purple nut sedge (*Cyperus rotundus*) was found to be the predominant weed species in sugarcane crop (Kuva *et al*., 2000). *Cynodon dactylon, Cyperus rotundus, Panicum millaceum, Portulaca oleracea, Trianthema monogyna, Convolvulus arvensis* and *Xanthium strumarium* were the major weed of Indian Institute of Sugarcane Research, Lucknow (Chauhan and Srivastava, 2002). In well drained sandy soil, the weed species found in sugarcane crop were *Cynodon dactylon, Cyperus rotundus, Panicum repens, Portulaca quadrifida* and *Trianthema portulacastrum* (Asokan and Mahadevaswamy, 2003). Durigan (2005) reported that the purple nutsedge population of 58 to 246 shoots m^{-2} reduced sugarcane yield by 14 per cent and a shoot populations of 675 to 1198 m^{-2} reduced sugarcane yield by 45 per cent. The common weed flora observed in the ratoon sugarcane crop were *Cyperus rotundus*, *Cynadon dactylon*, *Sporobolus* sp., *Digitaria sanguinalis, Trianthema portulocastrum, Amaranthus viridis, Gyanandropsis pentaphylla*, *Cleome viscosa*, *Euphobia hirta* and *Tridax procumbens. Cyperus rotundus* among sedges and *Trianthema portulocastrum* and *Cleome viscosa* among dicots were predominant and these species occupied about 70 per cent of the total weed density **(**Chitkala devi *et al*., 2010). *Cyperus rotundus, Dactyloctenium aegyptium* and *Trianthema portulocastrum* were the major weeds observed in Sugarcane Breeding Institute Karnal (Singh *et al*., 2011).

Khan and Hashmi (1987) reported that *Anagallis arvensis*, *Chenopodium album*, *Amaranthus spinosis*, *Medicago sativa*, *Ranunculus muricatus*, *Fumaria polymorpha*, *Sonchus aspera, Conyza bonariensis*, *Cyperus rotundus*, C*ynodon dactylon* and *Elusine indica* were the major weeds reported in sugarcane field of India. Vasuki (2005) reported that in Tamil Nadu, C*ynodon dactylon, Dactyloctenium aegyptium, Echinochloa colonum, Cyperus rotundus*, *Commelina benghalensis*, *Cleome viscose, Eclipta alba* and *Trianthema portulacastrum* were the major weeds. At Coimbatore, the major weed flora of the sugarcane field was *Trianthema portulacastrum, Portulaca quadrifida, Corchorus olitorius, Datura fastuosa, Digera arvensis Cyperus rotundus*, C*ynodon dactylon, Dactyloctenium aegyptium, Chloris barbata* and *Setaria verticillata* were the major weeds (Kalaiyarasi, 2012).

2. 2. Crop weed competition

2.2.1. Critical period of weed competition

Weeds compete with cultivated crops for growth factors (water, light, nutrients and space), and harbour pests and plant pathogens. Knowledge and through understanding on the critical period of the crop weed competition is essential to formulate the suitable weed management practices for enhancing the productivity of sugarcane.
The competition depends upon the crops stand and weed population as well as competition period. The critical period of weed competition is the shortest time span during the crop growth

when weeding results in highest yield and economic returns. The initial period of weed competition starts with beginning of interference from weeds and ends when crop covers 80 per cent of soil. Singh and Singh (1979) concluded that weed crop competition is effective for 120 days of crop growth and zero weed crop competition for the first 120 days of growth period enhanced cane yield by 45 per cent. However, after 120 days, zero competition was not advantageous.

Lakshmikantham (1983) reported that weed crop competition for first two months (60 days) after sowing the crop reduced cane yield by 8.0 per cent at harvest over weed free. Srinivasan *et al*. (1981) and Srinivasan (1988) reported that the critical period of weed competition was greater up to 96 days after planting. The critical period of the weed competition was found to be high up to 120 days of crop growth as reported by Singh and Pant (1987). Khan and Hashmi (1987) observed that sugarcane can tolerate 3-4 weeks of weed competition and yield was reduced when weeds competed with crop beyond 8-9 weeks after crop emergence. Early control of weeds from the crop fields resulted in greater number of tillers, plant height and cane yield. Early season weed competition (up to 6 weeks) resulted in 9-39 per cent reduction in sugar yield (Millhollon, 1988).

Once the sugarcane crop attained one metre height (150 DAP) with 12 to 15 leaves, it has the capacity of smothering the weeds (Lal, 1990). Nayyar *et al*. (1994) revealed that 86.7 t ha^{-1} cane yields was obtained from weed free duration up to 90 days, closely followed by weed free duration up to 56 days with an average yield of 80 t ha^{-1}. Rao *et al*. (1995) stated that when the weeds were not removed within the first three months, the cane and sugar yields were reduced by 34.9 and 5.4 t ha^{-1}, respectively. The review indicated that during the crop growth period, the first three or four months period is the critical period for the crop-weed competition.

In a sugarcane field, where the purple nut sedge (*Cyperus rotundus*) was predominant weed species, weed crop competition started even at the initial sugarcane sprouting stage. However, the purple nut sedge is very sensitive to sugarcane canopy shading and low temperature. Hence, competitions ended at 22 DAP (Kuva *et al*., 2000).

The length of critical period of weed competition depends on the nature of crops, its competitive ability, variety, growth habit, field conditions and planting techniques.

As plant grows, leaf area index and root density increase, leading to mutual interference in the absorption of one or more growth factors (Reddy and Reddi, 2002). In India, it is reported that critical period of weed crop competition in sugarcane ranged between 27 and 50 days (Srivastava, 2003).

Sugarcane field that was kept weed free up to 150 DAP gave higher cane height, number of millable canes ha^{-1}, cane yield, C.C.S. as well as higher economic returns (Patel *et al*., 2007). Weeds compete throughout the life cycle of main crop, but it is more sensitive to presence of weeds at a specific period during which it causes maximum yield losses. It was reported that critical period of weed crop competition in sugarcane ranged between 100 to 105 days (Zafar *et al*., 2010).

2.2.2. Competition of weeds for moisture

Mustafee and Ray (1976) stated that the weeds utilized a sizable amount of soil moisture and transpired it. Thus, the weeds consumed large quantities of water during their vegetative growth phase and their control at early crop growth stages is an important factor in moisture conservation.

Generally, it is estimated that for the production of one tonne of cane, 200 to 250 tonnes of water are required (SBI, 1987). Sugarcane requires frequent irrigation and high dose of fertilizers during the early growth phase, which provided favorable growth condition for the weed seeds for germination and further growth (Rao *et al*., 1989). Weeds absorb more soil moisture and removed as much as 750 to 1250 tonnes of water in one hectare of land (Srivastava and Chauhan, 2002).

Sugarcane required about 30-40 irrigations on an average. In early stage of crop growth (45 DAP) frequent irrigation increased the weed density and weed dry weight and the optimum moisture level is 50 per cent ASM (Jeyaraman *et al*., 2002). Since weeds remove more amount of moisture from the soil, number of irrigations need to be increased. To conserve the moisture, advanced irrigation methods need to be adopted (Nair, 2011).

2.2.3. Competition of weeds for nutrients

Nitrogen removal by weeds in sugarcane field was to the tune of 40 kg ha^{-1} in unweeded control plot (Chauhan *et al*., 1984). According to Srinivasan (1988), the weeds removed four times of N and P and two and half times of K as that of the sugarcane crop during the period of first seven weeks. Chinnusamy (1990) also reported that a higher quantity of NPK was removed from unweeded control plot compared to the herbicide treated plot. A quantity of 86.4 kg of N, 19.1 kg of P_2O_5 and 97.2 kg of K_2O ha^{-1} was removed by the weeds from one hectare of sugarcane within 90 days (Sathyavelu, 1990).

Honyal and Raddar (1994), Peeples (1995) and Gouthaman (1997) reported that the application of herbicides reduced the nutrient uptake of weeds in sugarcane. Amount of major nutrients removed by the weeds has got direct influence on the availability of the same to the main crop and in turn to the cane yield. Management practices that would minimise the nutrient loss through the weeds have got added advantage in obtaining better return. At all stages of crop growth, unweeded control registered the highest NPK removal (Janagarathinum, 2004) The unweeded control treatment recorded higher NPK removal as compared to herbicidal weed control method (Vasuki, 2005). Kalaiyarasi (2012) also reported that nutrient removal by weeds in unweeded control was 47.4 per cent higher than the herbicide treated plot.

2.2.4. Competition of weeds for light and space

It was reported that the weeds especially, those with large and coarse leaves restrict the photosynthetic activity of the crop by shading (Crafts and Robbin, 1973). Since sugarcane is having initial slow growth and germination phase took about 30 days and then two months period to cover the ground by foliage and during this period the soil nutrient, space and light left as unutilised by the crop were utilized effectively by the weeds (Rao *et al*., 1995).

In unweeded control, growth parameters were lower and it was due to the competition for light and space between the crop and weeds (Sharma and Gupta, 2010). Weeds compete with the crop more efficiently for light, moisture and nutrients at initial stage of the crop compared to later stage. It is due to initial slow growth of sugarcane crop (Kadam *et al*., 2011).

2.3. Weed competition and crop growth

The competitive ability of weeds can be understood clearly by studying growth pattern of crop and weeds under cropped conditions. Mehra *et al*. (1989) reported that the sugarcane crop suffered more from weed competition during initial stages of growth because of the slow emergence and growth of the cane shoot during the early stage. Control of weeds is an important component of its management. In its early stages, sugarcane germinated and grown very slowly, while weeds show a rapid growth due to the lack competition from the crop (Cheema *et al*., 2010)

2.3.1. Effect of weeds on germination

Significant reduction in germination of sugarcane due to the weed infestation was reported by Chinnusamy (1982). Heavy infestation of weeds found to reduce the germination of buds by 53 per cent (Sathyavelu, 1990). Similarly, Umarhatha (1997) reported that the heavy infestation of weeds was found to reduce the germination of buds by 25.9 per cent. Germination percentage was slightly lesser in unweeded control plot compared to herbicide applied plot (Kalaiyarasi, 2012).

2.3.2. Effect of weeds on tillering and millable cane production

Weed infestation caused considerable reduction in tiller production (Rao *et al*., 1989; Chitkala and Rao, 1990; Sathyavelu, 1990). Salunkhe *et al.* (1990) stated that the tillering ratio was only 2.78 in the unweeded plot, whereas, it was 3.91 in the hand weeded plot. An inverse relationship between the weed population and number of millable cane was established with a loss of 45.5 per cent in the number of millable cane population due to the weed infestation.

In north Indian condition (Punjab) there was a reduction of tillers (63.4 %) in unweeded control compared with the best treatment of application of atrazine @ 2.0 kg a.i. ha^{-1}. Likewise the number of millable cane also higher in herbicide treated plots compared with unweeded control (Singh *et al*., 2001). There was a loss of 40 per cent in the number of millable cane population due to weed infestation (Sathyavelu *et al*., 2002). Chauhan and Srivastava (2002) observed in reduction of number of millable canes and cane yield, where weeds were allowed to compete with the crop beyond initial 30 days in sugarcane. Number of millable cane was lower (90.4) in control plot, where as it was higher in hand weeded plot (135.7) (Sharma and Gupta, 2010).

2.3.3. Effect of weeds on growth

Weed infestation affected the production of leaves, the length and width of leaf blades, the formation and elongation of the internodes resulted in the stunted growth and lesser dry matter production (Chitkala and Rao, 1990). Salunkhe and Gaur (1990) reported that the cane height observed in the unweeded plot was only 207.8 cm, whereas, it was 259.73 cm in the hand weeded plot.

Singh *et al.* (2001) reported that the cane height, number of tillers and millable cane was lower in unweeded control due to heavy weed infestation. Vasuki (2005) revealed that leaf area index and crop growth rate was lower unweeded control whereas, application of metribuzin at 1.0 kg ha^{-1} as pre emergence along with 2,4-D at 1.0 kg ha^{-1} as post emergence recorded higher growth parameters due to complete weed control at early stages of sugarcane cultivation. Patel *et al*. (2007) reported lower plant height and leaf area index was in weedy check when compared with different weed-crop competition periods. The lowest (2.14 m) plant height was recorded in weedy check (full season weed-crop competition) in both the seasons, whereas maximum plant height of sugarcane (3.48 m) was recorded in zero weed competition. Decrease in LAI and CGR with an increase in weed-crop competition period was also observed in this experiment (Zafar *et al*., 2010).

2.3.4. Effect of weeds on cane yield

A galaxy of researchers reported that the yield loss was ranging from 12 to 83 per cent due to the weeds in sugarcane field (Jha *et. al*., 1992; Sandhu and Valia, 1993; Hossain *et al*., 2001; Pechiappan, 2001; Veeranna *et al*., 2001). The yield reduction in cane was noticed to the tune of 49.5 per cent due to weeds at Sugarcane Research Station, Cuddalore (Marimuthu *et al*., 2002). According to Chauhan and Srivastava (2002), the reduction in cane yield of 52.7 per cent was observed in weedy check. The reduction in cane yield due to weeds was calculated as 43.4 per cent during first crop and 43.9 per cent during second crop (Tomar *et al*., 2003b). In Tamil Nadu, unweeded control recorded the reduced the yield of 67 t ha^{-1}, whereas, the herbicide treated plot recorded 134 t ha^{-1} which was 50 per cent higher (Ramesh and Sundari, 2006). In Karnal, 37.9 per cent yield reduction due to weeds was observed (Singh *et al*., 2011).

2.3.5. Effect of weeds on quality of cane

Different weed control treatments had little effect on sucrose percentage in juice but, commercial cane sugar was 53 per cent lesser in weedy check compared with mechanical weed control (Singh *et al*., 1995a). Similarly, Singh *et al*. (2002) observed that various weed control methods did not result in any significant difference in brix content, sucrose per cent, purity per cent, polarity per cent and commercial cane sugar per cent. Sathyavelu *et al*. (2002) reported that the quality of the cane was not affected significantly by the weed infestation. Various weed control methods did not result in any significant difference in brix content, sucrose per cent, purity per cent, polarity per cent and commercial cane sugar per cent (Sharma and Gupta, 2010).

2.4. Weed control methods

A much wider range and intensity of weed problems occur in sugarcane. Weeds vary in their growth habit and life cycle. Weeds growing in the furrows along the sugarcane row have been found to be more harmful than the weeds growing on ridges between the two rows. Hence the method of weed control should be effective to address the control of weeds in furrows (Sundra, 1991) Weeds can be controlled manually, mechanically, biologically and chemically. Manual weeds control is laborious, time consuming and expensive than chemical weed control. Mechanical weed control may damage crop plants. Chemical weed control by herbicides is relatively efficient and economical (Little *et al*., 2006).

2.4.1. Cultural methods

Weed control could be achieved through crop rotations, intercropping, crop competition, mulching, clean cultivation. Intercropping with sunhemp, single row on the ridge, suppressed the weeds growth and registered higher weed control efficiency and also in-situ incorporation has increased the cane yield to the tune of 145 t ha^{-1} at Tiruchirappalli, Tamil Nadu (Kathiresan, 2000). Crop rotation practices help in breaking weed chain and thus, help in the destruction of particular type of weeds. For example, growing paddy in rotation needs a puddled soil condition by which effective reduction of monocot weeds was possible, which are otherwise difficult to control. Several twining weeds can be controlled by growing sugarcane with paddy in rotation (Vasuki, 2005). Intercropping also provides another means of reducing weed population.

In Maharastra, among the intercrops such as soybean, greengram, groundnut and cowpea, growing of groundnut as an intercrop in sugarcane ratoon was found to be beneficial which increases the yield and commercial cane sugar yield (Nigade *et al*., 2004). In Punjab Intercropping of okra reduced the cane yield, whereas it recorded the highest mean cane equivalent yield (74.2 t ha^{-1}) as well as net return among other intercropping system (Bhullar *et al*., 2006). Fast growing short duration intercrops are useful for this purpose. In sugarcane, blackgram, greengram, soybean, sunflower, groundnut, can be grown as intercrops and they help in smothering weeds (Iqbal, 2010).

2.4.1.1. Mulching in sugarcane

Mulching with sugarcane trash helps in suppressing weeds substantially. Uniform spread of 5 to 10 cm thick trash blanket in between the rows and also in the inter-plant spaces help in suppressing weeds. It is necessary to give a thorough hoeing and weeding in the field before spreading the trash, particularly if the field has been weedy. In places, where obnoxious grassy weeds are in abundance the trash cover has to be a little thicker, 10 to 15 cm thick. Besides weed control, trash mulching saves water, labour costs and gives higher yields of cane. Bagasse, paddy husk, hay, straw, can also be used as mulching material (Srivastava and Chauhan, 2002).

Janagarathinam (2004) compared trash mulching with post emergence application of paraquat, glyphosate and hand weeding and found that trash mulched plots had higher cane yield when compared to other treatments. Similarly, Khan *et al*. (2004b) reported that the trash mulching on ridges before life irrigation was found to be most effective in controlling the weeds in sugarcane fields which in turn resulted in enhanced cane and sugar yields (117 t ha^{-1} and 15 t ha^{-1}, respectively) than without mulching.

2.4.2. Manual weed control methods

Sugarcane yield can be increased by good crop husbandry. Hand weeding is an effective and most adopted practice of weed control for any crop and it is also the most common direct weed control method for sugarcane in tropical Asia. Hand hoeing and weeding by manual labour is most effective post planting operation for weed control, extensively practiced in sugarcane fields. Elimination of annual and biennial weeds can be efficiently carried out by hand pulling of weeds (Sankaran, 1998). This is the oldest, the simplest and most direct method known to crop growers. According to Srivastava (2001), manual hand hoeing performed at 30, 60 and 90 days after planting (DAP) suppressed the weed population and weed dry matter most effectively and resulted in enhanced number of millable canes and cane yield.

Removal of weeds is an important component of crop husbandry as higher cane yield (65.43 t ha^{-1}) and profit with conventional practice (3 hoeing and weeding at 15, 30 and 45 days after planting) were achieved compared to unweeded control (Singh *et al.*, 2001). The result of the study at Kerala showed that the weeds were effectively controlled in treatments with three hoeings at 30, 60 and 90 DAP. It also reduced the weed density and weed dry weight significantly (Mathew *et al*., 2002).

Tomar *et al*. (2003a) reported the lowest weed density and weed dry matter and thereby increased the number of millable canes, cane yield, commercial cane sugar and net returns, in weed free control and three hoeings at 30, 60 and 90 DAP. Whereas, hand hoeing 4 times (45, 75, 105 and 140 DAP) gave the highest yield of sugarcane (49.67 t ha^{-1}) which was 26.71 per cent higher than control. Manual hoeing at 20, 40 and 60 DAP resulted in minimum weed density (58.3 m^{-2}) as well as weed drymatter (15.1 g m^{-2}) and proved to be highly effective in controlling the weeds. The highest weed control efficiency of 42.6, 58.5 and 67.8 per cent was obtained in 60, 90 and 120 DAP respectively (El-Shafai *et al*., 2010). Another study at Kolhapur showed that three hoeings at 1^{st}, 4^{th} and 7^{th} week after ratoon initiation, increased the growth parameters and cane yield by suppression of weed density and weed dry weight in sugarcane genotype CO 86032 (Kadam *et al*., 2011).

Deep ploughing and collection of grassy weeds is an effective method of controlling problem weeds particularly, the *Cyperus* spp. and *Cynodon dactylon*. Primary and secondary tillage operations were also help in burying the weed seeds deep into the soil and thus, making them ineffective (Srivasatva and Chauhan, 2002). Mechanical methods of weed control were effective only for removing inter row weeds whereas, intra-row weeds are removed only by hand weeding which is a costly operation (Jeyaraman *et al*., 2002). Working the Junior-hoe along the ridges and using the hand hoe in furrows at 25, 55 and 85 days after planting removed the weeds through proper stirring of the soil. Otherwise, power tiller fitted with tynes could be an alternate option for inter cultivation (Srivasatva and Chauhan, 2002).

2.4.3. Chemical method of weed control

Herbicides are being extensively used for weed control because of plantation scale cultivation of sugarcane and shortage of labour for manual weeding. In view of the growing scarcity of labour, the manual weeding is costly, time consuming and laborious. These drawbacks in manual weed control resulted in inadequate weed control (Vasuki, 2005). Herbicides relieve much of the drudgery of work labour involved in cultivation, hoeing and hand pulling. In India, commercial use of herbicides came into existence only in the eighties. The consumption of herbicides increased from 890 MT in 1975 to12000 MT in 2003. Thus, chemical weed control became an alternative and promising option in crop production.

Herbicides are chemical substances that kill/suppress plant growth by affecting one or more of the processes – cell division, tissue development, chlorophyll formation, photosynthesis, respiration, nitrogen metabolism and enzyme activity that are vital to plant survival (Rao, 2000).

For successful and economic use of herbicides, it is important to understand how these chemicals work and their limitations. In many instances, herbicides offer the most practical, effective and economical means of reducing weed competition, crop losses and production cost. Nearly 300 herbicides, often chemically and functionally diverse and highly selective and available for use in various crops including sugarcane throughout the world.

2.4.3.1. Pre emergence herbicides

Pre-emergence herbicides are applied to the soil surface after planting, but, before the emergence of weeds. Pre-emergence herbicidal weed control would be more appropriate not only for minimising early weed competition, but also, an alternative to manual weeding especially during the peak period of labour demand. Pre emergence herbicide application is important, so that sugarcane crop has the initial competitive advantage over weeds. Pre emergence herbicide applications in conjunction with mechanical cultivation, helps to ensure the early season advantage but the development of resistance in weeds and environmental safety are the major concerns against herbicide use (Chattha *et al.*, 2004).

Pendimethalin at 0.75 kg ha^{-1} as pre emergence herbicide resulted in 96.3 per cent of weed control efficiency in sugarcane (Mehra *et al*., 1991). However, Rao *et al.* (1995) reported that atrazine at 2.0 kg ha^{-1} was not effective against monocot weeds, but, application of isogaurd plus (Isoproturon+2,4-D) at 2.5 kg ha^{-1} as pre emergence herbicide effectively controlled the monocot weeds in sugarcane fields. metribuzine at 1.25 kg ha^{-1} as pre emergence application resulted in a weed control efficiency of 53.33 per cent (Singh *et al*., 1995b). However, Singh *et al.* (1997) observed that the application of diuron as pre emergence herbicide had higher weed control efficiency than atrazine and metribuzine. Vasuki (2005) reported that metribuzine at 1.0 kg ha^{-1} as pre emergence herbicide had lower weed density and higher weed control efficiency.

However, reports indicated that metribuzine is used on approximately 19 per cent of the sugarcane cultivated area. Growers depend on these triazines to control many broadleaved and grassy weeds, particularly during the first 8 to 10 weeks after cane emergence and expect these herbicides to provide residual weed control throughout the establishment period (Smith *et al*., 2008). Whereas, combined application of metribuzine at 1.5 kg ha^{-1} supplemented with post emergence application of 2,4 D Na salt at 1.0 kg ha^{-1} was good for controlling all weeds in sugarcane (El-Shafai *et al*., 2010).

2.4.3.1.1. Atrazine

To realize the full potential of this herbicides, the time of application is the way. Pre emergence herbicides are applied generally on 3 DAP. Atrazine is used on more than 70 per cent of sugarcane area for weed control. Pre emergence application of atrazine at 2.0 kg ha^{-1} or simazine at 2.0 kg ha^{-1} has been found highly effective in controlling most of the dicot and other broad leaved weeds in sugarcane (Chauhan *et al*., 1984).

A large number of experiments throughout the country have indicated that for sole crop of sugarcane, atrazine is the most effective. It controls most of the seed germinated dicot weeds and grasses when applied as pre emergence spray. It gives a more or less a complete weed free condition for about 30 to 45 days (Lavya, 1985). Atrazine controls most of the broad leaved weeds, but does not control bermuda grass completely (Richard and Griffin, 1993).

Atrazine at 1.0 kg a.i. ha^{-1} mixed with 50 kg sand and spread uniformly on the field as pre emergence along with one hand weeding on 30 DAP resulted in the maximum weed control efficiency (Kathiresan, 2000). Similarly, Patel *et al.* (2003) found that application of atrazine at 2.0 kg ha^{-1} was very effective in controlling the weed growth and had higher weed control efficiency of 88.4 per cent followed by metribuzine at 0.5 kg ha^{-1} (66 %) and was comparable with two hand weedings at 20 and 60 DAP. Among the herbicide treatments, atrazine at 2.0 kg ha^{-1} provide efficient weed control, gave the lowest weed drymatter and was equally better with application of metribuzine at 1000 g ha^{-1} and diuron at 1.0 kg ha^{-1} in cane yield (Singh *et al*., 2003).

Atrazine herbicide can be applied even upto 8.9 kg ha^{-1} to sugarcane per year, usually in two equal splits of 4.45 kg ha^{-1} (CDMS, 2009). Atrazine at 2.0 kg ha^{-1} as pre emergence application on 3 DAP + hand hoeing at 30 DAP were good for controlling all weeds in sugarcane (El-Shafai *et al*., 2010). Pre emergence application of atrazine 2.0 kg ha^{-1} followed by 2,4-D 1.0 kg ha^{-1} at 45 days after ratoon initiation recorded highest cane yield (94.76 t ha^{-1}) over the control treatment which was followed by trash mulching (94 t ha^{-1}) in Kolhapur, Maharashtra (Suryavanshi *et al*., 2012).

2.4.3.2. Post emergence herbicides

Post-emergence herbicides are applied to the soil surface after weeds emerge. Shah *et al.* (1983) reported that the application of metribuzine at 1.5 kg ha^{-1} as post emergence herbicide had the highest weed control efficiency. Whereas, Agarwal *et al.* (1986) reported that post emergence application of paraquat at 2.5 kg ha^{-1} resulted in better weed control in sugarcane. Good control of perennial grasses (85-100 %) was achieved by the post emergence directed spray of glyphosate at 1.7 to 2.5 kg ha^{-1} (Singh, 1988).

Mehra *et al.* (1989) noted that post emergence application of simazine at 1.0 kg ha^{-1} and its incorporation in soil reduces, the dry weight of weeds by 61.0 per cent compared to the unweeded control, while Mahadevaswamy *et al.* (1994) achieved better weed control with the post emergence application of 2,4-D at 2.0 kg ha^{-1}.

Charles *et al.* (1994) observed that the control of *Cyperus rotundus* ranged from 42 to 75 per cent with the post emergence application of glyphosate at 1.1 kg ha^{-1}. The post emergence application of metribuzine at 1.4 kg ha^{-1} gave the higher weed control efficiency of 69.3 per cent compared to the unweeded control (Singh *et al*., 1995b).

Post emergence directed spray of glyphosate gave the best control of *Cynodan dactylon* (Landrey *et al*., 1993; Brandt, 1995). The sequential pre emergence application of atrazine at 2.0

kg ha^{-1} + 2,4-D at1.0 kg ha^{-1} (60 DAP) reduced the weed population and drymatter accumulation of weeds compared to weedy check on 60 and 100 DAP (Srivastava, 2001).

Ametryn is used around 94 per cent of sugarcane production as post emergence for weed control during early stages (Smith *et al*., 2008). El-Shafai *et al*. (2010) reported that metribuzine at 1.5 kg ha^{-1} as pre-emergence followed by 2,4 D Na salt (80 %) as post emergence at 2.0 kg ha^{-1} produced higher cane yield and commercial cane sugar yield, which were 36.32 and 50.10 per cent, respectively higher than weedy check.

2.4.3.2.1. Halosulfuron methyl (Methyl 5-[((4, 6-dimethoxy- 2 pyrimidinyl)amino) carbonyl aminosulfonyl]-3-chloro-1- methy l-1 H-pyrazole – 4 - carboxylate)

Halosulfuron methyl is a selective herbicide belongs to sulfonyl urea group of herbicides. It is a selective herbicide for post-emergence control of sedges and other weeds in turf. Mode of action of halosulfuron-methyl is by interference with Aceto Lactate Synthase (ALS) enzyme, resulting in a rapid cessation of cell division and plant growth in both roots and shoots. The half-life of halosulfuron-methyl is 55 days (EPRI, 1999)

Halosulfuron, trifloxysulfuron and sulfentrazone, a protoporphyrinogen oxidase inhibitor are currently labeled for use in sugarcane (Anon., 2009b). Research evidence has shown that the halosulfuron post emergence application controls purple nutsedge (Vencill *et al*., 1995; Czarnota and Bingham, 1997; Molin *et al*., 1999; Blum *et al*., 2000; Grichar *et al*., 2003).

2.4.3.2.1.1. Purple nut sedge control

Czarnota and Bingham (1997) reported that single application of halosulfuron at 70 g ha^{-1} controlled purple nutsedge to an extent of 95 per cent. However, Blum *et al.* (2000) reported that the halosulfuron applied as early post emergence herbicide followed by late post emergence application at 70 g ha^{-1} controlled purple nutsedge shoots up to 81 per cent but control was not better than that observed with a single application of halosulfuron as early post emergence spray. Further, it was reported that single applications of halosulfuron provided 28 per cent purple nutsedge control, but control improved to 94 per cent following a sequential application in Bermuda grass (Blum *et al*., 2000).

Purple nutsedge shoot density in bermuda grass was reduced by 66 per cent with single applications of halosulfuron at 72 g ha^{-1} in bermuda grass (Molin *et al*., 1999). Sequential applications of halosulfuron reduced purple nutsedge tuber viability (Molin *et al*., 1999; Blum *et al*., 2000). Halosulfuron-methyl and imazethapyr provided good control of more than 85 per cent and 70 per cent, respectively of *Cyperus brevifolius* during the growing season in pasture. Multiple application of herbicide was necessary to suppress the weed because the major source of reinfestation was by seedling emergence (Dear and Sandral, 1994).

Purple nutsedge shoot densities were reduced in cultivated and non cultivated corn-corn and corn-cotton rotation by the application of MON 12037 at 72 g ha^{-1}, whereas, purple nutsedge tuber population was reduced only in cultivated crops (Webster and Coble, 1997). Rick and Yelverton (2000) reported that sequential application of halosulfuron at 70 g ha^{-1} controlled purple nutsedge population more effectively and yellow nutsedge population. Whereas single and sequential application of halosulfuron at 70 g ha^{-1} reduced the tuber viability to 33 and 30 per cent compared to 84 per cent in the non treated control. The herbicide halosulfuron methyl at 15 days after application showed weed control efficiency of higher than 90 per cent however at 30 and 45 days after application the weed control percentage decreased to 73 per cent and 64 per cent respectively in sweet pepper (Gutiérrez *et al*., 2002). Treatments that included halosulfuron provided greater control of redroot pigweed than clomazone + ethalfluralin, and red root pigweed control from halosulfuron treatments was similar to the weed-free control in Secale cereal (Walters *et al*., 2005).

The halosulfuron methyl 75 WG 90, 100 and 120 g ha^{-1} was highly effective against C*yperus rotundus* as these treatments controlled 79 per cent to 84 per cent over pre treatment population as against an increase of 11.8, 15.15 and 32.03 per cent in atrazine + hand weeding and unweeded control (Chinnusamy *et al*., 2012).

2.4.3.2.2. Chlorimuron ethyl (ethyl 2 -[[[[(4-chloro- 6 - methoxy- 2 - pyrimidinyl) amino] carbonyl] amino] sulfonyl] benzoic acid ethyl ester

Chlorimuron ethyl is a sulfonyl urea herbicide. It is a selective herbicide for pre emergence and early post emergence applications to control annual broad leaved weeds. Mode of action of chlorimuron ethyl is by inhibiting plant cell division of rapidly growing tips of roots and shoots and by inhibition of amino acid synthesis resulting in cessation of plant growth.

Lower density of *Ipomoea* spp. was recorded with atrazine at 2000 g ha^{-1} applied just after hoeing and metsulfuron-methyl + chlorimuron ethyl at 4.0 g ha^{-1} applied at 3 DAP compared to weedy check (Vasuki, 2005). Chlorimuron ethyl provided greater than 95 per cent foliar control of volunteer horse radish. Further, 69 per cent reduction of horse radish root biomass was also observed by Rundle *et al*. (2007). Dry biomass of wheat had negative relationships with increasing concentrations of chlorimuron-ethyl (Caixia *et al*., 2010).

Reduced yield of chickpea was obtained with chlorimuron at 4.0 g ha^{-1} as compared with other herbicides like imazethapyr, quizalofop (Khope *et al*., 2011). Post emergence application of chlorimuron at 6.0 and 8.0 g ha^{-1} provided good control (90 - 92 %) of weeds but due to severe injury, 20 to 30 per cent yield reduction was observed (Punia *et al*., 2011).

Kulal *et al*. (2012) reported that soybean seed yield was higher in weed free check which was on par with pendimethalin at 75.0 g ha^{-1} + HW at 30 DAS, imazethapyr POE at 75.0 g ha^{-1} at 21 DAS and tankmix quizalfop ethyl POE at 40.0 g ha^{-1} + chlorimuron ethyl POE at 12.0 g ha^{-1} at 20 DAS were superior to rest of the treatments. In groundnut, post emergence combined application of imazethapyr and chlorimuron (100 + 24 g ha^{-1}) arrested weed biomass and weed density and increased the yield (Dubey and Gangwar, 2012). Similarly, combined application of imazethapyr and chlorimuron (100 + 24 g ha^{-1}) paralysed the weed growth (98.12 %) and increased the yield of groundnut (Singh *et al*., 2012)

2.4.4. Effect of herbicides on growth parameters

2.4.4.1. Germination of sugarcane

Germination of sugarcane buds was not affected by herbicidal use (Singh and Singh, 1979; Sathyavelu, 1990). Whereas, the application of cyanazine at 2.5 kg ha^{-1} + diuron at 0.9 kg ha^{-1} had no adverse effect on sprouting of buds in sugarcane (Chaugule and Patel, 1983). Pre emergence application of atrazine (2.18 kg ha^{-1}) or oxyfluorfen (0.188 kg ha^{-1}) improved the germination of sugarcane setts (Ponnusamy *et al*., 1996). Umarhatha (1997) also observed that the per emergence application of atrazine (1.98 kg ha^{-1}) followed by the post emergence application of ethoxysulfuron (80 g ha^{-1}) on 15 and 30 DAP increased the germination to the tune of 45.5 per cent than unweeded control. Whereas, the pre-plant incorporation of pendimethalin at

1.0 and 2.0 kg ha^{-1} produced adverse effect on sprouting of sugarcane as a consequent of heavy rainfall received in the evening (Srivastava, 2001).

Jonathan *et al.* (2004) concluded that 2,4-D application did not affect the emergence of cane. Germination percentage of sugarcane was not affected by the weed management practices like chemical, intercultural operation and integrated weed management methods (Lal *et al*., 2006). The application of herbicides and other treatments thus, had no effect on germination of sugarcane (Cheema *et al*., 2010).

2.4.4.2. Tiller production

The number of tillers were higher in herbicide applied plots than the unweeded plot (Salunkhe *et al.*, 1990). The tillering capacity was improved by the pre emergence application of atrazine or oxyfluorfen (Ponnusamy *et al*., 1996). When comparing the time of application of herbicides, pre emergence application of atrazine performed better as compared with post emergence application of ethoxysulfuron (Umarhatha, 1997).

Herbicides like atrazine, (2 kg a.i. ha^{-1}) metribuzine (1.5 kg a.i. ha^{-1}) and pendimethalin (2 kg a.i. ha^{-1}) did not show any detrimental effect on tiller production and number of millable canes. On contrary, application of glyphosate at 1.0 litre a.i. ha^{-1} as directed spray on 30 DAP reduced the tiller production (Mathew *et al*., 2002). Post emergence application of 2,4-D and alachlor recorded higher tiller production compared to unweeded control (Kathiresan *et al*., 2004). Effective control of weeds in herbicide treated plot and hand hoed plot resulted in higher tiller production than the unweeded plot (Bhullar *et al*., 2006). Zafar *et al.* (2010) reported that zero weed competition gave same number of tillers as produced by crop facing weed competition up to 60 days.

High weed density depressed the tillering in the weedy check, which produced the lowest number of tillers (2.39) plant^{-1}. However, the variation among the various treatments could reach the statistical significance level (Cheema *et al.*, 2010). Kalaiyarasi (2012) also reported that herbicide application of sulfentrazone increased the number of tillers compared to unweeded control plot.

2.4.4.3. Cane height

Application of atrazine as pre emergence herbicide followed by the post spray of glyphosate on 30 DAP or the pre emergence application of atrazine followed by one hand weeding on 60 DAP recorded 40 and 20 per cent increased plant height, respectively over the unweeded check (Sathyavelu, 1990). Ponnusamy *et al.* (1996) also observed that pre emergence application of atrazine increased the plant height considerably. Umarhatha (1997) observed that the pre emergence application of atrazine at 1.7 kg ha^{-1} followed by the post emergence application of ethoxysulfuron at 80.0 g ha^{-1} at 15, 30 and 45 DAP recorded an increased cane height of 50 per cent as compared to unweeded check.

In sugarcane, control of Italian rye grass by the herbicide like paraquat was improved the plant height considerably (Griffin *et al*., 2004). The cane stalk height and diameter were increased by weed control treatments and three hand hoeing. However, the lowest values were recorded in the unweeded plots due to the severe competition of weeds with sugarcane plants (El-Shafai *et al*., 2010).

2.4.4.4. Effect of herbicide on millable cane

Application of 2,4-D Na salt at 1.0 kg ha^{-1} and paraquat at 0.5 kg ha^{-1} on 20 and 60 DAP or atrazine at 2 kg ha^{-1} and paraquat at 0.5 kg ha^{-1} on 20 and 60 DAP or atrazine 2 kg ha^{-1} as pre emergence recorded highest number of millable cane (Patil, 1990). Umarhatha (1997) also reported that the per emergence application of atrazine followed by post emergence application of ethoxysulfuron increased the millable cane population by 50.4 per cent.

Pre plant incorporation of pendimethalin at 2.0 kg ha^{-1}, pre emergence application of atrazine 2.0 kg ha^{-1} + 2,4-D at 1.0 kg ha^{-1} on 60 DAP and 3 hoeings recorded in significant increase in number of millable canes over weedy check (Srivastava, 2001). The number of millable canes were increased when atrazine or alachlor was applied as pre emergence herbicides followed by hand weeding at 60 DAP. The increase was about 40 per cent higher over the unweeded check (Sathyavelu *et al*., 2002). Increased number of millable cane was recorded with weed free plots followed by manual hoeing at 30 DAT followed by 2,4-D ester 1.0 kg ha^{-1} at 35 DAT followed by 2,4-D ester 1.0 kg ha^{-1} + metribuzine 0.88 kg ha^{-1} at 60 DAT (Singh *et al*., 2011)

2.4.4.5. Effect of herbicides on cane girth, cane weight and number of internodes

Enhancement in cane weight to an extent of 37.2 per cent was recorded with atrazine + 2,4-D and oxyfluorfen + 2,4-D tank mix, respectively (Ponnusamy, 1982). Sivamani (1984) recorded that increased the cane weight by 43.4 per cent and 42.9 per cent with atrazine, atrazine + dicamba, respectively. The weed control treatments favourably influenced the yield contributing characters such as number of millable cane, cane length and diameter (Patil, 1990). Chinnusamy (1990) observed that increased number of internodes of sugarcane provided with weed free situation.

Weed control treatments recorded higher cane weight compared with weedy check (Chauhan and Srivastava., 2002). Sugarcane that received three hand hoeings recorded higher cane weight and millable cane followed by metribuzine (Ramesh and Sundari, 2006). Higher cane length, cane girth and single cane weight were recorded under weed free situation compared with weedy check (Singh *et al*., 2011).

Salunkhe and Gaur (1990) observed that more number of the internodes per cane *viz.*, 12.55, 18.68 and 22.96 at 270, 330 and 390 days, respectively in the hand weeded plot compared to unweeded control. Sathyavelu (1990) reported that the reduction of cane girth and number of internodes per cane were 20.1 and 37.7 per cent, respectively in the unweeded plot as compared to the weedy check. Raskar (2004) stated that pre emergence application of metribuzine at 1.5 kg ha^{-1} followed by 2,4-D Na salt at 1.0 kg ha^{-1} increased the weed control efficiency and number of internodes per cane. Vasuki (2005) reported that pre emergence application of metribuzine at 1.0 kg ha^{-1} + post emergence directed spray of glyphosate at 1.0 kg ha^{-1} enhanced the number of internodes to an extent of 85.7 and 88.6 per cent during mid and special seasons, respectively over pre emergence application alone.

2.4.4.6. Cane yield

Application of herbicides in sugarcane was found to enhance the yield by way of timely control of weeds. The combined application of simazine and 2,4-D (Singh and Singh 1979), diuron, 2,4-D and simazine (Hunsigi, 1993) was found to increase the yield by 29.1, 121.3 per cent, respectively over unweeded control plot. The post emergence application of 2,4-D Na salt (1.0 kg ha^{-1}) with paraquat (0.5 kg ha^{-1}) and hand weeded plots recorded higher yields compared to control. Honyal and Radder

(1994) observed that higher cane yield was achieved only in atrazine + 2,4-D treated plot, which was comparable with hand weeded plot.

Pre emergence application of atrazine at 2.0 kg ha^{-1} + 2,4-D at 1.0 kg ha^{-1} at three weeks after planting gave higher cane yield than one hoeing followed by metribuzine at 1.0 kg ha^{-1} applied at six weeks after planting (Singh *et al*., 2002). Weed control treatments resulted in increased yield to an extent of 41.6 per cent in both the season. atrazine recorded the highest yield which was on par with metribuzine and two hand weedings (Patel *et al*., 2003). Vasuki (2005) reported that pre emergence application of metribuzine at 1.0 kg ha^{-1} + post emergence directed spray of glyphosate at 1.0 kg ha^{-1} had 89.37 and 88.67 per cent higher cane yield in the mid and special seasons, respectively over pre emergence application of atrazine.

The weed control treatments enhanced the yield of sugarcane to the tune of 26.7 per cent compared to uncontrolled weed growth. pendimethalin and trifluralin produced equal cane yield with two hand hoeings which recorded the highest yield (Bhullar *et al*., 2006). Ramesh and Sundari (2006) reported that application of atrazine and metribuzine recorded higher cane yield which was followed by glufosinate ammonia.

In a two seasons of study, controlling weeds with triclopyr-butoyl, bromoxynil, bentazon and tribenuron-methyl increased cane yield by 6.32, 5.77, 4.53 and 3.64 t ha^{-1} respectively compared with unweeded check. However, hoeing weeds manually three times controlled the weeds to a large extent and resulted in getting the highest cane yield of 10.96 tons as compared to control (El-Shafai *et al*., 2010).

2.4.4.7. Quality of cane juice

Quality of cane juice was not affected by the weed control treatments. Different weed control treatments had little effect on sucrose percentage of juice and commercial cane sugar, but mechanical weed control yielded 53 per cent more commercial cane sugar than weedy check (Singh *et al*., 1995a). However, Singh *et al.* (1997) reported that the juice quality was not influenced due to herbicide application. Similarly, Singh *et al*. (2002) observed that various weed control methods did not exert any influence on brix content, sucrose percentage, purity percentage, polarity per centage and commercial cane sugar percentage.

The quality of the cane was not affected by different weed management practices as reported earlier by several workers (Sathyavelu *et al*., 2002; Janagarathinam, 2004 and Vasuki, 2005). Cheema *et al.* (2010) also reported that the quality parameters of sugarcane such as sucrose, brix, polarity, purity and CCS did not show any marked difference between weed control treatments. No difference was observed in brix, sucrose and sugar recovery percentages in case of applying of triclopyr-butoyl and bromoxynil herbicides followed by hoeing once and practicing three hand hoeing (El-Shafai *et al*., 2010).

2.4.4.8. Effect of herbicide on sugar yield

The herbicides have no direct effect on the sugar yield but the increase in cane yield due to effective weed control ultimately increased the sugar yield (Rao *et al*., 1982). Patel *et al*. (2003) observed that pre emergence application of atrazine recorded significantly higher sugar yield which was followed by metribuzine. Sugar yield was higher (10.1 t ha^{-1} during 2001-2002 and 9.3 t ha^{-1} during 2002-03) in weed free treatment of three hoeing (30, 60 and 90 DAP) which was closely followed by herbicidal weed control treatment (Tomar *et al*., 2003a).

Crops grown with three manual hoeings, one hoeing + atrazine, atrazine or metribuzine or pendimethalin supplemented with 2,4-D at 60 DAP gave 48.9, 50.3, 37.4, 40.3 and 34.5 per cent, respectively more commercial cane sugar yield than weedy check (Rana and Singh, 2004). Sinare *et al.* (2007) reported that commercial cane sugar yield was higher in herbicide treated plot compared with unweeded control.

Single application of triclopyr-butoyl, bromoxynil, bentazon and tribenuron-methyl resulted in higher sugar yield of 2.03, 1.98, 1.76 and 1.72 t ha^{-1} respectively than unweeded plots (El-Shafai *et al*., 2010). Kadam *et al*. (2011) reported that pre emergence application of atrazine at 2.0 kg a.i. ha^{-1} and post emergence application of 2,4-D at 1.0 kg a.i. ha^{-1} at 45 Days After Ratoon Initiation (DARI) and metribuzine at 1.0 kg a.i. ha^{-1} as pre emergence and one hand weeding at 45 DARI recorded higher commercial cane sugar yield of 13.68 t ha^{-1}.

2.4.5. Integrated weed management

Complete weed control cannot be achieved by using any one single method. To have more dependable, economical and desirable weed control without environmental problems, it is advisable to have a proper combination of agronomical, cropping, rotational and biological methods along with the use of herbicides.

Integrated weed management with the application of atrazine at 2.0 kg ha^{-1} after 2-3 DAP followed by application of 2,4-D Na salt at 1.0 kg a.i. ha^{-1} at 60 DAP combined with one manual weeding at 90 DAP controlled all types of weeds effectively and produced 79.0 t ha^{-1} cane yields which was 30.0 per cent higher than the farmers' practice of weed management (Janagarathinam, 2004).

Chauhan and Srivastava (2002) reported that the best treatment for controlling weeds in sugarcane was atrazine at 870 g a.i. ha^{-1} applied immediately after planting coupled with manual hoeing at 45 days after planting. Mishra *et al*. (2003) concluded that pre-emergence application of ametryn with one hoeing at 60 days after planting (DAP) recorded lower weed flora and dry weight and higher average cane yield of 149.8 t ha^{-1}. Similarly, yield of sugarcane increased with atrazine application at 1500, 2000, 2500 g ha^{-1} as pre or post-emergence herbicide and hand hoeing compared to the untreated control. Singh *et al.* (2005) reported that atrazine at 1.5 and 2.0 kg ha^{-1} after hoeing and manual hoeing twice gave higher cane yields equal to weed-free treatment. The best weed control with higher yield of 82.5 t ha^{-1} was achieved by CGA 362 + ametryn at 3.0 kg ha^{-1} compared to the earlier recommended herbicides in (yield) Nigeria (Gana *et al*., 2006).

In India, results of the field experiment revealed that pre- and post emergence application of oxyfluorfen at 3.0 liters ha^{-1} had effectively controlled the weeds and produced the highest cane and sugar yields. This was comparable with cultural practices with three hoeings at 30, 60, and 90 days after planting (DAP) and pre-emergence application of metribuzine at 1.5 kg a.i. ha^{-1} and post emergence application of 2,4-D at 1.0 kg a.i. ha^{-1} at 60 DAP. The juice quality was found unaffected due to weed control methods (Mathew *et al*., 2002).

Sathyavelu *et al.* (2002) reported that reduction in weed population was obtained when atrazine or alachlor was applied as pre-emergence followed by glyphosate 2.0 kg or glyphosate 2.0 kg + 2, 4-D at 1.0 kg ha^{-1} applied as post emergence directed spray at 30 DAP. Hand weeding and the chemical weed control (application of metribuzine as pre-emergence followed by 2,4-D as post-emergence, each at 2.0 kg ha^{-1} and glyphosate at 3.0 liters ha^{-1} as post emergence) produced the same cane yield and higher than the other treatments, except for glyphosate at 2.5 liters ha^{-1}.

The increase in cane yield by herbicides like atrazine 1.0 kg ha^{-1} and alachlor 1.5 kg ha^{-1} was due to reduction in dry weight of weeds. Weed control efficiency of 78.3, 71.7 per cent, respectively was observed with these herbicides (Singh *et al*., 2002).

In planted sugarcane, the integrated method of one hoeing after first irrigation followed by spraying atrazine at 2 kg ha^{-1} after second irrigation proved to be the best weed control strategy in terms of effective weed control and higher yield (Lal *et al*., 2006). In Indian Institute of Sugarcane Research, Luknow, intercultivation followed by application of glyphosate at 1.0 kg ha^{-1} on 30 days after initiation of ratoon gave better yield and it was equal with three manual hoeing (Srivastava and Chauhan, 2006). On contrary, Cuddalore in Tamil Nadu three hand hoeing(1^{st}, 4^{th} and 7^{th} week after ratoon initiation) recorded higher cane yield and it was on par with pre emergence application of metribuzine at 1.0 kg ha^{-1} with one hand weeding on 45 DARI (Manickam *et al*., 2010).

2.5. Economics of weed control methods in sugarcane

Weed management with herbicides in sugarcane has been found to be economical as reported by several workers. Application of herbicides was cheaper than the manual method of weed control (Mani and Salunkhe, 1976; Narwal and Malik, 1981). Bose and Zaman (1977) and Narwal and Malik (1981) also reported that application of 2,4-D combined with paraquat resulted in higher monetary returns than unweeded control. Similarly, Chinnusamy (1990) and Sathyavelu (1990) reported that the herbicidal weed control increased the net return over unweeded check. Toor *et al*. (1996) too observed that pre emergence application of metribuzine followed by mulching was cheaper than other weed control methods.

The highest net income of Rs.27,403 ha^{-1} and B:C of 2.19 was observed with sugarcane trash mulch at 10 t ha^{-1} in sugarcane (Maliwai *et al*., 1999). Singh *et al*. (2001) stated the net profit was the highest with atrazine at 1.0 kg a.i ha^{-1} (Rs. 30,310) followed by metribuzine + trash mulching. Maximum net profit was realised with the use of simazine and 2,4-D in the plant and ratoon crops (Jeyaraman *et al*., 2002). Highest net return was obtained with pre-emergence application of ametryn with one hoeing at 60 DAP (Mishra *et al*., 2003).

Vasuki (2005) reported that pre emergence application of metribuzine at 1.0 kg ha^{-1} followed by post emergence directed spray of glyphosate at 1.0 kg ha^{-1} resulted in higher net returns of

Rs.1,47,804 and B:C of 3.70 compared to pre emergence atrazine. Patel *et al*. (2007) revealed that sugarcane field kept weed free up to 150 DAP gave the highest gross return of Rs.72,192 ha^{-1} and additional income over control (Rs. 30,000 ha^{-1}). Pre emergence application of metribuzine 1.0 kg ha^{-1} followed by one hand hoeing on 90 days after ratoon initiation resulted with maximum benefit cost ratio of 2.02 as against three hand hoeing (Manickam *et al*., 2010)

2.6. Residual effect of herbicides on succeeding crops

A wide spectrum of herbicides was found to be effective in weed control which resulted in higher crop yields. However, identification of effective herbicide dosage for sugarcane without causing any residual toxicity is most important. Herbicide dissipation is a bio chemical and environment dependant factor. Soil incorporated herbicides are exposed to variable microbial, hydrolysis, soil pH, organic matter and other factors that may limit their activity. However, herbicide adsorption to soil colloids with subsequent hysteresis may extend activity and thus, potential for either weed control or carryover to subsequent crops.

Post emergence applied herbicide dissipation can be influenced by chemical properties such as water solubility, photo degradation, volatility and environmental aspects such as rainfall and irrigation volumes, plant interception and absorption. While herbicide dissipation differs with respect to application method and many of the same factors influence fate of herbicides in the environment (EPA, 2011).

Residual toxicity of herbicides on the succeeding crops is the main constraint in the use of chemical weed control. Grichar *et al.* (2003) reported that the principle underlining in the technique is that the phytotoxicity of chemical in the soil is reflected on germination, vegetative production and growth of the indicator plants. No injury to succeeding wheat crop was observed with the application of chlorimuron (20-140 g ha^{-1}) and imazethapyr (50-300 g ha^{-1}) applied in soybean (Talbert *et al*, 1989; Krausz *et al*., 1992).

Despite the observed phytotoxicity symptoms, halosulfuron did not reduce cowpea yield. Halosulfuron is safe to use with these breeding lines and cultivar, at the 0.054 kg ha^{-1} rate, but may delay cowpea maturity almost one week in soils of close to neutral pH or higher. Differences in cucumber yields were not detected with second crop treatments. Cucumbers appear to have adequate tolerance to halosulfuron (Webster and Culpepper, 2005). Chlorimuron and imazethapyr, irrespective of their dose and time of application, did not cause any injury to wheat, barely and chickpea planted as succeeding crop after harvest of clusterbean (Punia *et al*., 2011).

Sunflower and millets are the sensitive crop and it can be used for assessing the residual toxicity of herbicides. Bioassay procedures, based on the root growth of maize (*Zea mays* L.), sunflower (*Helianthus annuus* L.), lentil (*Lens esculenta* M.) and sugar-beet (*Beta vulgaris* L.) and millets were used to study the phytotoxicity and persistence of the herbicides chlorsulfuron, tribenuron-methyl, triasulfuron, and metsulfuron-methyl (Eleni kotoula-syka *et al*., 1993). The phytotoxicity and persistence of herbicides like imazamax, fomesafen, acifluorfen were assessed by using the sensitive crops like sunflower and pearlmillet (Hello *et al*., 1998)

2.7. Phytotoxicity

The highest concentrations of the herbicide residues in soil correspond to the desirable effect of weed control (residual power). Over time, the herbicide concentration in soil decreases to levels that no weed control, but its concentration can affect crops in succession to that in which the herbicide was applied originally; their presence can be detected by symptoms of phytotoxicity expressed in these crops when they are sensitive.

Khope *et al*. (2011) reported that application of chlorimuron ethyl resulted in severe phytotoxicity in chickpea crop resulting in complete mortality of chickpea. Whereas, sulfonyl urea herbicides like azimsulfuron did not show any phytotoxicity even in double dose of tested herbicide (Barui and Ghosh, 2012). Likewise, pyrazosulfuron ethyl also did not show any phytotoxicity and residual effect in rice (Hareesh *et al*., 2012). Ezhilarasi *et al*. (2012) also reported that there was no phytotoxicity symptoms observed in succeeding crop of rice. Where as in groundnut application of chlorimuron ethyl at 9.37 g ha^{-1} showed severe phytotoxicity (Hulihalli *et al*., 2012).

2.8. Effect of herbicides on soil micro flora

When herbicides are applied, most of the spray solution contacts the soil and affect soil microorganisms that are important for sustainable agriculture, recycling of plant nutrients and maintenance of soil structure (Rosana *et al*., 2007). Gonzalez *et al*. (1999) did not found any significant effect of the herbicides metribuzinee, acetochlor, metolachlor, trifluralin, imazaquin, imazethapyr and chlorimuron ethyl on soybean nodulation and consequently on yield.

Arruda *et al.* (2001) demonstrated that nodule number and nodule dry weight in soybean decreases as a function of increased rates of sulfentrazone. On the other hand, the nodule numbers were smaller in plants grown in soil treated with sulfentrazone in all developmental stages of the crop in soybean. The number of nodules and dry weight of nodules plant^{-1} was more affected by higher doses of sulfentrazone application in soybean. Repeated annual applications of sulfentrazone, could affect the microbial community and their functions in the soil (Rosana *et al*, 2007). The herbicides exerted significant detrimental effect on soil bacteria, fungi and actinomycetes and reduced the microbial count in all samples collected upto 90 days after herbicides application. Thereafter, microbial population started to recover slowly (Chowdhury *et al*., 2012)

Under hand-weeded plots (weed free check), the microbial population increased continuously. At later stage of 60 days after spray these herbicides in sugarcane lost their potency and degraded in the soil. The herbicides do not leave any adverse effect on the soil microflora after few days or months of their application (Ohmes *et al*., 2000). There was a reduction in growth due to the presence of sulfonyl urea herbicides was due to the inhibition of the enzyme ALS (Boldt and Jacobsen, 2006). Bacterial, fungal and actinomycetes populations decreased upon treatment with herbicides (atrazine, paraquat, diquat and glyphosate) when compared to the control (Sebiomo *et al*., 2011).

2.9. Soil weed seed bank

A soil seed bank is the reserve of viable seeds present on the surface and in the soil. The seed bank is an indicator of past and future weed problems. Usage of herbicides also influence the species composition of the seed bank and may increase or decrease it, depending on the chemicals used (Ball, 1992) and they can also cause species shifting (Robert *et al*., 1992). In general, it can be said that interaction among herbicides, land preparation and cultural practice have altered the size and nature of seed banks (Roberts and Neilson, 1981).

Knowledge and better understanding of the weed seed bank is very important because it provides evidence of past field management and may facilitate forecasts on future weed problems (Frank *et al*., 1992).

Schweizer and Zimdahl (1984) reported that seed bank was reduced by 98 per cent after the application of atrazine in a corn field, during six years. Ramsdale *et al*. (2006) reported that no-till and conventional system, soil seed banks consisted of about 87 per cent broadleaf and 13 per cent grasses species, whereas, the mulch-till system soil seed bank consisted of 68 per cent broadleaf and 32 per cent grasses species in the spring wheat-soybean cropping systems.

2.10. Herbicide residue

2.10.1. Residue analysis

The residue level of imazethapyr in soil, soybean grains and straw was 0.008, 0.102 and 0.301 µg g^{-1}, respectively (Sondhia and Dixit, 2007). They also reported that the persistence of imazethapyr residues applied to soybean at double the recommended dose (200 g a.i. ha^{-1}) in soil, grain and stover of soybean. Soil collected at 0-15 cm depth from treated plots at 15, 30, 45, 60 and 75 days after application of herbicide and after harvest of the crop showed a higher residual effect of sulfentrazone at higher doses (0.5-1.2 kg ha^{-1}) over time, with 80 per cent at 60 days after application in sugarcane cultivation (Melo *et al*., 2010).

2.10.2. Persistence and residue

Vencill and Banks (1994) reported that the time for 50 per cent dissipation of bioavailable chlorimuron in nine soils in southern United States varied by year and soil between 5 and 20 days. In soil, chlorimuron dissipation was described by first-order kinetics and half-life ranged from 17 to 22 days (Gaynor *et al*., 1997). In the two soils, halosulfuron-methyl was dissipated faster with increasing temperature and lowering of soil pH. However, increasing moisture contents increased the dissipation rate of halosulfuron-methyl (Kuwatsuka and Yamamoto, 1997). They also reported that halosulfuron sorption was highly correlated with soil organic content and inversely correlated with soil pH.

Sulfonyl urea herbicides are widely applied in the control of most broad-leaved weeds and annual grasses in a variety of agricultural crops due to their low application rates (3 to 40 g ha^{-1}), low mammalian toxicity and unprecedented herbicidal activity (Battaglin *et al.,* 2000; Cessna *et al*., 2006). The residual phytotoxicity and persistence of chlorimuron and metsulfuron increased in the two soils with increasing rate of application (Castro *et al*., 2002). Eventhough the sulfonyl urea herbicides is having less persistence in soil, few members of the family and their secondary metabolites were reported to persist longer in soil.

In tropical and sub tropical and high rainfall areas, the herbicides degraded rapidly by chemical and biological process and hence the residues are generally below detectable level (Sondhia and Gopal, 2012). Chowdhury *et al*. (2012) reported that sulfonyl urea herbicides like ethoxysulfuron was completely degraded and the residue was below detectable level at harvest. Likewise, pyrazosulfuron ethyl did not show any phytotoxicity and residual effect in rice (Hareesh *et al*., 2012). Chlorimuron ethyl showed persistence in soyabean crop up to 15 days after application however the level of persistence reduced after 30 days after application (Arora *et al*., 2012). Residual effect of pyrasosulfuron in rice was not observed by Ezhilarasi *et al.* (2012).

2.11. Problems of existing herbicide

From 1950s onwards, triazine group have been a mainstay for control of grasses and broad leaved weeds. Among these, atrazine is the most widely used herbicide. Atrazine is used as herbicide on more than 70 per cent of sugarcane production. Continuous use of the same herbicide resulted in weed shift from annuals to perennials.

The continuous use of triazines (atrazine, simazine and metribuzine) in the crop in Ontario/Canada altered the species composition and resulted in an increase in resistant plants to the products (Cavers and Benoit, 1989). Under such circumstances, atrazine would not only to ensure the broad spectrum control of grasses, sedges and broadleaf weeds. The alternate herbicides like halosulfuron methyl and chlorimuron ethyl and their combinations may address problematic weeds like *Cyperus* sp and broad leaved weeds in sugarcane, soybean, tobacco, potato and beans crops and cropping system.

From the foregoing review, it is clearly evident that there is need to evaluate the bioefficacy of alternate new formulation herbicides for achieving broad spectrum control and also targeting problematic weeds like *Cynodon dactylon* and *Cyperus* sp. .For any new herbicide evaluation, proper method of application and dose of herbicide should be studied. Hence, an attempt has been made to formulate a research programme to evaluate a newly available herbicides halosulfuron methyl, chlorimuron ethyl and combination of both for weed control in sugarcane and their residual effect on succeeding crops.

Materials and Methods

CHAPTER III

MATERIAL AND METHODS

Field experiments were conducted at Eastern Block farm of Tamil Nadu Agriculture University, Coimbatore during main (Oct.-Nov.) season 2011-12 and late (April-May) season 2012-13 to study the effect of early post emergence herbicides *viz.*, halosulfuron methyl, chlorimuron ethyl and halosulfuron methyl + chlorimuron ethyl for the weed management in sugarcane and their residual effects on succeeding crops. The details of the experimental material used and the methods adopted during the course of investigation are presented in this chapter.

3.1. MATERIAL

3.1.1. Location

Field experiments were conducted in field No. 74 and NA5 of Eastern Block farm, Tamil Nadu Agricultural University, Coimbatore during main (Oct.-Nov.) season 2011 and late (April-May) season 2012. The farm is located in the Western agroclimatic zone of Tamil Nadu at 11^{o}N latitude, 77^{o}E longitude and at an altitude of 426.72 m above mean sea level.

3.1.2. Climate and weather

Coimbatore is geographically situated in Semi Arid Tropics. The normal weather condition of Coimbatore based on the 63 years of weather data indicated that a mean annual rainfall of 657 mm is received in 47 rainy days. The mean maximum and minimum temperature are 31.5 and 21.4^{0}C, respectively. The relative humidity ranges from 91.0 per cent (0722 hrs) to 68.0 per cent (1422 hrs). The mean solar radiation is measured at 429.0 cal cm^{-2} day^{-1}.

3.1.3. Weather prevailed during crop growth period

The normal weather conditions at Coimbatore (Mean of 62 years 1951-2012) are as follows. A mean annual rainfall of 701.1 mm was received in 58.4 rainy days. The maximum and minimum temperatures were 31.6°C and 21.4°C, respectively. Mean relative humidity was 64.4 per cent and the mean bright sunshine hours per day were 7.1 hours with a mean solar radiation of 400.5 cal $cm^{-2}day^{-1}$. The data on the weather conditions prevailed during the cropping periods are presented in Appendix I and II and depicted in Fig. 1 and 2.

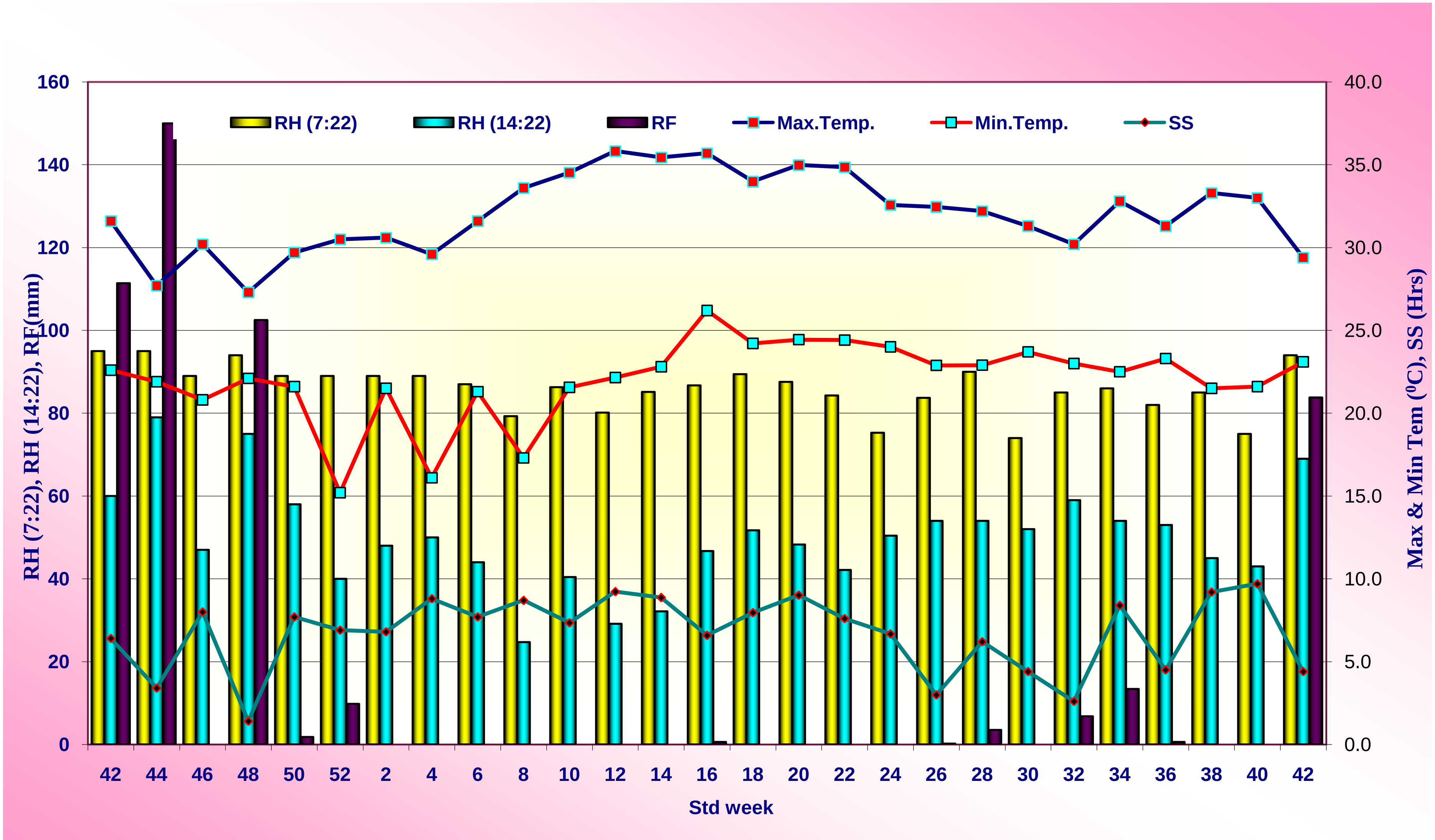

Fig. 1. Weather parameters prevailed during the cropping period (2010 -11)

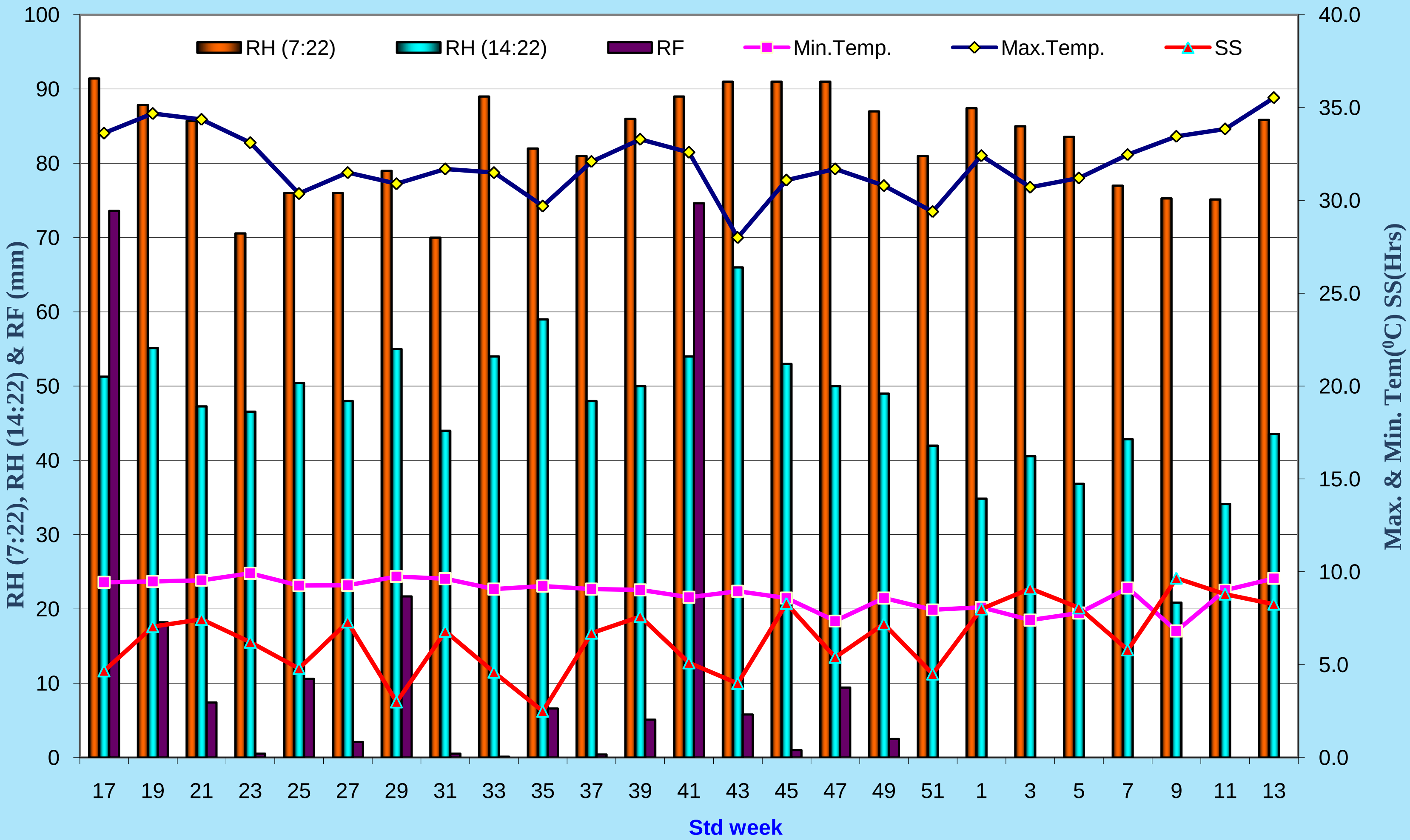

Fig. 2. Weather parameters prevailed during the cropping period (2012-13)

During main season 2011-12, maximum and minimum temperatures prevailed during the cropping period were 31.8°C and 22.0°C, respectively. A total rainfall of 845 mm was received in 33 rainy days during the cropping period. The mean sunshine hours during the cropping period was 6.68 hrs and the mean day relative humidity and the night relative humidity were 50.0 and 85.3 per cent, respectively.

During late season 2012-13, maximum and minimum temperatures prevailed during the cropping period were 32.0°C and 22.2°C, respectively. A total rainfall of 465.6 mm was received in 26 rainy days during the cropping period. The mean sunshine hours during the cropping period was 6.7 hrs and the mean day relative humidity and the night relative humidity were 47.0 and 84.0 per cent, respectively.

3.1.4. Soil of experimental site

The soil of the experimental fields was of clay loam texture with moderate drainage. The soil is classified taxonomically as *Typic Haplustalf*. Composite soil samples were collected prior to the experiment and analyzed for various physical and chemical characteristics. The soil fertility status of the experimental site was low in available nitrogen, medium in available phosphorus and high in available potassium respectively. The details on physical and chemical characteristics of the soil are given in Table 1 and the procedures followed for the soil and plant analyses are furnished in Table 2.

Table 1. Soil characteristics of the experimental fields

Season	Special season 2011	Main season 2012-13
A. Mechanical analysis		
Clay (%)	47.1	32.7
Silt (%)	9.0	18.36
Sand (%)	42.6	48.9
Textural class	Clay loam	Sandy clay loam
Lime status	Calcareous	Calcareous
B. Physical analysis		
Field capacity (%)	42.15	42.23

Permanent wilting point (%)	31.51	35.4
Available soil moisture (%)	9.89	11.2
Bulk density (Mg m^{-3})	1.24	1.21
C. Chemical analysis		
pH (1: 2 of soil : water)	9.13	8.26
Electrical conductivity (dS m^{-1})	0.63	0.18
Organic carbon (%)	0.57	0.33
Available nitrogen (kg ha^{-1})	253	276
Available phosphorus (kg ha^{-1})	22.3	12.2
Available potassium (kg ha^{-1})	688	510
Cu (ppm)	1.35	1.33
Mn (ppm)	1.70	1.71
Fe (ppm)	0.90	1.1
Zn (ppm)	1.67	1.73

Table. 2. Methods employed for soil analysis

Particulars	**Method**	**Reference**
I. Soil analysis		
A. Mechanical analysis	Robinson's International pipette method	Piper (1966)
B. Chemical analysis		
1. Available nitrogen	Alkaline permanganate method	Subbiah and Asija (1956)
Particulars	**Method**	**Reference**
2. Available phosphorus	Using 0.5 M $NaHCO_3$ of pH 8.5	Olsen *et al*. (1954)

	using colorimeter	
3. Available potassium	Flame photometric method using neutral normal ammonium acetate extract	Stanford and English (1949)
4. Organic carbon	Chromic acid wet digestion method	Walkley and Black (1934)
5. pH (Soil: water = 1: 2)	Using glass electrode in the ELICO pH meter	Jackson (1973)
6. Electrical conductivity (Soil: water = 1: 2)	Using ELICO conductivity bridge	Jackson (1973)

3.2. METHODS

3.2.1. Experimental details

The experiments were laid out in a Randomised Complete Block Design with three replications. The field layout plan of both the seasons is given in Fig. 3 and 4. The experiments consisted of fifteen treatments involving four doses in each of early post emergence herbicides *viz.*, halosulfuron methyl , chlorimuron ethyl and halosulfuron methyl + chlorimuron ethyl along with recommended pre emergence formulation of atrazine, hand weeding on 30 DAP (HW) and unweeded control

3.2.2. Treatments

The treatment details are as follows ;

T_{1}-EPOE- Halosulfuron methyl at 45.0 g a.i. ha^{-1}

T_{2}-EPOE- Halosulfuron methyl at 67.5 g a.i. ha^{-1}

T_{3}-EPOE- Halosulfuron methyl at 90.0 g a.i. ha^{-1}

T_{4}-EPOE- Halosulfuron methyl at 135.5 g a.i. ha^{-1}

T_{5}-EPOE- Halosulfuron methyl + Chlorimuron ethyl (Combi) at 45.0 g a.i. ha^{-1}

T_{6}-EPOE- Halosulfuron methyl + Chlorimuron ethyl (Combi) at 67.5 g a.i. ha^{-1}

T_{7}-EPOE- Halosulfuron methyl + Chlorimuron ethyl (Combi) at 90.0 g a.i. ha^{-1}

T_{8}-EPOE- Halosulfuron methyl + Chlorimuron ethyl (Combi) at.135.5 g a.i. ha^{-1}

T_{9}-EPOE- Chlorimuron ethyl at 6.0 g a.i. ha^{-1}

T_{10}-EPOE- Chlorimuron ethyl at 9.0 g a.i. ha^{-1}

T_{11}-EPOE- Chlorimuron ethyl at 12.0 g a.i. ha^{-1}

T_{12}-EPOE- Chlorimuron ethyl at 18.0 g a.i. ha^{-1}

T_{13}-PE- Atrazine at 1.0 kg a.i. ha^{-1}

T_{14}-HW on 30

T_{15}-Unweeded control

EPOE - early post emergence (2-3 leaf stage of weeds). halosulfuron methyl + chlorimuron ethyl is combination of halosulfuon methyl and chlorimuron ethyl. PE – pre emergence.

3.2.3. Season and varieties

In the first year of field experiment, the planting of sugarcane (variety CO 86032) was done on 22.10.2011 during main season (Oct. – Nov.) and the planting of second year experiment was done with the same variety on 27.04.2012 during late season (April- May). The details of the cultivars are given in Table 3.

Table 3. Characteristics of sugarcane cultivar used in the experiments

Parameters	Particulars
Variety	CO 86032
Duration	10-12 months
Parentage	CO 62198 × COC 671
Leaf size	Medium
Leaf colour	Dark green
Spines	Few, hard, deciduous

Sheath colour	Green with purple
Stem colour	Reddish pink (exposed) Greenish yellow (unexposed
Girth	Medium
Joint	Cylindrical
Bud groove	Absent
Size	Medium
Average yield	110 t ha^{-1}
CCS (%)	13 .0
CCS (t ha^{-1})	14.7

It is a high yielding and high sucrose containing early mid season variety with attractive dark green canopy. The canes are medium thick and reddish pink in colour with prominent ivory marks and purple leaf sheath. The variety is resistant to smut disease. It has high potential for tillering and ratoonability with mean sugar yield of 14.7 t ha^{-1} (SBI, 1993).

3.2.4. Field preparation

The experimental fields were initially disc ploughed once and twice with tractor drawn cultivator and the soil was brought to a fine tilth condition. The ridges and furrows (using Bullock drawn ridger) were formed at 90 cm apart uniformly. Plots were marked as per the specified size. The plots were provided with irrigation and drainage channels all around the experimental field.

3.2.5. Cane setts planting

The seven months old cane nursery (short crop) was used for the preparation of CO 86032 setts and the seed materials were obtained from Bannari Amman Sugars, Ltd Sathyamangalam. A seed rate of 75,000 two budded setts ha^{-1} was adopted. The setts were soaked with fungicide (Carbendazim 0.1% + 2.5 kg urea in 250 litres of water) and then *Azospirillum* at 2000 g ha^{-1} was applied in the field before planting. After irrigating the plots, the setts were planted horizontally in the furrows continuously. The cropping details are given in table 4.

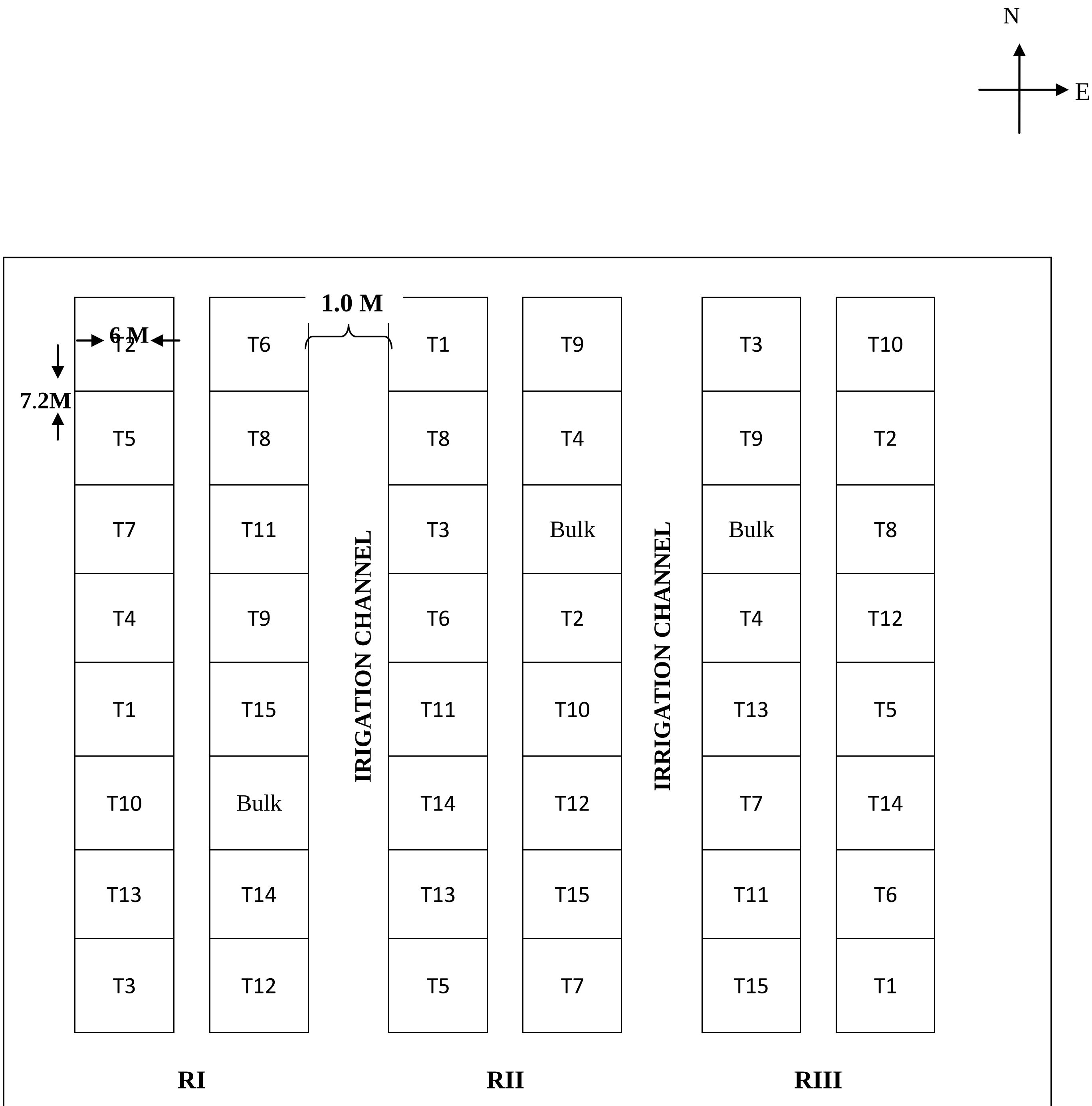

Fig. 3. Field layout of experimental field; Main season (2011 - 12)

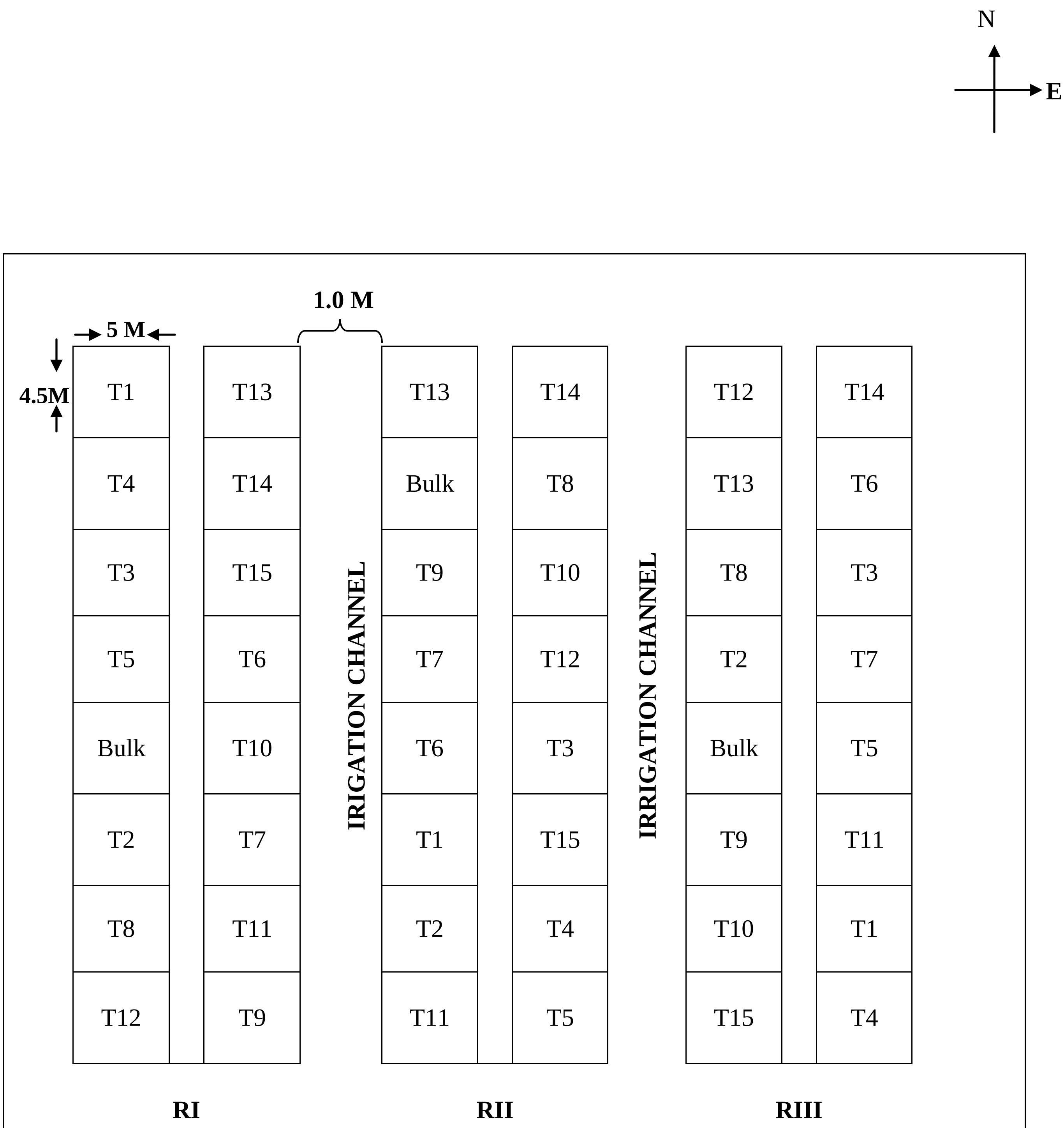

Fig. 4. Field layout of experimental field; Late season (2012 - 13)

Table 4. Cropping details

Particulars	Main season (Oct. – Nov.) 2011	Late season (April - May) 2012
Date of planting	22.10.2011	27.04.2012
Spacing	90 cm row spacing	90 cm row spacing
Gross plot size	6.0 m × 7.2 m	5.0 m × 4.5 m
Net plot size	5.0 m × 5.4 m	4.0 m × 2.7 m
Date of harvest	07.09.2012	23.02.2013

3.2.6. Water management

Before planting, the field was irrigated to keep it under saturated condition to facilitate easy planting and uniform crop establishment. Third day after planting, life irrigation was given. Thereafter, the crop was irrigated as per the requirement. Irrigation was withheld 30 days prior to harvest.

3.2.7. Fertilizers application

The farm yard manure was applied at 12.5 t ha^{-1} at last ploughing, incorporated and then leveled. The fertilizer dose of 275:62.5:112.5 kg N: P_2O_5 : K_2O ha^{-1}, respectively was adopted. The entire quantity of P was applied as basal dose as Diammonium phosphate, while nitrogen in the form of urea and potassium as muriate of potash were applied in four equal splits at 30, 60, 90 and 120 DAP.

3.2.8. Biofertilizers

Azospirillum at 2400 g ha^{-1} was mixed with 25 kg well composted FYM and 25 kg sand for uniform application throughout the field at 30 and 60 DAP.

3.2.9. Management of treatments

Calculated quantity of early post emergence herbicides (T_1 to T_{12}) for the respective treatment plot was diluted in water at 750 lit ha^{-1} and sprayed with a Knapsack sprayer fitted with fan type WFN 40 nozzle at 20 days after planting (DAP) by maintaining optimum soil moisture in the field. Atrazine as pre emergence herbicide (T_{13}) was applied at 3 DAP. The hand weeding (T_{14}) was done at 30 DAP. All treatments received partial earthing up at 60 DAP except unweeded control. Unweeded control plots were kept undisturbed during the entire cropping period. The details of the herbicides used in the present study (*viz.,* atrazine, halosulfuron methyl and chlorimuron ethyl) are given in Appendix III.

3.2.10. Plant protection

Need based plant protection measures were taken up against termite. Chlorpyriphos 20 per cent EC at 0.04 per cent was sprayed against termite whenever it occurred. Monocrotophos spray at 1.0 lit ha^{-1} were given twice at 35 and 60 days after planting for stem borer control.

3.2.11. Intercultivation

Partial earthing up was given at 60 DAP to all the treatments except unweeded check. Final earthing up was carried out at 90 DAP. The crop was detrashed (removal of dried leaves) by hand at 150 and 210 DAP.

3.2.12. Harvesting

Harvesting of the cane was done at the age of 11 months. The canes from the net plot area were harvested and weighed for recording cane yield.

3.2.13. Residue crops cultivation

To study the residual effect of herbicides applied to sugarcane, in both the seasons the succeeding crops *viz.,* pearl millet (CO 9) and sunflower (CO 4) were raised without disturbing the layout of sugarcane experiment. After harvesting the sugarcane, the follow up crops were sown (two rows of each) and maintained by adopting recommended package of practices.

3.2.14. Sampling technique

Four quadrats of size 0.5 m x 0.5 m ($0.25m^2$) were placed in each plot and the weeds falling within the frames of the quadrats were counted, recorded and the mean values were expressed in number m^{-2}. The densities of grasses, sedges and broad leaved weeds and the total weeds were recorded at 30, 60, 90 and 120 DAP and expressed in number m^{-2}. Also, the weeds falling within the frames of the quadrats were collected and washed free of soil and shade dried. They were later dried in hot-air oven at 80^oC for 72 hr and dry weight of grasses, sedges and broadleaved weeds were recorded separately at 30, 60, 90 and 120 DAP. The individual dry weights were summed up to arrive total weed dry weight (g m^{-2}).

3.3. Biometric observations

Within the net plot area, five plants were selected at random, tagged and subsequently used for recording all biometric observations. Biometric observations were recorded at 30, 60, 90 and 120 DAP and at harvest stages of crop growth.

3.3.1. Visual toxicity rating

After herbicide applications, the plants were observed for phytotoxicity effects. The herbicide injury were rated using 0 to 10 scale where 0 denotes no injury and 10 denotes complete destruction. The observation on phytotoxicity rating were done at 10, 20 and 30 Days After Herbicide Spray (DAHS). The visual toxicity rating was adopted in the present study as suggested by Rao (2000) and is depicted in Table 5.

Table 5. Phytotoxic symptom scoring and rating on weeds and crop

Weed control rating	Crop injury symptom	Rating	Effect
No control	No injury, normal	0	None
Very poor control	Slight stunting, injury or discoloration	1	Slight
Poor control	Some stand loss, stunting / discoloration	2	Slight
Poor to deficient control	Injury more pronounced, but not persistent	3	Slight
Deficient control	Moderate injury, recovery possible	4	Moderate
Deficient to moderate control	Injury more persistent, recovery doubtful	5	Moderate

Weed control rating	Crop injury symptom	Rating	Effect
Moderate control	More severe injury, no recovery possible	6	Moderate
Satisfactory control	Severe injury, stand loss	7	Severe
Good control	Almost destroyed few plants surviving	8	Severe
Good to excellent control	Very few plants alive	9	Severe
Complete control	Complete destruction	10	Complete

3.4. Weed characters

Weed characters *viz.*, weed flora, weed intensity, relative weed density, weed dry weight, weed control efficiency and weed index were recorded at 30, 60, 90 and 120 DAP in sugarcane and 30 and 60 DAS in the succeeding crops (pearl millet and sunflower). Nutrient removal by weeds in sugarcane was estimated at 30, 60, 90 and 120 DAP.

3.4.1. Weed flora

Weed species that occurred in the experimental site were observed and categorised as grasses, sedges and broad leaved weeds from the unweeded control plot and are listed in tables.

3.4.2. Weed density

Weed count was recorded using 0.25 m^2 quadrate from four randomly selected places in each plot and expressed as number m^{-2}. The weeds were classified as grasses, sedges, broad leaved weeds and species wise and expressed as number m^{-2}.

3.4.3. Weed dry weight

The quadrate of 0.25 m^2 was placed in four places at random and the weeds were removed, shade dried and oven dried at 80 ^{o}C till constant weight was arrived. The dry weight was recorded and expressed in g m^{-2}.

3.4.4. Weed control efficiency

The formula suggested by Mani *et al.* (1973) was adopted to calculate weed control efficiency.

$$\text{WCE (\%)} = \frac{\text{WDWc} - \text{WDWt}}{\text{WDWc}} \times 100$$

Where,

WCE - Weed control efficiency in percentage,

WDWc - Dry weight (g m^{-2}) of weeds in unweeded check plot, and

WDWt - Dry weight (g m^{-2}) of weeds in particular treatment plot.

3.4.5. Relative density

Relative density was calculated using the number of individual weed species and total number of weeds and expressed in percentage. The formula is as follows:

$$\text{Relative density} = \frac{\text{Number of individual weed species}}{\text{Total number of weeds}} \times 100$$

3.4.6. Weed index (WI)

Weed index was calculated by following the formula suggested by Gill and Vijayakumar (1966).

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

Where,

X - Yield from weed free plot (t ha^{-1}) and

Y - Yield in the respective treated plot (t ha^{-1}).

3.5. Crop characters

3.5.1. Growth parameters

Within the net plot area, five plants in each plot were selected at random, tagged and subsequently used for recording all biometric observations. Growth parameters were recorded at 30, 60, 90 and 120 DAP and at harvest stages of crop growth.

3.5.1.1. Germination percentage

Germination count was recorded at 30 and 45 DAP and expressed as percentage of germinated buds to the total number of buds planted.

3.5.1.2. Cane height

The vigour and growth of the cane were measured in terms of plant height. The representative canes were selected at random in each plot and tags were fixed near the bottom of randomly selected canes and height measurements recorded from the ground level to the third visible dew lap of the cane (Dillewijn, 1952). Height measurement were recorded at 30, 60, 90 and 120 DAP and the mean height of the selected canes at each stage was taken as the height of the cane and expressed in cm.

3.5.1.3. Tiller production

Tiller count was recorded at 60, 90 and 120 DAP in each of the treatmental plots and expressed as tillers ‘000 ha^{-1}.

3.5.1.4. Tillering capacity (TC)

Tillering capacity per germinated bud was calculated by using the formula as given by Chinnusamy (1990).

$$\text{Tillering Capacity} = \frac{\text{Total No. of tillers produced on 60 DAP}}{\text{Total No. of buds germinated at 30 DAP}}$$

3.5.1.5. Survival capacity

From the total number of tillers and the final millable cane population at harvest, the survival capacity of the tiller in percentage was worked out using the formula as given by Chinnusamy (1990).

$$\text{Survival capacity (\%)} = \frac{\text{Millable cane population at harvest}}{\text{Tiller production at 90 DAP}} \times 100$$

3.5.1.6. Total Dry Matter Accumulation (TDMA)

For estimating TDMA, the entire cane was pulled out at 30, 60, 90 and 120 DAP and partioned into the stem, leaf and sheath portion. They were weighed after drying the plants at 70 ± 2^{o}C for 48 hours. The total dry matter accumulation was arrived and the values expressed as t ha^{-1}. Same samples were powdered and used for chemical analysis.

3.6. Physiological characters

3.6.1. Leaf Area Index (LAI)

The leaf area of the third leaf from the top of the cane was taken as index leaf in the main stem. The leaf length and maximum width were measured and the LAI was calculated by employing the following formula suggested by Mongerland (1968). The LAI at 30, 60, 90 and 120 DAP was worked out using the formula.

$$\text{LAI} = \frac{(L \times B \times N \times K)}{\text{Ground area occupied}}$$

Where,

L - Length (cm) of the ith leaf,

B - Breath (cm) of the ith leaf,

N - Total number of leaves and

K - Constant factor (0.701) determined separately for the variety CO 86032.

3.6.2. Crop Growth Rate (CGR)

The crop growth rate was estimated by adopting the formula of Watson (1952) and expressed in g m^{-2} day^{-1}

$$\text{CGR} = \frac{W_2 - W_1}{P(t_2 - t_1)}$$

Where ,

W_2 and W_1	-	Whole plant dry weight (g) at stages of t_2 and t_1, respectively,
t_2-t_1	-	Time interval in days and
P	-	Land area occupied by the plant (m^2).

3.6.3. Relative Growth Rate (RGR)

The relative growth rate was estimated by adopting the formula as suggested by Watson (1952) and expressed in g g^{-1} day^{-1}.

$$RGR = \frac{\log W_2 - \log W_1}{(t_2 - t_1)}$$

Where ,

W_2 and W_1	-	Whole plant dry weight (g) at stages of t_2 and t_1 respectively and
t_2 - t_1	-	Time interval in days.

3.7. Nutrio-physiological analyses

Nutrient uptake by crop was estimated at 30, 60, 90 and 120 DAP stages and expressed in kg ha^{-1}.

3.7.1. Nitrogen uptake

The total nitrogen content of different plant parts (leaf, stem, leaf sheath) was estimated by micro Kjeldhal methods as proposed by Humphries (1956) and total N uptake at different stages was worked out by summing up the uptake in different parts of the plant after multiplying the total dry matter of the plant parts with the corresponding N content and expressed as kg ha^{-1}.

3.7.2. Phosphorus uptake

The dried plant samples of different parts collected at different phenophases were determined for total P content (%) calorimetrically from triple acid extract (Jackson, 1973) and P uptake was worked out and expressed as kg ha^{-1}.

3.7.3. Potassium uptake

The potassium content of the plant samples in different part of the plant drawn at various phenophases were analyzed by flame photometry using triple acid extract (Jackson, 1973) and expressed as percentage on dry weight basis. The total K uptake was then calculated and expressed as kg ha^{-1}.

3.8. Nutrient removal by weeds

Nutrient removal by weed samples were estimated at 30, 60, 90 and 120 DAP and expressed in kg ha^{-1}. The methods employed were given in Table 6.

3.8.1. Nitrogen

Total nitrogen content in weed samples was estimated and nitrogen removal by weeds was expressed in kg ha^{-1}.

3.8.2. Phosphorus

Total phosphorus content in weed samples was estimated and phosphorus removal by weeds was expressed in kg ha^{-1}.

3.8.3. Potassium

Total potassium content in weed samples was estimated and potassium removal by weeds expressed in kg ha^{-1}.

Table 6. Details of the analytical methods employed in plant analysis

S.No.	Parameters	Methods	Reference
1	Total nitrogen	Micro Kjeldahl method	Humphries (1956)
2	Total phosphorous	Colorimetry – Triple acid digestion	Jackson (1973)
3	Total potassium	Flame photometry – Triple acid digestion	Jackson(1973)

3.9. Microbial analysis

Microbial population (bacteria, actinomycetes and fungi) of soil was enumerated by standard plate count (Allen, 1953). One gram of moist soil was weighed and transferred to 100 ml sterile water blank and thoroughly shaken. This gave the dilution of 10^{-2}, from this using a sterile pipette, one ml of the suspension was transferred to 9 ml water blank to get a dilution of 10^{-3}. Subsequent dilution *viz.*, 10^{-4}, 10^{-5} and 10^{-6} were also made accordingly. One ml of each from the dilution was transferred to 3 petri-dishes, respectively. The respective media were melted, cooled and poured into the petri-dishes carrying the respective dilution and the plates were incubated at 30^{0}C and colonies were counted after incubation period and expressed as colony forming units g^{-1} of soil. The details of the microbial analysis are given in Table 7. Media used to asses the population dynamics of different microbial communities are furnished in Appendix IV.

Table 7. Details of the microbial analysis

S. No.	Organism	Dilution used	Incubation period (days)	Colony character
1	Bacteria	10^{-6}	2	Individual single colony forming units
2	Fungi	10^{-4}	5	Cottony growth
3	Actinomycetes	10^{-2}	7	Powdery colonies with pin pointed raised centre

3.10. Yield components and yield

For assessing the relationship between yield and its components, the following parameters were recorded at the time of harvest. The details of the method employed for estimating each character are indicated below.

3.10.1. Number of internodes cane^{-1}

In each treatment and replication, number of internodes were counted in the randomly selected canes from the net plot at harvest and expressed as number of internodes cane^{-1}.

3.10.2. Length of internode

The length of internodes was recorded at the middle from the randomly selected canes at harvest and expressed in cm.

3.10.3. Cane diameter

Diameter of randomly selected cane samples was measured by using Vernier Caliper at bottom, middle and top portion of the cane at harvest and the mean values were expressed in cm.

3.10.4. Number of millable canes

At the time of harvest, the total number of millable canes from the net plots were counted and expressed in thousands ha^{-1}.

3.10.5. Length of millable canes

Length of millable cane was measured at harvest and expressed in cm.

3.10.6. Single cane weight

Total cane weight was recorded at harvest from the already selected sample canes. The mean single cane weight was expressed as kg $cane^{-1}$.

3.10.7. Cane yield

Harvested canes were weighed from the net plot and the yield was expressed in t ha^{-1}. The sample cane harvested from the net plot for juice analysis was also added to the net plot weight.

3.11. Quality parameters

For quality parameters, ten cane samples were collected from each net plot area at random and crushed in a small three-roller cane crusher and the extracted juice was analysed for the following quality parameters.

3.11.1. Total Soluble Solids (TSS)

The total solids (Brix %) were recorded from the juice by using Brix hydrometer and corrected readings were worked out by noting the room temperature at the time of observation with the help of bar standards and expressed in percentage (Meade and Chen, 1977).

3.11.2. Sucrose content

The sucrose percent of juice was estimated by Hornes lead acetate clarification method by using polariscope (Meade and Chen, 1977).

3.11.3. Purity coefficient

The purity coefficient of juice was worked out from the total solids (Brix) and sucrose percentage with the following formula

$$\text{Purity coefficient (\%)} = \frac{\text{Sucrose (\%)}}{\text{Brix (\%)}} \times 100$$

3.11.4. Commercial cane sugar percentage (CCS %)

Commercial cane sugar percentage is the amount of white sugar commercially attainable from the unit weight of cane. It was worked out by using the formula.

$$\text{CCS (\%)} = 1.022\ S - 0.292\ B$$

Where,

S - Sucrose percentage of juice and

B - Brix percentage of juice.

3.11.5. Sugar yield

Sugar yield was calculated from the commercial cane sugar per cent at harvest and sugar yield expressed in t ha^{-1}

$$\text{Sugar yield (t ha}^{-1}\text{)} = \frac{\text{CCS (\%)} \times \text{Cane yield (t ha}^{-1}\text{)}}{100}$$

3.12. Residual analysis

3.12.1. Bio assay of herbicide residues

After the harvest of the main crop (sugarcane), two test crops namely, pearl millet and sunflower were raised as succeeding crops. The observations such as germination percentage at

10 DAS, plant height and dry matter production at 30 and 60 DAS and at harvest were taken from residual crops.

3.12.2. Observation in succeeding crops

3.12.2. Pearl millet

3.12.2.1. Germination

Pearl millet seeds were dibbled after harvesting and cleaning the sugarcane field. The germination count was taken at ten days after sowing.

3.12.2.2. Plant height

The plant height of the plants was measured on 30 and 60 DAS.

3.12.2.3. Dry matter production

Five plants plot^{-1} were removed at random from the sample area on 30 and 60 DAS and air dried. The air dried samples were oven dried at 80 ^{o}C till a constant weight was obtained and expressed in kg ha^{-1}.

3.12.2.4. Grain yield

On yellowing and shedding of leaves, the earheads were harvested from the net plot area and threshed. The grain was sun dried, cleaned and weighed and adjusted to 14 per cent moisture level and the grain yield was recorded plot wise and expressed in kg ha^{-1}.

3.12.2.5. Straw yield

The plants were cut above the ground level. The stover was sun dried, weighed and expressed in kg ha^{-1}.

3.12.3. Sunflower

3.12.3.1. Germination

Sunflower seeds were dibbled after harvesting and cleaning the sugarcane field. The germination count was taken on ten days after sowing.

3.12.3.2. Plant height

The plant height of the plants was measured on 30 and 60 DAS.

3.12.3.3. Dry matter production

Five plants plot^{-1} were removed at random from the sample area on 30 and 60 days and air dried. The air dried samples were oven dried at 80 ^{o}C till a constant weight was obtained and expressed in kg ha^{-1}.

3.12.3.4. Seed yield

On yellowing and shedding of leaves, the heads were harvested from the net plot area and threshed. The seeds were sun dried, cleaned weighed and adjusted to 14 per cent moisture level and the grain yield was recorded plot wise and expressed in kg ha^{-1}.

3.12.3.5. Haulm yield

The plants were cut above the ground level. The stalk was sun dried, weighed and expressed in kg ha^{-1}.

3.13. Residue analysis

3.13.1. Herbicide residue analysis in soil

The soil samples were collected from halosulfuron methyl and chlorimuron ethyl treated plots at harvest stage and analysed for the herbicide residue content.

3.13.1.1. Halosulfuron methyl

Halosulfuron methyl was extracted from the soil sample (10 g) with 10 ml of acetonitrile and 10 ml dichloromethane and the pH of the solution was adjusted to 3.0 with orthophosphoric acid. The sample with extractant was vertexed for 2 minutes. Subsequently the sample was added with 1.0 g magnesium sulphate ($MgSO_4$) and 4 g sodium chloride (NaCl) and 2 g of florocil. The sample was again vertexed for 2 minutes and the solvent/soil suspension was centrifuged at 3000 rpm for 5 minutes. Supernatant solution of the sample was separated and added with 1.0 g magnesium sulphate ($MgSO_4$), 0.6 gram sodium chloride (NaCl) and 30 mg of Primary Secondary Amine (PSA). Subsequently, solvent/soil suspension was centrifuged at 3000 rpm for 5 minutes.The extracts of the suspension was filtered and the filterate was dried by using water bath at 80^{0}C and the final extract was made up to 2 ml with HPLC acetonitrile and it was injected into the HPLC.

Instrumental conditions

Instrument	:	HPLC with DAD (Agilent 1200 series)
Mobile phase	:	Acetonitrile : Distilled water with 0.01 per cent acetic acid 70/ 30 (0.01% H_3PO_4)
Flow rate	:	1 µl/min
Wave length (nm)	:	238
Injection volume	:	10 µl (using auto sampler)
Temperature	:	Ambient
Column	:	Eclipse XDB C_{18} ; 5 cm; 4.6 x 150 mm
Retention time	:	4.393 min (±0.2 min)

3.13.1.2. Chlorimuron ethyl

Chlorimuron ethyl was extracted from the soil sample (40 g) with 80 ml of acetonitrile and the pH of the solution was adjusted to 3.0 using orthophosphoric acid. The sample with extractant was vertexed for 2 minutes. Subsequently, the sample was added with 12 g magnesium sulphate and 8.0 g sodium chloride salt. The sample was again vertexed for 2 minutes and the solvent/soil suspension was centrifuged at 3000 rpm for 5 minutes. Supernatant solution of the sample was separated and added with 2.0 g magnesium sulphate, 1.2 g sodium chloride salt and 60 mg of PSA. Subsequently, solvent/soil suspension was centrifuged at 3000 rpm for 5 minutes. The extracts of the suspension was filtered and the filterate was dried by using water bath at 80 ^{0}C and the final extract was made up to 2 ml with HPLC acetonitrile and it was injected into the HPLC.

Instrumental conditions

Instrument	:	HPLC with DAD (Agilent 1200 series)
Mobile phase	:	Acetonitrile : Distilled water with 0.01 per cent acetic acid 70/ 30 (0.01% H_3PO_4)
Flow rate	:	1 µl/min
Wave length (nm)	:	234

Injection volume	:	10 µl (using auto sampler)
Temperature	:	Ambient
Column	:	Eclipse XDB C_{18} ; 5 cm; 4.6 x 150 mm
Retention time	:	3.813 min (±0.2 min)

Validation of methods and recovery

The soil samples of known weight were taken and spiked with the halosulfuron and chlorimuron ethyl at different concentrations viz., 0, 0.5, 1.0, 2.5 and 5 ppm levels in three replicates. After one hour of spiking, halosulfuron and chlorimuron residue from the soil samples were extracted by following the procedures detailed in 3.13. Then the residue was determined using HPLC-DAD. Average recovery of halosulfuron methyl in soil is 83.0 per cent and chlorimuron ethyl is 81.25 per cent. The standard chromatogram is given in Appendix VI and VII.

3.14. Soil weed seed bank

The soil samples taken from individual treatment plots at two depths (0-15 and 15-30 cm) were spread on a shallow plastic trays 20 x 20 x 6 cm (holding two kg of individual soil sample) and left undisturbed with exposure to sun at optimum soil moisture. Individual weed seed germination was recorded cumulatively up to ninety days. After identification, the weeds were removed from seed bank trays at 45th day. After 45 days, the soil was treated with GA_3 to induce dormant weed seeds for germination and further seed germination was recorded for every kg of soil. This method was suggested by Adams and Steigerwalt (2008).

3.15. Economics

The expenditure incurred from planting to harvest was worked out and expressed in Rs. ha^{-1}. Total income obtained from cane yield was calculated for individual treatments. Gross and net returns were worked out. Unit cost of inputs and produce are furnished in Appendix V.

3.15.1. Gross return

Gross return was calculated using cane yield for sugarcane based on market price and expressed as Rs. ha^{-1}.

3.15.2. Net return

Net return was calculated by deducting the cost of cultivation from gross returns as detailed and presented in Rs. ha^{-1}.

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

3.15.3. Benefit-cost ratio

Benefit-cost ratio was calculated based on gross returns and cost of cultivation as given.

$$\text{Benefit-cost ratio (B:C)} = \frac{\text{Gross return (Rs. ha}^{-1}\text{)}}{\text{Cost of cultivation (Rs. ha}^{-1}\text{)}}$$

3.16. Statistical analysis

The data collected were subjected to statistical analysis in Randomized Complete Block Design following the method of Gomez and Gomez (2010). For weeds, the original values were transformed using $\sqrt{(X+2)}$ transformation and analysed statistically as suggested by Snedecor and Cochran (1967). Wherever the treatment difference were found significant (F test), critical difference were worked out at five per cent probability level and the values were furnished. If there are no significant difference between treatments, it was denoted by the symbol NS.

Experimental Results

CHAPTER IV

EXPERIMENTAL RESULTS

Field experiments were conducted in the Eastern Block farm of Tamil Nadu Agricultural University, Coimbatore during main (Oct.-Nov.) and late seasons (April-May) of 2011 and 2012, respectively to study the effect of early post emergence herbicides *viz.*, halosulfuron methyl, chlorimuron ethyl and halosulfuron methyl + chlorimuron ethyl for the weed management in sugarcane and their residual effects on succeeding crops. The results of field experiments are presented in this chapter.

4.1. Effect of herbicides on weeds

4.1.1. Weed flora (Table 8)

The weed flora of the experimental field was recorded and their absolute and relative density were presented in Table 8. The weed density was grouped into grasses, sedges and broad leaved weeds. Major broad leaved weeds of the experimental fields were *Trianthema portulacastrum, Digera arvensis, Amaranthus viridis, Cleome gynandra*, *Partheneium hysterophorus* and *Datura fastuosa*. Predominant grassy weeds found in the experimental site were *Dactyloctenium aegyptium, Echinochloa colonum, Setaria verticillata* and *Dinebra retroflexa. Cyperus rotundus* was the only predominant sedge weed observed in the experimental fields.

4.1.2. Composition of weeds (Table 9 and 10)

During both the seasons of experimentation, broad leaved weeds dominated which recorded higher proportion and it was followed by grasses and sedges.

During main season 2011, broad leaved weeds found to dominate among the weed flora at all the stages of crop growth *viz*., 30, 60, 90 and 120 DAP with relative density value of 52.16, 47.52, 58.36 and 58.37 respectively. This was followed by grasses and sedges. The relative density of grasses were 30.41, 38.66, 31.15 and 32.02 per cent at 30 ,60, 90 and 120 DAP respectively while that of sedges ranged from 9.62 to17.37 at 30 and 120 DAP respectively. Regarding individual weed species at initial stages, absolute density of *Setaria verticillata* was higher among grasses and *Dactyloctenium aegyptium* at later stages of crop growth than other weeds. Among the broad leaved

Table 8. Weed flora of the experimental fields

Botanical name	Common name	Habit
I. Broad leaved weeds		
**Trianthema portulacastrum* L.	Saranai (T), Pig weed (E)	Annual
Portulaca quadrifida L.	Siru pasarai (T)	Annual
**Digera arvensis*	Thooya keerai (T)	Annual
Commelina benghalensis L.	Bhrama thandu (T)	Annual
**Cleome gynandra* L.	Nalla velai (T)	Annual
**Datura fastuosa* L.	Umattam (T)	Annual
Amaranthus viridis L.	Kuppai kerai (T)	Annual
Corchorus olitorius L.	Perum punnakku poondu (T)	Annual
Cyanotis cucullata Kunth.	Nayini poondu (T)	Annual
Parthenium hysterophorus L.	Visha poondu (T), Congress weed (E)	Annual
II. Grasses		
**Dactyloctenium aegyptium* Beauv	Crowfoot grass (E)	Annual
**Echinochloa colonum* L.	Barnyard grass (E)	Annual
**Dinebra retroflexa* Panzeer	Pulimanja pullu (T)	Annual
Chloris barbata L.	Myilkondai pullu (T)	Annual
**Setaria verticillata* L.	Ottupul (T)	Annual
Cynodon dactylon L. Pers.	Arugampullu (T), Bermuda grass (E)	Perennial
III. Sedges		
Cyperus rotundus L.	Korai (T), Nut sedge (E)	Perennial

T-Tamil ; E-English ; * - Predominant weeds

Table 9. Absolute Density (AD) (No. m^{-2}) and relative Density (RD) (%) of weeds in sugarcane (2011-12)

Weeds	Main season 2011							
	30 DAP		60 DAP		90 DAP		120 DAP	
	AD	RD	AD	RD	AD	RD	AD	RD
Grasses								
Dactyloctenium aegyptium	18.7	11.08	30.5	13.17	13.2	11.55	17.3	16.63
Echinochloa colonum	12.7	7.53	36.7	15.85	11.3	9.89	7.3	7.02
Setaria verticillata	20.0	11.86	22.0	9.50	10.7	9.36	8.7	8.37
Total grass	51.3	30.41	89.5	38.66	35.6	31.15	33.3	32.02
Sedge								
Cyperus rotundus	29.3	17.37	32.0	13.82	12.0	10.50	10.0	9.62
BLW								
Trianthema portulacastrum,	28.7	17.01	37.3	16.11	19.3	16.89	17.3	16.63
Digeria arvensis	27.3	16.18	34.7	14.99	22.7	19.86	19.3	18.56
Amaranthus viridis	19.3	11.44	22.0	9.50	14.7	12.86	16.0	15.38
Parthenenium hysterophorus	12.7	7.53	16.0	6.91	10.0	8.75	8.0	7.69
Total BLW	88.0	52.16	110.0	47.52	66.7	58.36	60.7	58.37
Total weed density	168.7	100.0	231.5	100.0	114.3	100.0	104.0	100.0

Table 10. Absolute Density (AD) (No. m^{-2}) and relative Density (RD) (%) of weeds in sugarcane (2012-13)

Weeds	Late season 2012							
	30 DAP		60 DAP		90 DAP		120 DAP	
	AD	RD	AD	RD	AD	RD	AD	RD
Grasses								
Dactyloctenium aegyptium	16.7	10.01	26.5	11.43	15.2	14.18	14.0	15.10
Echinochloa colonum	14.7	8.818	46.7	20.14	13.3	12.41	9.3	10.03
Dinebra retroflexa	20.0	12.00	21.3	9.18	14.7	13.71	12.7	13.70
Total grass	51.3	30.77	94.5	40.75	43.2	40.30	36.0	38.83
Sedge								
Cyperus rotundus	29.3	17.58	38.0	16.39	12.0	11.19	10.0	10.79
BLW								
Trianthema portulacastrum,	30.0	18.00	33.3	14.36	17.3	16.14	15.3	16.50
Digeria arvensis	24.0	14.40	26.6	11.47	14.7	13.71	17.3	18.66
Cleome gynandra,	19.3	11.58	23.3	10.05	10.0	9.33	7.3	7.87
Datura fastuosa	12.7	7.618	16.0	6.90	10.0	9.33	6.7	7.23
Total BLW	86.0	51.58	99.3	42.82	52.09	48.59	46.7	50.38
Total weed density	166.7	100.0	231.9	100.0	107.2	100.0	92.7	100.0

weeds, *Trianthema portulacastrum* registered higher values of both absolute density and relative density at early stage and *Digera arvensis* at later stages of crop growth.

Similarly, during late season 2012, broad leaved weeds were found to dominate at all the stages of crop growth *viz.*, 30, 60, 90 and 120 DAP by recording higher percentage of relative density value 51.58, 42.82, 48.59 and 50.38 respectively. This was followed by grasses and sedge group of weeds. The relative density of grasses was 30.77, 40.75, 40.30 and 38.83 at 30, 60, 90 and 120 DAP, respectively. The relative density of sedge was higher at initial stages (16.39 -17.58) and at later stages, the relative density was reduced to 10.79. Regarding individual weed species, at initial stages absolute density of *Dinebra retroflexa* was higher among grasses and *Dactyloctenium aegyptium* at later stages of crop growth. Among the broad leaved weeds, *Trianthema portulacastrum* was higher at all stages of crop growth. This was followed by *Cyperus rotundus* the only sedge observed in the experimental field. The absolute density values of *Cyperus rotundus* was found to decline as the crop growth advanced.

4.1.3. Weed density

4.1.3.1. Density of *Dactyloctenium aegyptium* (Table 11)

During main 2011, EPOE application of higher doses of halosulfuron methyl + chlorimuron ethyl at 135.5 g a.i. ha^{-1} and halosulfuron methyl at 135.5 g a.i. ha^{-1} recorded lower weed density at 30 DAP. This was followed by halosulfuron methyl at 90 g a.i. ha^{-1}, halosulfuron methyl + chlorimuron ethyl at 90 g a.i. ha^{-1} and atrazine at 1.0 kg a.i. ha^{-1}. Among herbicide treatments chlorimuron ethyl (T_9), halosulfuron methyl (T_1) and halosulfuron methyl + chlorimuron ethyl (T_5) at lower doses resulted in higher weed density. However, at 60 DAP higher doses of test herbicides (T_3, T_4, T_7, T_8, T_{11}, T_{12}, T_{13} and T_{14}) recorded lower weed density (16.0 -24.5 m^{-2}) while the density was relatively higher with low doses of the same herbicides (23.6 -28.0 m^{-2}). At 90 DAP, halosulfuron methyl + chlorimuron ethyl at 135.5 and 90 g a.i. ha^{-1} recorded significantly lower weed density of *Dactyloctenium aegyptium* (0.7 and 1.3 m^{-2}, respectively) as compared with rest of the treatments. This was followed by chlorimuron ethyl at 9, 12 and 18 g a.i. ha^{-1} and halosulfuron methyl at 90 and 135.5 g a.i. ha^{-1}. Similar trend was followed at 120 DAP.

EPOE application of halosulfuron methyl + chlorimuron ethyl at 135.5 g a.i. ha^{-1}, recorded the lowest weed density at 30 DAP in late season crop also. This was followed by halosulfuron methyl + chlorimuron ethyl at 90 g a.i. ha^{-1}, halosulfuron methyl at

Table 11. Effect of different weed control treatments on density of *Dactyloctenium aegyptium* (No. m^{-2}) in sugarcane

Treatments	Main season 2011				Late season 2012			
	30 DAP	**60 DAP**	**90 DAP**	**120 DAP**	**30 DAP**	**60 DAP**	**90 DAP**	**120 DAP**
T_1 - EPOE-Halo. 45 g a.i. ha^{-1}	4.08 (14.7)	5.48 (28.0)	3.20 (8.0)	3.59 (10.9)	3.83 (12.7)	5.10 (24.0)	3.58 (10.8)	2.87 (6.2)
T_2 – EPOE-Halo. 67.5 g a.i. ha^{-1}	3.5 0(10.7)	5.23 (25.3)	2.48 (4.2)	2.96 (6.7)	3.37 (9.3)	4.90 (21.3)	2.96 (6.7)	2.42 (3.8)
T_3 - EPOE-Halo. 90 g a.i. ha^{-1}	3.16 (8.0)	5.15 (24.5)	2.16 (2.7)	2.58 (4.7)	2.94 (6.7)	4.74 (20.5)	2.71 (5.3)	2.00 (2.0)
T_4 - EPOE-Halo. 135.5 g a.i. ha^{-1}	2.71 (5.3)	4.90 (22.0)	2.08 (2.0)	2.36 (3.6)	2.45 (4.0)	4.83 (18.0)	2.52 (4.3)	2.00 (2.0)
T_5 - EPOE-Combi. 45 g a.i. ha^{-1}	3.92 (13.3)	5.16 (24.7)	3.05 (7.3)	3.27 (8.7)	3.65 (11.3)	4.76 (20.7)	3.36 (9.3)	2.45 (4.0)
T_6 - EPOE-Combi. 67.5 g a.i. ha^{-1}	3.37 (9.3)	4.69 (20.0)	2.31(3.3)	2.83 (6.0)	3.06 (7.3)	4.24 (16.0)	2.71 (5.3)	2.00 (2.0)
T_7 - EPOE-Combi. 90 g a.i. ha^{-1}	2.71 (5.3)	4.38 (17.2)	1.83 (1.3)	2.45 (4.0)	2.45 (4.0)	3.90 (13.2)	2.31 (3.3)	2.00 (2.0)
T_8 - EPOE-Combi. 135.5 g a.i. ha^{-1}	2.45 (4.0)	4.25 (16.0)	1.63 (0.7)	2.00 (2.0)	2.00 (2.0)	3.74 (12.0)	2.16 (2.7)	1.83 (1.3)
T_9 - EPOE-Chlori. 6 g a.i. ha^{-1}	3.83 (12.7)	5.10 (24.0)	2.94 (6.7)	3.46 (10.0)	3.56 (10.7)	4.83 (20.0)	3.27 (8.7)	2.94 (6.7)
T_{10} - EPOE-Chlori. 9 g a.i. ha^{-1}	3.74 (12.0)	5.06 (23.6)	2.83 (6.0)	3.25 (8.6)	3.46 (10.0)	4.64 (19.6)	3.04 (7.2)	2.43 (3.9)
T_{11} - EPOE-Chlori. 12 g a.i. ha^{-1}	3.74 (12.0)	4.76 (20.7)	2.83 (6.0)	3.35 (9.2)	3.46 (10.0)	4.32 (16.7)	3.16 (8.0)	2.42 (3.8)
T_{12} - EPOE-Chlori. 18 g a.i. ha^{-1}	3.56 (10.7)	4.62 (19.3)	2.60 (4.8)	3.06 (7.3)	3.27 (8.7)	4.16 (15.3)	2.96 (6.8)	2.03 (2.1)
T_{13} - PE-Atrazine 1.0 kg a.i. ha^{-1}	3.06 (7.3)	4.62 (19.3)	2.00 (2.0)	2.59 (4.7)	2.83 (6.0)	4.16 (15.3)	2.45 (4.0)	2.00 (2.0)
T_{14} - HW on 30 DAP	4.40 (17.3)	4.47 (18.0)	2.00 (2.0)	2.70 (5.3)	4.16 (15.3)	4.00 (14.0)	2.45 (4.0)	2.00 (2.0)
T_{15} - Unweeded control	4.55 (18.7)	5.70 (30.5)	3.90 (13.2)	4.40 (17.3)	4.32 (16.7)	5.34 (26.5)	4.15 (15.2)	4.00 (14.0)
SEd	**0.16**	**0.40**	**0.15**	**0.14**	**0.20**	**0.49**	**0.14**	**0.08**
CD (P=0.05)	**0.32**	**0.82**	**0.31**	**0.30**	**0.42**	**0.99**	**0.29**	**0.17**

Figures in the parenthesis are original values

135.5 g a.i. ha^{-1}, atrazine at 1.0 kg a.i. ha^{-1}. These treatments were comparable interms of recording lesser density of *Dactyloctenium aegyptium*. Lower doses of test herbicides like chlorimuron ethyl (T_9), halosulfuron methyl (T_1) and halosulfuron methyl + chlorimuron ethyl (T_5) recorded higher weed density of *Dactyloctenium aegyptium* (10.7 to 12.7 m^{-2}). At 60 DAP, higher doses of test herbicides (T_4, T_7, T_8, T_{12}, T_{13} and T_{14}) recorded lower weed density (12.0 to 18.0 m^{-2}) while lower doses (T_1, T_2, T_5, T_9 and T_{10}) resulted in higher weed density (19.6 to 24.0 m^{-2}) than unweeded control. There was no significant difference between the higher and lower doses of test herbicides. Unweeded control recorded significantly higher weed population. At 90 DAP, halosulfuron methyl + chlorimuron ethyl at 135.5 and 90 g a.i. ha^{-1} recorded significantly lesser weed density of *Dactyloctenium aegyptium* compared to other treatments (2.7 and 2.3 m^{-2}, respectively). This was followed by halosulfuron methyl at 135.5, atrazine at 1.0 kg a.i. ha^{-1} and hand weeding on 30 DAP which was similar effect in containing the density of *Dactyloctenium aegyptium*. Similar trend was followed at 120 DAP. Unweeded control recorded maximum density of *Dactyloctenium aegyptium* at all the stages of observation during both the seasons.

4.1.3.2. Density of *Echinochloa colonum* (Table 12)

During main season 2011, at 30 DAP, EPOE application of higher doses of halosulfuron methyl + chlorimuron ethyl at 135.5 g a.i. ha^{-1}, 90 g a.i. ha^{-1} and halosulfuron methyl at 135.5 g a.i. ha^{-1} and atrazine at 1.0 kg a.i. ha^{-1} recorded lower weed density of *Echinochloa colonum* (1.3 to 2.7 m^{-2}) compared to other herbicides tested. Test herbicides at lower doses, chlorimuron ethyl (T_9), halosulfuron methyl (T_1) and halosulfuron methyl + chlorimuron ethyl (T_5) recorded higher weed density (6.7 to 8.7 m^{-2}) than higher doses. However, at 60 DAP, higher doses of test herbicides (T_3, T_4, T_7, T_8, T_{11}, T_{12}, T_{13} and T_{14}) recorded lower weed density (15.3 to 20.0 m^{-2}) and lower doses (T_1, T_2, T_5, T_9 and T_{10}) recorded higher weed density (22.7 to 20.0 m^{-2}).

Table 12. Effect of different weed control treatments on density of *Echinochloa colonum* (No. m^{-2}) in sugarcane

Treatments	Main season 2011				Late season 2012			
	30 DAP	**60 DAP**	**90 DAP**	**120 DAP**	**30 DAP**	**60 DAP**	**90 DAP**	**120 DAP**
T_1 - EPOE-Halo. 45 g a.i. ha^{-1}	3.27 (8.7)	4.97 (22.7)	2.94 (6.7)	2.44 (4.0)	2.94 (6.7)	5.88 (32.7)	3.26 (8.7)	2.82 (6.0)
T_2 – EPOE-Halo. 67.5 g a.i. ha^{-1}	2.58 (4.7)	4.56 (18.7)	2.44 (4.0)	2.00 (2.0)	2.58 (4.7)	5.53 (28.7)	2.82 (6.0)	2.44 (4.0)
T_3 - EPOE-Halo. 90 g a.i. ha^{-1}	2.31 (3.3)	4.40 (17.3)	2.16 (2.7)	1.82 (1.3)	2.30 (3.3)	5.41 (27.3)	2.58 (4.7)	2.30 (3.3)
T_4 - EPOE-Halo. 135.5 g a.i. ha^{-1}	2.16 (2.7)	4.32 (16.7)	2.00 (2.0)	1.82 (1.3)	2.00 (2.0)	5.35 (26.7)	2.44 (4.0)	2.30 (3.3)
T_5 - EPOE-Combi. 45 g a.i. ha^{-1}	3.06 (7.3)	4.83 (21.3)	2.82 (6.0)	2.30 (3.3)	2.94 (6.7)	5.77 (31.3)	3.16 (8.0)	2.70 (5.3)
T_6 - EPOE-Combi. 67.5 g a.i. ha^{-1}	2.31(3.3)	4.40 (17.3)	2.00 (2.0)	2.00 (2.0)	2.30 (3.3)	5.41 (27.3)	2.44 (4.0)	2.44 (4.0)
T_7 - EPOE-Combi. 90 g a.i. ha^{-1}	2.00 (2.0)	4.24 (16.0)	1.82 (1.3)	2.00 (2.0)	2.00 (2.0)	5.29 (26.0)	2.30 (3.3)	2.44 (4.0)
T_8 - EPOE-Combi. 135.5 g a.i. ha^{-1}	1.83 (1.3)	4.16 (15.3)	1.82 (1.3)	2.00 (2.0)	1.82 (1.3)	5.22 (25.3)	2.30 (3.3)	2.44 (4.0)
T_9 - EPOE-Chlori. 6 g a.i. ha^{-1}	2.94 (6.7)	4.76 (20.7)	2.70 (5.3)	2.16 (2.7)	2.94 (6.7)	5.71 (30.7)	3.05 (7.3)	2.58 (4.7)
T_{10} - EPOE-Chlori. 9 g a.i. ha^{-1}	2.83 (6.0)	4.69 (20.0)	2.44 (4.0)	2.00 (2.0)	2.94 (6.7)	5.65 (30.0)	2.82 (6.0)	2.44 (4.0)
T_{11} - EPOE-Chlori. 12 g a.i. ha^{-1}	2.83 (6.0)	4.69 (20.0)	2.44 (4.0)	1.82 (1.3)	2.70 (5.3)	5.65 (30.0)	2.82 (6.0)	2.30 (3.3)
T_{12} - EPOE-Chlori. 18 g a.i. ha^{-1}	2.45 (4.0)	4.47 (18.0)	2.44 (4.0)	1.82 (1.3)	2.44 (4.0)	5.47 (28.0)	2.82 (6.0)	2.30 (3.3)
T_{13} - PE-Atrazine 1.0 kg a.i. ha^{-1}	2.00 (2.0)	4.24 (16.0)	2.30 (3.3)	2.00 (2.0)	2.16 (2.7)	5.29 (26.0)	2.70 (5.33)	2.44 (4.0)
T_{14} - HW on 30 DAP	3.65 (11.3)	4.16 (15.3)	1.63 (0.67)	1.63 (0.67)	3.83 (12.7)	5.22 (25.3)	2.16 (2.7)	2.16 (2.7)
T_{15} - Unweeded control	3.83(12.7)	6.22 (36.7)	3.65 (11.3)	3.05 (7.3)	4.08 (14.7)	6.97 (46.7)	3.91 (13.3)	3.36 (9.3)
SEd	**0.19**	**0.35**	**0.22**	**0.17**	**0.20**	**0.28**	**0.17**	**0.16**
CD (P=0.05)	**0.39**	**0.72**	**0.44**	**0.36**	**0.41**	**0.58**	**0.36**	**0.32**

Figures in the parenthesis are original values

At 90 DAP, hand weeding on 30 DAP which recorded significantly lower weed density (0.7 m^{-2}) of *Echinochloa colonum* and this was comparable with halosulfuron methyl + chlorimuron ethyl at 135.5 and 90 g a.i. ha^{-1} which recorded lower weed density of 1.3 m^{-2}. This was followed by halosulfuron methyl at 135.5 g a.i. ha^{-1} and 90 g. a.i. ha^{-1} and atrazine 1.0 kg a.i. ha^{-1}. These treatments were comparable with chlorimuron ethyl at 12 and 18 g a.i. ha^{-1}. Similar trend was observed at 120 DAP.

4.1.3.3. Density of *Cyperus rotundus* (Table 13)

During main season 2011, at 30 and 60 DAP, halosulfuron methyl at 90 and 135.5 g a.i. ha^{-1} as early post emergence spray recorded considerably lesser number of *Cyperus rotundus* over other treatments. EPOE application of halosulfuron methyl + chlorimuron ethyl at 90 and 135.5 g a.i. ha^{-1} stood next in recording lesser number of *Cyperus rotundus* both at 30 and 60 DAP. At 90 DAP, halosulfuron methyl + chlorimuron ethyl at 135.5 and 90 g a.i. ha^{-1} and halosulfuron methyl at 90 and 135.5 g a.i. ha^{-1} were equally effective in controlling *Cyperus rotundus* which was reflected by more or less similar values of *Cyperus rotundus*. Higher population of *Cyperus rotundus* was noticed in atrazine at 1.0 kg a.i. ha^{-1} sprayed plot which is indicative of the non effectiveness of the herbicide on *Cyperus rotundus.* The same trend was noticed at 120 DAP.

During the second year of the experiment halosulfuron methyl at higher doses was found to be effective in controlling *Cyperus rotundus* at 30 and 60 DAP. This herbicide at higher doses recorded the least density of *Cyperus rotundus*. This was followed by EPOE application of halosulfuron methyl + chlorimuron ethyl at 90 and 135.5 g a.i. ha^{-1} in recording lesser population of *Cyperus rotundus* than others. At 90 DAP, halosulfuron methyl + chlorimuron ethyl at higher doses (135.5 g a.i. ha^{-1}) recorded lesser number of *Cyperus rotundus.* halosulfuron methyl + chlorimuron ethyl and halosulfuron methyl at lower doses were not effective against *Cyperus rotundus*. More population of *Cyperus rotundus* was noticed in atrazine applied plots at all the three stages of observation and thus it

Table 13. Effect of different weed control treatments on density of *Cyperus rotundus* (No. m^{-2}) in sugarcane

Treatments	Main season 2011				Late season 2012			
	30 DAP	60 DAP	90 DAP	120 DAP	30 DAP	60 DAP	90 DAP	120 DAP
T_1 - EPOE-Halo. 45 g a.i. ha^{-1}	3.46 (10.0)	2.44 (4.0)	2.30 (3.3)	2.00 (2.0)	3.83 (12.7)	2.82 (6.0)	2.30 (3.3)	2.00 (2.0)
T_2 – EPOE-Halo. 67.5 g a.i. ha^{-1}	3.36 (9.3)	2.30 (3.3)	2.16 (2.7)	1.63 (0.67)	3.55 (10.7)	2.44 (4.0)	2.30 (3.3)	2.00 (2.0)
T_3 - EPOE-Halo. 90 g a.i. ha^{-1}	2.58 (4.7)	1.63 (0.67)	1.82 (1.3)	1.63 (0.67)	2.94 (6.7)	1.63 (0.67)	2.00 (2.0)	1.63 (0.67)
T_4 - EPOE-Halo. 135.5 g a.i. ha^{-1}	2.44 (4.0)	1.41 (0.0)	1.63 (0.67)	1.63 (0.67)	2.44 (4.0)	1.41 (0.0)	2.00 (2.0)	1.63 (0.67)
T_5 - EPOE-Combi. 45 g a.i. ha^{-1}	4.61 (19.3)	3.46 (10.0)	2.30 (3.3)	2.00 (2.0)	4.61 (19.3)	3.55 (10.7)	2.30 (3.3)	2.00 (2.0)
T_6 - EPOE-Combi. 67.5 g a.i. ha^{-1}	3.16 (8.0)	2.00 (2.0)	2.16 (2.7)	1.63 (0.67)	3.05 (7.3)	1.82 (1.3)	2.16 (2.7)	2.00 (2.0)
T_7 - EPOE-Combi. 90 g a.i. ha^{-1}	2.70 (5.3)	1.82 (1.3)	1.82 (1.3)	1.41 (0.0)	2.58 (4.7)	1.82 (1.3)	2.00 (2.0)	1.82 (1.3)
T_8 - EPOE-Combi. 135.5 g a.i. ha^{-1}	2.58 (4.7)	1.63 (0.67)	1.63 (0.67)	1.41 (0.0)	2.44 (4.0)	1.41 (0.0)	1.82 (1.3)	1.63 (0.67)
T_9 - EPOE-Chlori. 6 g a.i. ha^{-1}	4.96 (22.7)	3.36 (9.3)	2.44 (4.0)	2.30 (3.3)	5.03 (23.3)	3.46 (10.0)	2.58 (4.7)	2.44 (4.0)
T_{10} - EPOE-Chlori. 9 g a.i. ha^{-1}	4.61 (19.3)	3.55 (10.7)	2.44 (4.0)	2.30 (3.3)	4.61 (19.3)	3.55 (10.7)	2.58 (4.7)	2.30 (3.3)
T_{11} - EPOE-Chlori. 12 g a.i. ha^{-1}	4.47 (18.0)	3.55 (10.7)	2.30 (3.3)	2.16 (2.7)	4.54 (18.7)	3.46 (10.0)	2.58 (4.7)	2.30 (3.3)
T_{12} - EPOE-Chlori. 18 g a.i. ha^{-1}	4.24 (16.0)	3.46 (10.0)	2.30 (3.3)	2.16 (2.6)	4.39 (17.3)	3.46 (10.0)	2.44 (4.0)	2.30 (3.3)
T_{13} - PE-Atrazine 1.0 kg a.i. ha^{-1}	4.00 (14.0)	3.83 (12.7)	2.94 (6.7)	2.82 (6.0)	5.35 (26.7)	3.55 (10.7)	2.94 (6.7)	3.05 (7.3)
T_{14} - HW on 30 DAP	5.47 (28.0)	3.05 (7.3)	2.30 (3.3)	2.82 (6.0)	5.47 (28.0)	3.16 (8.0)	2.44 (4.0)	2.58 (4.7)
T_{15} - Unweeded control	5.59 (29.3)	5.83 (32.0)	3.74 (12.0)	3.46 (10.0)	5.59 (29.3)	6.32 (38.0)	3.74 (12.0)	3.46 (10.0)
SEd	**0.25**	**0.23**	**0.23**	**0.17**	**0.21**	**0.17**	**0.16**	**0.18**
CD (P=0.05)	**0.52**	**0.47**	**0.48**	**0.35**	**0.43**	**0.35**	**0.34**	**0.38**

Figures in the parenthesis are original values

is inferred that atrazine is not effective against *Cyperus rotundus*. At 120 DAP also, halosulfuron methyl + chlorimuron ethyl at higher doses recorded lesser population of *Cyperus rotundus* than other test herbicides. Invariably in both the years, at all the stages of observation, unweeded check registered the highest density of *Cyperus rotundus*.

4.1.3.4. Density of *Trianthema portulacastrum* (Table 14)

The density of *Trianthema portulacastrum* was significantly lesser and comparable with EPOE application of halosulfuron methyl + chlorimuron ethyl at 135.5 g a.i. ha^{-1} (4.7 m^{-2}) and atrazine at 1.0 kg a.i. ha^{-1} (3.3 m^{-2}) , chlorimuron ethyl at 9, 12 and 18 g a.i. ha^{-1} (6.7 to 8.0 m^{-2}) and halosulfuron methyl + chlorimuron ethyl at 90 g a.i. ha^{-1} (7.3 m^{-2}) at 30 DAP. During 60 day of observation, the same weed management treatment and hand weeding on 30 DAP registered lesser density of *Trianthema portulacastrum* than others. Both 30 and 60 day of growth stages, halosulfuron methyl was not effective in containing the population of *Trianthema portulacastrum* where higher density of *Trianthema portulacastrum* was noticed compared to atrazine. At 90 DAP, halosulfuron methyl + chlorimuron ethyl at 135.5 and 90 g a.i. ha^{-1}, atrazine at 1.0 kg a.i. ha^{-1} and chlorimuron ethyl at 18 g a.i. ha^{-1} recorded significantly lower weed density of *Trianthema portulacastrum* (4.7 to 6.0 m^{-2}). These treatments were comparable interms of recording lesser weed density. Similar trend as that of 90 DAP was observed at 120 DAP also.

During late season 2012, at 30 DAP, EPOE application of higher dose of halosulfuron methyl + chlorimuron ethyl at 135.5 g a.i. ha^{-1} and atrazine at 1.0 kg a.i. ha^{-1} recorded lesser density (6.0 and 4.7 m^{-2}) and this was followed by chlorimuron ethyl at 18 g a.i. ha^{-1}. chlorimuron ethyl at 6 g a.i. ha^{-1}, halosulfuron methyl at 45 g a.i. ha^{-1} and halosulfuron methyl + chlorimuron ethyl at 45 g a.i. ha^{-1} at lower doses was not effective in controlling *Trianthema portulacastrum* as these treatments recorded higher density of weeds. At 60 DAP, the same trend was observed in controlling the broad leaved weed. At 90 DAP, halosulfuron methyl + chlorimuron ethyl at 135.5 and 90 g a.i. ha^{-1}, atrazine at 1.0 kg a.i. ha^{-1} and hand weeding on 30 DAP recorded significantly lower weed density of *Trianthema portulacastrum* and this was followed by chlorimuron ethyl at 12 and 18 g a.i. ha^{-1} and halosulfuron methyl + chlorimuron ethyl at 90 g a.i. ha^{-1}. At 120 DAP,

Table 14. Effect of different weed control treatments on density of *Trianthema portulacastrum* (No. m^{-2}) in sugarcane

Treatments	Main season 2011				Late season 2012			
	30 DAP	**60 DAP**	**90 DAP**	**120 DAP**	**30 DAP**	**60 DAP**	**90 DAP**	**120 DAP**
T_1 - EPOE-Halo. 45 g a.i. ha^{-1}	5.16 (24.7)	5.94 (33.3)	3.91 (13.3)	2.70 (5.3)	5.29 (26.0)	5.59 (29.3)	3.65 (11.3)	2.44 (4.0)
T_2 – EPOE-Halo. 67.5 g a.i. ha^{-1}	4.76 (20.7)	5.59 (29.3)	3.05 (7.3)	2.58 (4.7)	4.89 (22.0)	5.22 (25.3)	3.46 (10.0)	2.16 (2.7)
T_3 - EPOE-Halo. 90 g a.i. ha^{-1}	4.47 (18.0)	5.35 (26.7)	3.91 (13.3)	2.44 (4.0)	4.61 (19.3)	4.96 (22.7)	3.65 (11.3)	2.16 (2.7)
T_4 - EPOE-Halo. 135.5 g a.i. ha^{-1}	4.32 (16.7)	5.22 (25.3)	3.55 (10.7)	2.16 (2.7)	4.47 (18.0)	4.83 (21.3)	3.26 (8.7)	2.00 (2.0)
T_5 - EPOE-Combi. 45 g a.i. ha^{-1}	3.74 (12.0)	4.76 (20.7)	3.46 (10.0)	2.82 (6.0)	3.91 (13.3)	4.32 (16.7)	3.16 (8.0)	2.44 (4.0)
T_6 - EPOE-Combi. 67.5 g a.i. ha^{-1}	3.74 (12.0)	4.76 (20.7)	3.26 (8.7)	2.58 (4.7)	3.91 (13.3)	4.32 (16.7)	2.94 (6.7)	2.16 (2.7)
T_7 - EPOE-Combi. 90 g a.i. ha^{-1}	3.05 (7.3)	4.24 (16.0)	2.82 (6.0)	2.00 (2.0)	3.26 (8.7)	3.74 (12.0)	2.44 (4.0)	2.00 (2.0)
T_8 - EPOE-Combi. 135.5 g a.i. ha^{-1}	2.58 (4.7)	3.91 (13.3)	2.58 (4.7)	1.63 (0.67)	2.82 (6.0)	3.36 (9.3)	2.16 (2.7)	1.82 (1.3)
T_9 - EPOE-Chlori. 6 g a.i. ha^{-1}	3.65 (11.3)	4.69 (20.0)	3.55 (10.7)	2.94 (6.7)	3.83 (12.7)	4.24 (16.0)	3.26 (8.7)	2.58 (4.7)
T_{10} - EPOE-Chlori. 9 g a.i. ha^{-1}	3.16 (8.0)	4.32 (16.7)	3.36 (9.3)	2.70 (5.3)	3.36 (9.3)	3.83 (12.7)	3.16 (8.0)	2.30 (3.3)
T_{11} - EPOE-Chlori. 12 g a.i. ha^{-1}	3.05 (7.3)	4.24 (16.0)	3.05 (7.3)	2.30 (3.3)	3.26 (8.7)	3.74 (12.0)	2.82 (6.0)	1.82 (1.3)
T_{12} - EPOE-Chlori. 18 g a.i. ha^{-1}	2.94 (6.7)	4.16 (15.3)	2.70 (5.3)	1.82 (1.3)	3.16 (8.0)	3.65 (11.3)	2.70 (5.3)	1.82 (1.3)
T_{13} - PE-Atrazine 1.0 kg a.i. ha^{-1}	2.30 (3.3)	3.26 (8.7)	2.82 (6.0)	2.58 (4.7)	2.58 (4.7)	3.05 (7.3)	2.44 (4.0)	2.00 (2.0)
T_{14} - HW on 30 DAP	5.53 (28.7)	3.26 (8.7)	3.16 (8.0)	2.44 (4.0)	5.65 (30.0)	3.16 (8.0)	2.44 (4.0)	2.00 (2.0)
T_{15} - Unweeded control	5.53 (28.7)	6.27 (37.3)	4.61 (19.3)	4.39 (17.3)	5.65 (30.0)	5.94 (33.3)	4.39 (17.3)	4.16 (15.3)
SEd	**0.16**	**0.31**	**0.19**	**0.27**	**0.19**	**0.31**	**0.21**	**0.16**
CD (P=0.05)	**0.32**	**0.65**	**0.40**	**0.57**	**0.39**	**0.64**	**0.44**	**0.33**

Figures in the parenthesis are original values

higher doses of halosulfuron methyl at 135.5 g a.i. ha^{-1}, chlorimuron ethyl at 12 and 18 g a.i. ha^{-1}, halosulfuron methyl + chlorimuron ethyl at 135.5 and 90 g a.i. ha^{-1}, atrazine at 1.0 kg a.i. ha^{-1} and hand weeding on 30 DAP recorded lower weed density than lower doses of test herbicides. However unweeded control recorded the highest density of *Trianthema portulacastrum* at all the stages of observation during both crop periods.

4.1.3.5. Density of *Digera arvensis* (Table 15)

Pre emergence application of atrazine at 1.0 kg a.i. ha^{-1} registered significantly lesser population of *Digera arvensis* at 30 and 60 DAP (2.0 and 3.3 m^{-2}, respectively) compared to other test herbicides during main season 2011. This was followed by halosulfuron methyl + chlorimuron ethyl at 90 and 135.5 g a.i. ha^{-1} and chlorimuron ethyl at 18 g a.i. ha^{-1}. At initial stages of crop growth, atrazine at 1.0 kg a.i. ha^{-1} was effective in containig the population of *Digera arvensis*, where as at 90 days of crop growth, halosulfuron methyl + chlorimuron ethyl at 67.5, 90 and 135.5 g a.i. ha^{-1} controlled the *Digera arvensis* effectively. This was comparable with chlorimuron ethyl at 12 and 18 g a.i. ha^{-1}, atrazine at 1.0 kg a.i. ha^{-1} and hand weeding on 30 DAP. The similar trend was also observed at 120th day of crop growth also.

During late season 2012, at 30 and 60 DAP, pre emergence application of atrazine at 1.0 kg a.i. ha^{-1} and halosulfuron methyl + chlorimuron ethyl at 90 and 135.5 g a.i. ha^{-1} were effective in controlling the population of *Digera arvensis* whcih was reflected by the low density of this weed under these treatments. Atrazine and halosulfuron methyl + chlorimuron ethyl were equally effective against the control of *Digera arvensis* during 30 and 60 DAP. Whereas at 90 DAP, the weed control treatments exhibited similar trend as that of 90 DAP in main season. At 120 DAP, higher doses of halosulfuron methyl at 135.5 g a.i. ha^{-1}, chlorimuron ethyl at 12 and 18 g a.i. ha^{-1}and halosulfuron methyl + chlorimuron ethyl at 135.5 and 90 g a.i. ha^{-1}, atrazine at 1.0 kg a.i. ha^{-1} and hand weeding on 30 DAP recorded lower weed density than rest of the treatments. However unweeded control recorded significantly higher density of *Digera arvensis* at all the stages of observation over other treatments during both the crop periods.

Table 15. Effect of different weed control treatments on density of *Digera arvensis* (No. m^{-2}) in sugarcane

Treatments	Main season 2011				Late season 2012			
	30 DAP	**60 DAP**	**90 DAP**	**120 DAP**	**30 DAP**	**60 DAP**	**90 DAP**	**120 DAP**
T_1 - EPOE-Halo. 45 g a.i. ha^{-1}	4.83 (21.3)	5.09 (24.0)	3.55 (10.7)	2.94 (6.7)	4.47 (18.0)	4.76 (20.7)	3.26 (8.7)	2.58 (4.7)
T_2 – EPOE-Halo. 67.5 g a.i. ha^{-1}	4.69 (20.0)	5.03 (23.3)	3.36 (9.3)	2.70 (5.3)	4.32 (16.7)	4.61 (19.3)	3.05 (7.3)	2.30 (3.3)
T_3 - EPOE-Halo. 90 g a.i. ha^{-1}	4.83 (21.3)	5.09 (24.0)	3.26 (8.7)	2.58 (4.7)	4.47 (18.0)	4.61 (19.3)	2.82 (6.0)	2.16 (2.7)
T_4 - EPOE-Halo. 135.5 g a.i. ha^{-1}	4.54 (18.7)	4.76 (20.7)	3.26 (8.7)	2.58 (4.7)	4.16 (15.3)	4.47 (18.0)	2.82 (6.0)	2.16 (2.7)
T_5 - EPOE-Combi. 45 g a.i. ha^{-1}	4.47 (18.0)	4.76 (20.7)	3.05 (7.3)	2.70 (5.3)	4.08 (14.7)	4.39 (17.3)	2.58 (4.7)	2.30 (3.3)
T_6 - EPOE-Combi. 67.5 g a.i. ha^{-1}	3.55 (10.7)	3.83 (12.7)	2.30 (3.3)	2.00 (2.0)	3.05 (7.3)	3.55 (10.7)	2.16 (2.7)	2.16 (2.7)
T_7 - EPOE-Combi. 90 g a.i. ha^{-1}	3.05 (7.3)	3.36 (9.3)	2.16 (2.7)	1.82 (1.3)	2.44 (4.0)	2.94 (6.7)	2.16 (2.7)	1.82 (1.3)
T_8 - EPOE-Combi. 135.5 g a.i. ha^{-1}	2.94 (6.7)	3.26 (8.7)	2.00 (2.0)	1.82 (1.3)	2.30 (3.3)	2.82 (6.0)	2.00 (2.0)	1.63 (0.67)
T_9 - EPOE-Chlori. 6 g a.i. ha^{-1}	4.54 (18.7)	4.83 (21.3)	3.26 (8.7)	2.58 (4.7)	4.16 (15.3)	4.47 (18.0)	2.70 (5.3)	2.30 (3.3)
T_{10} - EPOE-Chlori. 9 g a.i. ha^{-1}	4.39 (17.3)	4.69 (20.0)	3.16 (8.0)	2.44 (4.0)	4.00 (14.0)	4.32 (16.7)	2.44 (4.0)	2.00 (2.0)
T_{11} - EPOE-Chlori. 12 g a.i. ha^{-1}	3.65 (11.3)	4.08 (14.7)	2.30 (3.3)	2.00 (2.0)	3.16 (8.0)	3.46 (10.0)	2.16 (2.7)	1.82 (1.3)
T_{12} - EPOE-Chlori. 18 g a.i. ha^{-1}	3.26 (8.7)	3.74 (12.0)	2.30 (3.3)	2.00 (2.0)	3.05 (7.3)	3.36 (9.3)	2.16 (2.6)	1.82 (1.3)
T_{13} - PE-Atrazine 1.0 kg a.i. ha^{-1}	2.00 (2.0)	2.30 (3.3)	2.16 (2.7)	2.00 (2.0)	1.82 (1.3)	2.44 (4.0)	2.00 (2.0)	2.00 (2.0)
T_{14} - HW on 30 DAP	5.65 (30.0)	2.30 (3.3)	2.44 (4.0)	2.30 (3.3)	5.35 (26.7)	2.94 (6.7)	2.00 (2.0)	2.00 (2.0)
T_{15} - Unweeded control	5.41 (27.3)	6.05 (34.7)	4.96 (22.7)	4.61 (19.3)	5.09 (24.0)	5.35 (26.6)	4.08 (14.7)	4.39 (17.3)
SEd	**0.29**	**0.24**	**0.19**	**0.19**	**0.29**	**0.24**	**0.25**	**0.20**
CD (P=0.05)	**0.59**	**0.50**	**0.39**	**0.39**	**0.59**	**0.50**	**0.51**	**0.42**

Figures in the parenthesis are original values

Table 16. Effect of different weed control treatments on density of weeds (No. m^{-2}) in sugarcane

Treatments	Main season 2011				Late season 2012			
	Setaria verticillata				*Dinebra retroflexa*			
	30 DAP	**60 DAP**	**90 DAP**	**120 DAP**	**30 DAP**	**60 DAP**	**90 DAP**	**120 DAP**
T_1 - EPOE-Halo. 45 g a.i. ha^{-1}	3.83 (12.7)	4.39 (17.3)	3.05 (7.3)	2.70 (5.3)	3.65 (11.3)	3.91 (13.3)	2.94 (6.7)	2.44 (4.0)
T_2 – EPOE-Halo. 67.5 g a.i. ha^{-1}	3.46 (10.0)	4.00 (14.0)	2.58 (4.7)	2.30 (3.3)	3.36 (9.3)	3.55 (10.7)	2.44 (4.0)	2.00 (2.0)
T_3 - EPOE-Halo. 90 g a.i. ha^{-1}	3.26 (8.7)	4.00 (14.0)	2.44 (4.0)	2.30 (3.3)	3.16 (8.0)	3.55 (10.7)	2.30 (3.3)	2.00 (2.0)
T_4 - EPOE-Halo. 135.5 g a.i. ha^{-1}	3.16 (8.0)	3.74 (12.0)	2.30 (3.3)	2.16 (2.7)	3.16 (8.0)	3.55 (10.7)	2.16 (2.7)	2.00 (2.0)
T_5 - EPOE-Combi. 45 g a.i. ha^{-1}	3.65 (11.3)	4.08 (14.7)	2.58 (4.7)	2.30 (3.3)	3.55 (10.7)	3.91 (13.3)	2.82 (6.0)	2.44 (4.0)
T_6 - EPOE-Combi. 67.5 g a.i. ha^{-1}	3.46 (10.0)	3.74 (12.0)	2.58 (4.7)	2.30 (3.3)	3.36 (9.3)	3.65 (11.3)	2.58 (4.7)	2.16 (2.7)
T_7 - EPOE-Combi. 90 g a.i. ha^{-1}	3.26 (8.7)	3.65 (11.3)	2.44 (4.0)	2.16 (2.7)	3.16 (8.0)	3.46 (10.0)	2.30 (3.3)	2.00 (2.0)
T_8 - EPOE-Combi. 135.5 g a.i. ha^{-1}	3.16 (8.0)	3.55 (10.7)	2.30 (3.3)	2.16 (2.7)	2.94 (6.7)	3.26 (8.7)	2.00 (2.0)	1.82 (1.3)
T_9 - EPOE-Chlori. 6 g a.i. ha^{-1}	3.55 (10.7)	3.91 (13.3)	2.44 (4.0)	2.44 (4.0)	3.26 (8.7)	3.55 (10.7)	2.44 (4.0)	2.00 (2.0)
T_{10} - EPOE-Chlori. 9 g a.i. ha^{-1}	3.46 (10.0)	3.83 (12.7)	2.30 (3.3)	2.30 (3.3)	3.16 (8.0)	3.46 (10.0)	2.30 (3.3)	2.00 (2.0)
T_{11} - EPOE-Chlori. 12 g a.i. ha^{-1}	3.46 (10.0)	3.74 (12.0)	2.30 (3.3)	2.30 (3.3)	3.16 (8.0)	3.46 (10.0)	2.30 (3.3)	1.82 (1.3)
T_{12} - EPOE-Chlori. 18 g a.i. ha^{-1}	3.26 (8.7)	3.65 (11.3)	2.30 (3.3)	2.30 (3.3)	3.05 (7.3)	3.36 (9.3)	2.30 (3.3)	1.82 (1.3)
T_{13} - PE-Atrazine 1.0 kg a.i. ha^{-1}	3.16 (8.0)	3.46 (10.0)	2.16 (2.7)	2.00 (2.0)	2.58 (4.7)	2.82 (6.0)	2.00 (2.0)	2.00 (2.0)
T_{14} - HW on 30 DAP	4.76 (20.7)	2.70 (5.3)	1.82 (1.3)	1.82 (1.3)	4.83 (21.3)	2.82 (6.0)	1.82 (1.3)	1.82 (1.3)
T_{15} - Unweeded control	4.69 (20.0)	4.89 (22.0)	3.55 (10.7)	3.26 (8.7)	4.69 (20.0)	4.83 (21.3)	4.08 (14.7)	3.83 (12.7)
SEd	**0.18**	**0.26**	**0.23**	**0.19**	**0.22**	**0.23**	**0.20**	**0.19**
CD (P=0.05)	**0.37**	**0.54**	**0.48**	**0.40**	**0.46**	**0.47**	**0.41**	**0.39**

Figures in the parenthesis are original values

4.1.3.6. Density of *Setaria verticillata* (Table 16)

During main season 2011, *Setaria verticillata* was the dominant grassy weed species. Higher doses of test herbicides were effective in controlling *Setaria verticillata* than lower doses. At 30 DAP, halosulfuron methyl + chlorimuron ethyl at 90 and 135.5 g a.i. ha^{-1}, halosulfuron methyl 90 and 135.5 g a.i. ha^{-1}, chlorimuron ethyl at 12 and 18 g a.i. ha^{-1} and atrazine at 1.0 kg a.i. ha^{-1} recorded comparable and lesser weed density of *Setaria verticillata.*

These weed control treatments were comparable in registering lesser density. Lower doses of test herbicides (T_1, T_5 and T_9) recorded significantly higher weed density (10.7 to 12.7 m^{-2}). However, at 60 DAP, hand weeding on 30 DAP recorded the least weed density of 5.3 m^{-2}. This was followed by halosulfuron methyl + chlorimuron ethyl at 90 (11.3 m^{-2}) and 135.5 g a.i. ha^{-1} (10.7 m^{-2}) and chlorimuron ethyl at 18 g a.i. ha^{-1} (10.0 m^{-2}). At 90 DAP, halosulfuron methyl + chlorimuron ethyl at 67.5, 90 and 135.5 g a.i. ha^{-1}, chlorimuron ethyl at 12 and 18 g a.i. ha^{-1} recorded significantly lower weed density of *Setaria verticillata* and it was comparable with atrazine at 1.0 kg a.i. ha^{-1} and hand weeding on 30 DAP. Similar trend was also noticed at 120 DAP. Irrespective of stages, unweeded control recorded significantly higher density of *Setaria verticillata*.

4.1.3.7. Density of *Dinebra retroflexa* (Table 16)

During late season 2012, at 30 DAP, EPOE application of higher dose of halosulfuron methyl + chlorimuron ethyl at 135.5 g a.i. ha^{-1} and atrazine at 1.0 kg a.i. ha^{-1} recorded lesser weed density of 6.7 and 4.7 m^{-2}, respectively. This was followed by chlorimuron ethyl at 12 and 18 g a.i. ha^{-1}, halosulfuron methyl at 90 and 135.5 g a.i. ha^{-1} and halosulfuron methyl + chlorimuron ethyl 90 g a.i. ha^{-1}. Test herbicides of chlorimuron ethyl at 6 g a.i. ha^{-1}, halosulfuron methyl at 45 g a.i. ha^{-1} and halosulfuron methyl + chlorimuron ethyl 45 g a.i. ha^{-1} recorded higher weed density (8.7 to 11.3 m^{-2}). At 60 DAP, similar trend was observed as that of 30 DAP. Unweeded control recorded significantly the highest weed population.

At 90 DAP, halosulfuron methyl + chlorimuron ethyl at 135.5 g a.i. ha^{-1}, halosulfuron methyl at 135.5 g a.i. ha^{-1}, atrazine at 1.0 kg a.i. ha^{-1} and hand weeding on 30 DAP were equally effective and comparable in controlling the population of *Dinebra retroflexa* over other weed control treatments. This was followed by chlorimuron ethyl at 12 and 18 g a.i. ha^{-1} and halosulfuron methyl + chlorimuron ethyl at 90 g a.i. ha^{-1}. At 120 DAP, except lower doses of halosulfuron methyl at 45 g a.i. $ha^{-1}$and halosulfuron methyl + chlorimuron ethyl at 45 and 67.5 g a.i. ha^{-1}, other weed control treatments recorded significantly lower weed density. However, unweeded control resulted in higher density of *Dinebra retroflexa* at all the stages of observation.

4.1.3.8. Density of *Amaranthus viridis* (Table 17)

During the first year of experiment (main season 2011), halosulfuron methyl + chlorimuron ethyl at 90 and 135.5 g a.i. ha^{-1}, chlorimuron ethyl at 12 and 18 g a.i. ha^{-1} at higher doses registered significantly lower weed density at 30 DAP than rest of the treatments. These treatments were comparable with atrazine at 1.0 kg a.i. ha^{-1} in containing the population of *Amaranthus viridis.* At 60, 90 and 120 DAP stages of crop growth, halosulfuron methyl + chlorimuron ethyl at 135.5 g a.i. ha^{-1}, chlorimuron ethyl at 12 and 18 g a.i. ha^{-1} and atrazine at 1.0 kg a.i. ha^{-1} as well as hand weeding on 30 DAP were comparable in registering lesser weed population of *Amaranthus viridis*. Invariably, lower doses of test herbicides resulted in higher density of *Amaranthus viridis*. Unweeded control recorded significantly the highest weed population at all the stages of observation.

4.1.3.9. Density of *Cleome gynandra* (Table 17)

During late season 2012, at 30 DAP, pre emergence application of atrazine at 1.0 kg a.i. ha^{-1} recorded significantly lower weed density (0.67 m^{-2}) and this was followed by higher dose of halosulfuron methyl + chlorimuron ethyl at 67.5, 90 and 135.5 g a.i. ha^{-1} and chlorimuron ethyl at 12 and 18 g a.i. ha^{-1}. Lower doses of test herbicides *viz.*, chlorimuron ethyl at 6 g a.i. ha^{-1}, halosulfuron methyl at 45 g a.i. ha^{-1} and halosulfuron methyl + chlorimuron ethyl 45 g a.i. ha^{-1} recorded higher weed density (6.7 to 11.3 m^{-2}). Unweeded control and hand weeding on 30 DAP recorded higher weed density of 19.3 m^{-2}. Whereas at 60 DAP, the lowest population was observed in hand weeding on 30 DAP and atrazine at 1.0 kg a.i. ha^{-1}. Test herbicides performed similarly as that of 30 DAP.

Table 17. Effect of different weed control treatments on density of weeds (No. m^{-2}) in sugarcane

Treatments	Main season 2011				Late season 2012			
	Amaranthus viridis				*Cleome gynandra*			
	30 DAP	**60 DAP**	**90 DAP**	**120 DAP**	**30 DAP**	**60 DAP**	**90 DAP**	**120 DAP**
T_1 - EPOE-Halo. 45 g a.i. ha^{-1}	3.05 (7.3)	3.46 (10.0)	2.30 (3.3)	2.30 (3.3)	3.65 (11.3)	4.16 (15.3)	2.94 (6.7)	2.16 (2.7)
T_2 – EPOE-Halo. 67.5 g a.i. ha^{-1}	2.82 (6.0)	3.26 (8.7)	2.30 (3.3)	2.16 (2.7)	3.36 (9.3)	3.91 (13.3)	2.70 (5.3)	2.16 (2.7)
T_3 - EPOE-Halo. 90 g a.i. ha^{-1}	2.58 (4.7)	3.05 (7.3)	2.16 (2.7)	2.00 (2.0)	3.36 (9.3)	3.91 (13.3)	2.58 (4.7)	2.00 (2.0)
T_4 - EPOE-Halo. 135.5 g a.i. ha^{-1}	2.58 (4.7)	3.05 (7.3)	2.16 (2.7)	2.00 (2.0)	3.26 (8.7)	3.83 (12.7)	2.58 (4.7)	2.00 (2.0)
T_5 - EPOE-Combi. 45 g a.i. ha^{-1}	2.70 (5.3)	3.16 (8.0)	2.16 (2.7)	2.30 (3.3)	3.16 (8.0)	3.74 (12.0)	2.70 (5.3)	2.44 (4.0)
T_6 - EPOE-Combi. 67.5 g a.i. ha^{-1}	2.44 (4.0)	2.94 (6.7)	2.16 (2.7)	2.16 (2.7)	2.58 (4.7)	3.36 (9.3)	2.58 (4.7)	2.00 (2.0)
T_7 - EPOE-Combi. 90 g a.i. ha^{-1}	2.16 (2.7)	2.70 (5.3)	2.00 (2.0)	1.63 (0.67)	2.58 (4.7)	3.36 (9.3)	2.00 (2.0)	1.63 (0.67)
T_8 - EPOE-Combi. 135.5 g a.i. ha^{-1}	2.00 (2.0)	2.58 (4.7)	1.82 (1.3)	1.63 (0.67)	2.16 (2.7)	2.94 (6.7)	1.82 (1.3)	1.63 (0.67)
T_9 - EPOE-Chlori. 6 g a.i. ha^{-1}	2.70 (5.3)	3.05 (7.3)	2.30 (3.3)	2.44 (4.0)	2.94 (6.7)	3.55 (10.7)	2.30 (3.3)	2.44 (4.0)
T_{10} - EPOE-Chlori. 9 g a.i. ha^{-1}	2.58 (4.7)	3.05 (7.3)	2.30 (3.3)	2.58 (4.7)	2.82 (6.0)	3.46 (10.0)	2.16 (2.7)	2.44 (4.0)
T_{11} - EPOE-Chlori. 12 g a.i. ha^{-1}	2.16 (2.7)	2.70 (5.3)	2.16 (2.7)	2.16 (2.7)	2.30 (3.3)	3.16 (8.0)	2.00 (2.0)	2.00 (2.0)
T_{12} - EPOE-Chlori. 18 g a.i. ha^{-1}	2.16 (2.7)	2.70 (5.3)	2.16 (2.7)	2.00 (2.0)	2.16 (2.7)	2.94 (6.7)	2.00 (2.0)	2.00 (2.0)
T_{13} - PE-Atrazine 1.0 kg a.i. ha^{-1}	1.82 (1.3)	2.58 (4.7)	2.30 (3.3)	2.16 (2.7)	1.63 (0.67)	2.30 (3.3)	2.44 (4.0)	2.00 (2.0)
T_{14} - HW on 30 DAP	4.61 (19.3)	2.94 (6.7)	2.00 (2.0)	2.00 (2.0)	4.61 (19.3)	2.44 (4.0)	2.30 (3.3)	2.00 (2.0)
T_{15} - Unweeded control	4.61 (19.3)	4.89 (22.0)	4.08 (14.7)	4.24 (16.0)	4.61 (19.3)	5.03 (23.3)	3.46 (10.0)	3.05 (7.3)
SEd	**0.16**	**0.13**	**0.19**	**0.19**	**0.21**	**0.21**	**0.16**	**0.13**
CD (P=0.05)	**0.34**	**0.27**	**0.40**	**0.40**	**0.43**	**0.44**	**0.33**	**0.27**

Figures in the parenthesis are original values

At 90 DAP, halosulfuron methyl + chlorimuron ethyl at 90 and 135.5 g a.i. ha^{-1}, chlorimuron ethyl at 12 and 18 g a.i. ha^{-1} recorded significantly lower weed density of *Cleome gynandra* (1.3 to 2.0 m^{-2}) compared to rest of the treatments. This was followed by hand weeding on 30 DAP and chlorimuron ethyl at 9 g a.i. ha^{-1}. At 120 DAP, halosulfuron methyl + chlorimuron ethyl at 90 and 135.5 g a.i. ha^{-1} recorded the lowest weed population of 0.67 m^{-2}. Except lower doses of halosulfuron methyl at 45 g a.i. ha^{-1} and halosulfuron methyl + chlorimuron ethyl at 45 and 67.5 g a.i. ha^{-1}, other treatments recorded lower weed density (2.7 to 4.0 m^{-2}). However, unweeded control recorded the highest density of *Cleome gynandra* at all the stages of observations.

4.1.3.10. Density of *Partheneium hysterophorus* (Table 18)

During main season 2011, at 30 DAP, EPOE application of higher doses of halosulfuron methyl + chlorimuron ethyl at 135.5 g a.i. ha^{-1} and atrazine at 1.0 kg a.i. ha^{-1} recorded lesser weed density of 2.7 and 1.3 m^{-2}, compared to rest of the treatments respectively. This was comparable with halosulfuron methyl + chlorimuron ethyl at 90 g a.i. ha^{-1} and chlorimuron ethyl at 12 and 18 g a.i. ha^{-1}. Lowest dose of test herbicides *viz.,*chlorimuron ethyl, halosulfuron methyl and halosulfuron methyl + chlorimuron ethyl registered higher weed density (7.3 to 12.0 m^{-2}) than higher doses.

At 60 DAP, atrazine at 1.0 kg a.i. ha^{-1} and hand weeding on 30 DAP recorded significantly lower weed density (3.3 and 4.0 m^{-2}) and it was followed by halosulfuron methyl + chlorimuron ethyl at 90 and 135.5 g a.i. ha^{-1}. At 90 DAP, halosulfuron methyl + chlorimuron ethyl at 135.5 and 90 g a.i. ha^{-1}, atrazine at 1.0 kg a.i. ha^{-1} and chlorimuron ethyl at 12 and 18 g a.i. ha^{-1} and hand weeding on 30 DAP realised significantly lower weed density of *Partheneium hysterophorus* compared to unweeded control**.** This was followed by halosulfuron methyl at 135.5 g a.i. ha^{-1}. Similar trend as that of 90 DAP was followed at 120 DAP also. Invariably lower doses of test herbicides recorded higher weed density and vice-versa. Unweeded control recorded the highest weed population at all stages of crop growth.

Table 18. Effect of different weed control treatments on density of weeds (No. m^{-2}) in sugarcane

Treatments	Main season 2011				Late season 2012			
	Partheneium hysterophorus				*Datura fastuosa*			
	30 DAP	**60 DAP**	**90 DAP**	**120 DAP**	**30 DAP**	**60 DAP**	**90 DAP**	**120 DAP**
T_1 - EPOE-Halo. 45 g a.i. ha^{-1}	3.74 (12.0)	4.32 (16.7)	2.82 (6.0)	2.30 (3.3)	3.46 (10.0)	4.08 (14.7)	2.94 (6.6)	2.16 (2.7)
T_2 – EPOE-Halo. 67.5 g a.i. ha^{-1}	3.46 (10.0)	4.16 (15.3)	2.70 (5.3)	2.30 (3.3)	3.36 (9.3)	4.08 (14.7)	2.82 (6.0)	2.16 (2.7)
T_3 - EPOE-Halo. 90 g a.i. ha^{-1}	3.46 (10.0)	4.16 (15.3)	2.44 (4.0)	2.16 (2.7)	3.36 (9.3)	4.00 (14.0)	2.58 (4.7)	2.16 (2.7)
T_4 - EPOE-Halo. 135.5 g a.i. ha^{-1}	3.46 (10.0)	3 .91 (13.3)	2.44 (4.0)	2.16 (2.7)	3.36 (9.3)	3.74 (12.0)	2.58 (4.7)	2.00 (2.0)
T_5 - EPOE-Combi. 45 g a.i. ha^{-1}	3.26 (8.7)	4.16(15.3)	2.94 (6.7)	2.44 (4.0)	3.36 (9.3)	4.32 (16.7)	3.16 (8.0)	2.44 (4.0)
T_6 - EPOE-Combi. 67.5 g a.i. ha^{-1}	2.82 (6.0)	3.65 (11.3)	2.70 (5.3)	2.16 (2.7)	3.16 (8.0)	3.74 (12.0)	2.70 (5.3)	2.16 (2.7)
T_7 - EPOE-Combi. 90 g a.i. ha^{-1}	2.58 (4.7)	3.36 (9.3)	2.30 (3.3)	1.82 (1.3)	2.82 (6.0)	3.36 (9.3)	2.16 (2.7)	2.00 (2.0)
T_8 - EPOE-Combi. 135.5 g a.i. ha^{-1}	2.16 (2.7)	3.05 (7.3)	2.00 (2.0)	1.82 (1.3)	2.44 (4.0)	3.16 (8.0)	2.00 (2.0)	2.00 (2.0)
T_9 - EPOE-Chlori. 6 g a.i. ha^{-1}	3.05 (7.3)	3.83 (12.7)	2.44 (4.0)	2.58 (4.7)	3.16 (8.0)	3.91 (13.3)	2.44 (4.0)	2.58 (4.7)
T_{10} - EPOE-Chlori. 9 g a.i. ha^{-1}	2.94 (6.7)	3.65 (11.3)	2.30 (3.3)	2.44 (4.0)	3.05 (7.3)	3.74 (12.0)	2.30 (3.3)	2.44 (4.0)
T_{11} - EPOE-Chlori. 12 g a.i. ha^{-1}	2.44 (4.0)	3.46 (10.0)	2.30 (3.3)	2.16 (2.7)	2.58 (4.7)	3.55 (10.7)	2.16 (2.7)	2.16 (2.7)
T_{12} - EPOE-Chlori. 18 g a.i. ha^{-1}	2.70 (5.3)	3.46 (10.0)	2.16 (2.7)	2.16 (2.7)	2.44 (4.0)	3.36 (9.3)	2.00 (2.0)	2.00 (2.0)
T_{13} - PE-Atrazine 1.0 kg a.i. ha^{-1}	1.82 (1.3)	2.30 (3.3)	2.30 (3.3)	2.00 (2.0)	2.00 (2.0)	2.58 (4.7)	2.16 (2.7)	2.00 (2.0)
T_{14} - HW on 30 DAP	3.83 (12.7)	2.44 (4.0)	2.30 (3.3)	2.00 (2.0)	3.74 (12.0)	2.58 (4.7)	2.30 (3.3)	2.00 (2.0)
T_{15} - Unweeded control	3.83 (12.7)	4.24 (16.0)	3.46 (10.0)	3.16 (8.0)	3.83 (12.7)	4.24 (16.0)	3.46 (10.0)	2.94 (6.7)
SEd	**0.20**	**0.16**	**0.16**	**0.19**	**0.19**	**0.18**	**0.18**	**0.13**
CD (P=0.05)	**0.42**	**0.33**	**0.34**	**0.40**	**0.40**	**0.37**	**0.37**	**0.28**

Figures in the parenthesis are original values

4.1.3.11. Density of *Datura fastuosa* (Table 18)

During late season 2012, at 30 DAP, pre emergence application of atrazine at 1.0 kg a.i. ha^{-1} recorded significantly lesser weed density (2.0 m^{-2}) and this was followed by higher dose of halosulfuron methyl + chlorimuron ethyl at 90 (6.0 m^{-2}) and 135.5 g a.i. ha^{-1} (4.0 m^{-2}) and chlorimuron ethyl at 12 (4.7 m^{-2}) and 18 g a.i. ha^{-1} (4.0 m^{-2}). Low doses of test herbicides *viz.,* chlorimuron ethyl at 6 g a.i. ha^{-1}, halosulfuron methyl at 45 g a.i. ha^{-1} and halosulfuron methyl + chlorimuron ethyl 45 g a.i. ha^{-1} recorded higher weed density (8.0 to 10.0 m^{-2}) than higher doses. Unweeded control and hand weeding on 30 DAP recorded higher weed density of 12.7 and 12.0 m^{-2} respectively. Whereas at 60 DAP, the lower density was observed under hand weeding on 30 DAP and atrazine at 1.0 kg a.i. ha $^{-1}$. This was comparable with higher doses of herbicide combination of halosulfuron methyl + chlorimuron ethyl at 90 and 135.5 g a.i. ha^{-1} and chlorimuron ethyl at 12 and 18 g a.i. ha^{-1}.

At 90 DAP, halosulfuron methyl + chlorimuron ethyl at 90 (2.7 m^{-2}) and 135.5 (2.0 m^{-2}) g a.i. ha^{-1}, chlorimuron ethyl at 12 (2.7 m^{-2}) and 18 (2.0 m^{-2}) g a.i. ha^{-1}, atrazine at 1.0 kg a.i. ha^{-1} (2.7 m^{-2}) and hand weeding on 30 DAP (3.3 m^{-2}) recorded significantly lesser weed density of *Datura fastuosa.* This was followed by chlorimuron ethyl at 9 g a.i. ha^{-1}. There was no significant difference between the treatments of higher doses of halosulfuron methyl + chlorimuron ethyl , halosulfuron methyl and chlorimuron ethyl. The same trend as that of 90 DAP was observed at 120 DAP also. However unweeded control recorded higher density of *Datura fastuosa* at all the stages of observations.

4.1.3.12. Density of total grass (Table 19)

During main season 2011, at 30 DAP, EPOE application of higher doses of halosulfuron methyl + chlorimuron ethyl at 90 and 135.5 g a.i. ha^{-1}, halosulfuron methyl at 90 and 135.5 g a.i. ha^{-1}, chlorimuron ethyl at 18 g a.i. ha^{-1} and atrazine at 1.0 kg a.i. ha^{-1} recorded lower population of grassy weeds compared to others. chlorimuron ethyl, halosulfuron methyl and halosulfuron methyl + chlorimuron ethyl at low doses recorded higher total grass weed density. At 60 DAP higher doses of test herbicides (T_7, T_8, T_{12}, T_{13} and T_{14}) recorded significantly lesser density of grassy weed while these herbicides at low doses recorded significantly higher weed density. At 90 DAP, halosulfuron methyl +

Table 19. Effect of different weed control treatments on density of total grass weeds (No. m^{-2}) in sugarcane

Treatments	Main season 2011				Late season 2012			
	30 DAP	60 DAP	90 DAP	120 DAP	30 DAP	60 DAP	90 DAP	120 DAP
T_1 - EPOE-Halo. 45 g a.i. ha^{-1}	6.16 (36.0)	8.36 (68.4)	4.89 (22.0)	4.71 (20.2)	5.71 (30.7)	8.48 (70.0)	5.30 (26.2)	4.26 (16.2)
T_2 – EPOE-Halo. 67.5 g a.i. ha^{-1}	5.19 (25.0)	7.74 (58.0)	3.85 (12.8)	3.75 (12.1)	5.03 (23.3)	7.91 (60.7)	4.33 (16.8)	3.44 (9.8)
T_3 - EPOE-Halo. 90 g a.i. ha^{-1}	4.66 (19.8)	7.56 (55.3)	3.35 (9.2)	3.35 (9.3)	4.45 (17.8)	7.73 (57.9)	3.89 (13.2)	3.04 (7.3)
T_4 - EPOE-Halo. 135.5 g a.i. ha^{-1}	4.24 (16.0)	7.25 (50.7)	3.05 (7.3)	3.09 (7.6)	4.00 (14.0)	7.57 (55.3)	3.60 (11.0)	3.05 (7.3)
T_5 - EPOE-Combi. 45 g a.i. ha^{-1}	5.83 (32.0)	7.91 (60.7)	4.46 (18.0)	4.16 (15.3)	5.56 (29.0)	7.77 (58.3)	5.02 (23.3)	3.91 (13.3)
T_6 - EPOE-Combi. 67.5 g a.i. ha^{-1}	4.96 (22.7)	7.16 (49.3)	3.46 (10.0)	3.65 (11.3)	4.69 (20.0)	7.52 (54.7)	4.00 (14.0)	3.26 (8.7)
T_7 - EPOE-Combi. 90 g a.i. ha^{-1}	4.24 (16.0)	6.81 (44.34)	2.94 (6.7)	3.26 (8.7)	4.00 (14.0)	7.15 (49.2)	3.46 (10.0)	3.16 (8.0)
T_8 - EPOE-Combi. 135.5 g a.i. ha^{-1}	3.91 (13.3)	6.63 (42.1)	2.70 (5.3)	2.94 (6.7)	3.46 (10.0)	6.93 (46.0)	3.16 (8.0)	2.94 (6.7)
T_9 - EPOE-Chlori. 6 g a.i. ha^{-1}	5.65 (30.0)	7.74 (58.0)	4.24 (16.0)	4.32 (16.7)	5.28 (25.9)	7.95 (61.3)	4.69 (20.0)	3.91 (13.3)
T_{10} - EPOE-Chlori. 9 g a.i. ha^{-1}	5.47 (28.0)	7.63 (56.2)	3.91 (13.3)	3.98 (13.9)	5.16 (24.7)	7.84 (59.6)	4.30 (16.6)	3.44 (9.9)
T_{11} - EPOE-Chlori. 12 g a.i. ha^{-1}	5.47 (28.0)	7.39 (52.7)	3.91 (13.3)	3.98 (13.9)	5.03 (23.3)	7.65 (56.7)	4.39 (17.3)	3.24 (8.5)
T_{12} - EPOE-Chlori. 18 g a.i. ha^{-1}	5.03 (23.3)	7.11 (48.7)	3.75 (12.1)	3.74 (12.0)	4.69 (20.0)	7.39 (52.7)	4.25 (16.1)	2.96 (6.8)
T_{13} - PE-Atrazine 1.0 kg a.i. ha^{-1}	4.47 (18.0)	6.88 (45.3)	3.16 (8.0)	3.21 (8.3)	3.91 (13.3)	7.02 (47.3)	3.65 (11.3)	3.16 (8.0)
T_{14} - HW on 30 DAP	7.16 (49.3)	6.37 (38.7)	2.44 (4.0)	3.04 (7.3)	7.16 (49.3)	6.88 (45.3)	3.16 (8.0)	2.82 (6.0)
T_{15} - Unweeded control	7.30 (51.3)	9.56 (89.5)	6.12 (35.6)	5.94 (33.3)	7.30 (51.3)	9.82 (94.5)	6.72 (43.2)	6.16 (36.0)
SEd	**0.45**	**0.36**	**0.20**	**0.20**	**0.48**	**0.40**	**0.30**	**0.14**
CD (P=0.05)	**0.93**	**0.73**	**0.41**	**0.40**	**0.98**	**0.82**	**0.62**	**0.30**

Figures in the parenthesis are original values

chlorimuron ethyl at 135.5 g a.i. ha^{-1} and hand weeding on 30 DAP treatments recorded significantly lesser total grass weed density. This was followed by halosulfuron methyl at 135.5 g a.i. ha^{-1}, halosulfuron methyl + chlorimuron ethyl at 90 g a.i. ha^{-1} and atrazine 1.0 kg a.i. ha^{-1}. The weed control treatments had similar effect on the density of grassy weed as that of 30^{th} day of observation.

During late season 2012, at 30 DAP, EPOE application of higher doses of halosulfuron methyl + chlorimuron ethyl at 90 and 135.5 g a.i. ha^{-1} (14.0 and 10.0 m^{-2}), halosulfuron methyl at 90 and 135.5 g a.i. ha^{-1} and atrazine at 1.0 kg a.i. ha^{-1} recorded lesser grassy weed density and this was followed by halosulfuron methyl + chlorimuron ethyl 67.5 g a.i. ha^{-1} and chlorimuron

ethyl at 18 g a.i. ha^{-1}. Lowest dose of test herbicides *viz.,* chlorimuron ethyl at 6 g a.i. ha^{-1}, halosulfuron methyl at 45 g a.i. ha^{-1} and halosulfuron methyl + chlorimuron ethyl 45 g a.i. ha^{-1} recorded higher weed density of 25.9, 29.0 and 30.7 m^{-2}, respectively than higher doses. At 60 DAP, also higher doses of test herbicidal treatments (T_4, T_7, T_8, T_{11}, T_{12}, T_{13} and T_{14}) recorded significantly lesser weed density and lower doses of test herbicides recorded significantly higher weed density. At 90 DAP, halosulfuron methyl + chlorimuron ethyl at 135.5 g a.i. ha^{-1} and hand weeding on 30 DAP recorded significantly lesser weed density and this was on par with halosulfuron methyl + chlorimuron ethyl 90 g a.i. ha^{-1}. At 120 DAP, the density of total grassy weed exihibited similar trend as that of 30^{th} day of observation. Unweeded control treatment recorded higher density of grassy weed at all the stages of observation during both crop periods.

4.1.3.13. Density of total sedges (Table 20)

Cyperus rotundus was the only sedge weed observed in the experimental field. During main season 2011, at 30 and 60 DAP, halosulfuron methyl at 90 and 135.5 g a.i. ha^{-1} as early post emergence spray recorded considerably lesser number of *Cyperus rotundus* over other treatments. The next best treatment was EPOE application of halosulfuron methyl + chlorimuron ethyl at 90 and 135.5 g a.i. ha^{-1}, also recorded lesser number of *Cyperus rotundus* both at 30 and 60 DAP. At 90 DAP halosulfuron methyl +

Table 20. Effect of different weed control treatments on density of total sedge weeds (No. m^{-2}) in sugarcane

Treatments	Main season 2011				Late season 2012			
	30 DAP	60 DAP	90 DAP	120 DAP	30 DAP	6 DAP	90 DAP	120 DAP
T_1 - EPOE-Halo. 45 g a.i. ha^{-1}	3.46 (10.0)	2.44 (4.0)	2.30 (3.3)	2.00 (2.0)	3.83 (12.7)	2.82 (6.0)	2.30 (3.3)	2.00 (2.0)
T_2 – EPOE-Halo. 67.5 g a.i. ha^{-1}	3.36 (9.3)	2.30 (3.3)	2.16 (2.7)	1.63 (0.67)	3.55 (10.7)	2.44 (4.0)	2.30 (3.3)	2.00 (2.0)
T_3 - EPOE-Halo. 90 g a.i. ha^{-1}	2.58 (4.7)	1.63 (0.67)	1.82 (1.3)	1.63 (0.67)	2.94 (6.7)	1.63 (0.67)	2.00 (2.0)	1.63 (0.7)
T_4 - EPOE-Halo. 135.5 g a.i. ha^{-1}	2.44 (4.0)	1.41 (0.0)	1.63 (0.67)	1.63 (0.67)	2.44 (4.0)	1.41 (0.0)	2.00 (2.0)	1.63 (0.7)
T_5 - EPOE-Combi. 45 g a.i. ha^{-1}	4.61 (19.3)	3.46 (10.0)	2.30 (3.3)	2.00 (2.0)	4.61 (19.3)	3.55 (10.7)	2.30 (3.3)	2.00 (2.0)
T_6 - EPOE-Combi. 67.5 g a.i. ha^{-1}	3.16 (8.0)	2.00 (2.0)	2.16 (2.7)	1.63 (0.67)	3.05 (7.3)	1.82 (1.3)	2.16 (2.7)	2.00 (2.0)
T_7 - EPOE-Combi. 90 g a.i. ha^{-1}	2.70 (5.3)	1.82 (1.3)	1.82 (1.3)	1.41 (0.0)	2.58 (4.7)	1.82 (1.3)	2.00 (2.0)	1.82 (1.3)
T_8 - EPOE-Combi. 135.5 g a.i. ha^{-1}	2.58 (4.7)	1.63 (0.67)	1.63 (0.67)	1.41 (0.0)	2.44 (4.0)	1.41 (0.0)	1.82 (1.3)	1.63 (0.7)
T_9 - EPOE-Chlori. 6 g a.i. ha^{-1}	4.96 (22.7)	3.36 (9.3)	2.44 (4.0)	2.30 (3.3)	5.03 (23.3)	3.46 (10.0)	2.58 (4.7)	2.44 (4.0)
T_{10} - EPOE-Chlori. 9 g a.i. ha^{-1}	4.61 (19.3)	3.55 (10.7)	2.44 (4.0)	2.30 (3.3)	4.61 (19.3)	3.55 (10.7)	2.58 (4.7)	2.30 (3.3)
T_{11} - EPOE-Chlori. 12 g a.i. ha^{-1}	4.47 (18.0)	3.55 (10.7)	2.30 (3.3)	2.16 (2.7)	4.54 (18.7)	3.46 (10.0)	2.58 (4.7)	2.30 (3.3)
T_{12} - EPOE-Chlori. 18 g a.i. ha^{-1}	4.24 (16.0)	3.46 (10.0)	2.30 (3.3)	2.16 (2.6)	4.39 (17.3)	3.46 (10.0)	2.44 (4.0)	2.30 (3.3)
T_{13} - PE-Atrazine 1.0 kg a.i. ha^{-1}	4.00 (14.0)	3.83 (12.7)	2.94 (6.7)	2.82 (6.0)	5.35 (26.7)	3.55 (10.7)	2.94 (6.7)	3.05 (7.3)
T_{14} - HW on 30 DAP	5.47 (28.0)	3.05 (7.3)	2.30 (3.3)	2.82 (6.0)	5.47 (28.0)	3.16 (8.0)	2.44 (4.0)	2.58 (4.7)
T_{15} - Unweeded control	5.59 (29.3)	5.83 (32.0)	3.74 (12.0)	3.46 (10.0)	5.59 (29.3)	6.32 (38.0)	3.74 (12.0)	3.46 (10.0)
SEd	**0.25**	**0.23**	**0.23**	**0.17**	**0.21**	**0.17**	**0.16**	**0.18**
CD (P=0.05)	**0.52**	**0.47**	**0.48**	**0.35**	**0.43**	**0.35**	**0.34**	**0.38**

Figures in the parenthesis are original values

chlorimuron ethyl at 135.5 and 90 g a.i. ha^{-1} and halosulfuron methyl at 90 and 135.5 g a.i. ha^{-1} were equally effective in controlling *Cyperus rotundus* which was reflected by more or less similar values of *Cyperus rotundus* . The higher population of *Cyperus rotundus* was noticed in atrazine at 1.0 kg a.i. ha^{-1} sprayed plot which is indicative of the non effectiveness of the herbicide on *Cyperus rotundus.* The same trend was noticed at 120 DAP.

During the second year of the experiment also (late season, 2012), halosulfuron methyl at higher doses was found to be effective in controlling *Cyperus rotundus* at 30 and 60 DAP. This herbicide at higher doses recorded significantly lesser density of *Cyperus rotundus*. This was followed by EPOE application of halosulfuron methyl + chlorimuron ethyl at 90 and 135.5 g a.i. ha^{-1} in recording lesser population of *Cyperus rotundus.* At 90 DAP, halosulfuron methyl + chlorimuron ethyl at higher doses recorded lesser number of *Cyperus rotundus.* halosulfuron methyl + chlorimuron ethyl and halosulfuron methyl at lower doses were not effective against *Cyperus rotundus*. More population of *Cyperus rotundus* was noticed at all the three stages of observation and thus it is inferred that atrazine is not effective against *Cyperus rotundus*. At 120 DAP also, halosulfuron methyl + chlorimuron ethyl at higher doses recorded lesser population of *Cyperus rotundus*. Invariably in both the years, at all the stages of observation unweeded check registered significantly higher density of *Cyperus rotundus*.

4.1.3.14. Density of total broad leaved weeds (Table 21)

Broad leaved weeds density varied markedly due to different weed control treatments during main season 2012. The lowest BLW density of 8.0 m^{-2} was observed with pre emergence application of atrazine at 1.0 kg a.i. ha^{-1} at 30 DAP. This was followed by EPOE application of higher doses of halosulfuron methyl + chlorimuron ethyl at 90 and 135.5 g a.i. ha^{-1} which was comparable with chlorimuron ethyl at 12 and 18 g a.i. ha^{-1}. At 60 DAP, atrazine at 1.0 kg a.i. ha^{-1} (20.0 m^{-2}) and hand weeding on 30 DAP (22.7 m^{-2}),halosulfuron methyl + chlorimuron ethyl at 90 (40.0 m^{-2}) and 135.5 (34.0 m^{-2}) g a.i. ha^{-1} , chlorimuron ethyl at 18 g a.i. ha^{-1} (42.7 m^{-2}) recorded significantly lesser density of total BLW than others. Low doses of test herbicides registered

Table 21. Effect of different weed control treatments on density of total broad leaved weeds (No. m^{-2}) in sugarcane

Treatments	Main season 2011				Late season 2012			
	30 DAP	60 DAP	90 DAP	120 DAP	30 DAP	60 DAP	90 DAP	120 DAP
T_1 - EPOE-Halo. 45 g a.i. ha^{-1}	8.20 (65.3)	9.27 (84.0)	5.94 (33.3)	4.54 (18.7)	8.20 (65.3)	9.05 (80.0)	5.94 (33.4)	4.00 (14.0)
T_2 – EPOE-Halo. 67.5 g a.i. ha^{-1}	7.65 (56.7)	8.86 (76.7)	5.22 (25.3)	4.24 (16.0)	7.70 (57.3)	8.64 (72.7)	5.53 (28.7)	3.65 (11.3)
T_3 - EPOE-Halo. 90 g a.i. ha^{-1}	7.44 (53.4)	8.63 (72.6)	5.51 (28.4)	3.89 (13.2)	7.57 (55.4)	8.40 (68.6)	5.32 (26.4)	3.45 (9.9)
T_4 - EPOE-Halo. 135.5 g a.i. ha^{-1}	7.21 (50.0)	8.28 (66.7)	5.29 (26.0)	3.74 (12.0)	7.30 (51.3)	8.12 (64.0)	5.09 (24.0)	3.26 (8.7)
T_5 - EPOE-Combi. 45 g a.i. ha^{-1}	6.78 (44.0)	8.16 (64.7)	5.35 (26.7)	4.54 (18.7)	6.88 (45.3)	8.04 (62.7)	5.29 (26.0)	4.16 (15.3)
T_6 - EPOE-Combi. 67.5 g a.i. ha^{-1}	5.88 (32.7)	7.30 (51.3)	4.69 (20.0)	3.74 (12.0)	5.94 (33.3)	7.11 (48.7)	4.61 (19.3)	3.46 (10.0)
T_7 - EPOE-Combi. 90 g a.i. ha^{-1}	4.89 (22.0)	6.48 (40.0)	4.00 (14.0)	2.70 (5.3)	5.03 (23.4)	6.27 (37.3)	3.65 (11.3)	2.82 (6.0)
T_8 - EPOE-Combi. 135.5 g a.i. ha^{-1}	4.24 (16.0)	6.00 (34.0)	3.46 (10.0)	2.44 (4.0)	4.24 (16.0)	5.65 (30.0)	3.16 (8.0)	2.58 (4.7)
T_9 - EPOE-Chlori. 6 g a.i. ha^{-1}	6.63 (42.0)	7.95 (61.3)	5.35 (26.7)	4.69 (20.0)	6.68 (42.7)	7.78 (58.7)	4.83 (21.5)	4.32 (16.7)
T_{10} - EPOE-Chlori. 9 g a.i. ha^{-1}	6.21 (36.7)	7.57 (55.3)	5.09 (24.0)	4.47 (18.0)	6.21 (36.7)	7.30 (51.3)	4.47 (18.0)	3.91 (13.3)
T_{11} - EPOE-Chlori. 12 g a.i. ha^{-1}	5.22 (25.3)	6.92 (46.0)	4.32 (16.7)	3.55 (10.7)	5.16 (24.7)	6.53 (40.7)	3.91 (13.3)	3.05 (7.3)
T_{12} - EPOE-Chlori. 18 g a.i. ha^{-1}	5.03 (23.3)	6.68 (42.7)	4.00 (14.0)	3.16 (8.0)	4.89 (22.0)	6.21 (36.7)	3.74 (12.0)	2.94 (6.7)
T_{13} - PE-Atrazine 1.0 kg a.i. ha^{-1}	3.16 (8.0)	4.69 (20.0)	4.16 (15.3)	3.65 (11.3)	3.26 (8.7)	4.61 (19.3)	3.83 (12.7)	3.16 (8.0)
T_{14} - HW on 30 DAP	9.62 (90.7)	4.96 (22.7)	4.39 (17.3)	3.65 (11.3)	9.48 (88.0)	5.03 (23.3)	3.82 (12.7)	3.16 (8.0)
T_{15} - Unweeded control	9.48 (88.0)	10.58 (110.0)	8.28 (66.7)	7.91 (60.7)	9.38 (86.0)	10.0 (99.3)	7.34 (52.19)	6.97 (46.7)
SEd	**0.16**	**0.13**	**0.19**	**0.19**	**0.21**	**0.21**	**0.16**	**0.13**
CD (P=0.05)	**0.34**	**0.27**	**0.40**	**0.40**	**0.43**	**0.44**	**0.33**	**0.27**

Figures in the parenthesis are original values

significantly higher density over other weed control treatments. At 90 DAP, halosulfuron methyl + chlorimuron ethyl at 90 and 135.5 and g a.i. ha^{-1}, atrazine at 1.0 kg a.i. ha^{-1} and chlorimuron ethyl at 12 and 18 g a.i. ha^{-1} recorded significantly leser weed density over other treatments. At 120 DAP, halosulfuron methyl + chlorimuron ethyl at 90 and 135.5 g a.i. ha^{-1}, chlorimuron ethyl at 18 g a.i. ha^{-1}, atrazine at 1.0 kg a.i. ha^{-1} and hand weeding on 30 DAP had similar effect on total BLW as that of 90 DAP.

During late season 2012, at 30 DAP, the lowest BLW density of 8.7 m^{-2} was observed halosulfuron methyl + chlorimuron ethyl at 135.5 (16.0 m^{-2}) and 90 (23.4 m^{-2}) g a.i. ha^{-1} and chlorimuron ethyl at 18 (22.0 m^{-2}) g a.i. ha^{-1}. At 60 DAP, atrazine at 1.0 kg a.i. ha^{-1} and hand weeding on 30 DAP recorded significantly lesser weed density which was followed by halosulfuron methyl + chlorimuron ethyl at 135.5 g a.i. ha^{-1}, chlorimuron ethyl at 12 and 18 g a.i ha^{-1} and halosulfuron methyl + chlorimuron ethyl at 90 g a.i. ha^{-1}. At 90 DAP, halosulfuron methyl + chlorimuron ethyl at 90 and 135.5 g a.i. ha^{-1}, chlorimuron ethyl at 12 and 18 g a.i. ha^{-1}, atrazine at 1.0 kg a.i. ha^{-1} and hand weeding on 30 DAP recorded significantly lesser weed density. At 120 DAP, higher doses of halosulfuron methyl + chlorimuron ethyl at 135.5 (4.7 m^{-2}) and 90 g a.i. ha^{-1} (6.0 m^{-2}) and chlorimuron ethyl at 12 (7.3 m^{-2}) and 18 g a.i. ha^{-1} (6.7 m^{-2}) recorded lesser weed density than rest of the treatments. This was comparable with atrazine at 1.0 kg a.i. ha^{-1} (8.0 m^{-2}) and hand weeding on 30 DAP (8.0 m^{-2}). Unweeded control registered significantly higher total BLW density at all the stages of observation during both the years.

4.1.3.15. Density of total weeds (Table 22)

Significant variation in total weed density was observed among the weed control treatments. The lowest total weed density of 34.0 m^{-2} was observed with EPOE application of halosulfuron methyl + chlorimuron ethyl at 135.5 g a.i. ha^{-1} during 2011, at 30 DAP, which was comparable with EPOE application of halosulfuron methyl + chlorimuron ethyl at 90 g a.i. ha^{-1} and pre emergence application of atrazine at 1.0 kg a.i. ha^{-1}. At 60 DAP, halosulfuron methyl + chlorimuron ethyl at 90 and 135.5 g a.i. ha^{-1}, chlorimuron ethyl at 12 and 18 g a.i. ha^{-1} , atrazine at 1.0 kg a.i. ha^{-1}, halosulfuron methyl at 90 and 135.5 g a.i. ha^{-1} and hand weeding on 30 DAP recorded lesser total weed density than unweeded control. At 90 DAP, halosulfuron methyl + chlorimuron ethyl at

Table 22. Effect of different weed control treatments on total weed density (No. m^{-2}) in sugarcane

Treatments	Main season 2011				Late season 2012			
	30 DAP	60 DAP	90 DAP	120 DAP	30 DAP	60 DAP	90 DAP	120 DAP
T_1 - EPOE-Halo. 45 g a.i. ha^{-1}	10.65 (111.3)	12.57 (156.0)	7.79 (58.7)	6.55 (40.9)	10.52 (108.7)	12.57 (156.0)	8.05 (62.9)	5.85 (32.3)
T_2 – EPOE-Halo. 67.5 g a.i. ha^{-1}	9.64 (91.0)	11.83 (138.0)	6.54 (40.8)	5.55 (28.7)	9.66 (91.3)	11.80 (137.3)	7.12 (48.8)	5.01 (23.2)
T_3 - EPOE-Halo. 90 g a.i. ha^{-1}	8.90 (77.9)	11.39 (127.7)	6.37 (38.9)	4.99 (23.1)	9.00 (79.1)	11.31 (125.9)	6.57 (41.2)	4.43 (17.7)
T_4 - EPOE-Halo. 135.5 g a.i. ha^{-1}	8.49 (70.0)	10.92 (117.3)	6.00 (34.0)	4.72 (20.2)	8.44 (69.3)	11.01 (119.3)	6.24 (37.0)	4.34 (16.8)
T_5 - EPOE-Combi. 45 g a.i. ha^{-1}	9.87 (95.3)	11.72 (135.3)	7.07 (48.0)	6.16 (36.0)	9.78 (93.7)	11.56 (131.7)	7.39 (52.6)	5.71 (30.7)
T_6 - EPOE-Combi. 67.5 g a.i. ha^{-1}	8.08 (63.3)	10.23 (102.7)	5.89 (32.7)	5.10 (24.0)	7.91 (60.7)	10.33 (104.7)	6.16 (36.0)	4.76 (20.7)
T_7 - EPOE-Combi. 90 g a.i. ha^{-1}	6.73 (43.3)	9.37 (85.71)	4.90 (22.0)	4.00 (14.0)	6.63 (42.0)	9.48 (87.9)	5.03 (23.3)	4.16 (15.3)
T_8 - EPOE-Combi. 135.5 g a.i. ha^{-1}	6.00 (34.0)	8.87 (76.70)	4.24 (16.0)	3.56 (10.7)	5.67 (30.3)	8.83 (76.0)	4.39 (17.3)	3.74 (12.0)
T_9 - EPOE-Chlori. 6 g a.i. ha^{-1}	9.83 (94.7)	11.43 (128.7)	6.98 (46.7)	6.48 (40.0)	9.69 (91.9)	11.49 (130.0)	6.93 (46.0)	6.00 (34.0)
T_{10} - EPOE-Chlori. 9 g a.i. ha^{-1}	9.27 (84.0)	11.15 (122.2)	6.58 (41.3)	6.10 (35.2)	9.09 (80.7)	11.12 (121.6)	6.42 (39.2)	5.34 (26.6)
T_{11} - EPOE-Chlori. 12 g a.i. ha^{-1}	8.56 (71.3)	10.55 (109.3)	5.94 (33.3)	5.40 (27.2)	8.28 (66.7)	10.46 (107.3)	6.11 (35.3)	4.60 (19.2)
T_{12} - EPOE-Chlori. 18 g a.i. ha^{-1}	8.04 (62.7)	10.17 (101.3)	5.61 (29.4)	4.97 (22.7)	7.83 (59.3)	10.07 (99.3)	5.83 (32.1)	4.33 (16.8)
T_{13} - PE-Atrazine 1.0 kg a.i. ha^{-1}	6.48 (40.0)	8.94 (78.0)	5.66 (30.0)	5.26 (25.7)	7.11 (48.7)	8.91 (77.3)	5.71 (30.7)	5.03 (23.3)
T_{14} - HW on 30 DAP	13.04 (168.0)	8.41 (68.67)	5.16 (24.7)	5.16 (24.6)	12.94 (165.)	8.87 (76.7)	5.16 (24.7)	4.58 (19.0)
T_{15} - Unweeded control	13.06 (168.7)	15.28 (231.5)	10.78 (114.3)	10.30 (104.0)	12.99 (166.7)	15.29 (231.9)	10.45 (107.2)	9.73 (92.7)
SEd	**0.46**	**0.41**	**0.42**	**0.49**	**0.46**	**0.38**	**0.51**	**045**
CD (P=0.05)	**0.95**	**0.84**	**0.87**	**1.01**	**0.94**	**0.79**	**1.04**	**0.92**

Figures in the parenthesis are original values

90 and 135.5 g a.i. ha^{-1}, chlorimuron ethyl at 18 g a.i. ha^{-1}, atrazine at 1.0 kg a.i. ha^{-1} and hand weeding on 30 DAP recorded lesser total weed density. At 120 DAP, the same trend as that of 90 DAP was observed. Lower doses of test herbicides (T_1, T_2, T_5, T_9 and T_{10}) recorded significantly higher weed density.

Significantly the density of total weeds was less under EPOE application of halosulfuron methyl + chlorimuron ethyl at 135.5 g a.i. ha^{-1} at 30 DAP during late season 2012. The next best treatments were atrazine at 1.0 kg a.i. ha^{-1} and halosulfuron methyl + chlorimuron ethyl at 90 g a.i. ha^{-1} interms of recording lesser population of total weeds. At 60 and 90 days of observation, halosulfuron methyl + chlorimuron ethyl at 90 and 135.5 g a.i. ha^{-1}, chlorimuron ethyl at 18 g a.i. ha^{-1}, atrazine at 1.0 kg a.i. ha^{-1} and hand weeding on 30 DAP recorded significantly lesser weed density than lower doses of test herbicides. These treatments were comparable and equally effective in reducing the total weed density. At 120 DAP, higher doses of halosulfuron methyl + chlorimuron ethyl at 135.5 and 90 g a.i. ha^{-1}, chlorimuron ethyl at 12 and 18 g a.i. ha^{-1} and halosulfuron methyl at 135.5

and 90 g a.i. ha^{-1} recorded lesser weed density and this was comparable with atrazine at 1.0 kg a.i. ha^{-1} and hand weeding on 30 DAP. Unweeded check treatment recorded higher total weed density at all the stages of observation during both years of experimentation.

4.1.4. Relative density of weeds (Table 23, 24, 25 and 26)

Different weed management treatments had significant influence on the relative density of grasses, sedges and broad leaved weeds. In both the years of study, at all the stages of observation, broad leaved weeds dominated the weed flora in terms of relative density followed by grasses and sedges. During main season 2011, at 30 DAP, sedge weed density was lower in haloslfuron methyl at 135.5 and 90 g a.i. ha^{-1}. Similarly, broad leaved weed density was lower with atrazine at 1.0 kg a.i. ha^{-1} and chlorimuron ethyl at 12 and 18 g a.i. ha^{-1} compared to other test herbicides. Since halosulfuron methyl is specific to sedges, the relative density was lesser under this treatment at both rates. Likewise chlorimuron ethyl is specific to BLW, the relative density was lower in chlorimuron ethyl applied treatments. Since the total weed density was lower with halosulfuron methyl + chlorimuron ethyl at 135.5 and 90 g a.i. ha^{-1}, the relative density of sedges and BLW was slightly higher with halosulfuron methyl + chlorimuron ethyl at

Table 23. Effect of different weed control treatments on relative density of weeds (%) in sugarcane (2011-12)

Treatments	30 DAP			60 DAP		
	Grasses	Sedges	BLW	Grasses	Sedges	BLW
T_1 - EPOE-Halo. 45 g a.i. ha^{-1}	32.33	8.98	58.68	43.61	2.56	53.83
T_2 – EPOE-Halo. 67.5 g a.i. ha^{-1}	27.47	10.26	62.27	42.03	2.42	55.56
T_3 - EPOE-Halo. 90 g a.i. ha^{-1}	25.42	5.99	68.59	42.75	0.52	56.74
T_4 - EPOE-Halo. 135.5 g a.i. ha^{-1}	22.86	5.71	71.43	43.18	0.00	56.82
T_5 - EPOE-Combi. 45 g a.i. ha^{-1}	33.57	20.28	46.15	44.83	7.39	47.78
T_6 - EPOE-Combi. 67.5 g a.i. ha^{-1}	35.79	12.63	51.58	48.05	1.95	50.00
T_7 - EPOE-Combi. 90 g a.i. ha^{-1}	36.92	12.31	50.77	51.77	1.56	46.67
T_8 - EPOE-Combi. 135.5 g a.i. ha^{-1}	39.21	13.73	47.06	54.79	0.87	44.34
T_9 - EPOE-Chlori. 6 g a.i. ha^{-1}	31.69	23.94	44.37	45.08	7.25	47.67
T_{10} - EPOE-Chlori. 9 g a.i. ha^{-1}	33.33	23.02	43.65	46.00	8.73	45.27
T_{11} - EPOE-Chlori. 12 g a.i. ha^{-1}	39.25	25.23	35.51	48.17	9.76	42.07
T_{12} - EPOE-Chlori. 18 g a.i. ha^{-1}	37.23	25.53	37.23	48.03	9.87	42.11
T_{13} - PE-Atrazine 1.0 kg a.i. ha^{-1}	45.00	35.00	20.00	58.12	16.24	25.64
T_{14} - HW on 30 DAP	29.37	16.67	53.97	56.31	10.68	33.01
T_{15} - Unweeded control	30.43	17.39	52.18	38.67	13.82	47.51

Table 24. Effect of different weed control treatments on relative density of weeds (%) in sugarcane (2011-12)

Treatments	90 DAP			120 DAP		
	Grasses	Sedges	BLW	Grasses	Sedges	BLW
T_1 - EPOE-Halo. 45 g a.i. ha^{-1}	37.50	5.68	56.82	49.46	4.89	45.65
T_2 – EPOE-Halo. 67.5 g a.i. ha^{-1}	31.41	6.53	62.05	42.02	2.32	55.66
T_3 - EPOE-Halo. 90 g a.i. ha^{-1}	23.72	3.42	72.86	39.99	2.89	57.13
T_4 - EPOE-Halo. 135.5 g a.i. ha^{-1}	21.56	1.96	76.48	37.40	3.29	59.31
T_5 - EPOE-Combi. 45 g a.i. ha^{-1}	37.45	6.95	55.60	42.59	5.56	51.85
T_6 - EPOE-Combi. 67.5 g a.i. ha^{-1}	30.61	8.16	61.22	47.22	2.78	50.00
T_7 - EPOE-Combi. 90 g a.i. ha^{-1}	30.30	6.06	63.64	61.90	0.00	38.10
T_8 - EPOE-Combi. 135.5 g a.i. ha^{-1}	33.33	4.17	62.50	62.50	0.00	37.50
T_9 - EPOE-Chlori. 6 g a.i. ha^{-1}	34.29	8.57	57.14	41.67	8.33	50.00
T_{10} - EPOE-Chlori. 9 g a.i. ha^{-1}	32.26	9.68	58.06	39.43	9.46	51.11
T_{11} - EPOE-Chlori. 12 g a.i. ha^{-1}	40.00	10.00	50.00	50.94	9.81	39.25
T_{12} - EPOE-Chlori. 18 g a.i. ha^{-1}	41.12	11.32	47.56	52.94	11.76	35.29
T_{13} - PE-Atrazine 1.0 kg a.i. ha^{-1}	26.67	22.22	51.11	32.47	23.38	44.15
T_{14} - HW on 30 DAP	16.22	13.51	70.27	29.58	24.37	46.04
T_{15} - Unweeded control	31.13	10.51	58.36	32.05	9.62	58.33

Table 25. Effect of different weed control treatments on relative density of weeds (%) in sugarcane (2012-13)

Treatments	30 DAP			60 DAP		
	Grasses	Sedges	BLW	Grasses	Sedges	BLW
T_1 - EPOE-Halo. 45 g a.i. ha^{-1}	28.22	11.66	60.12	44.89	3.85	51.27
T_2 – EPOE-Halo. 67.5 g a.i. ha^{-1}	25.55	11.68	62.77	44.17	2.91	52.91
T_3 - EPOE-Halo. 90 g a.i. ha^{-1}	22.29	8.34	69.36	45.51	0.52	53.96
T_4 - EPOE-Halo. 135.5 g a.i. ha^{-1}	20.19	5.77	74.04	46.36	0.00	53.64
T_5 - EPOE-Combi. 45 g a.i. ha^{-1}	30.96	20.64	48.40	44.32	8.10	47.58
T_6 - EPOE-Combi. 67.5 g a.i. ha^{-1}	32.97	12.09	54.95	52.23	1.27	46.50
T_7 - EPOE-Combi. 90 g a.i. ha^{-1}	33.33	11.11	55.56	55.99	1.52	42.49
T_8 - EPOE-Combi. 135.5 g a.i. ha^{-1}	33.34	13.33	53.33	60.54	0.00	39.46
T_9 - EPOE-Chlori. 6 g a.i. ha^{-1}	28.18	25.39	46.43	47.18	7.69	45.13
T_{10} - EPOE-Chlori. 9 g a.i. ha^{-1}	30.58	23.97	45.45	48.99	8.78	42.23
T_{11} - EPOE-Chlori. 12 g a.i. ha^{-1}	35.00	28.00	37.00	52.79	9.32	37.89
T_{12} - EPOE-Chlori. 18 g a.i. ha^{-1}	33.71	29.21	37.08	53.02	10.07	36.91
T_{13} - PE-Atrazine 1.0 kg a.i. ha^{-1}	27.40	54.80	17.81	61.20	13.79	25.00
T_{14} - HW on 30 DAP	29.84	16.94	53.23	59.13	10.43	30.43
T_{15} - Unweeded control	30.80	17.60	51.60	40.77	16.39	42.84

Table 26. Effect of different weed control treatments on relative density of weeds (%) in sugarcane (2012-13)

Treatments	90 DAP			120 DAP		
	Grasses	Sedges	BLW	Grasses	Sedges	BLW
T_1 - EPOE-Halo. 45 g a.i. ha^{-1}	41.63	5.30	53.07	50.35	6.21	43.45
T_2 – EPOE-Halo. 67.5 g a.i. ha^{-1}	34.35	6.84	58.81	42.47	8.63	48.90
T_3 - EPOE-Halo. 90 g a.i. ha^{-1}	31.73	4.81	63.46	40.73	3.74	55.53
T_4 - EPOE-Halo. 135.5 g a.i. ha^{-1}	29.73	5.41	64.86	44.00	4.00	52.00
T_5 - EPOE-Combi. 45 g a.i. ha^{-1}	44.26	6.33	49.41	43.48	6.52	50.00
T_6 - EPOE-Combi. 67.5 g a.i. ha^{-1}	38.89	7.41	53.70	41.94	9.68	48.39
T_7 - EPOE-Combi. 90 g a.i. ha^{-1}	42.86	8.57	48.57	52.17	8.69	39.14
T_8 - EPOE-Combi. 135.5 g a.i. ha^{-1}	46.15	7.69	46.15	55.56	5.56	38.89
T_9 - EPOE-Chlori. 6 g a.i. ha^{-1}	43.46	10.14	46.40	39.21	11.76	49.03
T_{10} - EPOE-Chlori. 9 g a.i. ha^{-1}	42.21	11.90	45.89	37.24	12.55	50.21
T_{11} - EPOE-Chlori. 12 g a.i. ha^{-1}	49.06	13.21	37.74	44.39	17.38	38.24
T_{12} - EPOE-Chlori. 18 g a.i. ha^{-1}	50.16	12.46	37.38	40.37	19.88	39.76
T_{13} - PE-Atrazine 1.0 kg a.i. ha^{-1}	36.94	21.73	41.33	34.29	31.43	34.28
T_{14} - HW on 30 DAP	32.44	16.22	51.35	32.14	25.00	42.86
T_{15} - Unweeded control	40.32	11.19	48.49	38.85	10.79	50.36

Table 27. Effect of different weed control treatments on dry weight of grasses (g m^{-2}) in sugarcane

Treatments	Main season 2011				Late season 2012			
	30 DAP	60 DAP	90 DAP	120 DAP	30 DAP	60 DAP	90 DAP	120 DAP
T_1 - EPOE-Halo. 45 g a.i. ha^{-1}	4.05 (14.4)	6.54 (40.8)	2.73 (5.5)	2.72 (5.4)	3.85 (12.9)	6.42 (39.2)	2.64 (5.0)	2.75 (5.6)
T_2 – EPOE-Halo. 67.5 g a.i. ha^{-1}	3.48 (10.1)	6.06 (34.8)	2.28 (3.2)	2.61 (4.8)	3.43 (9.8)	5.99 (34.0)	2.41 (3.9)	2.53 (4.4)
T_3 - EPOE-Halo. 90 g a.i. ha^{-1}	3.33 (9.1)	5.92 (33.2)	2.30 (3.3)	2.38 (3.7)	3.32 (9.1)	5.86 (32.7)	2.37 (3.6)	2.48 (4.2)
T_4 - EPOE-Halo. 135.5 g a.i. ha^{-1}	3.23 (8.4)	5.69 (30.4)	2.26 (3.2)	2.37 (3.6)	3.24 (8.6)	5.74 (31.0)	2.35 (3.5)	2.47 (4.1)
T_5 - EPOE-Combi. 45 g a.i. ha^{-1}	3.84 (12.8)	6.19 (36.4)	2.54 (4.5)	2.85 (6.1)	3.74 (12.0)	6.21 (36.6)	2.71 (5.4)	2.81 (5.9)
T_6 - EPOE-Combi. 67.5 g a.i. ha^{-1}	3.32 (9.1)	5.62 (29.6)	2.12 (2.5)	2.55 (4.5)	3.22 (8.4)	5.71 (30.6)	2.28 (3.2)	2.40 (3.8)
T_7 - EPOE-Combi. 90 g a.i. ha^{-1}	2.89 (6.4)	5.35 (26.7)	2.16 (2.7)	2.33 (3.5)	2.80 (5.9)	5.61 (29.6)	2.07 (2.3)	2.20 (2.9)
T_8 - EPOE-Combi. 135.5 g a.i. ha^{-1}	2.70 (5.3)	5.21 (25.2)	2.08 (2.3)	2.16 (2.7)	2.49 (4.2)	5.45 (27.8)	2.15 (2.6)	2.28 (3.2)
T_9 - EPOE-Chlori. 6 g a.i. ha^{-1}	3.74 (12.0)	6.06 (34.8)	2.45 (4.0)	2.94 (6.7)	3.59 (10.9)	6.02 (34.4)	2.56 (4.6)	2.67 (5.2)
T_{10} - EPOE-Chlori. 9 g a.i. ha^{-1}	3.63 (11.2)	5.97 (33.7)	2.30 (3.3)	2.74 (5.6)	3.51 (10.4)	5.94 (33.4)	2.44 (4.0)	2.56 (4.6)
T_{11} - EPOE-Chlori. 12 g a.i. ha^{-1}	3.63 (11.2)	5.79 (31.6)	2.30 (3.3)	2.60 (4.8)	3.28 (8.8)	5.80 (31.7)	2.41 (3.8)	2.52 (4.4)
T_{12} - EPOE-Chlori. 18 g a.i. ha^{-1}	3.21 (8.4)	5.61 (29.5)	2.24 (3.0)	2.33 (3.5)	3.22 (8.4)	5.61 (29.5)	2.38 (3.7)	2.50 (4.3)
T_{13} - PE-Atrazine 1.0 kg a.i. ha^{-11}	2.98 (6.9)	5.40 (27.2)	2.00 (2.0)	2.33 (3.5)	2.75 (5.6)	5.33 (26.5)	2.14 (2.6)	2.27 (3.2)
T_{14} - HW on 30 DAP	4.66 (19.7)	5.02 (23.2)	1.73 (1.0)	2.21 (2.9)	4.76 (20.7)	5.23 (25.4)	2.05 (2.2)	2.19 (2.8)
T_{15} - Unweeded control	4.74 (20.5)	7.45 (53.5)	3.28 (8.8)	3.91 (13.3)	4.85 (21.6)	7.41 (52.9)	3.45 (9.9)	3.53 (10.5)
SEd	**0.25**	**0.40**	**0.12**	**0.12**	**0.38**	**0.47**	**0.16**	**0.18**
CD (P=0.05)	**0.53**	**0.83**	**0.24**	**0.25**	**0.78**	**0.97**	**0.33**	**0.37**

Figures in the parenthesis are original values

135.5 and 90 g a.i. ha^{-1}. Similar trend was also noticed at 60 and 90 DAP. At 120 DAP, halosulfuron methyl + chlorimuron ethyl at 135.5 and 90 g a.i. ha^{-1} registered lesser relative density of sedges and broad leaved weeds and chlorimuron ethyl at 18 g a.i. ha^{-1} recorded lesser relative density of broad leaved weeds.

During late season 2012, at 30 DAP, sedge weed density was lower with haloslfuron methyl at 135.5 and 90 g a.i. ha^{-1} while, broad leaved weed density was lower with atrazine at 1.0 kg a.i. ha^{-1} and chlorimuron ethyl at 12 and 18 g a.i. ha^{-1} than other herbicides.

4.1.5. Weed dry weight

4.1.5.1. Dry weight of grasses (Table 27)

Weed control treatments had significant influence on dry weight of grasses during both the years of study. EPOE application of halosulfuron methyl + chlorimuron ethyl at 135.5 (5.3 g m^{-2}) and 90 g a.i. ha^{-1} (6.4 g m^{-2}) and pre emergence spray of atrazine at 1.0 kg a.i. ha^{-1} (6.9 g m^{-2}) were equally effective in recording lesser total dry weight of grasses during main season 2011, at 30 DAP. Test herbicides at low doses as well as hand weeding on 30 DAP were registered higher dry weight of grasses compared to other herbicides. At 60, 90 and 120 DAP stages, halosulfuron methyl + chlorimuron ethyl, halosulfuron methyl and chlorimuron ethyl at higher rates as well as hand weeding on 30 DAP were found to be effective weed management treatments in terms of recording lesser dry weight of grasses than rest of the treatments.

During late season 2012, at 30 DAP, grass weed dry weight was significantly lesser with halosulfuron methyl + chlorimuron ethyl, halosulfuron methyl and chlorimuron ethyl at higher doses and atrazine at 1.0 kg a.i. ha^{-1} compared to other test herbicides. EPOE application of halosulfuron methyl + chlorimuron ethyl at 90 and 135.5 g a.i. ha^{-1}, atrazine at 1.0 kg a.i. ha^{-1} and hand weeding on 30 DAP were recorded lesser dry weight of grasses while at 90 DAP, in addition to these weed management practices. chlorimuron ethyl was also found to record lesser weed dry weight than other herbicides. At 120 DAP, halosulfuron methyl + chlorimuron ethyl at 90 and 135.5 g a.i. ha^{-1}, chlorimuron ethyl at 12 and 18 g a.i. ha^{-1}, halosulfuron methyl at 90 and 135.5 g a.i. ha^{-1}, atrazine at 1.0 kg a.i. ha^{-1} and hand weeding on 30 DAP were equally effective and

Table 28. Effect of different weed control treatments on dry weight of sedges (g m^{-2}) in sugarcane

Treatments	Main season 2011				Late season 2012			
	30 DAP	60 DAP	90 DAP	120 DAP	30 DAP	60 DAP	90 DAP	120 DAP
T_1 - EPOE-Halo. 45 g a.i. ha^{-1}	2.23 (3.0)	2.05 (2.2)	1.77 (1.2)	1.70 (0.9)	2.40 (3.8)	2.49 (4.2)	1.73 (1.0)	1.73 (1.0)
T_2 – EPOE-Halo. 67.5 g a.i. ha^{-1}	2.19 (2.8)	1.96 (1.9)	1.71 (0.93)	1.51 (0.3)	2.28 (3.2)	2.19 (2.8)	1.73 (1.0)	1.73 (1.0)
T_3 - EPOE-Halo. 90 g a.i. ha^{-1}	1.84 (1.4)	1.53 (0.37)	1.56 (0.47)	1.51 (0.3)	1.99 (2.0)	1.56 (0.47)	1.61 (0.6)	1.52 (0.33)
T_4 - EPOE-Halo. 135.5 g a.i. ha^{-1}	1.78 (1.2)	1.41 (0.0)	1.49 (0.23)	1.51 (0.3)	1.78 (1.2)	1.41 (0.0)	1.61 (0.6)	1.52 (0.33)
T_5 - EPOE-Combi. 45 g a.i. ha^{-1}	2.79 (5.8)	2.75 (5.6)	1.77 (1.2)	1.70 (0.9)	2.79 (5.8)	3.07 (7.5)	1.74 (1.0)	1.73 (1.0)
T_6 - EPOE-Combi. 67.5 g a.i. ha^{-1}	2.09 (2.4)	1.76 (1.1)	1.71 (0.93)	1.51 (0.3)	2.04 (2.2)	1.71 (0.93)	1.68 (0.8)	1.73 (1.0)
T_7 - EPOE-Combi. 90 g a.i. ha^{-1}	1.89 (1.6)	1.65 (0.75)	1.57 (0.47)	1.41 (0.0)	1.84 (1.4)	1.71 (0.93)	1.61 (0.6)	1.63 (0.67)
T_8 - EPOE-Combi. 135.5 g a.i. ha^{-1}	1.84 (1.4)	1.54 (0.37)	1.49 (0.23)	1.41 (0.0)	1.78 (1.2)	1.41 (0.0)	1.54 (0.4)	1.52 (0.33)
T_9 - EPOE-Chlori. 6 g a.i. ha^{-1}	2.96 (6.8)	2.68 (5.2)	1.84 (1.4)	1.87 (1.5)	3.00 (7.0)	3.00 (7.0)	1.84 (1.4)	2.00 (2.0)
T_{10} - EPOE-Chlori. 9 g a.i. ha^{-1}	2.79 (5.8)	2.82 (6.0)	1.84 (1.4)	1.87 (1.5)	2.79 (5.8)	3.07 (7.5)	1.84 (1.4)	1.91 (1.7)
T_{11} - EPOE-Chlori. 12 g a.i. ha^{-1}	2.72 (5.4)	2.82 (6.0)	1.78 (1.2)	1.78 (1.2)	2.75 (5.6)	3.00 (7.0)	1.84 (1.4)	1.91 (1.7)
T_{12} - EPOE-Chlori. 18 g a.i. ha^{-1}	2.60 (4.8)	2.75 (5.6)	1.78 (1.2)	1.78 (1.2)	2.68 (5.2)	3.00 (7.0)	1.78 (1.2)	1.91 (1.7)
T_{13} - PE-Atrazine 1.0 kg a.i. ha^{-1}	2.49 (4.2)	3.01 (7.1)	2.08 (2.3)	2.16 (2.7)	3.16 (8.0)	3.07 (7.5)	2.00 (2.0)	2.38 (3.7)
T_{14} - HW on 30 DAP	3.22 (8.4)	2.47 (4.1)	1.78 (1.2)	2.16 (2.7)	3.22 (8.4)	2.75 (5.6)	1.78 (1.2)	2.08 (2.3)
T_{15} - Unweeded control	3.28 (8.8)	4.46 (17.9)	2.49 (4.2)	2.55 (4.5)	3.28 (8.8)	5.34 (26.6)	2.36 (3.6)	2.64 (5.0)
SEd	**0.16**	**0.21**	**0.14**	**0.11**	**0.20**	**0.14**	**0.13**	**0.16**
CD (P=0.05)	**0.32**	**0.44**	**0.29**	**0.23**	**0.41**	**0.03**	**0.26**	**0.32**

Figures in the parenthesis are original values

comparable in recording lesser dry weight of grasses. In both the years, unweeded check recorded significantly higher dry weight.

4.1.5.2. Dry weight of sedges (Table 28)

The treatments evaluated exerted significant variation in sedge weed dry weight. During main season 2011, at 30 and 60 DAP, EPOE application of halosulfuron methyl + chlorimuron ethyl and halosulfuron methyl at higher doses (90 and 135.5 g a.i. ha^{-1}) recorded lesser weed dry weight than other treatments. At 90 DAP, except lower doses of chlorimuron ethyl (T_9 and T_{10}) and atrazine at 1.0 kg a.i. ha^{-1} other treatments recorded significantly lower weed dry weight of *Cyperus rotundus*. Similar trend was noticed at 120 DAP also. During late season 2012, similar trend was observed as that of main season 2011. In both the years of study low doses of test herbicide and unweeded check resulted in significantly more dry weight of sedges. Unweeded control recorded the highest weed dry weight of sedges at all the stages of observation during both crop periods.

4.1.5.3. Dry weight of BLW (Table 29)

Pre emergence application of atrazine at 1.0 kg a.i. ha^{-1}, EPOE application of higher doses of halosulfuron methyl + chlorimuron ethyl at 90 and 135.5 g a.i. ha^{-1} and chlorimuron ethyl at 12 and 18 g a.i. ha^{-1} were equally efffective in reducing the weed dry weight of BLW during main season 2011, at 30 DAP. At 60, 90 and 120 DAP, along with atrazine at 1.0 kg a.i. ha^{-1}, hand weeding on 30 DAP also recorded lesser weed dry weight and this was followed by halosulfuron methyl + chlorimuron ethyl at 90 and 135.5 g a.i. ha^{-1}, chlorimuron ethyl at 12 and 18 g a.i. ha^{-1} compared to test herbicides. Lower doses of test herbicides (T_1, T_2, T_5, T_9 and T_{10}) as well as unweeded control recorded significantly higher weed dry weight of BLW compared to higher doses.

In late season 2012, weed control treatments had significant effect on the dry weight of BLW. At 30 DAP, significantly lesser dry weight of BLW was recorded with pre emergence application of atrazine at 1.0 kg a.i. ha^{-1} (4.8 g m^{-2}), EPOE application at higher doses of halosulfuron methyl + chlorimuron ethyl at 90 (12.8 g m^{-2}) and 135.5 g a.i. ha^{-1} (8.8 g m^{-2}), chlorimuron ethyl at 12 (13.6 g m^{-2}) and 18 g a.i. ha^{-1} (12.1 g m^{-2}) than unweeded control. These treatments were equally effective in recording lesser dry weight

Table 29. Effect of different weed control treatments on dry weight of broad leaved weeds (g m^{-2}) in sugarcane

Treatments	Main season 2011				Late season 2012			
	30 DAP	**60 DAP**	**90 DAP**	**120 DAP**	**30 DAP**	**60 DAP**	**90 DAP**	**120 DAP**
T_1 - EPOE-Halo. 45 g a.i. ha^{-1}	5.88 (32.7)	7.79 (58.8)	3.46 (10.0)	3.30 (8.9)	6.15 (35.9)	7.87 (60.0)	3.46 (10.0)	3.53 (10.5)
T_2 – EPOE-Halo. 67.5 g a.i. ha^{-1}	5.50 (28.3)	7.46 (53.7)	3.09 (7.6)	3.28 (8.8)	5.79 (31.5)	7.51 (54.5)	3.25 (8.6)	3.24 (8.5)
T_3 - EPOE-Halo. 90 g a.i. ha^{-1}	5.36 (27.0)	7.26 (50.8)	3.24 (8.6)	3.04 (7.3)	5.70 (30.5)	7.31 (51.5)	3.15 (8.0)	3.07 (7.4)
T_4 - EPOE-Halo. 135.5 g a.i. ha^{-1}	5.19 (25.0)	6.97 (46.7)	3.13 (7.8)	2.93 (6.6)	5.49 (28.2)	7.07 (48.0)	3.03 (7.2)	2.91 (6.5)
T_5 - EPOE-Combi. 45 g a.i. ha^{-1}	4.89 (22.0)	6.87 (45.3)	3.16 (8.0)	3.50 (10.3)	5.18 (24.9)	7.00 (47.0)	3.13 (7.8)	3.67 (11.5)
T_6 - EPOE-Combi. 67.5 g a.i. ha^{-1}	4.28 (16.3)	6.15 (35.9)	2.82 (6.0)	2.93 (6.6)	4.50 (18.3)	6.20 (36.5)	2.79 (5.8)	3.08 (7.5)
T_7 - EPOE-Combi. 90 g a.i. ha^{-1}	3.60 (11.0)	5.47 (28.0)	2.49 (4.2)	2.22 (2.9)	3.85 (12.8)	5.47 (28.0)	2.32 (3.4)	2.54 (4.5)
T_8 - EPOE-Combi. 135.5 g a.i. ha^{-1}	3.16 (8.0)	5.07 (23.8)	2.23 (3.0)	2.04 (2.2)	3.28 (8.8)	4.95 (22.5)	2.09 (2.4)	2.34 (3.5)
T_9 - EPOE-Chlori. 6 g a.i. ha^{-1}	4.83 (21.3)	6.70 (42.9)	3.16 (8.0)	3.60 (11.0)	5.06 (23.6)	6.74 (43.5)	2.89 (6.4)	3.80 (12.5)
T_{10} - EPOE-Chlori. 9 g a.i. ha^{-1}	4.50 (18.3)	6.38 (38.7)	3.03 (7.2)	3.45 (9.9)	4.70 (20.2)	6.36 (38.5)	2.72 (5.4)	3.46 (10.0)
T_{11} - EPOE-Chlori. 12 g a.i. ha^{-1}	3.83 (12.7)	5.84 (32.2)	2.61 (5.0)	2.80 (5.9)	3.94 (13.6)	5.70 (30.5)	2.44 (4.0)	2.73 (5.5)
T_{12} - EPOE-Chlori. 18 g a.i. ha^{-1}	3.69 (11.7)	5.64 (29.9)	2.49 (4.2)	2.53 (4.4)	3.75 (12.1)	5.43 (27.5)	2.36 (3.6)	2.64 (5.0)
T_{13} - PE-Atrazine 1.0 kg a.i. ha^{-1}	2.44 (4.0)	4.00 (14.0)	2.56 (4.6)	2.85 (6.2)	2.60 (4.8)	4.06 (14.5)	2.40 (3.8)	2.82 (6.0)
T_{14} - HW on 30 DAP	6.88 (45.3)	4.22 (15.9)	2.68 (5.2)	2.86 (6.2)	7.09 (48.4)	4.41 (17.5)	2.40 (3.8)	2.82 (6.0)
T_{15} - Unweeded control	6.78 (44.0)	8.88 (77.0)	4.69 (20.0)	5.94 (33.4)	7.02 (47.3)	8.74 (74.5)	4.19 (15.6)	6.08 (35.0)
SEd	**0.33**	**0.41**	**0.30**	**0.23**	**0.36**	**0.47**	**0.19**	**0.21**
CD (P=0.05)	**0.68**	**0.85**	**0.62**	**0.49**	**0.75**	**0.98**	**0.40**	**0.43**

Figures in the parenthesis are original values

Table 30. Effect of different weed control treatments on dry weight of total weeds (g m^{-2}) in sugarcane

Treatments	Main season 2011				Late season 2012			
	30 DAP	60 DAP	90 DAP	120 DAP	30 DAP	60 DAP	90 DAP	120 DAP
T_1 - EPOE-Halo. 45 g a.i. ha^{-1}	7.21 (50.1)	10.18 (101.9)	4.32 (16.7)	4.15 (15.3)	7.39 (52.6)	10.27 (103.4)	4.24 (16.0)	4.36 (17.1)
T_2 – EPOE-Halo. 67.5 g a.i. ha^{-1}	6.57 (41.3)	9.60 (90.3)	3.70 (11.7)	3.99 (13.9)	6.82 (44.5)	9.65 (91.3)	3.93 (13.5)	3.99 (13.9)
T_3 - EPOE-Halo. 90 g a.i. ha^{-1}	6.28 (37.5)	9.29 (84.3)	3.77 (12.3)	3.62 (11.1)	6.59 (41.5)	9.25 (84.7)	3.76 (12.25)	3.71 (11.8)
T_4 - EPOE-Halo. 135.5 g a.i. ha^{-1}	6.05 (34.6)	8.89 (77.1)	3.63 (11.2)	3.54 (10.5)	6.32 (38.0)	8.99 (79.0)	3.65 (11.3)	3.59 (10.9)
T_5 - EPOE-Combi. 45 g a.i. ha^{-1}	6.52 (40.6)	9.44 (87.3)	3.95 (13.7)	4.39 (17.3)	6.69 (42.8)	9.64 (91.1)	4.02 (14.2)	4.51 (18.4)
T_6 - EPOE-Combi. 67.5 g a.i. ha^{-1}	5.45 (27.8)	8.28 (66.7)	3.38 (9.4)	3.66 (11.4)	5.56 (28.9)	8.36 (68.1)	3.43 (9.8)	3.78 (12.3)
T_7 - EPOE-Combi. 90 g a.i. ha^{-1}	4.58 (19.0)	7.58 (55.5)	3.05 (7.3)	2.89 (6.4)	4.70 (20.1)	7.77 (58.5)	2.88 (6.3)	3.16 (8.0)
T_8 - EPOE-Combi. 135.5 g a.i. ha^{-1}	4.09 (14.7)	7.168 (49.4)	2.75 (5.6)	2.62 (4.9)	4.02 (14.2)	7.23 (50.3)	2.72 (5.4)	3.00 (7.0)
T_9 - EPOE-Chlori. 6 g a.i. ha^{-1}	6.49 (40.1)	9.21 (83.0)	3.92 (13.4)	4.60 (19.2)	6.59 (41.6)	9.31 (84.9)	3.79 (12.4)	4.65 (19.7)
T_{10} - EPOE-Chlori. 9 g a.i. ha^{-1}	6.11 (35.3)	8.96 (78.4)	3.73 (11.9)	4.35 (17.0)	6.19 (36.3)	9.01 (79.2)	3.57 (10.8)	4.26 (16.2)
T_{11} - EPOE-Chlori. 12 g a.i. ha^{-1}	5.59 (29.3)	8.47 (69.7)	3.39 (9.5)	3.72 (11.9)	5.45 (27.8)	8.44 (69.3)	3.34 (9.2)	3.68 (11.5)
T_{12} - EPOE-Chlori. 18 g a.i. ha^{-1}	5.17 (24.8)	8.18 (65.0)	3.22 (8.4)	3.32 (9.05)	5.26 (25.7)	8.12 (64.0)	3.24 (8.5)	3.59 (11.0)
T_{13} - PE-Atrazine 1.0 kg a.i. ha^{-1}	4.13 (15.1)	7.09 (48.3)	3.30 (8.9)	3.78 (12.3)	4.51 (18.4)	7.10 (48.5)	3.22 (8.4)	3.85 (12.8)
T_{14} - HW on 30 DAP	8.68 (73.5)	6.72 (43.2)	3.06 (7.4)	3.72 (11.9)	8.91 (77.5)	7.10 (48.5)	3.04 (7.2)	3.62 (11.1)
T_{15} - Unweeded control	8.67 (73.3)	12.26 (148.4)	5.91 (33.0)	7.29 (51.2)	8.92 (77.7)	12.49 (154.0)	5.58 (29.1)	7.24 (50.5)
SEd	**0.47**	**0.48**	**0.34**	**0.23**	**0.47**	**0.46**	**0.25**	**0.23**
CD (P=0.05)	**0.97**	**0.98**	**0.71**	**0.47**	**0.91**	**0.96**	**0.52**	**0.49**

Figures in the parenthesis are original values

of BLW. At 60 DAP, atrazine at 1.0 kg a.i. ha^{-1} (14.5 g m^{-2}) and hand weeding on 30 DAP (17.5 g m^{-2}) and halosulfuron methyl + chlorimuron ethyl at 135.5 g a.i. ha^{-1} (22.5 g m^{-2}) recorded significantly lesser weed dry weight compared to other doses of test herbicides. At 90 and 120 DAP, atrazine at 1.0 kg a.i. ha^{-1} and hand weeding on 30 DAP, halosulfuron methyl + chlorimuron ethyl at 90 and 135.5 g a.i. ha^{-1}, chlorimuron ethyl at 12 and 18 g a.i. ha^{-1} had similar effect in recording lesser dry weight of BLW than control. At all the stages of observation, unweeded check resulted in recording the highest dry weight of BLW during both crop years of study.

4.1.5.4. Total weed dry weight (Table 30)

The total weed dry weight exhibited significant variation among weed control treatments. During main season 2011, at 30 DAP, EPOE application of halosulfuron methyl + chlorimuron ethyl at 135.5 (14.7 g m^{-2}) and 90 (19.0 g m^{-2}) g a.i. ha^{-1}, pre emergence application of atrazine at 1.0 kg a.i. ha^{-1} (15.1 g m^{-2}) resulted in significantly lesser total weed dry weight over other weed control treatments. The total weed dry weight was significantly reduced with halosulfuron methyl + chlorimuron ethyl 135.5 and 90 g a.i. ha^{-1}, chlorimuron ethyl at 18 g a.i. ha^{-1}, atrazine at 1.0 kg a.i. ha^{-1} and hand weeding on 30 DAP at the remaining growth faces of the crop. These treatments were equally effective and comparable in recording significantly lesser total weed dry weight over other weed control treatments.

During late season 2012, at 30 DAP, EPOE application of halosulfuron methyl + chlorimuron ethyl at 135.5 g a.i. ha^{-1} (14.2 g m^{-2}), atrazine at 1.0 kg a.i. ha^{-1} (18.4 g m^{-2}) and halosulfuron methyl + chlorimuron ethyl at 90 g a.i. ha^{-1} (20.1 g m^{-2}) resulted in significantly lesser total weed dry weight. The total weed dry weight was lesser under, halosulfuron methyl + chlorimuron ethyl at 90 and 135.5 g a.i. ha^{-1}, chlorimuron ethyl at 18 g a.i. ha^{-1}, atrazine at 1.0 kg a.i. ha^{-1} and hand weeding on 30 DAP at 60 DAP compared to unweeded control. At 90 and 120 DAP, halosulfuron methyl + chlorimuron ethyl at 90 and 135.5 g a.i. ha^{-1}, chlorimuron ethyl at 18 g a.i. ha^{-1}, hand weeding on 30 DAP and atrazine at 1.0 kg a.i. ha^{-1} recorded significantly lesser total weed dry over other weed control treatments. The total weed dry weight was higher under test

Table 31. Effect of different weed control treatments on nitrogen removal by weeds (kg ha^{-1}) in sugarcane

Treatments	Main season 2011			Late season 2012		
	30 DAP	**60 DAP**	**90 DAP**	**30 DAP**	**60DAP**	**90 DAP**
T_1 - EPOE-Halo. 45 g a.i. ha^{-1}	9.51	15.41	8.01	8.31	12.61	7.01
T_2 – EPOE-Halo. 67.5 g a.i. ha^{-1}	7.02	12.92	5.52	5.82	10.12	4.52
T_3 - EPOE-Halo. 90 g a.i. ha^{-1}	6.15	12.05	4.65	4.95	9.25	3.65
T_4 - EPOE-Halo. 135.5 g a.i. ha^{-1}	5.19	11.09	3.69	3.99	8.29	2.69
T_5 - EPOE-Combi. 45 g a.i. ha^{-1}	7.31	13.21	5.81	6.11	10.41	4.81
T_6 - EPOE-Combi. 67.5 g a.i. ha^{-1}	5.28	11.18	3.78	4.08	8.38	2.78
T_7 - EPOE-Combi. 90 g a.i. ha^{-1}	3.80	9.70	2.30	2.60	6.90	1.30
T_8 - EPOE-Combi. 135.5 g a.i. ha^{-1}	3.09	8.99	2.23	1.98	6.32	0.72
T_9 - EPOE-Chlori. 6 g a.i. ha^{-1}	7.63	13.53	6.13	6.43	10.73	5.13
T_{10} - EPOE-Chlori. 9 g a.i. ha^{-1}	6.36	12.26	4.86	5.16	9.46	3.86
T_{11} - EPOE-Chlori. 12 g a.i. ha^{-1}	4.98	10.88	3.48	3.78	8.08	2.48
T_{12} - EPOE-Chlori. 18 g a.i. ha^{-1}	4.22	10.12	2.72	3.02	7.32	1.72
T_{13} - PE-Atrazine 1.0 kg a.i. ha^{-1}	3.18	9.08	1.68	2.02	6.28	0.68
T_{14} - HW on 30 DAP	12.49	8.39	3..99	11.29	6.59	1.09
T_{15} - Unweeded control	11.73	17.63	10.23	10.53	14.83	9.23
SEd	**0.40**	**0.71**	**0.33**	**0.34**	**0.56**	**0.28**
CD (P=0.05)	**0.82**	**1.46**	**0.67**	**0.70**	**1.15**	**0.57**

herbicides at low doses and unweeded control compared to higher doses at all stages of observation during both the crop periods.

4.1.6. Weed analysis

4.1.6.1. Nitrogen removal (Table 31)

Significant variation in nitrogen removal by weeds due to weed control treatments was observed. At 30 DAP, in the main season crop, the N removal by weed was significantly checked by EPOE application of halosulfuron methyl + chlorimuron ethyl at 135.5 g a.i. ha^{-1} (3.09 kg ha^{-1}) and this was closely followed by halosulfuron methyl + chlorimuron ethyl at 90 g a.i. ha^{-1} (3.80 kg ha^{-1}), chlorimuron ethyl at 18 g a.i. ha^{-1} (4.22 kg ha^{-1}), atrazine at 1.0 kg a.i. ha^{-1} (3.18 kg ha^{-1})compared to rest of the treatments. At 60 DAP, higher removal of nitrogen was observed in all the treatments compared to 30 DAP. At 90 DAP, there was reduction in nitrogen removal by the weeds in all the treatments. The same trend of N removal was also recorded at 60 and 90 DAP as that of 30 DAP.

During the late season also, at 30 DAP, halosulfuron methyl + chlorimuron ethyl at 135.5 and 90 g a.i. ha^{-1} recorded lower nitrogen removal of 1.98 and 2.60 kg ha^{-1} respectively over other treatments. This was closely followed by atrazine at 1.0 kg a.i. ha^{-1} (2.02 kg ha^{-1}) and chlorimuron ethyl at 18 and 12 g a.i. ha^{-1} whcih recorded N removal values of 3.02 and 3.78 kg ha^{-1}, respectively. Similar trend was noticed at 60 and 90 DAP stages also. In both the years of study at all stages, lowest doses of test herbicides recorded highest removal of nitrogen by weeds. The highest removal of nitrogen was observed with unweeded control.

4.1.6.2. Phosphorus removal (Table 32)

Weed control treatments had significant influence on P removal by weeds. EPOE application of halosulfuron methyl + chlorimuron ethyl at 135.5 g a.i. ha^{-1} recorded the lowest removal of P (1.56 kg ha^{-1}) and this was closely followed by halosulfuron methyl + chlorimuron ethyl at 90 g a.i. ha^{-1} (1.95 kg ha^{-1}), and chlorimuron ethyl at 18 g a.i. ha^{-1} (2.25 kg ha^{-1}), atrazine at 1.0 kg a.i. ha^{-1} (2.10 kg ha^{-1}) at 30 DAP, during main season 2011. At 60 DAP, higher removal of phosphorus was observed in all the treatments compared to 30 DAP. At 90 DAP, there was reduction in phosphorus removal by the

Table 32. Effect of different weed control treatments on phosphorus removal by weeds (kg ha^{-1}) in sugarcane

Treatments	Main season 2011			Late season 2012		
	30 DAP	**60 DAP**	**90 DAP**	**30 DAP**	**60DAP**	**90 DAP**
T_1 - EPOE-Halo. 45 g a.i. ha^{-1}	5.01	7.11	4.31	4.78	6.13	5.38
T_2 – EPOE-Halo. 67.5 g a.i. ha^{-1}	3.52	5.62	2.82	2.28	4.64	3.89
T_3 - EPOE-Halo. 90 g a.i. ha^{-1}	2.25	4.35	1.55	1.42	2.77	2.02
T_4 - EPOE-Halo. 135.5 g a.i. ha^{-1}	2.15	4.25	1.45	1.01	2.36	1.61
T_5 - EPOE-Combi. 45 g a.i. ha^{-1}	4.16	6.26	3.46	2.57	3.92	3.18
T_6 - EPOE-Combi. 67.5 g a.i. ha^{-1}	3.82	5.92	3.12	2.30	3.65	2.90
T_7 - EPOE-Combi. 90 g a.i. ha^{-1}	1.95	4.75	1.95	1.30	2.05	1.30
T_8 - EPOE-Combi. 135.5 g a.i. ha^{-1}	1.56	3.66	0.86	0.80	1.90	1.15
T_9 - EPOE-Chlori. 6 g a.i. ha^{-1}	4.83	6.93	4.13	3.40	4.75	4.00
T_{10} - EPOE-Chlori. 9 g a.i. ha^{-1}	3.85	5.95	3.15	2.56	3.91	3.16
T_{11} - EPOE-Chlori. 12 g a.i. ha^{-1}	2.65	4.35	1.55	1.87	3.22	2.47
T_{12} - EPOE-Chlori. 18 g a.i. ha^{-1}	2.25	4.05	1.25	1.35	2.70	1.95
T_{13} - PE-Atrazine 1.0 kg a.i. ha^{-1}	2.10	4.20	1.40	1.23	2.58	1.83
T_{14} - HW on 30 DAP	7.99	4.09	2.29	7..35	2.70	1.95
T_{15} - Unweeded control	7.23	9.33	6.53	7.00	9.00	8.25
SEd	**0.22**	**0.31**	**0.17**	**0.16**	**0.25**	**0.21**
CD (P=0.05)	**0.46**	**0.64**	**0.34**	**0.32**	**0.51**	**0.43**

Table 33. Effect of different weed control treatments on potassium removal by weeds (kg ha^{-1}) in sugarcane

Treatments	Main season 2011			Late season 2012		
	30 DAP	60 DAP	90 DAP	30 DAP	60DAP	90 DAP
T_1 - EPOE-Halo. 45 g a.i. ha^{-1}	14.40	17.96	10.36	14.03	16.68	12.83
T_2 – EPOE-Halo. 67.5 g a.i. ha^{-1}	12.90	16.47	9.87	12.54	15.19	11.34
T_3 - EPOE-Halo. 90 g a.i. ha^{-1}	12.20	16.20	9.30	12.45	14.50	10.75
T_4 - EPOE-Halo. 135.5 g a.i. ha^{-1}	12.00	15.90	9.10	11.75	13.90	10.20
T_5 - EPOE-Combi. 45 g a.i. ha^{-1}	13.50	17.11	9.51	11.83	14.48	10.63
T_6 - EPOE-Combi. 67.5 g a.i. ha^{-1}	13.20	16.77	9.17	11.55	14.20	10.35
T_7 - EPOE-Combi. 90 g a.i. ha^{-1}	11.60	15.60	8.00	9.95	12.60	8.75
T_8 - EPOE-Combi. 135.5 g a.i. ha^{-1}	10.90	14.51	6.91	9.80	12.45	8.60
T_9 - EPOE-Chlori. 6 g a.i. ha^{-1}	14.20	17.78	10.18	12.65	15.30	11.45
T_{10} - EPOE-Chlori. 9 g a.i. ha^{-1}	13.20	16.80	9.20	11.81	14.46	10.61
T_{11} - EPOE-Chlori. 12 g a.i. ha^{-1}	12.00	15.20	7.60	11.12	13.77	9.92
T_{12} - EPOE-Chlori. 18 g a.i. ha^{-1}	11.30	14.90	7.30	10.48	12.88	9.03
T_{13} - PE-Atrazine 1.0 kg a.i. ha^{-1}	11.50	15.05	7.45	10.23	13.13	9.28
T_{14} - HW on 30 DAP	17.30	15..94	7.45	16.70	13.56	9.71
T_{15} - Unweeded control	16.60	20.18	12.58	16.90	19.55	15.70
SEd	**0.72**	**0.92**	**0.51**	**0.69**	**0.81**	**0.60**
CD (P=0.05)	**1.48**	**1.88**	**1.04**	**1.41**	**1.66**	**1.24**

weeds in all the treatments. At 60 and 90 DAP stages also, halosulfuron methyl + chlorimuron ethyl at 135.5 g a.i. ha^{-1} and 90 g a.i. ha^{-1}, chlorimuron ethyl at 18 g a.i. ha^{-1}, atrazine at 1.0 kg a.i. ha^{-1} recorded lesser removal of P by weeds.

During the second season also, at 30 DAP, halosulfuron methyl + chlorimuron ethyl at 135.5 and 90 g a.i. ha^{-1} recorded the lowest phosphorus removal of 0.80 and 1.30 kg ha^{-1}, respectively. This was closely followed by atrazine at 1.0 kg a.i. ha^{-1} (1.23 kg ha^{-1}), chlorimuron ethyl at 18 g a.i. ha^{-1}(1.35 kg ha^{-1}) and hand weeding on 30 DAP (1.35 kg ha^{-1}). The same trend was noticed at 60 and 90 DAP also. In both the years of study at all stages, lower doses of test herbicides recorded higher removal of phosphorus by weeds than higher doses. The highest removal of phosphorus was observed with unweeded control at all stages.

4.1.6.3. Potassium removal (Table 33)

Potassium removal by weeds was significantly influenced by different weed control treatments. EPOE application of halosulfuron methyl + chlorimuron ethyl at 135.5 g a.i. ha^{-1} recorded the lowest removal of potassium (10.90 kg ha^{-1}) and this was closely followed by chlorimuron ethyl at 18 g a.i. ha^{-1} (11.30 kg ha^{-1}), atrazine at 1.0 kg a.i. ha^{-1} (11.50 kg ha^{-1}) and halosulfuron methyl + chlorimuron ethyl at 90 g a.i. ha^{-1} (11.60 kg ha^{-1}), at 30 DAP during main season 2011. At 60 DAP, higher removal of potassium was observed in all the treatments as compared to 30 DAP. At 90 DAP, there was reduction in potassium removal by the weeds in all the treatments. The effect of weed control treatments on the K removal by weeds at 60 and 90 DAP was similar as that of 30 DAP.

During the late season also, at 30 DAP, halosulfuron methyl + chlorimuron ethyl at 135.5 and 90 g a.i. ha^{-1} recorded the lowest potassium removal of 9.80 and 9.95 kg ha^{-1}, respectively. This was closely followed by atrazine at 1.0 kg a.i. ha^{-1} (10.23 kg ha^{-1}), chlorimuron ethyl at 18 and 12 g a.i. ha^{-1} (10.48 and 11.12 kg ha^{-1}, respectively). The same trend was noticed at 60 and 90 DAP also. In both the years of study, at all stages, lower doses of test herbicides recorded higher removal of potassium than higher doses. The highest removal of potassium was observed with unweeded control.

Table 34. Effect of different weed control treatments on weed control efficiency (%) in sugarcane

Treatments	Main season 2011				Late season 2012			
	30 DAP	60 DAP	90 DAP	120 DAP	30 DAP	60 DAP	90 DAP	120 DAP
T_1 - EPOE-Halo. 45 g a.i. ha^{-1}	31.73	31.37	49.51	70.19	32.25	32.85	45.03	66.17
T_2 – EPOE-Halo. 67.5 g a.i. ha^{-1}	43.73	39.14	64.44	72.79	42.66	40.74	53.84	72.44
T_3 - EPOE-Halo. 90 g a.i. ha^{-1}	48.81	43.18	62.45	78.02	46.52	45.02	58.30	76.33
T_4 - EPOE-Halo. 135.5 g a.i. ha^{-1}	52.78	48.08	66.12	79.43	51.09	48.72	61.12	78.36
T_5 - EPOE-Combi. 45 g a.i. ha^{-1}	44.64	41.21	58.63	66.21	44.92	40.89	51.42	63.52
T_6 - EPOE-Combi. 67.5 g a.i. ha^{-1}	62.09	55.10	71.42	77.67	62.74	55.82	66.30	75.67
T_7 - EPOE-Combi. 90 g a.i. ha^{-1}	74.09	62.63	77.77	87.50	74.10	62.03	78.38	84.09
T_8 - EPOE-Combi. 135.5 g a.i. ha^{-1}	79.91	66.73	83.15	90.49	81.72	67.36	81.37	86.08
T_9 - EPOE-Chlori. 6 g a.i. ha^{-1}	45.27	44.11	59.41	62.57	46.50	44.92	57.45	61.06
T_{10} - EPOE-Chlori. 9 g a.i. ha^{-1}	51.82	47.15	63.85	66.88	53.22	48.51	62.98	67.88
T_{11} - EPOE-Chlori. 12 g a.i. ha^{-1}	60.09	52.99	71.22	76.82	63.99	55.05	68.40	77.14
T_{12} - EPOE-Chlori. 18 g a.i. ha^{-1}	66.16	56.21	74.58	82.32	66.91	58.45	70.82	78.34
T_{13} - PE-Atrazine 1.0 kg a.i. ha^{-1}	79.36	67.46	72.94	75.92	76.35	68.53	71.15	74.57
T_{14} - HW on 30 DAP	0.000	70.91	77.68	76.86	0.18	68.52	75.15	77.94
T_{15} - Unweeded control	-	-	-	-	-	-	-	-

4.1.7. Weed control efficiency (Table 34)

Weed control efficiency showed marked variation among weed control treatments. The weed control effeciency was higher with EPOE application of higher doses of halosulfuron methyl + chlorimuron ethyl at 135.5 g a.i. ha^{-1} (79.9 %) and atrazine at 1.0 kg a.i. ha^{-1} (79.4 %) during main season 2011, at 30 DAP. This was followed by halosulfuron methyl + chlorimuron ethyl at 90 g a.i. ha^{-1} and chlorimuron ethyl at 18 g a.i. ha^{-1}. At 60 DAP, generally weed control efficiency of all treatments was lower than 30 DAP. Weed control effeciency values were higher under atrazine at 1.0 kg a.i. ha^{-1} (67.5 %) and halosulfuron methyl + chlorimuron ethyl at 135.5 g a.i. ha^{-1} (66.7 %) than rest of treatments. At 90 DAP, halosulfuron methyl + chlorimuron ethyl at 135.5 g a.i. ha^{-1} recorded the highest weed control efficiency of 83.15 per cent. This was followed by halosulfuron methyl + chlorimuron ethyl at 90 g a.i. ha^{-1}(77.8 %) hand weeding on 30 DAP (77.7 %), atrazine at 1.0 kg a.i. ha^{-1} (72.9 %) and chlorimuron ethyl at 18 g a.i. ha^{-1} (74.6 %). At 120 DAP, there was a general increase in weed control efficency. halosulfuron methyl + chlorimuron ethyl at 135.5 g a.i. ha^{-1} recorded the highest weed control efficiency of 90.5 per cent and this was comparable with other treatments *viz*., halosulfuron methyl + chlorimuron ethyl at 90 g a.i. ha^{-1} (87.5 %) chlorimuron ethyl at 18 g a.i. ha^{-1} (82.3 %), atrazine at 1.0 kg a.i. ha^{-1} (75.9 %) and hand weeding on 30 DAP (76.9 %) .

During late season 2012, at 30 DAP, the highest weed control efficiency of 81.7 per cent was observed with halosulfuron methyl + chlorimuron ethyl at 135.5 g a.i. ha^{-1}. This was followed by atrazine at 1.0 kg a.i. ha^{-1} (76.4 %) and halosulfuron methyl + chlorimuron ethyl 90 g a.i. ha^{-1} (74.1%). Low doses of test herbicides like chlorimuron ethyl at 6 g a.i. ha^{-1}, halosulfuron methyl at 45 g a.i. ha^{-1} and halosulfuron methyl + chlorimuron ethyl at 45 g a.i. ha^{-1} and hand weeding on 30 DAP recorded lesser weed control efficiency. At 60 DAP, halosulfuron methyl + chlorimuron ethyl at 90 and 135.5 g a.i. ha^{-1}, atrazine at 1.0 kg a.i. ha^{-1} and hand weeding on 30 DAP recorded significantly higher weed control efficiency. This was followed by chlorimuron ethyl at 18 g a.i. ha^{-1}. The trend was similar at 90 DAP. At 120 DAP, higher doses of halosulfuron methyl + chlorimuron ethyl at 135.5 and 90 g a.i. ha^{-1} recorded higher weed control

Table 35. Effect of different weed control treatments on weed index (%)

Treatments	Weed index	
	Main season 2011	Late season 2012
T_1 - POE-Halo. 45 g a.i. ha^{-1}	19.41	17.60
T_2 – POE-Halo. 67.5 g a.i. ha^{-1}	18.27	16.55
T_3 - POE-Halo. 90 g a.i. ha^{-1}	16.80	15.20
T_4 - POE-Halo. 135.5 g a.i. ha^{-1}	15.28	13.81
T_5 - POE-Combi. 45 g a.i. ha^{-1}	19.27	17.47
T_6 - POE-Combi. 67.5 g a.i. ha^{-1}	18.08	16.38
T_7 - POE-Combi. 90 g a.i. ha^{-1}	0.79	0.48
T_8 - POE-Combi. 135.5 g a.i. ha^{-1}	0.00	0.00
T_9 - POE-Chlori. 6 g a.i. ha^{-1}	19.93	18.07
T_{10} - POE-Chlori. 9 g a.i. ha^{-1}	15.77	14.25
T_{11} - POE-Chlori. 12 g a.i. ha^{-1}	6.15	5.41
T_{12} - POE-Chlori. 18 g a.i. ha^{-1}	2.69	3.52
T_{13} - PE-Atrazine 1.0 kg a.i. ha^{-1}	3.30	1.72
T_{14} - HW on 30 DAP	0.07	1.46
T_{15} - Unweeded control	30.45	27.75

efficiency (86.1 and 84.1 %) and this was comparable with atrazine at 1.0 kg a.i. ha^{-1} (74.6 %) and hand weeding on 30 DAP (77.9 %), chlorimuron ethyl at 12 and 18 g a.i. ha^{-1} (77.1 and 78.3 %, respectively) and halosulfuron at 135.5 g a.i. ha^{-1}(78.4 %). Unweeded control recorded the least weeed control efficiency at all the stages of observation during both the years.

4.1.8. Weed index (Table 35)

During main season 2011, weed control treatments influenced the cane yield and thereby influenced the weed index also. The lowest weed index of 0.00 and 0.79 per cent was recorded with EPOE application of higher doses of halosulfuron methyl + chlorimuron ethyl at 135.5 and 90 g a.i. ha^{-1} respectively. This was followed by hand weeding on 30 DAP (0.07), atrazine at 1.0 kg a.i.ha^{-1}(3.30) and chlorimuron ethyl at 18 g a.i. ha^{-1} (2.69). Low doses of test herbicide recorded higher weed index values than higher doses. The highest weed index of 30.45 was recorded with unweeded control.

During late season 2012 also, the same trend was noticed. The lowest weed index of 0.00 and 0.48 per cent was recorded with EPOE application of higher doses of halosulfuron methyl + chlorimuron ethyl at 135.5 and 90 g a.i. ha^{-1} and this was followed by hand weeding on 30 DAP (1.46), atrazine at 1.0 kg a.i. ha^{-1}(1.72) and chlorimuron ethyl at 18 g a.i. ha^{-1}(3.52). Lower doses of test herbicide recorded higher weed index values and vice versa. Unweeded control resulted in the highest weed index of 27.75.

4.1.9. Weed control rating (Table 36)

Weed control rating was recorded at 30, 45 and 60 DAP during both the years and the mean values were worked out and presented. Complete control of weeds was denoted as rating 10 and good control of weeds was denoted as rating 9 and 8. The weed control rating of broad leaved weeds were higher with atrazine at 1.0 kg a.i. ha^{-1}, halosulfuron methyl + chlorimuron ethyl at 135.5 g a.i. ha^{-1} and chlorimuron ethyl at 18 g a.i. ha^{-1}. Excellent control of sedges was noticed under halosulfuron methyl at

135.5 g a.i. ha^{-1} and halosulfuron methyl + chlorimuron ethyl at 135.5 g a.i. ha^{-1}. Chlorimuron ethyl, halosulfuron methyl and halosulfuron methyl + chlorimuron ethyl at lower doses provided poor to deficient control of weeds (0-3). Regarding grassy weeds, atrazine at 1.0 kg a.i. ha^{-1} provided moderate contol (5). Test herbicides provided poor to deficient control of weeds.

Table 36. Weed control rating (mean scores of two seasons)

Treatments	30 DAP			45 DAP			60 DAP		
	Grasses	Sedges	BLW	Grasses	Sedges	BLW	Grasses	Sedges	BLW
T_1 - EPOE-Halo. 45 g a.i. ha^{-1}	4	8	3	3	7	3	3	7	3
T_2 – EPOE-Halo. 67.5 g a.i. ha^{-1}	4	9	3	3	9	3	3	9	3
T_3 - EPOE-Halo. 90 g a.i. ha^{-1}	4	9	3	3	9	3	3	9	3
T_4 - EPOE-Halo. 135.5 g a.i. ha^{-1}	5	10	3	3	10	2	3	10	3
T_5 - EPOE-Combi. 45 g a.i. ha^{-1}	4	8	8	2	7	7	4	7	7
T_6 - EPOE-Combi. 67.5 g a.i. ha^{-1}	5	8	9	3	7	8	4	7	8
T_7 - EPOE-Combi. 90 g a.i. ha^{-1}	5	8	8	3	9	8	5	9	9
T_8 - EPOE-Combi. 135.5 g a.i. ha^{-1}	5	9	9	3	9	9	5	9	9
T_9 - EPOE-Chlori. 6 g a.i. ha^{-1}	3	3	7	1	2	5	4	3	7
T_{10} - EPOE-Chlori. 9 g a.i. ha^{-1}	4	4	8	1	3	7	4	4	8
T_{11} - EPOE-Chlori. 12 g a.i. ha^{-1}	4	4	8	2	3	7	5	6	9
T_{12} - EPOE-Chlori. 18 g a.i. ha^{-1}	5	4	9	3	4	8	5	6	9
T_{13} - PE-Atrazine 1.0 kg a.i. ha^{-1}	6	0	9	6	0	9	6	1	9
T_{14} - HW on 30 DAP	0	0	0	7	8	9	8	8	9
T_{15} - Unweeded control	0	0	0	0	0	0	0	0	0

Table 37. Visual scoring for phytotoxicity symptoms in sugarcane (mean score of two years)

Treatments	**10 DAHS**	**20 DAHS**	**30 DAHS**
T_1 - POE-Halo. 45 g a.i. ha^{-1}	0	0	0
T_2 – POE-Halo. 67.5 g a.i. ha^{-1}	0	0	0
T_3 - POE-Halo. 90 g a.i. ha^{-1}	0	0	0
T_4 - POE-Halo. 135.5 g a.i. ha^{-1}	1	0	0
T_5 - POE-Combi. 45 g a.i. ha^{-1}	0	0	0
T_6 - POE-Combi. 67.5 g a.i. ha^{-1}	0	0	0
T_7 - POE-Combi. 90 g a.i. ha^{-1}	0	0	0
T_8 - POE-Combi. 135.5 g a.i. ha^{-1}	1	0	0
T_9 - POE-Chlori. 6 g a.i. ha^{-1}	0	0	0
T_{10} - POE-Chlori. 9 g a.i. ha^{-1}	0	0	0
T_{11} - POE-Chlori. 12 g a.i. ha^{-1}	0	0	0
T_{12} - POE-Chlori. 18 g a.i. ha^{-1}	0	0	0
T_{13} - PE-Atrazine 1.0 kg a.i. ha^{-1}	1	0	0
T_{14} - HW on 30 DAP	0	0	0
T_{15} - Unweeded control	0	0	0

Table 38. Effect of different weed control treatments on plant height (cm) in sugarcane

Treatments	Main season 2011				Late season 2012			
	30 DAP	**60 DAP**	**90 DAP**	**120 DAP**	**30 DAP**	**60 DAP**	**90 DAP**	**120 DAP**
T_1 - EPOE-Halo. 45 g a.i. ha^{-1}	43.27	118.9	149.3	180.8	92.03	129.7	188.9	224.8
T_2 – EPOE-Halo. 67.5 g a.i. ha^{-1}	43.13	120.9	152.8	184.4	93.40	131.1	192.1	228.6
T_3 - EPOE-Halo. 90 g a.i. ha^{-1}	43.33	121.1	153.4	185.2	102.8	134.6	193.4	231.6
T_4 - EPOE-Halo. 135.5 g a.i. ha^{-1}	43.80	122.3	156.2	186.8	102.7	135.1	195.1	235.2
T_5 - EPOE-Combi. 45 g a.i. ha^{-1}	44.13	122.4	149.9	179.8	97.40	135.2	190.5	232.8
T_6 - EPOE-Combi. 67.5 g a.i. ha^{-1}	50.27	126.3	153.2	184.7	98.00	135.9	199.6	235.7
T_7 - EPOE-Combi. 90 g a.i. ha^{-1}	61.13	138.7	166.4	197.6	108.8	147.3	212.7	248.4
T_8 - EPOE-Combi. 135.5 g a.i. ha^{-1}	62.83	143.0	169.4	203.4	112.9	150.3	215.3	254.3
T_9 - EPOE-Chlori. 6 g a.i. ha^{-1}	44.13	121.1	148.3	182.3	96.1	133.5	198.2	236.0
T_{10} - EPOE-Chlori. 9 g a.i. ha^{-1}	46.20	123.5	153.1	183.6	99.6	133.7	196.1	242.1
T_{11} - EPOE-Chlori. 12 g a.i. ha^{-1}	50.73	131.8	157.2	192.6	106.4	138.9	196.5	242.9
T_{12} - EPOE-Chlori. 18 g a.i. ha^{-1}	52.60	139.3	165.5	198.7	108.8	146.1	212.1	251.7
T_{13} - PE-Atrazine 1.0 kg a.i. ha^{-1}	61.53	138.8	166.2	201.4	120.0	150.0	214.4	243.3
T_{14} - HW on 30 DAP	42.60	138.6	165.9	199.4	78.23	149.5	209.7	250.1
T_{15} - Unweeded control	41.80	110.1	133.2	156.6	77.20	125.7	169.1	190.0
SEd	**3.77**	**5.63**	**6.15**	**6.98**	**7.39**	**6.66**	**8.23**	**8.04**
CD (P=0.05)	**7.73**	**11.53**	**12.60**	**14.29**	**1.14**	**13.64**	**16.88**	**16.48**

Table 39. Effect of different weed control treatments on tillers and millable cane in sugarcane (2011-12)

Treatments	Germination (%)		Tillers (000 ha^{-1})			Millable cane (000 ha^{-1})
	30 DAP	45 DAP	60DAP	90DAP	120DAP	
T_1 - EPOE-Halo. 45 g a.i. ha^{-1}	80	91	241.0	193.7	163.7	137.0
T_2 – EPOE-Halo. 67.5 g a.i. ha^{-1}	81	92	240.0	198.3	167.7	140.7
T_3 - EPOE-Halo. 90 g a.i. ha^{-1}	82	91	246.8	197.7	176.3	148.5
T_4 - EPOE-Halo. 135.5 g a.i. ha^{-1}	81	91	251.8	203.0	178.7	155.6
T_5 - EPOE-Combi. 45 g a.i. ha^{-1}	82	93	238.0	203.7	168.3	138.9
T_6 - EPOE-Combi. 67.5 g a.i. ha^{-1}	80	92	245.7	202.7	187.0	143.8
T_7 - EPOE-Combi. 90 g a.i. ha^{-1}	84	93	279.2	226.4	194.0	164.0
T_8 - EPOE-Combi. 135.5 g a.i. ha^{-1}	83	92	283.3	230.3	195.0	167.9
T_9 - EPOE-Chlori. 6 g a.i. ha^{-1}	80	90	235.2	203.7	171.7	136.6
T_{10} - EPOE-Chlori. 9 g a.i. ha^{-1}	81	94	241.0	202.7	176.0	151.9
T_{11} - EPOE-Chlori. 12 g a.i. ha^{-1}	81	93	261.0	220.3	177.7	154.3
T_{12} - EPOE-Chlori. 18 g a.i. ha^{-1}	82	93	280.1	227.4	181.3	157.0
T_{13} - PE-Atrazine 1.0 kg a.i. ha^{-1}	87	92	282.1	229.7	185.3	158.6
T_{14} - HW on 30 DAP	77	94	275.4	228.9	183.0	157.4
T_{15} - Unweeded control	76	89	200.3	174.3	150.3	116.0
SEd	**-**	**-**	**10.74**	**9.95**	**6.36**	**8.122**
CD (P=0.05)	**-**	**-**	**22.00**	**20.37**	**13.01**	**16.63**

Table 40. Effect of different weed control treatments on tillers and millable cane in sugarcane (2012-13)

Treatments	Germination (%)		Tillers (000 ha^{-1})			Millable cane (000 ha^{-1})
	30 DAP	45 DAP	60DAP	90DAP	120DAP	
T_1 - EPOE-Halo. 45 g a.i. ha^{-1}	92	94	247.0	196.3	183.3	144.0
T_2 – EPOE-Halo. 67.5 g a.i. ha^{-1}	92	95	249.3	198.7	187.0	146.0
T_3 - EPOE-Halo. 90 g a.i. ha^{-1}	90	94	255.3	203.7	189.3	150.0
T_4 - EPOE-Halo. 135.5 g a.i. ha^{-1}	89	96	258.7	204.5	189.3	152.0
T_5 - EPOE-Combi. 45 g a.i. ha^{-1}	91	94	250.7	194.0	190.0	143.0
T_6 - EPOE-Combi. 67.5 g a.i. ha^{-1}	90	93	259.7	197.0	191.3	150.4
T_7 - EPOE-Combi. 90 g a.i. ha^{-1}	91	95	281.3	218.3	214.0	168.0
T_8 - EPOE-Combi. 135.5 g a.i. ha^{-1}	89	94	283.3	222.0	217.3	172.0
T_9 - EPOE-Chlori. 6 g a.i. ha^{-1}	90	93	253.7	198.4	191.3	145.7
T_{10} - EPOE-Chlori. 9 g a.i. ha^{-1}	91	94	254.0	200.0	197.3	148.0
T_{11} - EPOE-Chlori. 12 g a.i. ha^{-1}	90	93	259.4	215.6	204.7	165.7
T_{12} - EPOE-Chlori. 18 g a.i. ha^{-1}	89	93	269.3	220.6	205.0	170.6
T_{13} - PE-Atrazine 1.0 kg a.i. ha^{-1}	90	94	281.0	221.3	209.0	168.3
T_{14} - HW on 30 DAP	88	94	283.3	219.6	211.0	168.6
T_{15} - Unweeded control	85	85	241.3	181.3	169.3	124.7
SEd	**-**	**-**	**11.11**	**11.31**	**9.04**	**8.46**
CD (P=0.05)	**-**	**-**	**22.75**	**23.17**	**18.53**	**17.33**

4.2. Effect of weed management methods on sugarcane

4.2.1. Plant characters

4.2.1. 1. Germination and phytotoxicity (Table 37, 39 and 40)

There was not much difference in germination of sugarcane observed during both seasons. The germination per cent varied from 89 to 94 per cent in the first season. In the second season, the germination per cent varied from 85 to 96 per cent.

The phytotoxicity symptoms of herbicides on sugarcane were observed during 2011-12 and 2012-13 at 10, 20 and 30 DAHS. At 10 DAHS, sugarcane plants were observed with slight stunting or discolouration (rating - 1) at halosulfuron 135.5 g a.i. ha^{-1}, halosulfuron methyl + chlorimuron ethyl at 135.5 g a.i. ha^{-1}, chlorimuron ethyl at 18 g a.i. ha^{-1} and atrazine at 1.0 kg a.i. ha^{-1}. After 20 DAHS, the sugarcane plants recovered completely and phytotoxicity was not evident there after. Thereafter, there was no visual phytotoxic symptoms were observed in sugarcane with application of halosulfuron methyl, halosulfuron methyl + chlorimuron ethyl, chlorimuron ethyl and atrazine at higher doses

4.2.1. 2. Plant height (Table 38)

Weed control treatments exhibited significant variation in plant height during main season 2011, at 30 DAP. Significantly taller plants were observed with halosulfuron methyl + chlorimuron ethyl at 135.5 g a.i. ha^{-1} (62.8 cm), halosulfuron methyl + chlorimuron ethyl at 90 g a.i. ha^{-1} and atrazine at 1.0 kg a.i. ha^{-1} compared to control. At 60 DAP, halosulfuron methyl + chlorimuron ethyl at 135.5 g a.i. ha^{-1}, chlorimuron ethyl at 12 and 18 g a.i. ha^{-1}, atrazine at 1.0 kg a.i. ha^{-1} and hand weeding on 30 DAP registered significantly higher plant height than rest of the treatments. Plant height increased progressively with advance of the age of the crop from 60 to 120 DAP. Similar trend was observed at 90 and 120 DAP wherein halosulfuron methyl + chlorimuron ethyl at 90 and 135.5 g a.i. ha^{-1}, chlorimuron ethyl at 12 and 18 g a.i. ha^{-1}, atrazine at 1.0 kg a.i. ha^{-1}, and hand weeding on 30 DAP treatments were equally effective and comparable interms of recording higher plant height over rest of the treatments.

During late season 2012, at 30 DAP, higher plant height of 120.0 cm was observed at atrazine at 1.0 kg a.i. ha^{-1} and this was comparable with halosulfuron methyl + chlorimuron ethyl at 90 and 135.5 g a.i. ha^{-1}, chlorimuron ethyl at 12 and 18 g a.i. ha^{-1}. At 60 DAP, also the same trend as that of 30 DAP was noticed and these treatments were comparable with hand weeding on 30 DAP. At 90 and 120 DAP, along with halosulfuron methyl + chlorimuron ethyl at 90 and 135.5 g a.i. ha^{-1}, hand weeding on 30 DAP, chlorimuron ethyl at 12 and 18 g a.i. ha^{-1} and atrazine at 1.0 kg a.i. ha^{-1} registered significantly higher plant height than rest of the treatments. Invariably test herbicide at low doses as well as unweeded control recorded shorter plants at all the stages of observation during both the years of study.

4.2.1. 3. Tiller population (Table 39 and 40)

During main season 2011, halosulfuron methyl + chlorimuron ethyl at 135.5 g a.i. ha^{-1} produced higher tillers of 283.3, 230.3, 195.0 000 ha^{-1} at 60, 90 and 120 DAP, respectively, followed by halosulfuron methyl + chlorimuron ethyl at 90 g a.i. ha^{-1}, chlorimuron ethyl at 12 and 18 g a.i. ha^{-1}, atrazine at 1.0 kg a.i. ha^{-1} and hand weeding on 30 DAP recorded significantly higher population of tillers over other treatments. Number of tillers was decreased progressively with advance of the age of the crop from 60 to 120 DAS.

The tiller production was significantly higher under halosulfuron methyl + chlorimuron ethyl at 135.5 g a.i. ha^{-1} (283.3, 222.0 and 217.3 000 ha^{-1} respectively at 60, 90 and 120 DAP) and this was comparable with atrazine at 1.0 kg a.i. ha^{-1}, halosulfuron methyl + chlorimuron ethyl at 90 and 135.5 g a.i. ha^{-1}, chlorimuron ethyl at 12 and 18 g a.i. $ha^{-1}$and hand weeding on 30 DAP at all stages of crop growth during late season 2012. In the both the seasons, the tiller production was comparitively lesser with test herbicides at low doses and vice versa. There was drastic reduction in tiller production in the cane crop where the weeds left uncontrolled.

4.2.1.4. Millable cane (Table 39 and 40)

The data on millable cane showed significant variation among different weed control treatments. The millable cane population was perciptably higher with halosulfuron methyl + chlorimuron ethyl at 135.5 g a.i. ha^{-1} (167.9 ‘000 ha^{-1}) halosulfuron methyl + chlorimuron ethyl at 90 g a.i. ha^{-1} (164.0 ‘000 ha^{-1}), chlorimuron

Table 41. Effect of different weed control treatments on tillering capacity and survival capacity (%)

Treatments	Main season 2011		Late season 2012	
	Tillering capacity	Survival capacity	Tillering capacity	Survival capacity
T_1 - POE-Halo. 45 g a.i. ha^{-1}	1.83	70.76	1.85	73.34
T_2 – POE-Halo. 67.5 g a.i. ha^{-1}	1.89	70.96	1.89	73.49
T_3 - POE-Halo. 90 g a.i. ha^{-1}	1.96	73.64	1.93	73.65
T_4 - POE-Halo. 135.5 g a.i. ha^{-1}	2.07	75.15	2.09	74.33
T_5 - POE-Combi. 45 g a.i. ha^{-1}	1.98	68.19	1.81	73.71
T_6 - POE-Combi. 67.5 g a.i. ha^{-1}	2.09	68.82	1.89	76.35
T_7 - POE-Combi. 90 g a.i. ha^{-1}	2.29	76.17	2.15	76.96
T_8 - POE-Combi. 135.5 g a.i. ha^{-1}	2.44	76.56	2.50	77.48
T_9 - POE-Chlori. 6 g a.i. ha^{-1}	1.98	67.07	1.79	73.42
T_{10} - POE-Chlori. 9 g a.i. ha^{-1}	1.99	74.93	1.81	74.00
T_{11} - POE-Chlori. 12 g a.i. ha^{-1}	2.17	72.68	1.98	76.86
T_{12} - POE-Chlori. 18 g a.i. ha^{-1}	2.22	73.82	2.03	77.33
T_{13} - PE-Atrazine 1.0 kg a.i. ha^{-11}	2.24	75.30	2.05	76.05
T_{14} - HW on 30 DAP	2.25	72.87	2.08	76.78
T_{15} - Unweeded control	1.68	66.54	1.64	68.75
SEd	**0.11**	**3.98**	**0.11**	**4.11**
CD (P=0.05)	**0.23**	**NS**	**0.22**	**NS**

ethyl at 12 (154.3 ‘000 ha^{-1}) and 18 (157.0 ‘000 ha^{-1}) g a.i. ha^{-1}, atrazine at 1.0 kg a.i. ha^{-1} (158.6 ‘000 ha^{-1}) and hand weeding on 30 DAP (157.4 ‘000 ha^{-1}) over other treatments. During late season also, millable cane population was higher with halosulfuron methyl + chlorimuron ethyl at 135.5 g a.i. ha^{-1} (172.0 ‘000 ha^{-1}), halosulfuron methyl + chlorimuron ethyl at 90 g a.i. ha^{-1} (168.0 ‘000 ha^{-1}), chlorimuron ethyl at 12 (165.7 ‘000 ha^{-1}) and 18 g a.i. ha^{-1} (170.6 ‘000 ha^{-1}) , atrazine at 1.0 kg a.i. ha^{-1} (168.3 ‘000 ha^{-1}) and hand weeding on 30 DAP (168.6 ‘000 ha^{-1}) than unweeded control. Comparitively lesser population of millable cane was observed with test herbicides at low doses. Invariably, unweeded check plot resulted in least population of millable cane in both the years (116.0 and 124.7 000 ha^{-1} respectively).

4.2.1.5. Tillering and survival capacity (Table 41)

During main season 2011, weed control treatments influenced the number of tillers greatly there by the tillering capacity and survival capacity. The highest tillering capacity of 2.44 and 2.29 was recorded with EPOE application of higher doses of halosulfuron methyl + chlorimuron ethyl at 135.5 and 90 g a.i. ha^{-1}. This was followed by hand weedings twice (2.25),

atrazine at 1.0 kg a.i. ha^{-1}(2.24) and chlorimuron ethyl at 18 g a.i. ha^{-1} (2.22). Lower doses of test herbicide recorded the lower tillering capacity. These treatments enhanced more or less similarly in influencing the tillering capacity and vice versa. The lower tillering capacity was recorded with un weeded control (1.68).

During late season 2012 also, the same trend was noticed. The highest tillering capacity of 2.50 and 2.15 was recorded in EPOE application of higher doses of halosulfuron methyl + chlorimuron ethyl at 135.5 and 90 g a.i. ha^{-1} and this was followed by hand weeding on 30 DAP (2.08), atrazine at 1.0 kg a.i. ha^{-1} (2.05) and chlorimuron ethyl at 18 g a.i. ha^{-1} (2.03) registered markedly higher values of tillering capacity over other weed control treatments. Lower doses of test herbicides recorded the lesser tillering capacity. The lowest tillering capacity was recorded with un weeded control (1.64) in both the seasons.

Table 42. Effect of different weed control treatments on leaf area index (LAI) in sugarcane

Treatments	Main season 2011				Late season 2012			
	30 DAP	**60 DAP**	**90 DAP**	**120 DAP**	**30 DAP**	**60 DAP**	**90 DAP**	**120 DAP**
T_1 - EPOE-Halo. 45 g a.i. ha^{-1}	0.152	1.167	2.084	2.278	0.401	1.988	2.036	3.714
T_2 – EPOE-Halo. 67.5 g a.i. ha^{-1}	0.194	1.253	2.117	2.281	0.412	2.396	2.433	3.781
T_3 - EPOE-Halo. 90 g a.i. ha^{-1}	0.221	1.283	2.159	2.319	0.515	2.508	3.895	3.936
T_4 - EPOE-Halo. 135.5 g a.i. ha^{-1}	0.459	1.393	2.187	2.348	0.566	2.547	4.124	4.416
T_5 - EPOE-Combi. 45 g a.i. ha^{-1}	0.173	1.320	2.120	2.292	0.415	2.081	3.063	3.613
T_6 - EPOE-Combi. 67.5 g a.i. ha^{-1}	0.271	1.534	2.352	2.280	0.446	2.638	3.264	4.049
T_7 - EPOE-Combi. 90 g a.i. ha^{-1}	0.443	1.550	2.414	2.609	0.645	3.145	3.600	5.020
T_8 - EPOE-Combi. 135.5 g a.i. ha^{-1}	0.668	1.603	2.440	2.635	0.775	3.668	4.047	5.282
T_9 - EPOE-Chlori. 6 g a.i. ha^{-1}	0.221	1.228	2.010	2.204	0.702	1.914	2.826	3.514
T_{10} - EPOE-Chlori. 9 g a.i. ha^{-1}	0.310	1.283	2.137	2.308	0.445	2.319	2.827	3.681
T_{11} - EPOE-Chlori. 12 g a.i. ha^{-1}	0.443	1.521	2.187	2.512	0.648	2.516	3.344	3.802
T_{12} - EPOE-Chlori. 18 g a.i. ha^{-1}	0.515	1.534	2.389	2.583	0.773	2.565	3.877	3.814
T_{13} - PE-Atrazine 1.0 kg a.i. ha^{-1}	0.491	1.415	2.397	2.548	0.771	3.612	4.079	4.436
T_{14} - HW on 30 DAP	0.165	1.439	2.404	2.632	0.268	3.096	3.429	5.059
T_{15} - Unweeded control	0.152	0.940	2.057	2.251	0.265	1.388	1.829	2.294
SEd	**0.030**	**0.070**	**0.110**	**0.120**	**0.030**	**0.230**	**0.260**	**0.220**
CD (P=0.05)	**0.070**	**0.150**	**0.230**	**0.250**	**0.070**	**0.470**	**0.530**	**0.450**

Similar to tillering capacity, the survival capacity also showed significant variation during weed control treatments. During the main season 2011, the survival capacity was higher under EPOE application of higher doses of halosulfuron methyl + chlorimuron ethyl at 135.5 (76.6 %) and 90 g a.i. ha^{-1} (76.2 %) and this was followed by atrazine at 1.0 kg a.i. ha^{-1} (75.3 %) hand weeding on 30 DAP (72.9 %), and chlorimuron ethyl at 18 g a.i. ha^{-1} (73.8 %) over the other weed control treatments. The survival capacity was found to be less under test herbicides evaluated at low doses. During late season 2012 also, halosulfuron methyl + chlorimuron ethyl at higher doses 135.5 (77.5 %) and 90 g a.i. ha^{-1}(76.9 %) , chlorimuron ethyl at 18 g a.i. ha^{-1} (77.3 %), atrazine at 1.0 kg a.i. ha^{-1} (76.1 %) and hand weeding on 30 DAP (76.8 %) resulted in higher values of survival capacity. In both the years of study, survival capacity was the least under unweeded check.

4.2.1.6. Leaf Area Index (LAI) (Table 42)

The data on leaf area index showed percepitable variation at all stages of observation during both the season. The results showed that there was an increment in LAI from 30 to 120 DAP. During main season 2011, at 30 DAP, the highest LAI values were recorded under halosulfuron methyl + chlorimuron ethyl at 135.5 g a.i. ha^{-1} (0.668). This was followed by chlorimuron ethyl at 18 g a.i. ha^{-1} (0.515) and atrazine at 1.0 kg a.i. ha^{-1} (0.491). At 60, 90 and 120 DAP, halosulfuron methyl + chlorimuron ethyl and chlorimuron ethyl at higher doses, atrazine at 1.0 kg a.i. ha^{-1} and hand weeding on 30 DAP recorded significantly higher values of LAI over rest of the treatments. The LAI values were found to be low with test herbicides at low doses as well as unweeded control.

During late season 2012, at 30 DAP, the LAI was higher with halosulfuron methyl + chlorimuron ethyl at 135.5 g a.i. ha^{-1} (0.770), atrazine at 1.0 kg a.i. ha^{-1} (0.770), chlorimuron ethyl at 12 (0.647) and 18 (0.774) g a.i. ha^{-1}. At 60 DAP, halosulfuron methyl + chlorimuron ethyl at 135.5 g a.i. ha^{-1} and atrazine at 1.0 kg a.i. ha^{-1} recorded significantly higher LAI over the rest of treatments. This was followed by halosulfuron methyl + chlorimuron ethyl at 90 g a.i. ha^{-1} and hand weeding on 30 DAP. However, at 90 DAP, along with halosulfuron methyl + chlorimuron ethyl at 135.5 g a.i. ha^{-1}, halosulfuron methyl at 135.5 g a.i. ha^{-1} also recorded the higher LAI and these treatments were onpar with halosulfuron methyl + chlorimuron ethyl at 90 g a.i. ha^{-1}, chlorimuron

Table 43. Effect of different weed control treatments on plant DMP (t ha^{-1}) in sugarcane

Treatments	Main season 2011				Late season 2012			
	30 DAP	60 DAP	90 DAP	120 DAP	30 DAP	60 DAP	90 DAP	120 DAP
T_1 - EPOE-Halo. 45 g a.i. ha^{-1}	1.153	1.649	4.230	8.17	2.240	2.984	6.123	11.33
T_2 – EPOE-Halo. 67.5 g a.i. ha^{-1}	1.160	1.729	4.700	8.34	2.280	3.056	6.350	12.69
T_3 - EPOE-Halo. 90 g a.i. ha^{-1}	1.200	1.978	5.716	10.25	2.300	3.142	6.970	14.25
T_4 - EPOE-Halo. 135.5 g a.i. ha^{-1}	1.220	2.016	5.846	11.34	2.300	3.186	7.130	14.78
T_5 - EPOE-Combi. 45 g a.i. ha^{-1}	1.150	1.980	4.793	9.57	2.293	3.142	6.307	11.89
T_6 - EPOE-Combi. 67.5 g a.i. ha^{-1}	1.213	2.092	4.913	10.05	2.447	3.361	7.236	13.78
T_7 - EPOE-Combi. 90 g a.i. ha^{-1}	1.367	2.394	7.320	13.40	2.463	3.431	7.504	14.57
T_8 - EPOE-Combi. 135.5 g a.i. ha^{-1}	1.393	2.456	7.647	14.20	2.473	3.541	7.682	15.85
T_9 - EPOE-Chlori. 6 g a.i. ha^{-1}	1.153	1.869	5.030	9.18	2.310	2.980	6.287	11.31
T_{10} - EPOE-Chlori. 9 g a.i. ha^{-1}	1.230	1.957	5.287	9.56	2.340	3.093	6.467	11.77
T_{11} - EPOE-Chlori. 12 g a.i. ha^{-1}	1.260	2.193	6.346	12.50	2.403	3.232	7.157	13.89
T_{12} - EPOE-Chlori. 18 g a.i. ha^{-1}	1.257	2.200	6.366	12.78	2.397	3.362	7.450	14.57
T_{13} - PE-Atrazine 1.0 kg a.i. ha^{-1}	1.283	2.236	6.450	12.37	2.197	3.230	6.950	14.13
T_{14} - HW on 30 DAP	0.893	1.800	5.456	12.94	1.937	2.987	6.350	13.57
T_{15} - Unweeded control	0.757	1.311	4.127	8.06	1.237	1.645	2.287	6.15
SEd	**0.075**	**0.106**	**0.303**	**0.57**	**0.057**	**0.170**	**0.361**	**0.72**
CD (P=0.05)	**0.133**	**0.218**	**0.621**	**1.18**	**0.117**	**0.350**	**0.739**	**1.47**

ethyl at 12 and 18 g a.i. ha^{-1}and standard method of weed control methods like atrazine at 1.0 kg a.i. ha^{-1}, hand weeding on 30 DAP. At 120 DAP, also the same trend as that of 90 DAP was observed.

4.2.1.7. Dry matter production (DMP) (Table 43)

Weed management practices had significant influence on the dry matter production of sugarcane at all four stages in both the years. The highest DMP of 1.39 t ha^{-1} was recorded in halosulfuron methyl + chlorimuron ethyl at 135.5 g a.i. ha^{-1} at 30 DAP during the first crop. This was onpar with chlorimuron ethyl at 18 g a.i. ha^{-1}, atrazine at 1.0 kg a.i. ha^{-1} and halosulfuron methyl + chlorimuron ethyl 90 g a.i. ha^{-1}. At 60 DAP, the higher DMP was observed in halosulfuron methyl + chlorimuron ethyl at 135.5 g a.i. ha^{-1} and this was comparable with halosulfuron methyl + chlorimuron ethyl at 90 g a.i. ha^{-1}, chlorimuron ethyl at 12 and 18 g a.i. ha^{-1}, atrazine at 1.0 kg a.i. ha^{-1} and hand weeding on 30 DAP than rest of the treatments. At 90 and 120 DAP, higher DMP of 7.64 and 14.20 t ha^{-1} was recorded with halosulfuron methyl + chlorimuron ethyl at 135.5 g a.i. ha^{-1} respectively. This was comparable with halosulfuron methyl + chlorimuron ethyl at 90 g a.i. ha^{-1}, chlorimuron ethyl at 12 and 18 g a.i. ha^{-1}, atrazine at 1.0 kg a.i. ha^{-1}, hand weeding on 30 DAP .

During late season 2012, at 30 DAP, the plant DMP was higher (2.47 t ha^{-1}) in halosulfuron methyl + chlorimuron ethyl at 135.5 g a.i. ha^{-1} than rest of the treatments. This was comparable with halosulfuron methyl + chlorimuron ethyl at 90 g a.i. ha^{-1}, chlorimuron ethyl at 18 g a.i. ha^{-1} and atrazine at 1.0 kg a.i. ha^{-1}. Whereas, at 60 DAP, halosulfuron methyl + chlorimuron ethyl at 135.5 g a.i. ha^{-1}, chlorimuron ethyl at 12 and 18 g a.i. ha^{-1} and atrazine at 1.0 kg a.i. ha^{-1} and hand weeding on 30 DAP recorded significantly higher plant DMP. This was followed by halosulfuron methyl + chlorimuron ethyl at 90 g a.i. ha^{-1}. Both the stages at 90 and 120 DAP, the highest plant DMP of 7.68 and 15.85 t ha^{-1} was recorded with halosulfuron methyl + chlorimuron ethyl at 135.5 g a.i. ha^{-1} respectively. This was onpar with halosulfuron methyl + chlorimuron ethyl at 90 g a.i. ha^{-1}, chlorimuron ethyl at 12 and 18 g a.i. ha^{-1}, atrazine at 1.0 kg a.i. ha^{-1} and hand weeding on 30 DAP. Significantly lesser DMP was recorded with test

Table 44. Effect of different weed control treatments on crop growth rate (g m^{-2} day^{-1}) in sugarcane

Treatments	Main season 2011			Late season 2012		
	30-60 DAP	60-90 DAP	90-120 DAP	30-60 DAP	60-90 DAP	90-120 DAP
T_1 - EPOE-Halo. 45 g a.i. ha^{-1}	1.652	8.604	27.22	2.480	10.46	17.35
T_2 – EPOE-Halo. 67.5 g a.i. ha^{-1}	1.897	9.903	27.81	2.587	10.98	21.14
T_3 - EPOE-Halo. 90 g a.i. ha^{-1}	2.593	12.460	34.17	2.807	12.76	24.27
T_4 - EPOE-Halo. 135.5 g a.i. ha^{-1}	2.653	12.767	37.80	2.953	13.15	25.50
T_5 - EPOE-Combi. 45 g a.i. ha^{-1}	2.767	9.377	31.90	2.829	10.55	18.62
T_6 - EPOE-Combi. 67.5 g a.i. ha^{-1}	2.929	9.402	33.49	3.049	12.92	21.81
T_7 - EPOE-Combi. 90 g a.i. ha^{-1}	3.423	16.420	44.67	3.226	13.58	23.54
T_8 - EPOE-Combi. 135.5 g a.i. ha^{-1}	3.543	17.303	47.33	3.559	13.80	27.23
T_9 - EPOE-Chlori. 6 g a.i. ha^{-1}	2.387	10.536	30.60	2.233	11.02	16.73
T_{10} - EPOE-Chlori. 9 g a.i. ha^{-1}	2.422	11.100	31.87	2.511	11.24	17.69
T_{11} - EPOE-Chlori. 12 g a.i. ha^{-1}	3.111	13.842	41.67	2.762	13.08	22.44
T_{12} - EPOE-Chlori. 18 g a.i. ha^{-1}	3.144	13.885	42.60	3.216	13.63	23.73
T_{13} - PE-Atrazine 1.0 kg a.i. ha^{-1}	3.176	14.047	41.23	3.443	12.40	23.92
T_{14} - HW on 30 DAP	3.022	12.187	43.13	3.500	11.21	24.07
T_{15} - Unweeded control	1.848	9.385	26.88	1.360	7.14	12.88

herbicides at low doses as well as unweeded control at all stages of crop, during the both the years of study compared to higher doses.

4.2.1. 8. Crop Growth Rate (CGR g m^{-2} day^{-1}) (Table 44)

Weed management practices had significant influence on the crop growth rate of sugarcane at all four stages in both the years. The highest CGR of 3.54 g m^{-2} day^{-1} was recorded in halosulfuron methyl + chlorimuron ethyl at 135.5 g a.i. ha^{-1} at 30 to 60 DAP during the first crop. This was comparable with chlorimuron ethyl at 18 g a.i. ha^{-1}, atrazine at 1.0 kg a.i. ha^{-1} and halosulfuron methyl + chlorimuron ethyl at 90 g a.i. ha^{-1}. Lower doses of test herbicides (T_1, T_2, T_5, T_9 and T_{10}) recorded significantly lower CGR and vice versa. At 60 to 90 DAP the highest CGR was observed in halosulfuron methyl + chlorimuron ethyl at 135.5 g a.i. ha^{-1} and this was onpar with halosulfuron methyl + chlorimuron ethyl at 90 g a.i. ha^{-1}, chlorimuron ethyl at 12 and 18 g a.i. ha^{-1}, atrazine at 1.0 kg a.i. ha^{-1} and hand weeding on 30 DAP. At 90 to 120 DAP, the highest CGR of 47.33 and 44.67 g m^{-2} day^{-1} was recorded with halosulfuron methyl + chlorimuron ethyl at 135.5 and 90 g a.i. ha^{-1}, respectively. This was onpar with chlorimuron ethyl at 12 and 18 g a.i. ha^{-1}, atrazine at 1.0 kg a.i. ha^{-1} and hand weeding on 30 DAP .

During 2012-13, at 30 to 60 DAP, the CGR was the highest (3.55 g m^{-2} day^{-1}) in halosulfuron methyl + chlorimuron ethyl at 135.5 g a.i. ha^{-1}. This was on par with halosulfuron methyl + chlorimuron ethyl at 90 g a.i. ha^{-1}, chlorimuron ethyl at 18 g a.i. ha^{-1} and atrazine at 1.0 kg a.i. ha^{-1}. Lowest dose of test herbicides like chlorimuron ethyl at 6 g a.i. ha^{-1}(T_9), halosulfuron methyl at 45 g a.i. ha^{-1} (T_1) and halosulfuron methyl + chlorimuron ethyl at 45 g a.i. ha^{-1} (T_5) and hand weeding on 30 DAP recorded lesser CGR. Whereas at 60 to 90 DAP, halosulfuron methyl + chlorimuron ethyl at 135.5 and 90 g a.i. ha^{-1}, chlorimuron ethyl at 18 g a.i. ha^{-1} and atrazine at 1.0 kg a.i. ha^{-1} recorded significantly higher CGR compared to rest of the treatment. This was followed by chlorimuron ethyl at 12 g a.i. ha^{-1} and hand weeding on 30 DAP. At 90 to 120 DAP, the highest CGR of 27.23 g m^{-2} day^{-1} was recorded with halosulfuron methyl + chlorimuron ethyl at 135.5 g a.i. ha^{-1}. This closely followed by halosulfuron methyl + chlorimuron ethyl at 90 g a.i. ha^{-1}, chlorimuron ethyl at 12 and 18 g a.i. ha^{-1}, atrazine at 1.0 kg a.i. ha^{-1} and hand weeding on 30 DAP .

4.2.1. 9. Relative Growth Rate (RGR) (g g^{-1} day^{-1}) (Table 45)

Relative growth rate had been significantly influenced by different weed control treatments of sugarcane at the four stages in both the years. The highest RGR of 1.89 and 3.78 was recorded in halosulfuron methyl + chlorimuron ethyl at 135.5 g a.i. ha^{-1} at 30 to 60 DAP during the first crop. This was on par with chlorimuron ethyl at 18 g a.i. ha^{-1}, atrazine at 1.0 kg a.i. ha^{-1} and halosulfuron methyl + chlorimuron ethyl at 90 g a.i. ha^{-1}. Lower doses of test herbicides (T_1, T_2, T_5, T_9 and T_{10}) recorded significantly lower RGR and vice versa. At 60 to 90 DAP, the highest RGR was observed in halosulfuron methyl + chlorimuron ethyl at 135.5 g a.i. ha^{-1} and this was onpar with halosulfuron methyl + chlorimuron ethyl at 90 g a.i. ha^{-1}, chlorimuron ethyl at 12 and 18 g a.i. ha^{-1}, atrazine at 1.0 kg a.i. $ha^{-1}$and hand weeding on 30 DAP. At 90 to 120 DAP, the highest CGR of 2.53 and 2.40 g g^{-1} day^{-1} was recorded with halosulfuron methyl + chlorimuron ethyl at 135.5 and 90 g a.i. ha^{-1}, respectively. This was onpar with chlorimuron ethyl at 12 and 18 g a.i. ha^{-1}, atrazine at 1.0 kg a.i. ha^{-1} and hand weeding on 30 DAP .

During 2012-13, at 30 to 60 DAP, the RGR was the highest (1.20 g g^{-1} day^{-1}) in halosulfuron methyl + chlorimuron ethyl at 135.5 g a.i. ha^{-1}. This was comparable with halosulfuron methyl + chlorimuron ethyl at 90 g a.i. ha^{-1}, chlorimuron ethyl at 18 g a.i ha^{-1} and atrazine at 1.0 kg a.i. ha^{-1}. Lowest dose of test herbicides like chlorimuron ethyl at 6 g a.i. ha^{-1}(T_9), halosulfuron methyl at 45 g a.i. ha^{-1} (T_1) and halosulfuron methyl + chlorimuron ethyl at 45 g a.i. ha^{-1} (T_5) and hand weeding on 30 DAP recorded lesser RGR than rest of the treatments. Whereas, at 60 to 90 DAP, halosulfuron methyl + chlorimuron ethyl at 135.5 g a.i. ha^{-1}, chlorimuron ethyl at 12 and 18 g a.i. ha^{-1} and atrazine at 1.0 kg a.i. ha^{-1} recorded significantly higher RGR. This was followed by halosulfuron methyl + chlorimuron ethyl at 90 g a.i. ha^{-1} and hand weeding on 30 DAP. At 90 to120 DAP, the highest RGR of 2.41 g g^{-1} day^{-1} was recorded with halosulfuron methyl + chlorimuron ethyl at 135.5 g a.i. ha^{-1}. This was comparable with halosulfuron methyl + chlorimuron ethyl at 90 g a.i. ha^{-1}, chlorimuron ethyl at 12 and 18 g a.i. ha^{-1}, atrazine at 1.0 kg a.i. ha^{-1} and hand weeding on 30 DAP .

Table 45. Effect of different weed control treatments on relative growth rate (g g^{-1} day^{-1}) in sugarcane

Treatments	Main season 2011			Late season 2012		
	30-60 DAP	60-90 DAP	90-120 DAP	30-60 DAP	60-90 DAP	90-120 DAP
T_1 - EPOE-Halo. 45 g a.i. ha^{-1}	1.1913	3.140	1.880	0.956	2.396	1.997
T_2 – EPOE-Halo. 67.5 g a.i. ha^{-1}	1.3304	3.333	1.912	0.976	2.438	2.231
T_3 - EPOE-Halo. 90 g a.i. ha^{-1}	1.6659	3.537	1.929	1.040	2.450	2.427
T_4 - EPOE-Halo. 135.5 g a.i. ha^{-1}	1.6742	3.549	1.966	1.086	2.516	2.528
T_5 - EPOE-Combi. 45 g a.i. ha^{-1}	1.8111	2.947	2.305	1.050	2.218	2.114
T_6 - EPOE-Combi. 67.5 g a.i. ha^{-1}	1.8158	2.846	2.385	1.059	2.556	2.147
T_7 - EPOE-Combi. 90 g a.i. ha^{-1}	1.8678	3.725	2.401	1.105	2.609	2.301
T_8 - EPOE-Combi. 135.5 g a.i. ha^{-1}	1.8902	3.786	2.530	1.196	2.677	2.414
T_9 - EPOE-Chlori. 6 g a.i. ha^{-1}	1.6097	3.299	1.955	0.849	2.385	1.957
T_{10} - EPOE-Chlori. 9 g a.i. ha^{-1}	1.5475	3.313	1.975	0.930	2.458	1.998
T_{11} - EPOE-Chlori. 12 g a.i. ha^{-1}	1.8477	3.541	2.260	0.987	2.549	2.163
T_{12} - EPOE-Chlori. 18 g a.i. ha^{-1}	1.8666	3.541	2.323	1.128	2.653	2.281
T_{13} - PE-Atrazine 1.0 kg a.i. ha^{-1}	1.8508	3.531	2.477	1.285	2.613	2.364
T_{14} - HW on 30 DAP	1.5833	3.696	2.405	1.444	3.178	2.158
T_{15} - Unweeded control	0.264	2.122	2.233	0.950	2.430	2.493

4.2.2. Yield attributes

4.2.2.1. Cane length (Table 46)

Different weed control methods exerted significant influence on cane length. The crop that received EPOE application of halosulfuron methyl + chlorimuron ethyl at 135.5 g a.i. ha^{-1} had produced lengthier cane (160.0 cm) and this was comparable with halosulfuron methyl + chlorimuron ethyl at 90 g a.i. ha^{-1}(155.3 cm), chlorimuron ethyl at 18 g a.i. ha^{-1}(155.2 cm), hand weeding on 30 DAP (155.0 cm) and atrazine at 1.0 kg a.i. ha^{-1} (154.3 cm). Sugarcane crop treated with test herbicide at lower doses invariably had shorter cane length than higher doses.

During the late season 2012, significantly higher cane length was observed under halosulfuron methyl + chlorimuron ethyl at 135.5(174.4 cm) and 90 g a.i. ha^{-1} (173.6 cm), atrazine at 1.0 kg a.i. ha^{-1}(173.4 cm) hand weeding on 30 DAP(173.3 cm) and chlorimuron ethyl at 18 g a.i. ha^{-1}(169.3cm) over other treatments. The cane crop left with uncontrolled weed growth resulted the least cane length during both the years of study (155.0 and 120.0 cm).

4.2.2.2. Cane girth (Table 46)

The cane girth was found to vary significantly due to weed management treatments in both the years of study. The cane girth was higher under halosulfuron methyl + chlorimuron ethyl at 135.5 g a.i. ha^{-1} (9.5 cm), chlorimuron ethyl at 18 g a.i. ha^{-1} (8.7 cm), atrazine at 1.0 kg a.i. ha^{-1} (8.7 cm) and hand weeding on 30 DAP (8.7 cm) during main season 2011.

In the late season 2012 also, the cane that received EPOE application of halosulfuron methyl + chlorimuron ethyl at 135.5 g a.i. ha^{-1}(10.5 cm), halosulfuron methyl + chlorimuron ethyl at 90 g a.i. ha^{-1} (9.6 cm) chlorimuron ethyl at 12 and 18 g a.i. ha^{-1}, atrazine at 1.0 kg a.i. ha^{-1} and hand weeding on 30 DAP produced significantly higher cane girth over rest of the weed control treatments. During both the years, the test herbicides at low doses resulted in lesser cane girth which ranged from 6.9 to 8.8 cm.

Table 46. Effect of different weed control treatments on yield parameters in sugarcane

Treatments	Main season 2011				Late season 2012			
	Cane length(cm)	**Cane girth(cm)**	**No.of internodes**	**Internode length(cm)**	**Cane length(cm)**	**Cane girth(cm)**	**No.of internodes**	**Internode length(cm)**
T_1 - EPOE-Halo. 45 g a.i. ha^{-1}	113.10	6.987	12.33	12.30	126.20	8.794	14.00	13.05
T_2 – EPOE-Halo. 67.5 g a.i. ha^{-1}	127.80	7.283	14.00	12.67	136.50	8.996	14.00	13.42
T_3 - EPOE-Halo. 90 g a.i. ha^{-1}	136.70	7.653	14.67	13.67	144.30	9.078	14.33	14.28
T_4 - EPOE-Halo. 135.5 g a.i. ha^{-1}	143.70	7.667	15.00	14.34	148.00	9.183	14.67	15.09
T_5 - EPOE-Combi. 45 g a.i. ha^{-1}	115.50	7.553	12.00	13.01	150.80	9.090	11.67	13.76
T_6 - EPOE-Combi. 67.5 g a.i. ha^{-1}	129.30	7.817	16.67	14.76	151.30	9.103	13.67	15.51
T_7 - EPOE-Combi. 90 g a.i. ha^{-1}	155.30	8.517	17.00	16.07	173.60	9.643	16.33	16.82
T_8 - EPOE-Combi. 135.5 g a.i. ha^{-1}	160.00	9.500	18.00	16.83	174.40	10.476	18.33	17.58
T_9 - EPOE-Chlori. 6 g a.i. ha^{-1}	126.00	6.997	14.00	13.54	154.60	8.097	13.67	14.29
T_{10} - EPOE-Chlori. 9 g a.i. ha^{-1}	138.40	7.907	14.67	13.67	155.50	9.181	14.00	14.42
T_{11} - EPOE-Chlori. 12 g a.i. ha^{-1}	158.30	8.377	15.33	15.15	163.40	9.165	16.33	15.90
T_{12} - EPOE-Chlori. 18 g a.i. ha^{-1}	155.20	8.707	17.33	15.94	169.30	9.750	17.00	16.69
T_{13} - PE-Atrazine 1.0 kg a.i. ha^{-1}	154.30	8.663	17.33	15.01	173.40	9.763	17.67	15.76
T_{14} - HW on 30 DAP	155.00	8.740	17.00	15.63	173.30	9.796	18.00	16.38
T_{15} - Unweeded control	96.00	6.760	9.00	11.63	120.20	8.383	13.67	12.38
SEd	**7.73**	**0.456**	**1.32**	**0.81**	**9.16**	**0.502**	**1.17**	**0.81**
CD (P=0.05)	**15.84**	**0.937**	**2.71**	**1.66**	**18.76**	**1.03**	**2.39**	**1.65**

The cane girth was drastically reducedunder uncontrolled weed growth treatments (6.7 and 8.3 cm) in both the years of study.

4.2.2.3. Number of internodes (Table 46)

The data on number of internodes revealed that the herbicide applied plots manifested considerably higher internodes in both the years. The highest number of internodes of 18 cane^{-1} was recorded with halosulfuron methyl + chlorimuron ethyl at 135.5 g a.i. ha^{-1} and this was comparable with halosulfuron methyl + chlorimuron ethyl at 90 g a.i. ha^{-1} (17.0 cane^{-1}) chlorimuron ethyl at 18 g a.i. ha^{-1} (17.3 cane^{-1}), atrazine at 1.0 kg a.i. ha^{-1} (17.3 cane^{-1}) and hand weeding on 30 DAP (17.0 cane^{-1}). Lower doses of test herbicides (T_1, T_2, T_5, T_9 and T_{10}) recorded significantly lower number of internodes (12.3 to 14.7cane^{-1}) compared to higher doses during first season.

During the late season 2012 also, significant difference in the number of internodes due to the weed management treatments was observed. Highest number of internodes of 18.3 cane^{-1} was recorded with halosulfuron methyl + chlorimuron ethyl at 135.5 g a.i. ha^{-1}. This was on par with hand weeding on 30 DAP (18.0 cane^{-1}), atrazine at 1.0 kg a.i. ha^{-1} (17.7 cane^{-1}), chlorimuron ethyl at 12 (16.3 cane^{-1}) and 18 g a.i. ha^{-1} (17.0 cane^{-1}) and halosulfuron methyl + chlorimuron ethyl at 90 g a.i. ha^{-1}(16.3 cane^{-1}). Lower doses of test herbicides (T_1, T_2, T_5, T_9 and T_{10}) recorded significantly lower number of internodes which ranged from 12 to 14.0 cane^{-1}. The number of internodes was significantly lesser under uncontrolled weed growth during both the years of study. The number of internodes under unweeded check was 9.0 and 13.6 cane^{-1} during main and late seasons respectively.

4.2.2.4. Internode length (Table 46)

The internode length was found to vary significantly due to weed management practices during both the years of study. The data on length revealed that the herbicide applied plots manifested considerably higher internode length in both the years. The highest internode length was recorded with halosulfuron methyl + chlorimuron ethyl at 135.5 g a.i. ha^{-1}(16.8 cm). This was on par with halosulfuron methyl + chlorimuron ethyl at 90 g a.i. ha^{-1} (16.1cm), chlorimuron ethyl at 18 g a.i. ha^{-1} (15.9cm) and hand weeding on 30 DAP (15.6 cm).

During the late season 2012 also, the highest internode length was recorded in halosulfuron methyl + chlorimuron ethyl at 135.5 g a.i. ha^{-1} (17.6 cm) and halosulfuron methyl + chlorimuron ethyl at 90 g a.i. ha^{-1} (16.8 cm), chlorimuron ethyl at 12 (15.9 cm) and 18 g a.i. ha^{-1} (16.7 cm) and hand weeding on 30 DAP (16.4 cm) recorded higher and comparable internode length over rest of the treatments. Lower doses of test herbicides (T_1, T_2, T_5, T_9 and T_{10}) recorded significantly lesser internode length during both the seasons and was ranged from 13.0 to 14.3 cm. The cane length under unweeded check treatments had significantly lesser in cane length in both the seasons. Lower internode length of 11.6 and 12.4 cm was recorded with unweeded control during main and late seasons, respectively.

4.2.3. Quality parameters (Table 47)

The brix , sucrose percent, purity coefficient and commercial cane sugar percentage of juice were estimated at the time of harvest. Weed management practices did not have any significant influence on the quality characters like brix percentage, sucrose percentage, purity coefficient and commercial cane sugar percentage during both the year of study.

4.2.4. Nutrient analysis

4.2.4.1. Nitrogen uptake (Table 48)

Weed control treatments exhibited significant variation in nitrogen uptake by crops. EPOE application of halosulfuron methyl + chlorimuron ethyl at 135.5 g a.i. ha^{-1} recorded significantly higher uptake of 39.44 kg $ha^{-1}$and this was closely followed by halosulfuron methyl + chlorimuron ethyl at 90 g a.i. ha^{-1} (38.84), chlorimuron ethyl at 18 g a.i. ha^{-1}(37.27 kg ha^{-1}), atrazine at 1.0 kg a.i. ha^{-1} (37.23 kg ha^{-1}) at 30 DAP during main season, 2011. At 60 and 90 DAP, halosulfuron methyl + chlorimuron ethyl at 90 and 135.5 g a.i. ha^{-1}, chlorimuron ethyl at 18 g a.i. ha^{-1}, atrazine at 1.0 kg a.i. ha^{-1} as well as hand weeding on 30 DAP were equally effective in controlling weeds which resulted in higher uptake of N than the rest of the treatments.

Table 47. Effect of different weed control treatments on quality parameters in sugarcane

Treatments	Main season 2011				Late season 2012			
	Brix(%)	Sucrose(%)	Purity (%)	CCS(%)	Brix(%)	Sucrose(%)	Purity (%)	CCS(%)
T_1 - EPOE-Halo. 45 g a.i. ha^{-1}	21.49	18.23	84.83	12.36	20.80	18.64	89.61	12.98
T_2 – EPOE-Halo. 67.5 g a.i. ha^{-1}	20.81	18.17	87.31	12.49	20.90	18.58	88.90	12.89
T_3 - EPOE-Halo. 90 g a.i. ha^{-1}	21.01	18.75	88.36	12.84	19.90	18.97	95.32	13.63
T_4 - EPOE-Halo. 135.5 g a.i. ha^{-1}	21.00	18.23	86.81	12.50	21.40	18.64	87.11	12.80
T_5 - EPOE-Combi. 45 g a.i. ha^{-1}	20.52	18.17	88.55	12.58	21.00	18.54	88.28	12.81
T_6 - EPOE-Combi. 67.5 g a.i. ha^{-1}	20.41	18.34	89.86	12.78	22.30	18.71	83.90	12.61
T_7 - EPOE-Combi. 90 g a.i. ha^{-1}	20.60	18.35	89.08	12.74	21.30	19.05	89.45	13.25
T_8 - EPOE-Combi. 135.5 g a.i. ha^{-1}	21.18	18.45	87.11	12.67	22.70	18.82	82.91	12.61
T_9 - EPOE-Chlori. 6 g a.i. ha^{-1}	20.30	18.23	89.80	12.70	19.80	18.65	94.19	13.28
T_{10} - EPOE-Chlori. 9 g a.i. ha^{-1}	20.79	18.65	89.71	12.99	21.40	19.07	89.11	13.24
T_{11} - EPOE-Chlori. 12 g a.i. ha^{-1}	19.84	18.7	94.25	12.80	20.40	19.12	93.73	13.58
T_{12} - EPOE-Chlori. 18 g a.i. ha^{-1}	21.60	18.23	84.40	12.84	19.70	18.65	94.67	13.31
T_{13} - PE-Atrazine 1.0 kg a.i. ha^{-1}	20.82	18.56	89.15	12.89	21.30	18.98	89.11	13.18
T_{14} - HW on 30 DAP	21.50	18.6	86.51	12.73	20.40	19.02	93.24	13.48
T_{15} - Unweeded control	21.79	18.3	83.98	12.34	19.80	18.72	94.55	13.35
SEd	**1.15**	**1.01**	**4.82**	**0.69**	**1.15**	**0.89**	**4.13**	**0.61**
CD (P=0.05)	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**

Table 48. Effect of different weed control treatments on nitrogen uptake (kg ha^{-1}) in sugarcane

Treatments	Main season 2011			Late season 2012		
	30DAP	60DAP	90DAP	30DAP	60DAP	90DAP
T_1 - EPOE-Halo. 45 g a.i. ha^{-1}	30.06	60.03	82.72	59.99	104.58	100.54
T_2 – EPOE-Halo. 67.5 g a.i. ha^{-1}	30.35	68.00	83.31	61.49	106.65	101.81
T_3 - EPOE-Halo. 90 g a.i. ha^{-1}	33.41	71.76	83.79	63.58	108.78	101.92
T_4 - EPOE-Halo. 135.5 g a.i. ha^{-1}	33.83	74.23	88.38	64.63	119.72	104.05
T_5 - EPOE-Combi. 45 g a.i. ha^{-1}	32.65	73.30	87.66	63.65	114.53	105.03
T_6 - EPOE-Combi. 67.5 g a.i. ha^{-1}	32.85	73.61	88.44	64.20	114.15	103.56
T_7 - EPOE-Combi. 90 g a.i. ha^{-1}	38.84	80.28	108.86	72.35	148.21	127.14
T_8 - EPOE-Combi. 135.5 g a.i. ha^{-1}	39.44	81.00	112.03	74.26	152.49	135.04
T_9 - EPOE-Chlori. 6 g a.i. ha^{-1}	31.06	64.41	87.47	59.55	105.87	101.78
T_{10} - EPOE-Chlori. 9 g a.i. ha^{-1}	31.82	66.76	89.03	60.42	105.70	102.21
T_{11} - EPOE-Chlori. 12 g a.i. ha^{-1}	32.71	74.17	105.40	61.34	112.79	103.38
T_{12} - EPOE-Chlori. 18 g a.i. ha^{-1}	37.27	77.61	111.59	71.29	151.09	127.50
T_{13} - PE-Atrazine 1.0 kg a.i. ha^{-1}	37.23	79.75	113.63	73.75	157.55	127.97
T_{14} - HW on 30 DAP	28.00	81.47	117.50	32.26	156.14	128.18
T_{15} - Unweeded control	19.08	42.83	63.58	27.17	36.05	81.55
SEd	**2.23**	**3.42**	**10.20**	**4.69**	**9.85**	**11.60**
CD (P=0.05)	**4.58**	**7.02**	**20.90**	**9.60**	**20.20**	**23.80**

During the late season 2012, at 30 DAP, halosulfuron methyl + chlorimuron ethyl at 135.5 and 90 g a.i. ha^{-1} recorded significantly higher nitrogen uptake of 74.26 and 72.35 kg ha^{-1}, respectively. This was closely followed by atrazine at 1.0 kg a.i. ha^{-1} (73.75 kg ha^{-1}), chlorimuron ethyl at 18 (71.29 kg ha^{-1}) and 12 g a.i. ha^{-1} (61.34 kg ha^{-1}). Similar trend as that of main season was observed at 60 and 90 DAP also. In both the years of study at all stages, low doses of test herbicides recorded lower uptake of nitrogen. Uncontrolled weed growth resulted the least uptake of N over higher doses at all stages of crop growth during both the years of experimentation.

4.2.4.2. Phosphorus uptake (Table 49)

Phosphorus uptake showed significant variation under various weed control treatments. The experimental plots received with EPOE application of halosulfuron methyl + chlorimuron ethyl at 135.5 g a.i. ha^{-1} recorded the highest uptake of 11.57 kg ha^{-1} and this was followed by halosulfuron methyl + chlorimuron ethyl at 90 g a.i. ha^{-1} (11.50 kg ha^{-1}), chlorimuron ethyl at 18 g a.i. ha^{-1}(10.94 kg ha^{-1}), atrazine at 1.0 kg a.i. ha^{-1} (11.46 kg ha^{-1}) at 30 DAP, during main season, 2011. At later stages (60 and 90 DAP), halosulfuron methyl + chlorimuron ethyl at 90 and 135.5 g a.i. ha^{-1}, chlorimuron ethyl at 18 g a.i. ha^{-1}, atrazine at 1.0 kg a.i. ha^{-1} as well as hand weeding on 30 DAP found to be performed better interms of recording higher phophorus uptake over other treatments.

During the late season 2012, at 30 DAP, halosulfuron methyl + chlorimuron ethyl at 135.5 and 90 g a.i. ha^{-1} recorded higher phosphorus uptake of 20.76 and 19.19 kg ha^{-1}, respectively. This was followed by atrazine at 1.0 kg a.i. ha^{-1} (18.05 kg ha^{-1}) and chlorimuron ethyl at 18 g a.i. ha^{-1} (18.66 kg ha^{-1}). At 60 and 90 DAP stages, halosulfuron methyl + chlorimuron ethyl at 135.5 and 90 g a.i. ha^{-1}, atrazine at 1.0 kg a.i. ha^{-1}, chlorimuron ethyl at 18 g a.i. ha^{-1} and hand weeding on 30 DAP recorded higher uptake of phosphorus. In both the years of study at all stages, test herbicides at low doses resulted in lower uptake of phosphrous. Unweeded control resulted in lesser uptake of phosphorus at all stages of crop growth during both the years of experimentation.

Table 49. Effect of different weed control treatments on phosphorus uptake (kg ha^{-1}) in sugarcane

Treatments	Main season 2011			Late season 2012		
	30DAP	60DAP	90DAP	30DAP	60DAP	90DAP
T_1 - EPOE-Halo. 45 g a.i. ha^{-1}	5.61	6.13	7.05	12.96	15.66	11.18
T_2 – EPOE-Halo. 67.5 g a.i. ha^{-1}	5.83	7.22	7.35	13.27	14.81	16.06
T_3 - EPOE-Halo. 90 g a.i. ha^{-1}	5.83	7.09	8.49	14.00	16.67	17.43
T_4 - EPOE-Halo. 135.5 g a.i. ha^{-1}	6.31	7.54	8.49	14.55	17.34	17.30
T_5 - EPOE-Combi. 45 g a.i. ha^{-1}	6.55	8.25	6.56	14.16	16.10	15.35
T_6 - EPOE-Combi. 67.5 g a.i. ha^{-1}	6.97	9.18	11.18	17.27	16.47	15.40
T_7 - EPOE-Combi. 90 g a.i. ha^{-1}	11.50	13.44	19.49	19.19	27.00	23.36
T_8 - EPOE-Combi. 135.5 g a.i. ha^{-1}	11.57	14.97	22.89	20.76	28.33	24.56
T_9 - EPOE-Chlori. 6 g a.i. ha^{-1}	6.68	7.84	7.57	9.62	12.29	8.17
T_{10} - EPOE-Chlori. 9 g a.i. ha^{-1}	6.93	8.26	8.43	10.66	12.38	9.00
T_{11} - EPOE-Chlori. 12 g a.i. ha^{-1}	7.84	12.15	16.25	12.52	15.62	14.00
T_{12} - EPOE-Chlori. 18 g a.i. ha^{-1}	10.94	14.37	20.89	18.66	19.82	19.11
T_{13} - PE-Atrazine 1.0 kg a.i. ha^{-1}	11.46	13.92	21.31	18.05	21.08	19.89
T_{14} - HW on 30 DAP	5.65	14.76	23.06	9.59	28.98	24.27
T_{15} - Unweeded control	4.15	5.15	5.98	7.89	8.12	10.25
SEd	**0.45**	**0.93**	**0.86**	**1.22**	**1.56**	**0.92**
CD (P=0.05)	**0.93**	**1.90**	**1.68**	**2.51**	**2.99**	**1.89**

4.2.4.3. Potassium uptake (Table 50)

Uptake of potassium was varied by different herbicidal weed control treatments. EPOE application of halosulfuron methyl + chlorimuron ethyl at 135.5 g a.i. ha^{-1} recorded the highest uptake of 64.54 kg ha^{-1} and this was followed by halosulfuron methyl + chlorimuron ethyl at 90 g a.i. ha^{-1} which recorded the uptake of 62.19 kg ha^{-1}. This was on par with chlorimuron ethyl at 18 g a.i. ha^{-1}, atrazine at 1.0 kg a.i. ha^{-1} at 30 DAP during main season, 2011.

During the late season 2012, at 30 DAP, halosulfuron methyl + chlorimuron ethyl at 135.5 and 90 g a.i. ha^{-1} recorded the highest nitrogen uptake of 114.80 and 113.30 kg ha^{-1}, respectively. This was comparable with atrazine at 1.0 kg a.i. ha^{-1} (110.10 kg ha^{-1}), chlorimuron ethyl at 18 g a.i. ha^{-1} (111.10 kg ha^{-1}). In both the years of study, at 60 and 90 DAP, halosulfuron methyl + chlorimuron ethyl at 90 and 135.5 g a.i. ha^{-1}, chlorimuron ethyl at 18 g a.i. ha^{-1}, atrazine at 1.0 kg a.i. ha^{-1} and hand weeding on 30 DAP were equally effective and comparable in potassium uptake by the crop. Herbicides at low doses as well as unweeded check recorded significantly lower uptake of potassium than higher doses.

4.2.5. Yield

4.2.5.1. Individual cane weight (Table 51)

Weed management practices had significant influence on the individual cane weight of sugarcane at harvest. The highest individual cane weight was recorded under halosulfuron methyl + chlorimuron ethyl at 135.5 g a.i. ha^{-1}(1.60 kg) and this was comparable with atrazine at 1.0 kg a.i. ha^{-1} (1.56 kg) and hand weeding on 30 DAP (1.47 kg), halosulfuron methyl + chlorimuron ethyl 90 g a.i. ha^{-1} (1.42 kg), chlorimuron ethyl at 18 g a.i. ha^{-1} (1.44 kg). Lower doses of test herbicides (T_1, T_2, T_5,T_9 and T_{10}) recorded significantly lower individual cane weight during first season than higher doses. Unweeded conrtol recorded significantly lower individual cane weight of 0.77 kg .

During the late season also, significant effect in the individual cane weight due to the weed management treatments was observed. The highest individual cane weight was recorded in halosulfuron methyl + chlorimuron ethyl at 135.5 g a.i. ha^{-1} (1.85 kg), halosulfuron methyl + chlorimuron ethyl at 90 g a.i. ha^{-1} (1.77 kg), atrazine at 1.0 kg a.i. ha^{-1}

Table 50. Effect of different weed control treatments on potassium uptake (kg ha^{-1}) in sugarcane

Treatments	Main season 2011			Late season 2012		
	30DAP	60DAP	90DAP	30DAP	60DAP	90DAP
T_1 - EPOE-Halo. 45 g a.i. ha^{-1}	44.80	66.82	123.2	94.46	113.47	151.2
T_2 – EPOE-Halo. 67.5 g a.i. ha^{-1}	46.54	78.17	124.8	97.66	126.77	178.6
T_3 - EPOE-Halo. 90 g a.i. ha^{-1}	49.85	84.97	130.9	100.78	134.85	187.2
T_4 - EPOE-Halo. 135.5 g a.i. ha^{-1}	50.67	85.33	139.7	101.10	138.44	195.5
T_5 - EPOE-Combi. 45 g a.i. ha^{-1}	48.71	82.35	126.4	99.61	125.18	157.6
T_6 - EPOE-Combi. 67.5 g a.i. ha^{-1}	51.14	86.25	134.0	101.93	135.51	196.3
T_7 - EPOE-Combi. 90 g a.i. ha^{-1}	62.19	96.36	176.4	113.29	169.32	206.8
T_8 - EPOE-Combi. 135.5 g a.i. ha^{-1}	64.54	97.95	186.9	114.80	170.13	220.8
T_9 - EPOE-Chlori. 6 g a.i. ha^{-1}	49.00	75.69	135.2	93.48	123.86	165.3
T_{10} - EPOE-Chlori. 9 g a.i. ha^{-1}	50.98	79.45	140.6	96.25	124.93	170.7
T_{11} - EPOE-Chlori. 12 g a.i. ha^{-1}	54.23	91.28	174.9	100.03	144.06	198.1
T_{12} - EPOE-Chlori. 18 g a.i. ha^{-1}	60.40	94.21	180.0	111.18	164.27	210.6
T_{13} - PE-Atrazine 1.0 kg a.i. ha^{-1}	60.17	92.26	170.9	110.11	168.33	212.8
T_{14} - HW on 30 DAP	39.90	97.44	196.0	57.32	170.84	221.8
T_{15} - Unweeded control	32.12	53.07	109.1	46.37	52.25	176.9
SEd	**3.21**	**4.09**	**11.20**	**4.28**	**10.04**	**12.90**
CD (P=0.05)	**6.59**	**8.37**	**23.00**	**8.77**	**20.60**	**25.80**

Table 51. Effect of different weed control treatments on cane and sugar yield in sugarcane

Treatments	Main season 2011			Late season 2012		
	Individual cane weight (kg)	Cane yield ($t\ ha^{-1}$)	Sugar yield ($t\ ha^{-1}$)	Individual cane weight (kg)	Cane yield ($t\ ha^{-1}$)	Sugar yield ($t\ ha^{-1}$)
T_1 - EPOE-Halo. 45 g a.i. ha^{-1}	0.833	96.78	11.96	1.183	107.60	13.97
T_2 – EPOE-Halo. 67.5 g a.i. ha^{-1}	1.050	98.15	12.26	1.400	109.00	14.05
T_3 - EPOE-Halo. 90 g a.i. ha^{-1}	1.073	99.92	12.83	1.423	110.80	14.26
T_4 - EPOE-Halo. 135.5 g a.i. ha^{-1}	1.167	101.74	12.72	1.517	112.60	14.75
T_5 - EPOE-Combi. 45 g a.i. ha^{-1}	1.200	96.95	12.19	1.428	107.80	13.69
T_6 - EPOE-Combi. 67.5 g a.i. ha^{-1}	1.367	98.38	12.58	1.617	109.20	13.77
T_7 - EPOE-Combi. 90 g a.i. ha^{-1}	1.423	119.14	15.18	1.773	130.00	17.22
T_8 - EPOE-Combi. 135.5 g a.i. ha^{-1}	1.600	120.09	15.22	1.850	130.60	17.78
T_9 - EPOE-Chlori. 6 g a.i. ha^{-1}	1.090	96.16	12.22	1.440	107.00	14.21
T_{10} - EPOE-Chlori. 9 g a.i. ha^{-1}	1.233	101.15	13.14	1.583	112.00	14.83
T_{11} - EPOE-Chlori. 12 g a.i. ha^{-1}	1.410	112.70	14.43	1.660	123.50	16.55
T_{12} - EPOE-Chlori. 18 g a.i. ha^{-1}	1.447	116.86	15.01	1.697	126.00	16.77
T_{13} - PE-Atrazine 1.0 kg a.i. ha^{-1}	1.467	116.13	14.97	1.817	128.40	16.92
T_{14} - HW on 30 DAP	1.473	120.00	15.28	1.823	128.70	17.35
T_{15} - Unweeded control	0.773	83.52	10.31	1.123	94.40	12.60
SEd	**0.068**	**5.75**	**0.70**	**0.085**	**8.33**	**0.84**
CD (P=0.05)	**0.139**	**11.77**	**1.43**	**0.173**	**17.06**	**1.71**

(1.82 kg) hand weeding on 30 DAP (1.82 kg) and was statistically at par with chlorimuron ethyl at 12 (1.66 kg) and 18 g a.i. ha^{-1} (1.69 kg). Lower doses of test herbicides (T_1, T_2, T_5, T_9 and T_{10}) recorded significantly lower individual cane weight during second season also. The Lowest individual cane weight of 1.1kg was recorded with unweeded control.

4.2.5.2. Cane yield (Table 51)

Weed control treatments had significant influence on cane yield during both the years of study. Among the weed control practices evaluated, EPOE application of halosulfuron methyl + chlorimuron ethyl at 135.5 g a.i. ha^{-1}(120.1t ha^{-1}), halosulfuron methyl + chlorimuron ethyl at 90 g a.i. ha^{-1} (119.1t ha^{-1}), atrazine at 1.0 kg a.i. ha^{-1} (116.1t ha^{-1}) and hand weeding on 30 DAP (120.0 t ha^{-1}), chlorimuron ethyl at 18 g a.i. ha^{-1} (116.7 t ha^{-1}) and chlorimuron ethyl at 12 g a.i. ha^{-1} (112.7 t ha^{-1}) resulted in higher and comparable cane yield over rest of the treatments during main season, 2011. Test herbicides at low doses recorded lesser cane yield which ranged from 96.2 to 96.8 t ha^{-1} .

During the late season 2012 also, halosulfuron methyl + chlorimuron ethyl at 135.5 g a.i. ha^{-1} (130.6 t ha^{-1}), halosulfuron methyl + chlorimuron ethyl at 90 g a.i. ha^{-1} (130.0 t ha^{-1}), atrazine at 1.0 kg a.i. ha^{-1} (128.4 t ha^{-1}) hand weeding on 30 DAP (128.7 t ha^{-1}) and chlorimuron ethyl at 18 and 12 g a.i. ha^{-1} (126.0 and 123.5 t ha^{-1}) performed better interms of recording higher cane yield compared to rest of the treatments. The cane yield was perceptibly lesser under test herbicides at low doses which ranged from 107.0 to 112.0 t ha^{-1} than higher doses. There was drastic reduction of cane yield under uncontrolled weed growth. Unweeded check treatment registered a cane yield of 83.5 to 94.4 t ha^{-1} during main and late seasons respectively.

4.2.5.3. Sugar yield (Table 51)

In data on sugar yield showed marked variation due to weed management practices. During both the years of study, significantly higher sugar yield was recorded under hand weeding on 30 DAP (15.28 t ha^{-1}), halosulfuron methyl + chlorimuron ethyl at 135.5 g a.i. ha^{-1} (15.22 t ha^{-1}) halosulfuron methyl + chlorimuron ethyl at 90 g a.i. ha^{-1} (15.18 t ha^{-1}), atrazine at 1.0 kg a.i. ha^{-1} (14.97 t ha^{-1}) chlorimuron ethyl at 18 g a.i. ha^{-1} (15.01 t ha^{-1})

and chlorimuron ethyl at 12 g a.i. ha^{-1}(14.40 t ha^{-1}) compared to the rest of the treatments. These treatments were comparable between each other in terms of higher sugar yield during main season, 2011.

During the late season, 2012 similar trend was noticed as that of main season 2011 wherein halosulfuron methyl + chlorimuron ethyl at 135.5 g a.i. ha^{-1} (17.78 t ha^{-1}) and halosulfuron methyl + chlorimuron ethyl at 90 g a.i. ha^{-1} (17.22 t ha^{-1}), atrazine at 1.0 kg a.i. ha^{-1} (16.92 t ha^{-1}) and chlorimuron ethyl at 18 g a.i. ha^{-1} (16.77 t ha^{-1}), chlorimuron ethyl at 12 g a.i. ha^{-1} (16.55 t ha^{-1}) and hand weeding on 30 DAP (17.35 t ha^{-1}) recorded higher and comparable sugar yield over rest of the weed management practices. During both the years of study, the sugar yield was the least significantly lesser (10.31and 12.60 t ha^{-1}) from the sugarcane crop where no weed control treatment was imposed.

4.2.6. Microorganism (Table 52, 53 and 54)

Microorganisms such as bacteria, fungi and actinomycetes of the soil were significantly influenced by weed management practices irrespective of the type and time of herbicide application. The experimental results revealed that the herbicide showed a significant detrimental effect on soil bacteria, fungi and actinomycetes and reduced the microbial population in all the samples collected in the herbicide treated plots at 1, 15, 30 and 60 DAHS. Microbial density started to recover slowly with the test herbicides like halosulfuron methyl, chlorimuron ethyl and halosulfuron methyl + chlorimuron ethyl and atrazine applied plots after 60 days of their application. In plots that were not applied with the herbicides (hand weeding and unweeded check), the microbial density increased continuously.

Lower doses of test herbicides did not have any effect on the population of bacteria, fungi and actinomycetes in the soil of the experimental field at 1, 15, 30 and 60 DHAS during both the years. In plots applied with higher doses of test herbicides like halosulfuron at 90 and 135.5 g a.i. ha^{-1}, chlorimuron ethyl at 12 and 18 g a.i. ha^{-1} and halosulfuron methyl + chlorimuron ethyl at 90 and 135.5 g a.i. ha^{-1} there was reduction in the population of micro organisms at 1, 15, 30 and 60 DAHS. At 60 days after spraying of the herbicides, population was found to be recovered slowly in all herbicide treated plots.

Table 52. Effect of different weed control treatments on soil bacterial population (x 10^6 CFU g^{-1}) in sugarcane

Treatments	Main season 2011				Late season 2012			
	1 DAHS	**15 DAHS**	**30 DAHS**	**60 DAHS**	**1 DAHS**	**15 DAHS**	**30 DAHS**	**60 DAHS**
T_1 - EPOE-Halo. 45 g a.i. ha^{-1}	19.50	27.00	28.70	33.90	45.20	57.50	72.00	84.10
T_2 – EPOE-Halo. 67.5 g a.i. ha^{-1}	17.50	24.70	26.20	30.90	44.00	55.00	70.00	82.00
T_3 - EPOE-Halo. 90 g a.i. ha^{-1}	17.09	22.80	24.30	28.40	44.10	53.10	68.10	83.00
T_4 - EPOE-Halo. 135.5 g a.i. ha^{-1}	12.70	17.90	19.40	24.10	39.20	48.20	60.50	81.30
T_5 - EPOE-Combi. 45 g a.i. ha^{-1}	18.07	27.20	28.70	33.40	48.50	57.50	72.50	86.20
T_6 - EPOE-Combi. 67.5 g a.i. ha^{-1}	15.67	22.00	23.50	28.20	42.50	52.30	65.00	87.00
T_7 - EPOE-Combi. 90 g a.i. ha^{-1}	12.50	17.70	19.20	23.90	39.00	48.00	63.00	85.40
T_8 - EPOE-Combi. 135.5 g a.i. ha^{-1}	10.53	14.80	16.30	21.00	35.50	45.10	60.10	85.00
T_9 - EPOE-Chlori. 6 g a.i. ha^{-1}	17.50	22.70	24.20	26.30	44.00	53.00	68.00	85.20
T_{10} - EPOE-Chlori. 9 g a.i. ha^{-1}	15.30	20.50	22.00	26.70	41.80	50.80	68.00	85.00
T_{11} - EPOE-Chlori. 12 g a.i. ha^{-1}	10.33	15.70	17.20	21.90	36.50	46.00	61.00	83.40
T_{12} - EPOE-Chlori. 18 g a.i. ha^{-1}	7.70	12.90	14.40	19.10	34.20	43.20	58.20	82.10
T_{13} - PE-Atrazine 1.0 kg a.i. ha^{-1}	8.80	14.00	15.50	20.20	35.30	44.30	60.30	80.20
T_{14} - HW on 30 DAP	22.50	26.70	28.20	34.20	46.00	57.00	74.00	86.40
T_{15} - Unweeded control	22.00	27.20	29.20	35.40	49.00	58.00	73.00	85.00
SEd	**0.97**	**1.36**	**1.39**	**1.64**	**2.38**	**2.96**	**3.73**	**4.59**
CD (P=0.05)	**1.99**	**2.78**	**2.85**	**3.36**	**4.87**	**6.06**	**7.64**	**NS**

Table 53. Effect of different weed control treatments on soil fungal population (x 10^4 CFU g^{-1}) in sugarcane

Treatments	Main season 2011				Late season 2012			
	1 DAHS	**15 DAHS**	**30 DAHS**	**60 DAHS**	**1 DAHS**	**15 DAHS**	**30 DAHS**	**60 DAHS**
T_1 - EPOE-Halo. 45 g a.i. ha^{-1}	10.85	13.35	14.35	10.03	18.08	22.80	28.80	33.64
T_2 – EPOE-Halo. 67.5 g a.i. ha^{-1}	10.25	12.35	13.10	9.270	17.43	22.00	28.00	32.80
T_3 - EPOE-Halo. 90 g a.i. ha^{-1}	10.20	11.29	12.03	14.06	17.46	21.03	26.97	32.87
T_4 - EPOE-Halo. 135.5 g a.i. ha^{-1}	7.850	8.950	9.700	7.580	15.68	19.28	24.20	32.52
T_5 - EPOE-Combi. 45 g a.i. ha^{-1}	12.50	13.60	14.10	9.900	18.52	23.00	29.00	34.48
T_6 - EPOE-Combi. 67.5 g a.i. ha^{-1}	9.500	11.00	11.75	8.600	17.00	20.92	26.00	34.80
T_7 - EPOE-Combi. 90 g a.i. ha^{-1}	7.750	8.850	9.600	7.530	15.60	19.20	25.20	34.16
T_8 - EPOE-Combi. 135.5 g a.i. ha^{-1}	6.600	7.400	8.150	6.800	14.20	18.04	24.04	34.00
T_9 - EPOE-Chlori. 6 g a.i. ha^{-1}	10.25	11.35	12.10	13.15	17.60	21.20	27.20	34.08
T_{10} - EPOE-Chlori. 9 g a.i. ha^{-1}	9.150	10.25	11.00	8.230	16.72	20.32	26.86	34.00
T_{11} - EPOE-Chlori. 12 g a.i. ha^{-1}	6.500	7.850	8.600	7.030	14.60	18.40	24.40	33.36
T_{12} - EPOE-Chlori. 18 g a.i. ha^{-1}	5.350	6.450	7.200	6.330	13.68	17.28	23.28	32.84
T_{13} - PE-Atrazine 1.0 kg a.i. ha^{-1}	5.900	7.000	7.750	6.600	14.12	17.72	24.22	32.08
T_{14} - HW on 30 DAP	11.28	13.67	14.35	17.10	19.40	23.00	29.60	34.56
T_{15} - Unweeded control	12.76	13.85	14.60	17.70	19.60	23.20	29.20	34.00
SEd	**0.32**	**0.59**	**0.44**	**0.34**	**0.50**	**0.47**	**0.55**	**0.75**
CD (P=0.05)	**0.65**	**1.22**	**0.90**	**0.70**	**1.03**	**0.97**	**1.12**	**1.53**

Table 54. Effect of different weed control treatments on soil actinomycetes population (x 10^2 CFU g^{-1}) in sugarcane

Treatments	Main season 2011				Late season 2012			
	1 DAHS	15 DAHS	30 DAHS	60 DAHS	1 DAHS	15 DAHS	30 DAHS	60 DAHS
T_1 - EPOE-Halo. 45 g a.i. ha^{-1}	14.80	19.50	24.60	26.90	31.00	34.50	37.00	41.00
T_2 – EPOE-Halo. 67.5 g a.i. ha^{-1}	13.30	17.50	22.10	23.23	29.00	32.00	34.33	38.23
T_3 - EPOE-Halo. 90 g a.i. ha^{-1}	13.27	15.44	20.00	21.19	28.81	29.80	32.77	39.50
T_4 - EPOE-Halo. 135.5 g a.i. ha^{-1}	8.500	10.70	16.30	17.10	24.20	25.20	25.50	38.20
T_5 - EPOE-Combi. 45 g a.i. ha^{-1}	16.50	20.00	24.10	26.39	32.00	34.00	37.50	43.10
T_6 - EPOE-Combi. 67.5 g a.i. ha^{-1}	11.80	14.80	19.40	21.20	27.50	29.30	30.00	43.90
T_7 - EPOE-Combi. 90 g a.i. ha^{-1}	8.300	10.50	15.10	16.90	24.00	25.33	28.00	42.30
T_8 - EPOE-Combi. 135.5 g a.i. ha^{-1}	7.100	7.600	14.60	14.00	23.10	22.10	25.10	41.90
T_9 - EPOE-Chlori. 6 g a.i. ha^{-1}	13.30	15.50	20.10	19.30	29.00	30.00	33.00	42.10
T_{10} - EPOE-Chlori. 9 g a.i. ha^{-1}	11.10	13.30	17.90	19.70	26.80	27.80	33.00	41.90
T_{11} - EPOE-Chlori. 12 g a.i. ha^{-1}	7.800	8.500	13.10	14.90	21.50	23.00	26.00	40.30
T_{12} - EPOE-Chlori. 18 g a.i. ha^{-1}	6.500	7.100	13.20	12.10	19.20	20.20	23.20	39.00
T_{13} - PE-Atrazine 1.0 kg a.i. ha^{-1}	6.100	10.80	11.40	13.20	23.63	21.31	25.28	37.10
T_{14} - HW on 30 DAP	15.30	20.00	24.60	27.20	33.50	34.50	38.73	43.30
T_{15} - Unweeded control	17.80	20.50	25.10	28.40	33.00	35.00	38.00	41.90
SEd	**0.51**	**0.40**	**0.56**	**0.61**	**1.31**	**0.845**	**0.78**	**0.95**
CD (P=0.05)	**1.05**	**0.82**	**1.15**	**1.24**	**2.69**	**1.71**	**1.60**	**1.95**

4.3. Weed seed bank

4.3.1. Weed density (Table 55 and 56)

High density of grasses, sedges and broad leaved weeds and total weeds were observed at 0-15 cm of soil depth as compared to 15-30 cm depth. Among the three group of weed flora, incidence of broad leaved weeds in the soil weed seed bank was higher in sugarcane throughout the cropping period compared to grasses in all the treatments at 0-15 and 15-30 cm depth of soil. In general, broad leaved weeds contributed the major share of weed density to the weed seed bank composition followed by grasses. Population of sedge was noticed at the minimum irrespective of the treatment during both the years. When compared to two different depths (0-15 and 15-30 cm depth) of soils, the higher weed density of all weeds was obtained with 0-15 cm depth.

The density of grasses, sedges, broad leaved weeds and total weeds in the weed seed bank were significantly influenced by weed management treatments during both the years. The lowest grasses, sedges, broad leaved weeds and total weed density were observed with EPOE application of higher doses of halosulfuron methyl + chlorimuron ethyl at 135.5 g a.i. ha^{-1}, halosulfuron methyl + chlorimuron ethyl at 90 g a.i. ha^{-1} and pre emergence application of atrazine at 1.0 kg a.i. ha^{-1}, chlorimuron ethyl at 12 and 18 g a.i. ha^{-1} than rest of the treatments. These treatments were comparable with each other in recording lesser weed density of grasses, broad leaved weeds, sedges and total weeds over rest of the treatments. Lower doses of test herbicides like chlorimuron ethyl, halosulfuron methyl and halosulfuron methyl + chlorimuron ethyl and unweeded control recorded higher density of grasses, sedges, broad leaved weeds and total weed density during 2011-12 and 2012-13.

4.4. Residue analysis of test herbicides (Table 57)

4.4.1. Herbicide residue in soil

The herbicide residues in the post harvest soil was analysed for various doses of halosulfuron methyl, chlorimuron ethyl and halosulfuron methyl + chlorimuron ethyl. The data on residue indicated that the residues were below detectable levels. All other treatments, except the highest dose of halosulfuron methyl, halosulfuron methyl + chlorimuron ethyl and chlorimuron ethyl recorded the terminal residues below detectable

Table 55. Effect of different weed control treatments on weed density (No. m^{-2}) of weed seed bank (0-15 cm) in sugarcane

Treatments	Main season 2011				Late season 2012			
	Total grass	**Total sedge**	**Total BLW**	**Total**	**Total grass**	**Total sedge**	**Total BLW**	**Total**
T_1 - EPOE-Halo. 45 g a.i. ha^{-1}	3.11 (7.7)	2.709 (5.3)	3.266 (8.7)	4.866 (21.7)	3.282 (8.77)	2.477(4.14)	3.687 (11.60)	5.116 (24.50)
T_2 – EPOE-Halo. 67.5 g a.i. ha^{-1}	2.97 (6.2)	2.582 (4.7)	2.828 (6.0)	4.415 (17.5)	3.102 (7.62)	2.339 (3.47)	3.55 (10.60)	4.867 (21.69)
T_3 - EPOE-Halo. 90 g a.i. ha^{-1}	2.875 (6.3)	2.302 (3.3)	2.698 (5.3)	4.086 (14.8)	3.048 (7.29)	2.019 (2.08)	3.469 (10.03)	4.591 (19.40)
T_4 - EPOE-Halo. 135.5 g a.i. ha^{-1}	2.828 (6.0)	2.16 (2.7)	2.646 (5.0)	3.958 (13.7)	3.053 (7.32)	1.862 (1.47)	3.483 (10.13)	4.537 (18.92)
T_5 - EPOE-Combi. 45 g a.i. ha^{-1}	2.762 (5.6)	2.708 (5.3)	3.266 (8.7)	4.651 (19.6)	3.035 (7.21)	2.477 (4.14)	3.578 (10.80)	4.914 (22.15)
T_6 - EPOE-Combi. 67.5 g a.i. ha^{-1}	2.707 (5.3)	2.582 (4.7)	2.309 (3.3)	3.915 (13.3)	3.056 (7.34)	2.338 (3.47)	3.255 (8.600)	4.627 (19.40)
T_7 - EPOE-Combi. 90 g a.i. ha^{-1}	2.704 (5.3)	2.28 (3.2)	2.149 (2.6)	3.623 (11.1)	3.02 (7.12)	2.00 (2.00)	2.898 (6.400)	4.186 (15.52)
T_8 - EPOE-Combi. 135.5 g a.i. ha^{-1}	2.646 (5.0)	2.16 (2.7)	2.149 (2.6)	3.505 (10.3)	2.953 (6.72)	1.862 (1.47)	2.687 (5.220)	3.925 (13.41)
T_9 - EPOE-Chlori. 6 g a.i. ha^{-1}	3.404 (9.6)	2.829 (6.0)	2.986 (6.9)	4.95 (22.5)	3.416 (9.67)	2.608 (4.8)	3.393 (9.510)	5.098 (23.98)
T_{10} - EPOE-Chlori. 9 g a.i. ha^{-1}	3.108 (7.7)	2.793 (5.8)	2.936 (6.6)	4.699 (20.1)	3.28 (8.76)	2.569 (4.6)	3.349 (9.220)	4.958 (22.58)
T_{11} - EPOE-Chlori. 12 g a.i. ha^{-1}	2.884 (6.3)	2.708 (5.3)	2.309 (3.3)	4.121 (15.0)	3.137 (7.84)	2.477 (4.14)	2.816 (5.930)	4.461 (17.91)
T_{12} - EPOE-Chlori. 18 g a.i. ha^{-1}	2.88 (63.0)	2.646 (5.0)	2.149 (2.6)	3.989 (14.0)	3.105 (7.64)	2.408 (3.8)	2.72 (5.400)	4.34 (16.84)
T_{13} - PE-Atrazine 1.0 kg a.i. ha^{-1}	2.772 (5.7)	3.214 (8.3)	1.826 (1.3)	4.165 (15.4)	2.983 (6.90)	3.022 (7.13)	2.436 (3.930)	4.468 (17.97)
T_{14} - HW on 30 DAP	2.707 (5.3)	2.695 (5.3)	2.371 (3.6)	4.027 (14.2)	3.017 (7.10)	2.463 (4.07)	2.867 (6.220)	4.403 (17.38)
T_{15} - Unweeded control	3.785 (12.3)	3.596 (10.3)	4.803 (21.1)	6.804 (44.3)	3.928 (13.43)	3.425 (9.73)	5.067 (23.67)	6.988 (46.83)
SEd	**0.081**	**0.117**	**0.130**	**0.277**	**0.208**	**0.179**	**0.179**	**0.207**
CD (P=0.05)	**0.168**	**0.240**	**0.267**	**0.569**	**0.428**	**0.366**	**0.367**	**0.424**

Table 56. Effect of different weed control treatments on weed density (No. m^{-2}) of weed seed bank (15-30 cm) in sugarcane

Treatments	Main season 2011				Late season 2012			
	Total grass	Total sedge	Total BLW	Total	Total grass	Total sedge	Total BLW	Total
T_1 - EPOE-Halo. 45 g a.i. ha^{-1}	2.583 (4.7)	2.31 (3.3)	2.768 (5.7)	3.959 (13.7)	2.423 (3.87)	2.31 (3.34)	3.011 (7.06)	4.034 (14.27)
T_2 – EPOE-Halo. 67.5 g a.i. ha^{-1}	2.412 (3.8)	2.161 (2.7)	2.236 (3.0)	3.389 (9.5)	2.28 (3.2)	2.161 (2.67)	2.898 (6.4)	3.777 (12.27)
T_3 - EPOE-Halo. 90 g a.i. ha^{-1}	2.288 (3.2)	1.813 (1.3)	2.063 (2.3)	2.962 (6.8)	2.157 (2.65)	2.02 (2.08)	2.56 (4.55)	3.359 (9.29)
T_4 - EPOE-Halo. 135.5 g a.i. ha^{-1}	2.236 (3.0)	1.628 (0.67)	2.000 (2.0)	2.769 (5.7)	2.117 (2.48)	1.931 (1.73)	2.49 (4.2)	3.226 (8.41)
T_5 - EPOE-Combi. 45 g a.i. ha^{-1}	2.152 (2.6)	2.309 (3.3)	2.769 (5.7)	3.692 (11.6)	2.2 (2.84)	2.309 (3.33)	2.775 (5.7)	3.725 (11.87)
T_6 - EPOE-Combi. 67.5 g a.i. ha^{-1}	2.081 (2.3)	2.16 (2.7)	2.516 (4.3)	3.366 (9.3)	2.112 (2.46)	2.09 (2.37)	2.53 (4.4)	3.351 (9.23)
T_7 - EPOE-Combi. 90 g a.i. ha^{-1}	2.076 (2.3)	1.789 (1.2)	2.081 (2.3)	2.800 (5.8)	1.944 (1.78)	1.789 (1.2)	2.394 (3.73)	2.951 (6.71)
T_8 - EPOE-Combi. 135.5 g a.i. ha^{-1}	2.000 (2.0)	1.630 (0.67)	2.081 (2.3)	2.645 (5.0)	1.8 (1.24)	1.931 (1.73)	2.285 (3.22)	2.862 (6.19)
T_9 - EPOE-Chlori. 6 g a.i. ha^{-1}	2.937 (6.6)	2.45 (4.0)	2.432 (3.9)	4.062 (14.5)	2.797 (5.82)	2.45 (4.0)	2.704 (5.31)	4.14 (15.14)
T_{10} - EPOE-Chlori. 9 g a.i. ha^{-1}	2.581 (4.7)	2.408 (3.8)	2.371 (3.6)	3.752 (12.1)	2.421(3.86)	2.408 (3.8)	2.49 (4.2)	3.723 (11.86)
T_{11} - EPOE-Chlori. 12 g a.i. ha^{-1}	2.307 (3.3)	2.309 (3.3)	2.081 (2.3)	3.314 (9.0)	2.191 (2.8)	2.309 (3.33)	2.394 (3.73)	3.444 (9.86)
T_{12} - EPOE-Chlori. 18 g a.i. ha^{-1}	2.301 (3.3)	2.236 (3.0)	2.081 (2.3)	3.26 (8.6)	2.12 (2.5)	2.236 (3.0)	2.394 (3.73)	3.351 (9.23)
T_{13} - PE-Atrazine 1.0 kg a.i. ha^{-1}	2.164 (2.7)	2.887 (6.3)	2.078 (2.3)	3.653 (11.3)	2.112 (2.46)	2.887 (6.33)	2.391 (3.72)	3.809 (12.51)
T_{14} - HW on 30 DAP	2.081 (2.3)	2.295 (3.3)	1.916 (1.7)	3.044 (7.3)	2.059 (2.24)	2.295 (3.27)	2.252 (3.07)	3.252 (8.58)
T_{15} - Unweeded control	3.366 (9.3)	3.306 (9.0)	4.009 (14.1)	5.863 (32.4)	2.902 (6.42)	2.909 (6.46)	3.493 (10.2)	5.008 (23.16)
SEd	**0.090**	**0.115**	**0.113**	**0.219**	**0.122**	**0.111**	**0.138**	**0.147**
CD (P=0.05)	**0.184**	**0.236**	**0.232**	**0.449**	**0.250**	**0.228**	**0.283**	**0.301**

Table 57. Residue of herbicides in soil at harvest (ppm)

Treatments	Residue in soil (ppm)
T_1 - POE-Halo. 45 g a.i. ha^{-1}	BDL
T_2 – POE-Halo. 67.5 g a.i. ha^{-1}	BDL
T_3 - POE-Halo. 90 g a.i. ha^{-1}	BDL
T_4 - POE-Halo. 135.5 g a.i. ha^{-1}	0.067
T_5 - POE-Combi. 45 g a.i. ha^{-1}	BDL
T_6 - POE-Combi. 67.5 g a.i. ha^{-1}	BDL
T_7 - POE-Combi. 90 g a.i. ha^{-1}	BDL
T_8 - POE-Combi. 135.5 g a.i. ha^{-1}	0.07
T_9 - POE-Chlori. 6 g a.i. ha^{-1}	BDL
T_{10} - POE-Chlori. 9 g a.i. ha^{-1}	BDL
T_{11} - POE-Chlori. 12 g a.i. ha^{-1}	BDL
T_{12} - POE-Chlori. 18 g a.i. ha^{-1}	0.092

levels in post harvest soil. Highest dose of halosulfuron methyl, halosulfuron methyl + chlorimuron ethyl and chlorimuron ethyl registered minimum residues in post harvest soil (0.065, 0.070 and 0.092 ppm, respectively). As such, there was no residue build up in soil.

4.5. Residual effect of herbicides on succeeding crops

4.5.1. Weed density (Table 58 and 59)

Significant variation in total weed density was observed among the weed control treatments in the residue crop also. The lowest total weed density of 6.0 m^{-2} was observed with halosulfuron methyl + chlorimuron ethyl at 135.5 g a.i. ha^{-1} during main season 2011, at 30 DAP. This was on par with EPOE application of higher doses of halosulfuron methyl + chlorimuron ethyl at 90 g a.i. ha^{-1} and pre emergence application of atrazine at 1.0 kg a.i. ha^{-1}. This was followed by chlorimuron ethyl at 12 and 18 g a.i. ha^{-1}. Lower doses of test herbicides like chlorimuron ethyl (T_9), halosulfuron methyl (T_1) and halosulfuron methyl + chlorimuron ethyl(T_5) recorded higher total weed density and vice versa. However, at 60 DAP, halosulfuron methyl + chlorimuron ethyl at 135.5 g a.i. ha^{-1} and hand weeding on 30 DAP recorded the lowest total weed density and this was on par with halosulfuron methyl + chlorimuron ethyl at 90 g a.i. ha^{-1}, chlorimuron ethyl at 12 and 18 g a.i. ha^{-1}, atrazine at 1.0 kg a.i. ha^{-1} and higher doses of halosulfuron methyl (T_3 and T_4). Lower doses of test herbicides (T_1, T_2, T_5, T_9 and T_{10}) recorded significantly higher weed density than higher doses.

During late season 2012, at 30 DAP, the total weed density of 6.3 m^{-2} was observed with halosulfuron methyl + chlorimuron ethyl at 135.5 g a.i. ha^{-1}. This was followed by atrazine at 1.0 kg a.i. ha^{-1} and halosulfuron methyl + chlorimuron ethyl at 90 g a.i. ha^{-1}. Lower dose of test herbicides like chlorimuron ethyl at 6 g a.i. ha^{-1} (T_9), halosulfuron methyl at 45 g a.i. ha^{-1} (T_1) and halosulfuron methyl + chlorimuron ethyl at 45 g a.i. ha^{-1} (T_5) and hand weeding on 30 DAP recorded highest weed density. At 60 DAP also, the same trend as that of 30 DAP was observed.

4.5.2. Germination (Table 60)

Germination of the residue crops *viz*., pearl millet and sunflower was not affected due to the application of herbicides to the preceding crop of sugarcane. There was no significant variation in germination percentage among the weed management treatments on the germination of residual crops in both the years of study.

Table 58. Residual effect of herbicides on total weed density (No. m^{-2}) of succeeding crop pearl millet

Treatments	Main season 2011		Late season 2012	
	30 DAP	60 DAP	30 DAP	60 DAP
T_1 - EPOE- Halo. 45 g a.i. ha^{-1}	4.47 (18.0)	4.62 (19.3)	4.72 (20.3)	4.66 (19.7)
T_2 – EPOE- Halo. 67.5 g a.i. ha^{-1}	4.16 (15.3)	4.16 (15.3)	4.43 (17.6)	4.28 (16.3)
T_3 - EPOE- Halo. 90 g a.i. ha^{-1}	3.725 (11.9)	3.89 (13.2)	3.77 (12.2)	3.95 (13.56)
T_4 - EPOE- Halo. 135.5 g a.i. ha^{-1}	3.51 (10.3)	3.69 (11.6)	3.55 (10.6)	3.56 (10.7)
T_5 - EPOE- Combi 45 g a.i. ha^{-1}	4.18 (15.5)	4.159 (15.3)	4.45 (17.8)	4.38 (17.2)
T_6 - EPOE- Combi 67.5 g a.i. ha^{-1}	3.51 (10.3)	3.61 (11.0)	3.55 (10.6)	3.74 (12.0)
T_7 - EPOE- Combi 90 g a.i. ha^{-1}	3.05 (7.3)	3.26 (8.6)	3.41(9.6)	3.05 (7.30)
T_8 - EPOE- Combi 135.5 g a.i. ha^{-1}	2.83 (6.0)	3.05 (7.3)	2.88 (6.3)	2.83 (6.00)
T_9 - EPOE- Chlori. 6 g a.i. ha^{-1}	4.36 (17.0)	4.51 (18.3)	4.62 (19.3)	4.55 (18.7)
T_{10} - EPOE- Chlori. 9 g a.i. ha^{-1}	3.91 (13.3)	4.07 (14.6)	4.20 (15.6)	4.12 (15.0)
T_{11} - EPOE- Chlori. 12 g a.i. ha^{-1}	3.27 (8.7)	3.46 (10.0)	3.05 (7.3)	3.52 (10.4)
T_{12} - EPOE- Chlori. 18 g a.i. ha^{-1}	3.05 (7.3)	3.26 (8.6)	2.95 (6.7)	3.11 (7.7)
T_{13} - PE-Atrazine 1.0 kg a.i. ha^{-1}	3.05 (7.3)	3.36 (9.3)	3.10 (7.6)	3.21 (8.3)
T_{14} - HW on 30 DAP	4.28 (16.3)	4.00 (14.0)	4.54 (18.6)	4.47 (18.0)
T_{15} - Unweeded control	5.13 (24.3)	5.20 (25.0)	5.35 (26.6)	5.29 (26.0)
SEd	**0.20**	**0.16**	**0.17**	**0.22**
CD (P=0.05)	**0.41**	**0.33**	**0.35**	**0.45**

Table 59. Residual effect of herbicides on total weed density (No. m^{-2}) of succeeding crop sunflower

Treatments	Main season 2011		Late season 2012	
	30 DAP	60 DAP	30 DAP	60 DAP
T_1 - EPOE- Halo. 45 g a.i. ha^{-1}	4.28 (16.3)	4.07 (14.6)	4.29 (16.4)	4.14 (15.1)
T_2 – EPOE- Halo. 67.5 g a.i. ha^{-1}	4.00 (14.0)	3.78 (12.3)	3.96 (13.7)	3.80 (12.4)
T_3 - EPOE- Halo. 90 g a.i. ha^{-1}	3.49 (10.2)	3.35 (9.3)	3.41 (9.6)	3.21 (8.3)
T_4 - EPOE- Halo. 135.5 g a.i. ha^{-1}	3.21 (8.3)	2.93 (6.6)	3.12 (7.7)	3.05 (7.3)
T_5 - EPOE- Combi 45 g a.i. ha^{-1}	3.98 (13.8)	3.76 (12.1)	3.99 (13.9)	3.82 (12.6)
T_6 - EPOE- Combi 67.5 g a.i. ha^{-1}	3.21 (8.3)	3.21 (8.3)	3.27 (8.7)	3.07 (7.4)
T_7 - EPOE- Combi 90 g a.i. ha^{-1}	2.76 (5.6)	2.88 (6.3)	2.83 (6.0)	2.95 (6.7)
T_8 - EPOE- Combi 135.5 g a.i. ha^{-1}	2.51 (4.3)	2.70 (5.3)	2.70 (5.3)	2.70 (5.3)
T_9 - EPOE- Chlori. 6 g a.i. ha^{-1}	4.09 (14.7)	3.87 (13.0)	4.17 (15.4)	4.01 (14.1)
T_{10} - EPOE- Chlori. 9 g a.i. ha^{-1}	3.69 (11.6)	3.45 (9.9)	3.70 (11.7)	3.52 (10.4)
T_{11} - EPOE- Chlori. 12 g a.i. ha^{-1}	3.00 (7.0)	2.95 (6.7)	3.05 (7.3)	2.94 (6.64)
T_{12} - EPOE- Chlori. 18 g a.i. ha^{-1}	2.76 (5.6)	2.88 (6.3)	2.95 (6.7)	2.72 (5.4)
T_{13} - PE-Atrazine 1.0 kg a.i. ha^{-1}	2.83 (6.0)	3.05 (7.3)	3.05 (7.3)	3.00 (7.0)
T_{14} - HW on 30 DAP	4.06 (14.5)	4.34 (16.8)	4.33 (16.7)	4.17 (15.4)
T_{15} - Unweeded control	4.96 (22.6)	4.79 (20.9)	4.97 (22.7)	4.84 (21.4)
SEd	**0.24**	**0.15**	**0.18**	**0.17**
CD (P=0.05)	**0.49**	**0.31**	**0.36**	**0.35**

Table 60. Effect of different weed control treatments on germination (%) on residual crop

Treatments	Main season 2011		Late season 2012	
	pearl millet	sunflower	pearl millet	sunflower
T_1 - EPOE-Halo. 45 g a.i. ha^{-1}	87.5	91.5	88.0	92.8
T_2 – EPOE-Halo. 67.5 g a.i. ha^{-1}	87.0	93.5	90.0	94.8
T_3 - EPOE-Halo. 90 g a.i. ha^{-1}	85.0	93.5	90.0	94.8
T_4 - EPOE-Halo. 135.5 g a.i. ha^{-1}	86.0	92.5	89.0	93.8
T_5 - EPOE-Combi. 45 g a.i. ha^{-1}	86.5	92.4	88.9	93.6
T_6 - EPOE-Combi. 67.5 g a.i. ha^{-1}	87.3	92.4	88.9	93.6
T_7 - EPOE-Combi. 90 g a.i. ha^{-1}	86.5	93.0	89.5	94.3
T_8 - EPOE-Combi. 135.5 g a.i. ha^{-1}	88.7	94.3	90.8	95.5
T_9 - EPOE-Chlori. 6 g a.i. ha^{-1}	87.3	93.5	90.0	94.8
T_{10} - EPOE-Chlori. 9 g a.i. ha^{-1}	86.5	92.4	88.9	93.6
T_{11} - EPOE-Chlori. 12 g a.i. ha^{-1}	87.5	93.5	90.0	94.8
T_{12} - EPOE-Chlori. 18 g a.i. ha^{-1}	84.5	94.5	91.0	95.8
T_{13} - PE-Atrazine 1.0 kg a.i. ha^{-1}	86.5	92.4	88.9	93.6
T_{14} - HW on 30 DAP	87.5	93.4	89.9	94.6
T_{15} - Unweeded control	85.5	94.0	90.5	95.3

4.5.3. Plant height (Table 61 and 62)

Weed management practices imposed on sugarcane did not significantly alter the plant height of succeeding crops at all the stages of observation. In the succeeding crop raised after sugarcane grown during 2011-12 and 2012-13, there was no significant difference observed on plant height. However, at all the stages plant height was lesser in unweeded check followed by lower doses of test herbicides as compared to other weed control treatments

4.5.4. Dry matter production (Table 63 and 64)

Weed management practices did not show any significant variation in dry matter production of succeeding crops at all the stages of observation. However, at all the stages, plant dry matter production was lesser with unweeded check followed by low doses of test herbicides as compared to rest of the treatments.

4.5.5. Yield of succeeding crops (Table 65 and 66)

In the succeeding crop raised after sugarcane grown during 2011-12 and 2012-13, there was no significant difference observed on yield of the succeeding crops. However, yield was lesser with unweeded check followed by lower doses of test herbicides as compared to rest of the treatments.

4.6. Correlation (Table 67 and 68)

Simple correlation coefficient (r) was worked out and presented. Growth characters such as plant height, tillers and plant DMP was positively correlated. Weed density and weed DMP was negatively correlated with yield.

During 2011-12, all the growth attributes and yield parameters were positivly correlated with cane yield. Cane yield was positively and highly significant correlation with plant height (r=0.951**), DMP (r=0.836**), cane length (r=0.939**), internode length (r = 0.936**), number of millable cane (r = 0.916**). There was negative correlation of cane yield was observed with weed density (r = 0.468) and weed dry weight (r = 0.492).

Table 61. Effect of different weed control treatments on plant height (cm) on succeeding crop pearl millet

Treatments	Main season 2011		Late season 2012	
	30 DAP	**60 DAP**	**30 DAP**	**60 DAP**
T_1 - EPOE- Halo. 45 g a.i. ha^{-1}	42.50	138.2	43.70	132.2
T_2 – EPOE- Halo. 67.5 g a.i. ha^{-1}	43.60	136.4	44.82	132.9
T_3 - EPOE- Halo. 90 g a.i. ha^{-1}	42.80	137.2	43.56	132.4
T_4 - EPOE- Halo. 135.5 g a.i. ha^{-1}	44.20	136.1	45.40	132.6
T_5 - EPOE- Combi 45 g a.i. ha^{-1}	46.30	132.7	47.80	129.2
T_6 - EPOE- Combi 67.5 g a.i. ha^{-1}	46.20	133.0	47.70	131.5
T_7 - EPOE- Combi 90 g a.i. ha^{-1}	47.30	133.1	48.47	132.3
T_8 - EPOE- Combi 135.5 g a.i. ha^{-1}	48.20	136.2	49.10	131.1
T_9 - EPOE- Chlori. 6 g a.i. ha^{-1}	43.70	134.6	44.80	132.7
T_{10} - EPOE- Chlori. 9 g a.i. ha^{-1}	43.10	133.6	44.20	130.1
T_{11} - EPOE- Chlori. 12 g a.i. ha^{-1}	47.20	132.6	44.10	129.1
T_{12} - EPOE- Chlori. 18 g a.i. ha^{-1}	43.00	136.2	45.50	131.3
T_{13} - PE-Atrazine 1.0 kg a.i. ha^{-1}	44.40	136.7	46.80	133.2
T_{14} - HW on 30 DAP	46.80	134.2	47.00	130.7
T_{15} - Unweeded control	42.70	130.2	42.10	126.7
SEd	**2.44**	**7.5**	**4.04**	**8.4**
CD (P=0.05)	**NS**	**NS**	**NS**	**NS**

Table 62. Effect of different weed control treatments on plant height (cm) on succeeding crop sunflower

Treatments	Main season 2011		Late season 2012	
	30 DAP	**60 DAP**	**30 DAP**	**60 DAP**
T_1 - EPOE-Halo. 45 g a.i. ha^{-1}	53.00	158.2	51.30	144.7
T_2 – EPOE-Halo. 67.5 g a.i. ha^{-1}	54.10	156.4	52.40	145.4
T_3 - EPOE-Halo. 90 g a.i. ha^{-1}	52.87	157.2	51.08	144.7
T_4 - EPOE-Halo. 135.5 g a.i. ha^{-1}	54.70	156.1	53.00	145.1
T_5 - EPOE-Combi. 45 g a.i. ha^{-1}	56.80	152.7	55.40	141.7
T_6 - EPOE-Combi. 67.5 g a.i. ha^{-1}	56.70	153.0	55.31	144.3
T_7 - EPOE-Combi. 90 g a.i. ha^{-1}	57.20	153.1	56.40	144.8
T_8 - EPOE-Combi. 135.5 g a.i. ha^{-1}	58.10	154.6	56.70	143.6
T_9 - EPOE-Chlori. 6 g a.i. ha^{-1}	54.50	156.2	52.39	145.2
T_{10} - EPOE-Chlori. 9 g a.i. ha^{-1}	53.60	153.6	51.80	142.6
T_{11} - EPOE-Chlori. 12 g a.i. ha^{-1}	53.00	152.6	51.70	141.6
T_{12} - EPOE-Chlori. 18 g a.i. ha^{-1}	53.40	154.8	53.10	143.8
T_{13} - PE-Atrazine 1.0 kg a.i. ha^{-1}	54.80	156.7	54.40	145.7
T_{14} - HW on 30 DAP	57.20	154.2	54.60	143.2
T_{15} - Unweeded control	53.10	150.2	49.70	139.2
SEd	**3.01**	**8.6**	**3.85**	**8.3**
CD (P=0.05)	**NS**	**NS**	**NS**	**NS**

Table 63. Effect of different weed control treatments on plant dry matter production (kg ha^{-1}) on succeeding crop pearl millet

Treatments	Main season 2011		Late season 2012	
	30 DAP	60 DAP	30 DAP	60 DAP
T_1 - EPOE-Halo. 45 g a.i. ha^{-1}	442.5	1245	475.1	1268
T_2 – EPOE-Halo. 67.5 g a.i. ha^{-1}	453.4	1236	486.0	1259
T_3 - EPOE-Halo. 90 g a.i. ha^{-1}	452.8	1310	485.4	1333
T_4 - EPOE-Halo. 135.5 g a.i. ha^{-1}	457.6	1320	490.2	1343
T_5 - EPOE-Combi. 45 g a.i. ha^{-1}	465.5	1265	514.6	1288
T_6 - EPOE-Combi. 67.5 g a.i. ha^{-1}	465.5	1275	515.0	1298
T_7 - EPOE-Combi. 90 g a.i. ha^{-1}	478.5	1340	511.1	1363
T_8 - EPOE-Combi. 135.5 g a.i. ha^{-1}	482.4	1345	512.4	1368
T_9 - EPOE-Chlori. 6 g a.i. ha^{-1}	460.3	1280	492.9	1303
T_{10} - EPOE-Chlori. 9 g a.i. ha^{-1}	473.5	1295	506.1	1318
T_{11} - EPOE-Chlori. 12 g a.i. ha^{-1}	472.0	1320	504.6	1343
T_{12} - EPOE-Chlori. 18 g a.i. ha^{-1}	482.4	1265	508.0	1288
T_{13} - PE-Atrazine 1.0 kg a.i. ha^{-1}	475.5	1278	508.1	1301
T_{14} - HW on 30 DAP	480.2	1285	512.8	1308
T_{15} - Unweeded control	450.2	1230	482.8	1253
SEd	**25.2**	**69.84**	**27.8**	**72.05**
CD (P=0.05)	**NS**	**NS**	**NS**	**NS**

Table 64. Effect of different weed control treatments on plant dry matter production (kg ha^{-1}) on succeeding crop sunflower

Treatments	Main season 2011		Late season 2012	
	30 DAP	**60 DAP**	**30 DAP**	**60 DAP**
T_1 - EPOE-Halo. 45 g a.i. ha^{-1}	651.4	3585	669.9	3601
T_2 – EPOE-Halo. 67.5 g a.i. ha^{-1}	662.3	3595	680.8	3611
T_3 - EPOE-Halo. 90 g a.i. ha^{-1}	665.4	3656	683.9	3672
T_4 - EPOE-Halo. 135.5 g a.i. ha^{-1}	664.7	3645	683.2	3661
T_5 - EPOE-Combi 45 g a.i. ha^{-1}	670.4	3678	688.9	3694
T_6 - EPOE-Combi 67.5 g a.i. ha^{-1}	672.3	3672	690.8	3688
T_7 - EPOE-Combi 90 g a.i. ha^{-1}	671.2	3675	689.7	3691
T_8 - EPOE-Combi 135.5 g a.i. ha^{-1}	667.3	3677	685.8	3693
T_9 - EPOE-Chlori. 6 g a.i. ha^{-1}	668.0	3594	686.5	3610
T_{10} - EPOE-Chlori. 9 g a.i. ha^{-1}	670.0	3610	688.5	3626
T_{11} - EPOE-Chlori. 12 g a.i. ha^{-1}	675.0	3678	693.5	3694
T_{12} - EPOE-Chlori. 18 g a.i. ha^{-1}	664.5	3640	683.0	3656
T_{13} - PE-Atrazine 1.0 kg a.i. ha^{-1}	665.3	3655	683.8	3671
T_{14} - HW on 30 DAP	670.2	3690	688.7	3706
T_{15} - Unweeded control	661.5	3570	680.0	3586
SEd	**36.6**	**199**	**33.9**	**202**
CD (P=0.05)	**NS**	**NS**	**NS**	**NS**

Table 65. Effect of different weed control treatments on yield (kg ha^{-1}) of succeeding crop pearl millet

Treatments	Main season 2011		Late season 2012	
	Grain yield	Straw yield	Grain yield	Straw yield
T_1 - EPOE-Halo. 45 g a.i. ha^{-1}	2120	3180	2174	3205
T_2 – EPOE-Halo. 67.5 g a.i. ha^{-1}	2156	3234	2210	3259
T_3 - EPOE-Halo. 90 g a.i. ha^{-1}	2200	3234	2254	3259
T_4 - EPOE-Halo. 135.5 g a.i. ha^{-1}	2210	3315	2264	3340
T_5 - EPOE-Combi 45 g a.i. ha^{-1}	2190	3285	2244	3310
T_6 - EPOE-Combi 67.5 g a.i. ha^{-1}	2120	3150	2243	3175
T_7 - EPOE-Combi 90 g a.i. ha^{-1}	2180	3270	2173	3295
T_8 - EPOE-Combi 135.5 g a.i. ha^{-1}	2215	3289	2257	3315
T_9 - EPOE-Chlori. 6 g a.i. ha^{-1}	2140	3210	2237	3235
T_{10} - EPOE-Chlori. 9 g a.i. ha^{-1}	2145	3190	2193	3215
T_{11} - EPOE-Chlori. 12 g a.i. ha^{-1}	2206	3309	2198	3334
T_{12} - EPOE-Chlori. 18 g a.i. ha^{-1}	2195	3293	2259	3318
T_{13} - PE-Atrazine 1.0 kg a.i. ha^{-1}	2220	3297	2248	3323
T_{14} - HW on 30 DAP	2180	3243	2273	3268
T_{15} - Unweeded control	2120	3163	2233	3188
SEd	**120**	**181**	**123**	**163**
CD (P=0.05)	**NS**	**NS**	**NS**	**NS**

Table 66. Effect of different weed control treatments on yield (kg ha^{-1}) of succeeding crop sunflower

Treaments	Main season 2011		Late season 2012	
	Grain	Haulm	Grain	Haulm
T_1 - EPOE-Halo. 45 g a.i. ha^{-1}	1402	4378	1434	4421
T_2 – EPOE-Halo. 67.5 g a.i. ha^{-1}	1438	4494	1470	4536
T_3 - EPOE-Halo. 90 g a.i. ha^{-1}	1460	4563	1492	4605
T_4 - EPOE-Halo. 135.5 g a.i. ha^{-1}	1492	4663	1524	4705
T_5 - EPOE-Combi 45 g a.i. ha^{-1}	1468	4587	1500	4629
T_6 - EPOE-Combi 67.5 g a.i. ha^{-1}	1402	4364	1434	4407
T_7 - EPOE-Combi 90 g a.i. ha^{-1}	1460	4563	1492	4606
T_8 - EPOE-Combi 135.5 g a.i. ha^{-1}	1499	4682	1531	4725
T_9 - EPOE-Chlori. 6 g a.i. ha^{-1}	1422	4444	1454	4486
T_{10} - EPOE-Chlori. 9 g a.i. ha^{-1}	1392	4337	1424	4380
T_{11} - EPOE-Chlori. 12 g a.i. ha^{-1}	1488	4650	1520	4693
T_{12} - EPOE-Chlori. 18 g a.i. ha^{-1}	1474	4607	1506	4649
T_{13} - PE-Atrazine 1.0 kg a.i. ha^{-1}	1502	4694	1534	4736
T_{14} - HW on 30 DAP	1452	4537	1484	4580
T_{15} - Unweeded control	1393	4354	1425	4397
SEd	**119**	**373**	**86**	**260**
CD (P=0.05)	**NS**	**NS**	**NS**	**NS**

Table 67. Analysis of correlation between weed characters, growth parameters, yield attributes and yield in sugarcane (2011-12)

	Weed density	Weed dry weight	Plant height	Tillers	Plant DMP	Cane length	Internode length	No.of Millable cane (NMC)	Cane yield
Weed density	**1**	0.994**	-0.601*	-0.702**	-0.492	-0.575*	-0.567*	-0.657**	-0.468
Weed dry weight		1	-0.613*	-0.701**	-0.510	-0.587*	-0.586*	-0.654**	-0.492
Plant height			1	0.880**	0.860**	0.932**	0.890**	0.941**	0.951**
Tillers				1	0.847**	0.861**	0.929**	0.914**	0.836**
Plant DMP					1	0.915**	0.961**	0.889**	0.939**
Cane length						1	0.918**	0.953**	0.936**
Internode length							1	0.901**	0.922**
No.of Millable cane (NMC)								1	0.916**
Cane yield									1

** Correlation is significant at the 0.01 level (2-tailed). * Correlation is significant at the 0.05 level (2-tailed).

Table 68. Analysis of correlation between weed characters, growth parameters, yield attributes and yield in sugarcane (2012-13)

	Weed density	Weed dry weight	Plant height	Tillers	Plant DMP	Cane length	Internode length	No.of Millable cane (NMC)	Cane yield
Weed density	1	0.990**	- 0.611*	- 0.540*	- 0.734**	- 0.521*	- 0.580*	- 0.558*	- 0.507
Weed dry weight		1	- 0.627*	- 0.579*	- 0.701**	- 0.569*	- 0.599*	- 0.586*	- 0.539*
Plant height			1	0.907**	0.873**	0.895**	0.858**	0.900**	0.866**
Tillers				1	0.765**	0.960**	0.929**	0.955**	0.973**
Plant DMP					1	0.727**	0.804**	0.842**	0.782**
Cane length						1	0.922**	0.914**	0.917**
Internode length							1	0.939**	0.919**
No.of Millable cane (NMC)								1	0.984**
Cane yield									1

Table 69. Effect of different weed control treatments on economics in sugarcane (2011-12)

Treatments	Cost of cultivation (Rs.)	Weed treatment charges (Rs.)	Total cost of cultivation (Rs.)	Gross Return (Rs.)	Net Return (Rs.)	B:C ratio
T_1 - EPOE-Halo. 45 g a.i. ha^{-1}	94627	625	95252	193552	98300	2.03
T_2 – EPOE-Halo. 67.5 g a.i. ha^{-1}	94627	638	95265	196292	101028	2.06
T_3 - EPOE-Halo. 90 g a.i. ha^{-1}	94627	650	95277	199833	104556	2.09
T_4 - EPOE-Halo. 135.5 g a.i. ha^{-1}	94627	675	95302	203473	108171	2.13
T_5 - EPOE-Combi. 45 g a.i. ha^{-1}	94627	625	95252	193892	98640	2.04
T_6 - EPOE-Combi. 67.5 g a.i. ha^{-1}	94627	638	95265	196759	101495	2.07
T_7 - EPOE-Combi. 90 g a.i. ha^{-1}	94627	650	95277	238277	143000	2.50
T_8 - EPOE-Combi. 135.5 g a.i. ha^{-1}	94627	675	95302	240180	144878	2.52
T_9 - EPOE-Chlori. 6 g a.i. ha^{-1}	94627	604	95231	192324	97094	2.01
T_{10} - EPOE-Chlori. 9 g a.i. ha^{-1}	94627	605	95232	202300	107068	2.12
T_{11} - EPOE-Chlori. 12 g a.i. ha^{-1}	94627	607	95234	225407	130173	2.37
T_{12} - EPOE-Chlori. 18 g a.i. ha^{-1}	94627	610	95237	233723	138486	2.45
T_{13} - PE-Atrazine 1.0 kg a.i. ha^{-1}	94627	1060	95687	232261	136574	2.42
T_{14} - HW on 30 DAP	94627	6000	100627	240000	139373	2.39
T_{15} - Unweeded control	94627	0	94627	167044	72417	1.77

Table 70. Effect of different weed control treatments on economics in sugarcane (2012-13)

Treatments	Cost of cultivation (Rs.)	Weed treatment charges (Rs.)	Total cost of cultivation (Rs.)	Gross Return (Rs.)	Net Return (Rs.)	B:C ratio
T_1 - EPOE-Halo. 45 g a.i. ha^{-1}	98427	625	99052	215219	116167	2.17
T_2 – EPOE-Halo. 67.5 g a.i. ha^{-1}	98427	638	99064	217959	118894	2.20
T_3 - EPOE-Halo. 90 g a.i. ha^{-1}	98427	650	99077	221500	122423	2.24
T_4 - EPOE-Halo. 135.5 g a.i. ha^{-1}	98427	675	99102	225139	126037	2.27
T_5 - EPOE-Combi. 45 g a.i. ha^{-1}	98427	625	99052	215559	116507	2.18
T_6 - EPOE-Combi. 67.5 g a.i. ha^{-1}	98427	638	99064	218426	119361	2.20
T_7 - EPOE-Combi. 90 g a.i. ha^{-1}	98427	650	99077	259944	160867	2.62
T_8 - EPOE-Combi. 135.5 g a.i. ha^{-1}	98427	675	99102	261230	162128	2.64
T_9 - EPOE-Chlori. 6 g a.i. ha^{-1}	98427	604	99030	213991	114960	2.16
T_{10} - EPOE-Chlori. 9 g a.i. ha^{-1}	98427	605	99032	223966	124934	2.26
T_{11} - EPOE-Chlori. 12 g a.i. ha^{-1}	98427	607	99034	247074	148040	2.49
T_{12} - EPOE-Chlori. 18 g a.i. ha^{-1}	98427	610	99037	252004	152967	2.54
T_{13} - PE-Atrazine 1.0 kg a.i. ha^{-1}	98427	1060	99487	256712	157225	2.58
T_{14} - HW on 30 DAP	98427	6000	104427	257393	152966	2.46
T_{15} - Unweeded control	98427	0	98427	188710	90283	1.92

During 2012-13, all the growth attributes and yield parameters were positivly correlated with cane yield. Cane yield was positively and highly significant correlation with plant height (r = 0.866**), DMP (r = 0.9738**), cane length (r = 0.782**) and number of millable cane (r = 0.984**). Negative correlation was observed between the yield and weed parameters like weed density and weed dry weight. From the data weed dry weight was significantly correlated with yield whereas, weed density was not significantly correlated with yield.

4.6. Economic analysis (Table 69 and 70)

The economic analysis of the weed control treatments revealed that the net returns were maximum with halosulfuron methyl + chlorimuron ethyl at 135.5 g a.i. ha^{-1} in both the years (Rs.1,44,878 and 1,62,128 for 2011-12 and 2012-13, respectively). During main season 2011, halosulfuron methyl + chlorimuron ethyl at 90 g a.i. ha^{-1}, hand weeding on 30 DAP, atrazine 1.0 kg a.i. ha^{-1} and chlorimuron ethyl at 18 g a.i. ha^{-1} also registered higher net returns, next to halosulfuron methyl + chlorimuron ethyl at 135.5 g a.i. ha^{-1}. During the year 2012-13 also, the trend was same as that of 2011-12.

Regarding B:C ratio, during main season 2011, halosulfuron methyl + chlorimuron ethyl at 135.5 and 90 g a.i. ha^{-1} both recorded higher B:C ratio of 2.52 and 2.50 respectively. This was followed by atrazine 1.0 kg a.i. ha^{-1} (2.42) and chlorimuron ethyl at 18 g a.i. ha^{-1} (1.45).

Halosulfuron methyl + chlorimuron ethyl at 135.5 and 90 g a.i. ha^{-1} both recorded higher B:C ratio of 2.64 and 2.62 , respectively during late season 2012. This was followed by atrazine 1.0 kg a.i. ha^{-1}(2.58) and chlorimuron ethyl at 18 g a.i. ha^{-1} (2.54). However, lower doses of test herbicide recorded lesser B:C ratio. Invariably, in both the seasons unweeded check recorded the lowest B:C ratio of 1.77 and 1.92 during 2011-12 and 2012-13, respectively.

Discussion

CHAPTER V

DISCUSSION

Sugarcane plays a distinct role in capturing the intercepted solar radiation and the conversion efficiency is relatively higher. Sugarcane being a long duration and widely spaced (60 to 90 cm row distance) crop, provides an ample opportunity for wide range of weeds to grow in vacant space, right from planting to till harvesting. Hence, crop canopy development which in turn affects photosynthesis and ultimately the dry matter produced by plant and might affect weed population inside sugarcane fields. Research results indicated that severe crop-weed competition occurs during early phase of sugarcane growth. If the weeds are not controlled at this critical period, the yield reduction of sugarcane ranges between 20 to 40 per cent. The critical period of crop-weed competition has been reported to be 60-120 days after planting in spring cane and 150 days in autumn cane (Kadam *et al*., 2011).

Losses due to weeds largely depend on density and type of weed flora and the changes that occur in composition of weed flora due to factors like tillage, cropping and weed management practices followed in that area. Timely and effective control of weeds is crucial for successful sugarcane production. Yield reductions are reported to be as high as 50 per cent in a cane crop with unchecked weed growth (Khan *et al.*, 2004a). Weed control methods such as hand hoeing and mechanical cultivation were widely practiced in the past. Hoeing not only controls the emergence of weeds, but it also, improves physical condition of soil which favours soil aeration and profuse cane root development. Factors like high cost of labour coupled with nonavailability of labour in time and only one or two hoeing operations by the cane growers result in inadequate weed control in cane fields.

With the discovery of chemicals that could selectively control some herbs and not others, the use of herbicides for weed control increased rapidly and has become an important component of the most weed control programs in sugarcane (Chand *et al.*, 2010). Keeping in view of above factor, the present study was carried out to assess the effect of chemical weed management practices in sugarcane with new herbicide formulations. Many herbicides that are chemically and functionally diverse are available for control of weeds in sugarcane. Among these herbicides, atrazine and metribuzin are commonly used herbicides. However, continuous use of the same herbicide over a period of time resulted in weed shift from annuals to perennials. Hence in the present study, different doses of halosulfuron methyl, chlorimuron ethyl and their combination are used to achieve broad spectrum control of weeds in sugarcane. For successful and economical weed control, it is necessary to understand the dose, time and method of application of these new herbicide formulations. Therefore, the present investigation was carried out to evaluate the new herbicide molecule for weed control in sugarcane at different doses in comparison with standard herbicide and hand weeding. The salient findings from the study are discussed hereunder.

5.1. Influence of weather on weed flora and cane productivity

5.1.1. Weed flora

In sugarcane, weeds are major threat in limiting the yield. The loss in cane yield may go up to 60-80 per cent (Kadam *et al*., 2011) depending upon the type of weed flora present and their intensity in crop field. Weeds that are present in the furrows i.e. along the cane rows cause more harm than those present in the inter row spaces during early crop growth period. Thus, the initial 90-120 days period of crop growth is considered as the most critical period of weed competition. Therefore, the weed management practices adopted should ensure a weed free field condition during the first 3-4 months crop period.

Weeds also harbour certain pest and diseases and that affect sugarcane productivity and thus lead to indirect losses. Bermuda grass (*Cynodon dactylon*) and Cogon grass (*Imperata cylindrica*) are known to play as alternate hosts to ratoon stunting disease of sugarcane. Thus, weeds essentially harm young sugarcane sprouts by depriving them of moisture, nutrients and sunlight. Further, poor growth of cane resulting from weed infestation also affects quality of cane.

In this present study, the weed flora of the experimental site consisted of broad leaved weeds, grassy weeds and sedges and the weed flora are listed out in the previous chapter along with the relative density of predominant weeds. During the first year of study, among grasses, *Setaria verticillata* and *Dactyloctenium aegyptium* accounted for 11.9 and 11.1 per cent relative density. Among the broad leaved weeds, *Trianthema* *portulacastrum* was the most predominant weed with 17.0 per cent relative density. These results showed that the experimental field to larger extent was invaded by *Setaria verticillata, Dactyloctenium aegyptium* among the grasses and *Trianthema portulacastrum* among the broad leaved weeds, which shared 40.0 per cent of the total weed density of the experimental field. The only one sedge weed *Cyperus rotundus* occupied 17.4 per cent of relative density, which was relatively lesser over total grasses (30.4 %) and broadleaved weeds (52.2 %). Other broad leaved and grassy weeds were at lower densities leaving maximum share to *Setaria verticillata*, *Dactyloctenium aegyptium* and *Trianthema portulacastrum* throughout crop growth period during the first season of experimental study.

During second season of study, *Dinebra retroflexa* (12.0 %) was relatively higher among grasses and *Trianthema portulacastrum* (18.0 %) among broad leaved weeds at all the growth stages of sugarcane which alone contributed by 30.0 per cent of total density. The only one sedge *Cyperus rotundus* was observed in the experimental field which contributed 17.6 per cent. The grassy and broad leaved weeds accounted for 30.8 and 51.6, per cent respectively. The difference in the weed species occurrence was attributed to the seasonal influence as well as to the variations in soil weed seed bank.

During first season crop, among the grassy weeds, *Setaria verticillata* and *Dactyloctenium aegyptium* was predominant due to higher weed seed bank in the soil. Among the broad leaved weeds, *Trianthema portulacastrum* was dominant which suppressed other broad leaved weeds. Enormous seed production and vigorous growth of the weed might be the reason for the dominance. Similar result was also pointed out by Kalaiyarasi (2012) who reported that the seed germinated BLW weeds produce large quantity of seeds.

During second season, among the grassy weeds, *Dinebra retroflexa* was predominant due to higher weed seed bank present in the field. High rainfall during second season induced the germination of *Trianthema portulacastrum* and also its unique suppressing character on other broad leaved weeds, were attributed as the possible reason for the dominant of particular weed. This also falls in line with findings of Mohammed and Sen

(1990) and Vasuki (2005). They pointed out that the higher density of *Trianthema portulacastrum* resulted in reduced density of other broad leaved weeds.

However, the total weed density observed during second season crop was higher when compared to first season sugarcane which might be due to native weed seed bank, dormant period of weed seeds and favourable conditions (Rainfall and temperature) prevailed during early crop stage for weed seeds germination. Similar result was also reported by Witharama *et al.* (2007) who observed that soil moisture availability and temperature are the important factors for weed seeds emergence.

5.1.2. Cane productivity

Weather elements play an important role in exploiting the yield potential of any crop. Sugarcane being a tropical crop thrives best in hot sunny climate where temperature, light and moisture are considered the principal factors that influence the cane yield.

In India, sugarcane is cultivated during different seasons and the time of planting varies from November to April depending upon the prevailing temperature conditions of the region. Experimental sugarcane crop during both the seasons (main and late season) had a flourishing weather conditions throughout the growth period. The crop experienced normal weather conditions during both the seasons except rainfall amount. The rainfall was 81.5 per cent lesser during late season (465.6 mm) as compared with main season (845.0 mm). The crop was supplemented with well irrigation besides through rainfall.

A mean average maximum and minimum temperature of 31.8, 32.0ºC and 22.0, 22.2ºC, average relative humidity of 85.3, 50.0 and 84.0, 47.0 per cent and average bright sunshine hour of 6.7 and 6.7 hours were recorded during first and second season, respectively. During the cropping period, a rainfall quantity of 845.0 and 465.6 mm with 33 and 26 rainy days during first and second season was received. Hence, irrigation had been regulated according to the crop requirement and rainfall moisture availability. For higher yields, the seasonal crop water requirements for sugarcane crop were estimated between 1500 to 2500 mm ha^{-1} under a range of climatic conditions and varying lengths of growing seasons (12-14 months) (Anon, 2011).

During first season, a total rainfall of 845 mm was received during the experimental period distributed in 33 rainy days. Wide average variation of diurnal temperature from 31.8 to 22.0^{o}C during crop growth after planting favouring profuse tillering, resulted in more number of millable canes at harvest. Sugarcane being a tropical crop thrives best in hot sunny areas where temperature, light and moisture are the principal factors that influence the cane yield (Humbert, 1968). Long warm summer growing season with adequate rainfall is the ideal climate condition for sugarcane production (Mangelsdrof, 1950). Higher average day time maximum and minimum temperature with adequate solar radiation during active growth phase of cane might have favoured higher photosynthetic activity which was reflected through higher dry matter production.

During second season, a total rainfall of 465.5 mm was received during the experimental period distributed in 26 rainy days. Wide average variation of diurnal temperature from 32.0 to 22.2^{o}C during 1st, 2nd and 3rd months coupled with adequate solar radiation during active growth phase of cane might have favoured higher photosynthetic activity and this was reflected through higher dry matter production. Similar favourable effect of good rainfall with wide variation of diurnal temperature produced higher cane yield was earlier reported by Malik and Tomar (2003).

According to Blackburn (1984) and Biswas (1988), the growing season of at least four to five months should be warm with mean day temperatures of around 30°C and with adequate moisture and high incident solar radiation for optimum growth and development. Bright sunny weather with moderate relative humidity during maturity and ripening phases are the optimum situations for high cane and sugar yields (Humbert, 1968). The above mentioned optimum weather parameters are required for higher cane productivity.

During growth and development stages of sugarcane, temperature variation was very high, that might have favoured better growth of sugarcane during both seasons. All the climatic variables registered during the crop growth period of main and late seasons were more or less same without much deviation over normal conditions and found to be optimum with the requirement of sugarcane crop. The planting season in April gave better cane yield of sugarcane than the planting in October-November which might be due to dry and cool climate prevailed from November to March for optimum maturity of sugarcane. The sugarcane productivity and juice quality are profoundly influenced by weather conditions prevailing during the various crop-growth sub-periods.

Sugar recovery is the highest when the weather is dry with low humidity, bright sunshine hours, cooler nights with wide diurnal temperature variations and very little rainfall during ripening period. These conditions favour higher sugar accumulation. A gap between maximum and minimum temperature (34 to 15°C) from November to March improves cane quality considerably. Similar result was earlier reported by Ramanujam and Venkataramana (1999) and Malik and Tomar (2003). In general, the climatic factors were found to be normal and optimum during crop period, which resulted in better growth and yield of sugarcane.

5.2. Weed management methods on productivity of sugarcane

5.2.1. Effect of treatments on cane yield

Due to better weed control resulting in favourable crop environment without weed interference by way of competition, post emergence application of halosulfuron methyl + chlorimuron ethyl 135.5 g a.i. ha^{-1} recorded the highest cane yield of 120.1 t ha^{-1} in main season and 130.6 t ha^{-1} in late season, which are 69.5 and 72.3 per cent increase over unweeded control (Fig. 5). This was closely followed by halosulfuron methyl + chlorimuron ethyl 90 g a.i. ha^{-1} which recorded a cane yield of 119.1 t ha^{-1} in main season and 130.0 t ha^{-1} in late season respectively. Similar results were reported by Mehra *et al*. (1994) and Singh *et al.* (2011). They reported that reduced weed population, weed dry matter, nutrients removal by weeds and thereby minimising the deleterious effect of weeds on crop might be the reason for higher yield of the crop. In both the seasons, hand weeding on 30 DAP (120.0 and 128.7 t ha^{-1}) and atrazine 1.0 kg a.i. ha^{-1} (116.1 and 128.4 t ha^{-1}) also recorded higher and comparable cane yields.

Higher doses of test herbicides (halosulfuron methyl and chlorimuron ethyl) stood next in the order with marginal, but not significant yield reduction as compared with best treatments of halosulfuron methyl + chlorimuron ethyl at 135.5 g a.i. ha^{-1}. However, sub leathal dose of halosulfuron methyl + chlorimuron ethyl 45 g a.i. ha^{-1} permitted severe competition by the weeds with crop and caused considerable yield reduction. An yield reduction of 19.3 per cent was recorded under this treatments over halosulfuron methyl +

chlorimuron ethyl at 135.5 g a.i. ha^{-1} during both the seasons. Unweeded control recorded the highest yield reduction of 69.5 and 72.3 per cent in main and late seasons, respectively over the best weed control treatment of halosulfuron methyl + chlorimuron ethyl 135.5 g a.i. ha^{-1}, indicating the need for effective control of weeds to realize higher yields in sugarcane.

Lower dose of halosulfuron methyl + chlorimuron ethyl (45 g a.i. ha^{-1}), halosulfuron methyl (45 g a.i. ha^{-1}) and chlorimuron ethyl (6 g a.i. ha^{-1}) recorded reduced cane yield compared to all other treatments, except unweeded control. It might be due to the subleathal dose of herbicide resulting in poor weed control. However, unweeded control recorded 70 per cent lesser yield compared to halosulfuron methyl + chlorimuron ethyl 135.5 g a.i. ha^{-1} due to severe weed competition and poor performance of the crop in terms of growth and development. Higher weed competition and lower availability of nutrients to the crops resulted in lesser cane and sugar yields in control plot and this was conformity with the findings of Vasuki (2005) and Kalaiyarasi (2012).

The increased cane yields in the above said best treatments clearly indicated the influence of weed free environment on cane production. Because of weed free conditions in sugarcane, the competition for moisture, light, space and nutrient was reduced resulting in better availability and uptake of the required nutrients by the crop. This favourable environment resulted in higher plant DMP with increased plant height, LAI, number of millable cane and other yield bearing attributes like single cane weight, cane length, CCS (%). The cumulative effect of all these factors enhanced the performance of the crop under the favorable weed free condition leading to higher cane and sugar yields. This was in conformity with the findings of Patel *et al*. (2007). They concluded that zero weed crop competition gave more cane yield than with different weed crop competition periods. Chauhan and Srivastava (2002) reported an yield loss of 32.0 to 45.5 per cent due to weed competition. Similarly, Singh and Tomar (2003) reported 20.5, 21.9, 49.7 and 74.5 per cent reduction in cane yield because of weed crop competition of 30, 45, 60 and 75 days, respectively. This was further supported by correlation studies. Growth component and yield components were positively correlated with yield. Thus, better control of weeds and limited crop-weed competition for resources might be the reason for

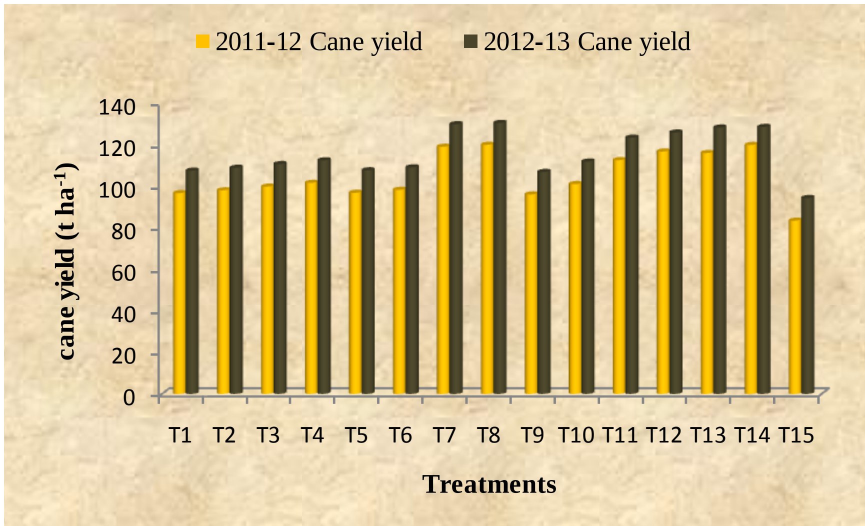

Fig. 5. Effect of different weed control treatments on cane yield

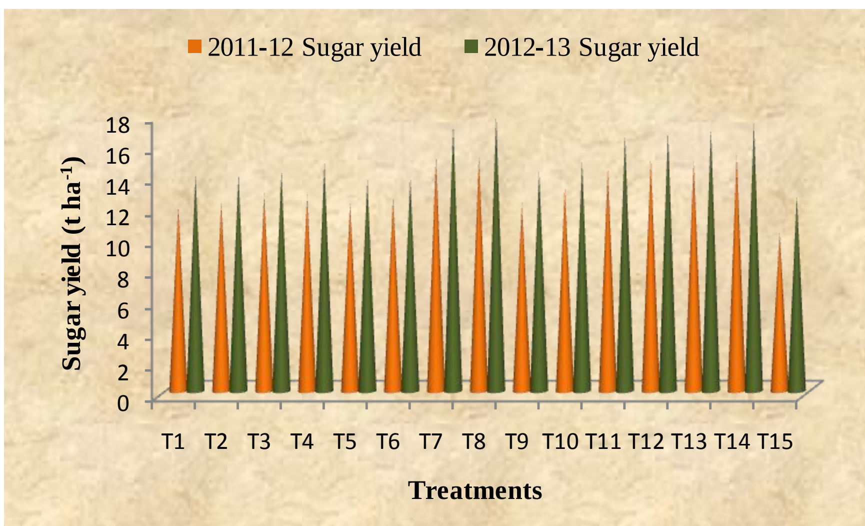

Fig. 5a. Effect of different weed control treatments on sugar yield

increased growth and yield parameters, which ultimately reflected on the final yield of the crop.

5.2.2. Sugar yield

Sugar yield is the product of total cane yield and commercial cane sugar per cent in cane. Sugar yield was significantly higher by 67.7 and 71.2 per cent with the treatment of EPOE application of halosulfuron methyl + chlorimuron ethyl at 135.5 g a.i. ha^{-1} during both seasons, respectively over unweeded control. The sugar yield under this treatment was comparable with post emergence application of halosulfuron methyl + chlorimuron ethyl at 90 g a.i. ha^{-1} and chlorimuron ethyl at 18 g a.i. ha^{-1} and pre emergence application atrazine which gave higher sugar yield of 15.18, 15.01 and 14.97 t ha^{-1}, respectively during main season. Likewise, during late season, halosulfuron methyl + chlorimuron ethyl at 90 g a.i. ha^{-1} and chlorimuron ethyl at 18 g a.i. ha^{-1} and pre emergence application atrazine recorded higher and comparable sugar yield with that of halosulfuron methyl + chlorimuron ethyl at 135.5 g a.i. ha^{-1} (Fig. 5a). In the present study, sugar yield also exhibited the same trend as that of cane yield, whereas, the treatment influence had no effect on the commercial cane sugar content. Due to better weed control resulting in favourable crop environment without weed competition is attributed as the possible reason for better crop growth which in turn resulted in higher sugar yield. Srivastava and Shivkumar (1996) and Singh *et al*. (1987) also reported similar findings.

Reduction in sugar yield was noticed with lower dose of halosulfuron methyl + chlorimuron ethyl at 45 g a.i. ha^{-1}, halosulfuron methyl at 45 g a.i. ha^{-1} and chlorimuron ethyl at 6 g a.i. ha^{-1}, which recorded the sugar yield of 12.19, 11.96 and 12.22 t ha^{-1} during main season and 13.69, 13.97 and 14.2 during late season, respectively.

The sugar yields observed under early post emergence application of halosulfuron methyl + chlorimuron ethyl at 135.5 and 90 g a.i. ha^{-1}, pre emergence application of atrazine at 1.0 kg a.i. ha^{-1} and hand weeding on 30 DAP were higher and comparable. The sugar yield of cane was remarkedly lower in the crop that had uncontrolled weed growth. Obviously unweeded control recorded the lowest sugar yield of 10.31 t ha^{-1} during main season. Higher weed competition and lower availability of nutrients to the crops resulted in lower sugar yield in control plot and this was conformity with the findings of Kalaiyarasi (2012). The yield of sugar obtained in the late season cane was higher than that of the main season cane. This might be due to the wider variation of diurnal temperature during maturity phase that enhanced the sugar yield. The increased sugar yield was due to the increase in cane yield along with nutrient uptake resulting from increased availability due to the reduced competition from weeds. This also falls in line with findings of Vasuki (2005).

Weed index is indirectly related to the reduction in yield due to higher weed density and weed dry weight. The extent of yield reduction due to weed competition as assessed through weed index has evidently indicated the suppressing effect of post emergence application of halosulfuron methyl + chlorimuron ethyl at 135.5 g a.i. ha^{-1}, which registered minimum weed competition and maximum cane yield. In unweeded control nearly, 43.8 and 38.3 per cent yield reduction was noticed during first and second year, respectively as compared with halosulfuron methyl + chlorimuron ethyl at 135.5 g a.i. ha^{-1}. This was due to increased magnitude of weed competition under unchecked weed growth.

Pre emergence application of atrazine at 1000 g a.i ha^{-1} and hand weeding on 30 DAP recorded higher sugar yield which was comparable with halosulfuron methyl + chlorimuron ethyl 90 and 135.5 g a.i. ha^{-1}, in both the seasons. Higher weed index resulting in reduced vegetative growth and nutrient availability to the crop could be the reason for yield reduction at lower doses of test herbicides. This emphasises the importance of proper weed management for increasing dry matter production of sugarcane with reduced weed indices, thereby increasing the crop growth and yield. Patel *et al*. (2007) and Avilkumar *et al*. (1998) reported similar results of reduced cane and sugar yield due to higher weed indices.

5.3. Weed management methods on yield attributes in sugarcane

Yield components *viz.*, number of millable cane, cane length, cane girth, number of internodes and single cane weight were positively influenced by the weed control treatments. There was a strong correlation between the growth parameters and yield attributes which have resulted in higher cane yield under various weed management practices.

The number of millable cane is one of the important yield attributes in determining the final yield of sugarcane. Effective weed management practices in sugarcane greatly enhanced the number of millable cane during both the seasons. The final output of sugarcane mainly depends on the number of millable cane. Millable cane production individually contributed to the yield of cane. Post emergence application of halosulfuron methyl + chlorimuron ethyl at 135.5 g a.i. ha^{-1} produced the highest NMC (Fig. 6 and 7). This was comparable with halosulfuron methyl + chlorimuron ethyl at 90 g a.i. ha^{-1}, pre emergence application of atrazine at 1.0 kg a.i. ha^{-1} and hand weeding on 30 DAP. Higher NMC was produced due to effective control of weeds that favoured the production of tillers which might be the reason for more NMC. This is in agreement with the findings of Srivastava (2003) who has reported that the effect of herbicides on weed control and thus resulting in marked enhancement in NMC and cane yield. Similar results have also been reported with application of atrazine and metribuzin which enhanced the NMC (Vasuki, 2005).

The same trend of treatmental influence was observed on rest of the yield attributing characters *viz*., cane length, cane girth, number of internodes and individual cane weight. The reason attributed for the increase in these parameters due to promising effectivecontrol of weeds at early growth stages from 30-120 DAP thereby improving the LAI, DMP, RGR and CGR which ultimately increased the yield parameters. These results are in collaboration with the findings of Sathyavelu (1990), Ponnusamy *et al*. (1996) and Gouthaman (1997) who have reported positive influence of various weed management treatments on the cane yield parameters. Decrease in LAI and CGR with an increase in weed-crop competition period could be the reason for decrease in number of tillers, millable canes, plant height and cane length in weedy check as reported earlier by Bruff *et al*. (1996) and Richard (1996).

Similarly, lower values of yield attributes (millable canes, cane length, cane girth and single cane weight) were observed with unweeded control and lower doses of test herbicides at 30 DAP. This was due to higher weed density and weed biomass creating a severe competition for the resources and thus, affecting the growth and development of cane. Chauhan and Srivastava (2002) and Patel *et al*. (2007). Srivastava (2001) also reported effective control of weeds by herbicides and consequent reduction in

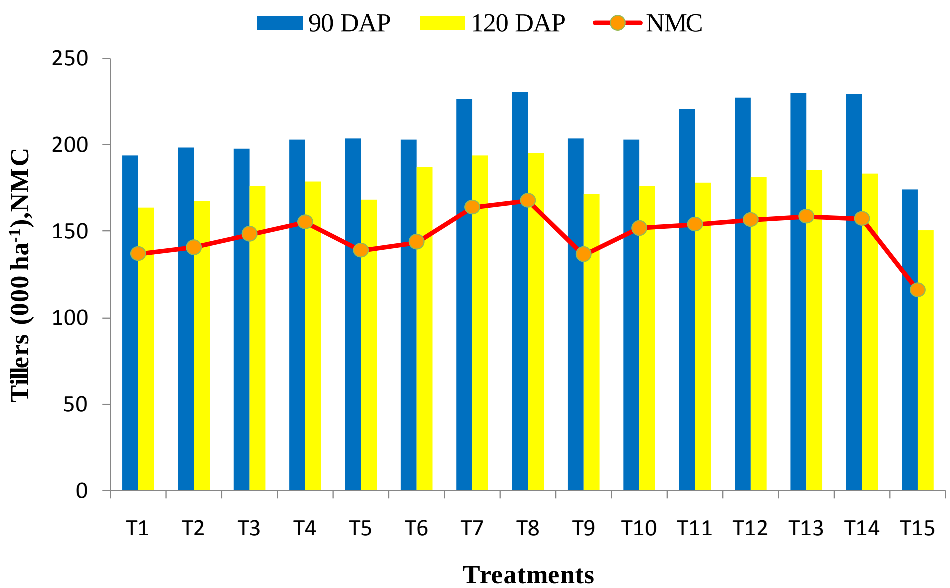

Fig. 6. Effect of different weed control treatments on tiller production and NMC in sugarcane (2011-12)

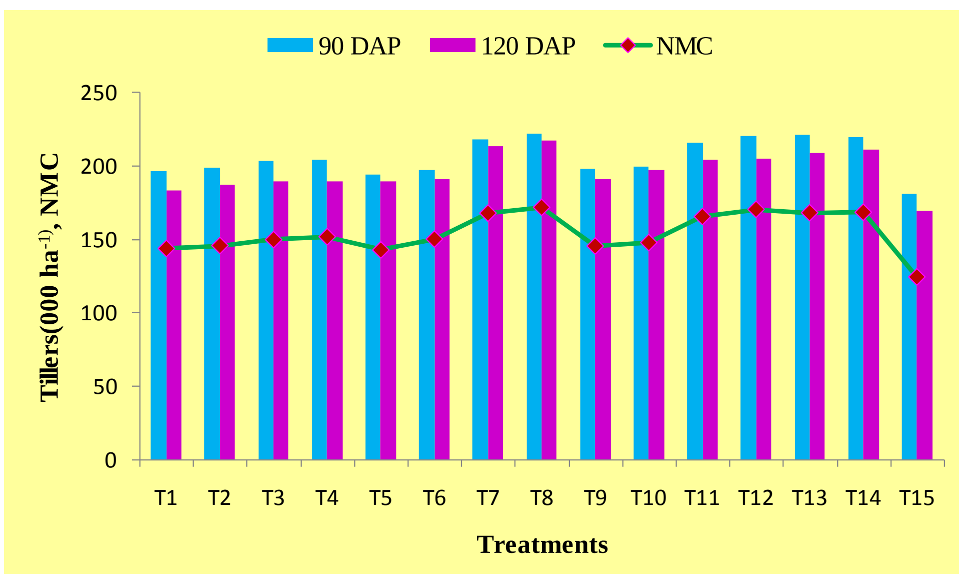

Fig. 7. Effect of different weed control treatments tiller production and NMC in sugarcane (2012-13)

competition by weeds for moisture, nutrients and sun light and thus favoured positive influence on millable canes.

5.4. Weed management methods on growth and physiological characters in sugarcane

5.4.1. Effect on germination and tiller production

The germination phase extended to 35 days in sugarcane. The difference in the percentage of germination of buds was not significant among the weed management treatments in sugarcane during both the seasons which implies that the herbicides have no adverse effect on the germination of buds. The above findings were in line with Sathyavelu *et al.* (2002), Vasuki (2005) and Zafer *et al.* (2010).

Higher WCE and greater check on depletion of nutrients by weeds under halosulfuron methyl + chlorimuron ethyl at 135.5 g a.i. ha^{-1} promoted the sink capacity of the crop and ultimately the final yield. Comparatively, weed free condition at tillering stage with halosulfuron methyl + chlorimuron ethyl at 135.5 g a.i. ha^{-1} favoured better tillering with more number of effective tillers. The tiller production though being a genetically controlled factor, it could also be altered to a certain extent through agronomic interventions such as weed management practices. The tiller production in the late season crop was higher over main season crop and this might be due to better weather conditions prevailed during crop growth period and higher weed control efficiency in late season cane. Similar result was earlier reported out by Sathyavelu (1998). Cane growth parameters like tillering, plant height and dry matter production were significantly influenced by weed control treatments. Mani and Salunkhe (1976) and Zafar *et al.* (2010) reported that weed control with various herbicides increased the tiller production markedly.

Tillers are branches that develop from the leaf axils at each un elongated node of the main shoot or from other tillers during vegetative growth. Tiller production was more with halosulfuron methyl + chlorimuron ethyl 135.5 g a.i. ha^{-1} followed by 90 g a.i. ha^{-1}, chlorimuron ethyl 18 g a.i. ha^{-1}, hand weeding on 30 DAP and atrazine at 1.0 kg a.i. ha^{-1} at all the stages and seasons. However, lower number of tillers were observed with lower doses of test herbicide halosulfuron methyl + chlorimuron ethyl at 45 g a.i. ha^{-1}, chlorimuron ethyl at 6 g a.i. ha^{-1} and halosulfuron methy at 45,67.5 and 90 g a.i. ha^{-1}

(Fig. 6 and 7). The sub lethal dose of test herbicides resulted in poor control of weeds which led to severe competition for nutrient and moisture. This resulted in reduced leaf size and shoot elongation and tiller initiation, poor nutrient uptake and ultimately poor tiller production. Similarly, unweeded control recorded the lowest number of tillers. It might be due to severe weed competition for resources right from the early stage of the crop onwards. These findings were conformity with the findings of El-Shafai *et al*. (2010).

5.4.2. Cane growth characters

Plant height, a parameter of growth is mainly governed by different factors such as light, space, water and nutrients. As a result of severe competition for resources exerted by uncontrolled weed growth, the plant height was lesser throughout the growth period in both the seasons. Srivastava (2003) reported significant reduction in plant height of sugarcane crop up to harvest due to weed competition. Plant height was maximum under post emergence application of halosulfuron methyl + chlorimuron ethyl 135.5 g a.i. ha^{-1} at 30, 60, 90 and 120 DAP in both the seasons. halosulfuron methyl + chlorimuron ethyl 135.5 g a.i. ha^{-1} recorded 50.3, 29.9, 27.2 and 29.8 per cent increased plant height over the unweeded control at 30, 60 and 90 DAP respectively during main season. Whereas in the late season, the per cent increase was 46.2, 19.6, 27.3 and 33.8 per cent over unweeded control. Halosulfuron methyl + chlorimuron ethyl 90 g a.i. ha^{-1}, atrazine 1.0 kg a.i. ha^{-1}, chlorimuron ethyl 18 g a.i. ha^{-1} and hand weeding on 30 DAP recorded higher plant height and was comparable with halosulfuron methyl + chlorimuron ethyl 135.5 g a.i. ha^{-1} (Fig. 8 and 9). It is evident from the results that weed competition was reduced in these treatment due to lesser weed population and weed biomass. As a result of better weed control and better utilization of available resources by the crop, the crop growth in terms of height was improved. Similar results were also reported by Patel *et al*. (2007) and Zafar *et al.* (2010). They observed higher plant height under minimum weed competition plots.

Shorter canes under unweeded control might be due to the aggressive weed growth. Hence, the availability of sunlight is reduced by the shadowing effect of weeds which in turn results in lesser resource availability to cane growth during critical stages. Furthermore, reduction in cane weight due to lesser plant height and cane length as a result of

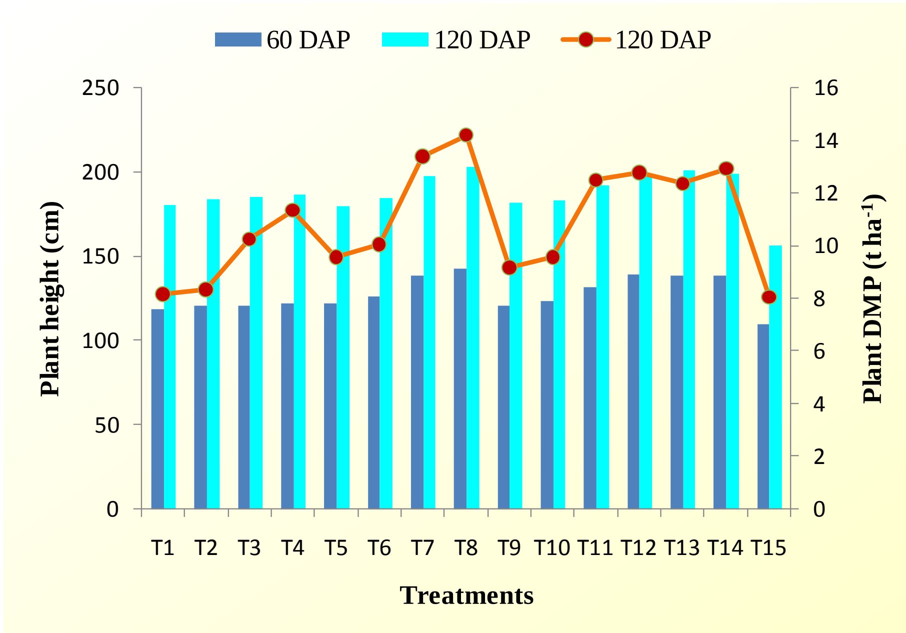

Fig. 8. Effect of different weed control treatments on plant height and DMP in sugarcane (2011-12)

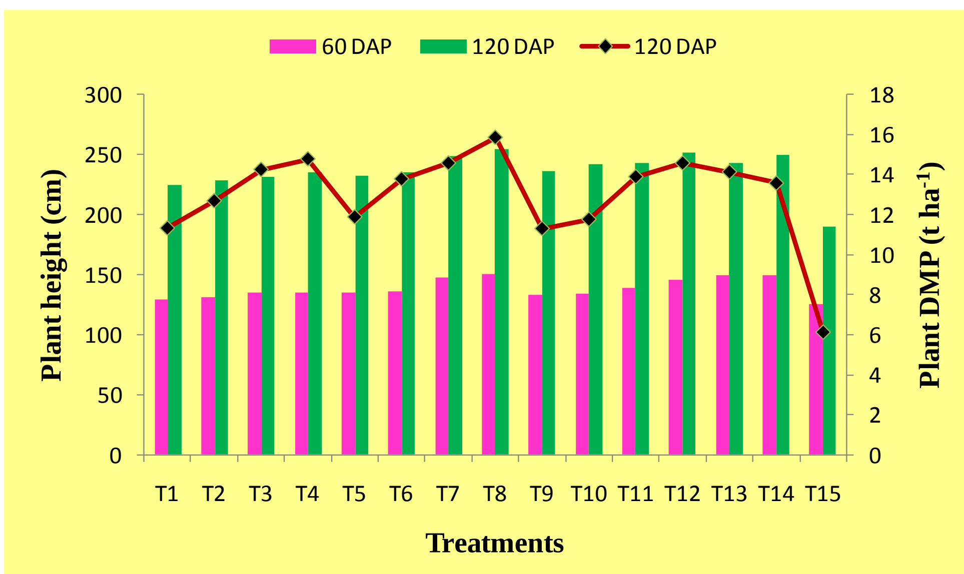

Fig. 9. Effect of different weed control treatments on plant height and DMP in sugarcane (2012-13)

severe competition under unweeded treatment was also reported by Nayyar *et al.* (1994) and Patel *et al*. (2007). Other experimental results showed that sugarcane growth was reduced when grassy weeds were present for 5 to 6 weeks after the start of the growing season (Bruff *et al.*, 1996 and Richard, 1996).

Weed control treatments positively influenced the dry matter production (DMP) of sugarcane at different growth stages. Effective weed control provided favourable weed free environment which in turn led to vigorous growth and increased nutrient availability to sugarcane under halosulfuron methyl + chlorimuron ethyl 135.5 and 90 g a.i. ha^{-1}, atrazine 1.0 kg ha^{-1}, chlorimuron ethyl 18 g a.i. ha^{-1} and hand weeding on 30 DAP treatments. These treatments recorded maximum dry matter production at 30 DAP to 120 DAP (Fig. 8 and 9). Minimum weed competition treatmental plots recorded maximum dry matter production, due to higher plant height, more number of tillers and leaf area index, which are the deciding parameter for dry matter production. The increased growth and yield parameters might be due to broad spectrum of weed control and selectivity to sugarcane crop. This results are in conformity with the results of Sathyavelu (1998) and Patel *et al*. (2007) who have recorded higher dry matter production in minimum weed competition plots.

Lower DMP of sugarcane was recorded under lower dose of halosulfuron methyl + chlorimuron ethyl (45 g a.i. ha^{-1}) halosulfuron methyl (45, 67.5 g a.i. ha^{-1}) and chlorimuron ethyl (6, 9 g a.i. ha^{-1}). However, the lowest DMP was recorded with unweeded condition which might be due to severe competition exerted by weeds throughout the growth period of rice. This observation is in conformity with the reports of Patel *et al*. (2007) who reported that weed competition during early stages of crop growth period increased the weed density, reduced the nutrient uptake by crop and ultimately reduced the DMP and finally the cane yield.

Less weed competition and improved nutrient availability enhanced the LAI and tiller production with halosulfuron methyl + chlorimuron ethyl 135.5 and 90 g a.i. ha^{-1} and ultimately resulted in more DMP in these treatments. Such positive influence on crop DMP was evident with other standard herbicide like atrazine at 1.0 kg a.i. ha^{-1} as well as manual weeding treatments. Unweeded control recorded lowest crop DMP compared to all other treatments. This might be due to maximum utilization of resources by weeds rather than crop, due to severe weed- crop competition.

5.4.3. Cane physiological parameters

Competition between weeds and crops is generally expressed by altered growth and development of both crop and weeds. Weeds normally compete with crop for nutrients, moisture, light and space. Competition for nutrients constitutes important aspect of crop weed competition, where weeds normally absorbs more mineral nutrients than many of the crop plants and accumulate in their tissues in relatively large quantity. In general, for producing equal amounts of dry matter, weeds transpire more water than crop plants. Weeds with higher leaf area have the competitive advantage over crop plants having slow growing nature during the early stages and crops with lesser leaf area as well. Hence, increase in weed density and weed biomass in unweeded control and lower doses of post emergence herbicides treatments provided favourable environment to weeds for the exploitation of environmental resources for a longer period of time as compared with weed free treatment and other herbicidal treatments as well.

As a consequence of reduced LAI, CGR and RGR as was observed under unweeded control and poor resource use efficiency of sugarcane crop due to stiff competition from weeds, which eventually hampered the establishment of crop canopy. Further, decrease in LAI and CGR might have resulted in reduced number of tillers, millable canes, plant height and cane length. Similarly, decrease in plant height and cane length caused reduction in stripped cane weight due to weed competition from 45 to 105 DAP in the weedy check treatment. Similar findings were also reported by Nayyar *et al.* (1994) and Patel *et al*. (2007).

Leaf area index was significantly higher in all the treatments except unweeded control in both seasons at all the stages of crop growth. Decreased leaf area index in treatments applied with lower dose of halosulfuron methyl + chlorimuron ethyl (45 g a.i. ha^{-1}), halosulfuron methyl (45 g a.i. ha^{-1}) and chlorimuron ethyl (6 g a.i. ha^{-1}) might be due to weed competition as a result of the inefficient weed control with the sub lethal dose of the chemical. Leaf area index was the highest with halosulfuron methyl + chlorimuron ethyl 135.5 g a.i. ha^{-1}. This was followed by halosulfuron methyl + chlorimuron ethyl 90 g a.i. ha^{-1}, hand weeding on 30 DAP and atrazine and chlorimuron ethyl at 18 g a.i. ha^{-1}. Lower LAI in unweeded control was due to poor crop growth and tiller production. Poor control of weed inhibits the leaf elongation there by affects the photosynthesis. Whereas, in other treatments, due to less weed competition, the leaf area index was improved. This result falls in line with Bruff *et al.* (1996) and Richard (1996).

Crop growth rate and relative growth rate are the physiological parameters representing photosynthetic efficiency of a plant which are very much based on the association between DMP and LAI. Maximum crop growth rate and relative growth rate were observed with halosulfuron methyl + chlorimuron ethyl at 135.5 g a.i ha^{-1}. This might be due to the weed free environment which favoured better utilization of moisture and nutrients resulting in higher values of CGR and RGR. Whereas, due to the smothering effect of weed in the unweeded control and lower doses of test herbicides, there was a marked reduction in the CGR and RGR throughout the crop growth period. CGR was found to be lesser in early stage (up to 30 DAP) because of the initial slow growth of the crop and tend to be maximum between 60, 90 and 120 DAP. The CGR was found to be associated with LAI in all the treatments. These findings are in accordance with the results obtained by Chinnusamy (1990), Pol and Deshmukh (1998) and Vasuki (2005) in sugarcane.

5.5. Weed management methods on nutrient contents

5.5.1. Nutrient uptake by crops

The uptake of major nutrients by the crop is a function of crop DMP and nutrient availability and nutrient concentration of the plants. The minimum weed competition with halosulfuron methyl + chlorimuron ethyl at 135.5 and 90 g a.i. ha^{-1} as well as atrazine, hand weeding on 30 DAP and chlorimuron ethyl throughout the crop period facilitated higher DMP and nutrient uptake by the crop. Reduction in nutrient uptake by lower doses of halosulfuron methyl + chlorimuron ethyl (45 and 67.5 g a.i ha^{-1}), halosulfuron methyl (45, 67.5 and 90 g a.i ha^{-1}) and chlorimuron ethyl (6, 9 and 12 g a.i ha^{-1}) was noticed due to lower crop DMP and ineffective control of weeds with lower dose. On the other hand, unweeded control recorded lowest nutrient uptake due to more weed competition and weed biomass. Because of this, the nutrient depletion by weeds was higher resulting in limited nutrients availability and uptake by the crop.

These findings emphasise that the cane plant is most vulnerable to weed competition during its early phases of growth. Higher weed density during the early stages of the crop upto 30 DAP would have smothered the crop growth completely and also hindered the photosynthetic activity of the crop, which might have in turn resulted in poor dry matter accumulation and uptake of nutrients. Similar result was earlier reported by Honyal and Radder (1994). Though similar trend was observed during both years of experimentation at all the stages, the nutrient uptake was higher during late season over main season, which might be due to better crop growth during late season because of lesser weed density observed when compared to first season and better environmental conditions prevailed during the crop period as pointed out by Vasuki (2005).

5.5.2. Nutrient removal by weeds

Removal of N, P and K by weeds at 30 and 60 DAP was minimum with early post emergence of halosulfuron methyl + chlorimuron ethyl 135.5 g a.i. ha^{-1} followed by halosulfuron methyl + chlorimuron ethyl 90 g a.i. ha^{-1}, chlorimuron ethyl at 12 and 18 g a.i. ha^{-1}, atrazine 1.0 kg a.i. ha^{-1}, hand weeding on 30 DAP. This might be due to reduced weed density and weed dry matter which ultimately resulted in better weed control efficiency of these treatments. The results are in accordance with the findings of Srinivasan (1988) who reported that weeds removed four times of N and P and two and half times of K as that of sugarcane if the crop is left unweeded. Similar to 30 and 60 DAP, lower nutrient removal of N at 90 DAP was also noticed with halosulfuron methyl + chlorimuron ethyl at 135.5 g a.i. ha^{-1} and halosulfuron methyl + chlorimuron ethyl at 90 g a.i. ha^{-1}. Effective control of weeds achieved by the herbicide treatments would have resulted in lesser weed competition for nutrients in the later stages and also reduced accumulation of dry matter of weeds. The P and K removal also showed the similar trend as that of N removal by total weeds in sugarcane. Honyal and Radder (1994), Peeples (1995) and Gouthaman (1997) opined that the application of herbicides reduced the nutrient uptake of weeds in sugarcane. Unweeded control and low doses of test herbicides removed highest amount of nutrients (N, P_2O_5 and K_2O) which might be due to higher weed density and weed dry weight at all the growth stages. Nutrient removal by weeds depends on the concentration of nutrients in weeds and weed dry matter which is further a reflection of growth and density of weeds. Weed posses not only a capacity for heavy nutrient absorption and accumulation but, also gather tremendous quantities of dry matter (Zimdahl, 1987).

5.6. Weed management methods on weed flora

Weed flora of the experimental fields during the cropping period primarily composed of grasses, sedges and broad leaved weeds. Broad leaved weeds constituted the major proportion of the weed flora followed by grasses and sedge. Among the individual weed species, *Setaria verticillata, Echinochloa colonum, Dinebra retroflexa, Dactyloctenium aegyptium*, *Cyperus rotundus*, *Datura fastuosa*, *Trianthema portulacastrum*, *Parthenium hysterophorus*, *Digera arvensis*, *Amaranthus viridis* and *Cleome gynandra* were predominant in sugarcane field during both the years. Among broad leaved weeds, *Digera arvensis* and *Trianthema portulacastrum* were the dominant weed flora during first and second year of the study. This might be due to the smothering effect of broad leaved weeds on monocots. Similar dominance of broad leaved weeds was earlier observed by Asokan and Mahadevaswamy (2003). Halosulfuron methyl + chlorimuron ethyl controls the sedges and broad leaved weeds which was onpar with atrazine and hand weeding on 30 DAP and further it check the regrowth of *Cyperus rotundus* through the reduction of tubers number. Halosulfuron methyl has the potential to control sedges especially problem weeds like *Cyperus* sp. (Chinnusamy *et al*., 2012) and chlorimuron ethyl which controlled many broad leaved weeds as earlier reported by Vasuki (2005).

5.6.1. Weed-crop competition

In the present study, the crop-weed competition during early stages of sugarcane (30-120 DAP) significantly affected the growth attributes such as plant height, LAI, CGR, RGR and DMP, yield parameters like cane length, cane girth, NMC and individual cane weight, cane and sugar yield during each year of investigation. Higher leaf area index of sugarcane was computed for crop kept weed free (zero competition) throughout the season during both the years of study. Significantly, the minimum growth attributes yield parameters and yield of sugarcane was calculated in unweeded control, which faced weed competition throughout the season.

Increase in weed population with an increase in weed-crop competition period could be due to more time availed by weed seeds to germinate, whereas, increase in weed biomass with time was due to utilization of environmental resources by weeds for a longer period of time compared with weed free treatment. Decrease in LAI and CGR with increased weed-crop competition periods had resulted due to more weed biomass or competition of weeds with crop, which might have reduced availability of environmental resources to crop plants which hampered the establishment of crop canopy. Decrease in LAI and CGR with an increase in weed-crop competition period could be the reason for decrease in number of tillers, millable canes, plant height and cane length. Furthermore, decrease in plant height and cane length caused reduction in cane weight from 45 to 120 DAP.

The decrease in above parameters was due to weed-crop competition period which prolonged from 45 to 120 DAP in weedy check. It was mainly due to decrease in weight per cane. These results are in line with Nayyar *et al.* (1994) and Patel *et al*. (2007) who concluded that zero weed-crop competition gave more cane yield than different weed-crop competition periods. Chauhan and Srivastava (2002) reported 32.0 to 45.5 per cent yield losses due to weed crop competition. Similarly, Singh and Tomar (2003) reported 20.5, 21.9, 49.7 and 74.5 per cent reduction in cane yield because of weed-crop competition of 30, 45, 60 and 75 days.

5.6.2. Weed density

Weed density at different stages exhibited significant variation among the weed management practices and showed increasing trend from 30 to 60 DAP. Results are in accordance with the findings of Janagarathinam (2004) who reported higher density of weeds at 60 DAP compared to later stages of the sugarcane crop. After 120 DAP the crop has dense foliage to cover the ground. This might be due to the suppressing effect of crops on weeds. The result corroborates with the findings of Singh *et al*. (2002) who reported the efficiency of good crop growth on controlling weeds in sugarcane at later stages.

Considerable reduction of grasses, sedges and broad leaved weeds was observed during both the seasons. Halosulfuron methyl + chlorimuron ethyl at 90 and 135.5 g a.i. ha^{-1} was effective in controlling sedges and broad leaved weeds compared to atrazine and hand weeded plots. This might be due to quick knock down effect of herbicides on seed germinated annual weeds, which is a desiccant in nature.

5.6.2.1. Grasses

Herbicide application was effective against the grasses when compared to unweeded control. Whereas the test herbicides like halosulfuron is effective against sedges and chlorimuron ethyl is effective against broad leaved weeds and the halosulfuron methyl + chlorimuron ethyl effective against both the sedges and broad leaved weeds. Hence, only marginal reduction was noticed in grassy weed density at halosulfuron methyl + chlorimuron ethyl 135.5 g a.i. ha^{-1} which was comparable with atrazine and hand weeding on 30 DAP. However, the reduction in weed density was also observed at lower doses of halosulfuron methyl + chlorimuron ethyl at 67.5 g a.i. ha^{-1} and 90 g a.i. ha^{-1} might be the potential herbicide due to inhibition of Aceto Lactate Synthase (ALS) enzyme, resulting in a rapid cessation of cell division and plant growth in both roots and shoots (EPRI, 1999). Halosulfuron methyl + chlorimuron ethyl might be effective against sedges and broad leaved weeds and to some extent to grasses.

5.6.2.2. Sedges

Cyperus rotundus was the only sedge weed present in the experiment site during both the years of study. Halosulfuron methyl at 90 and 135.5 g a.i. ha^{-1} and halosulfuron methyl + chlorimuron ethyl 90 and 135.5 g a.i. ha^{-1} were found to be effective in suppressing the growth of *Cyperus rotundus*. This might possibly due to the efficacy of the herbicide in control of *Cyperus rotundus.* Many workers reported that purple nutsedge was effectively controlled by the application of halosulfuron methyl as post emergence (Vencill *et al.,* 1995; Czarnota and Bingham, 1997; Molin *et al.,* 1999; Blum *et al*., 2000; Grichar *et al*., 2003).

Pre emergence application of halosulfuron methyl + chlorimuron ethyl and halosulfuron methyl at lower doses from 40 and 67.5 g a.i. ha^{-1} also controlled the *Cyperus rotundus,* but slightly less effective when compared to higher doses. Application of atrazine as pre emergence was found to be less effective when compared to application of halosulfuron methyl + chlorimuron ethyl and halosulfuron methyl even at lower doses due to less impact on *Cyperus rotundus* during early growth phases. This could be attributed by halosulfuron methyl + chlorimuron ethyl and halosulfuron which control the nutsedges through destruction of rhizomes, arrest the further production of tubers as observed by Blum *et al.* (2000). Halosulfuron at 70 g ha^{-1} controlled purple nut sedge to an extent of 95 per cent as reported earlier by Czarnota and Bingham (1997)

5.6.2.3. Broad Leaved Weeds

EPOE application of halosulfuron methyl + chlorimuron ethyl at 135.5 and 90 g a.i. ha^{-1}, chlorimuron ethyl at 18 g a.i. ha^{-1} and pre-emergence application of atrazine 1.0 kg a.i. ha^{-1} and hand weeding on 30 DAP produced significantly lesser density of broad leaved weeds throughout the crop growth period during both the years of study. Application of Combi (combination of halosulfuron methyl and chlorimuron ethyl) is effective against broadleaved and sedge weeds. It affects ALS and ALHS pathway of the weeds and it, causes necrosis and death of emerged weeds. Similarly, Singh *et al.* (2012) reported chlorimuron ethyl applied plots suppresses broad leaved weeds at early stage of crop period itself which eventually resulted in higher weed control efficiency. Similarly, application of atrazine as pre emergence herbicide also effectively controls the broad leaved weeds but not very effective on grasses and sedges. As the growth stage of the crop advanced, there was decline in density of broad leaved weeds during both the seasons of study. This could be due to better control of broad leaved weeds by the pre emergence herbicides resulting in favourable crop growth without competition by weeds. After 60 DAP, the shade effect of the crop might have suppressed the growth of weeds. Decline in the density of broad leaved weeds at 90 DAP due to the effect of herbicides and earthing up operation at 60 DAP.

5.6.2.4. Total weed density

Total weed density varied significantly among the different treatments from 30 DAP onwards. Early post emergence application of halosulfuron methyl + chlorimuron ethyl at 135.5 and 90 g a.i. ha^{-1}, controlled the both sedges and broad leaf weeds effectively and resulted in lowest total weed density. However, this was closely followed by pre emergence application of chlorimuron ethyl at 48 and 72 g a.i. ha^{-1}, pre emergence application of atrazine at 1.0 kg a.i. ha^{-1}, hand weeding on 30 DAP at all the

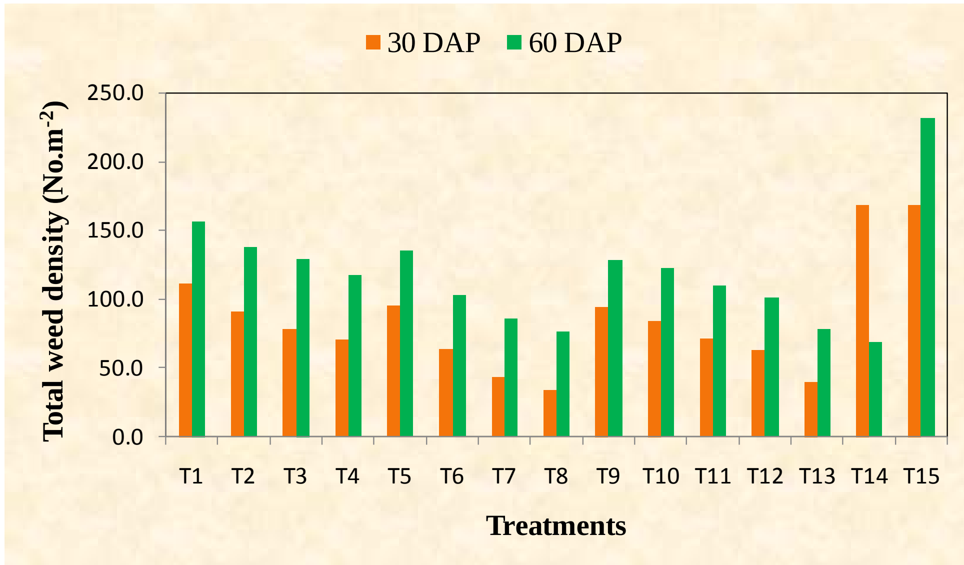

Fig. 10. Effect of different weed control treatments on total weed density in sugarcane (2011-12)

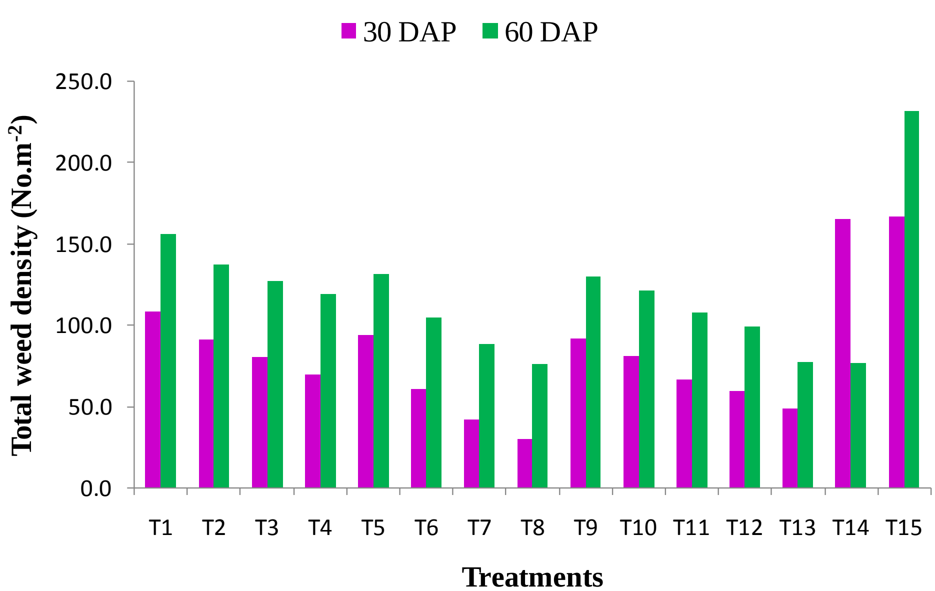

Fig.11. Effect of different weed control treatments on total weed density in sugarcane (2012-13)

stages of observation (Fig. 10 and 11). This might be due to quick knock down effect of halosulfuron methyl + chlorimuron ethyl on seed germinated broad leaved weeds and sedge weeds like *Cyperus rotundus*. Similarly, the sedges were controlled effectively at all the doses of halosulfuron methyl at 67.5, 90 and 135.5 g a.i. ha^{-1} due to effect of halosulfuron methyl + chlorimuron ethyl on reduction of further tuber production of *Cyperus rotundus*. Similar results were earlier obtained by Blum *et al.* (2000) who reported that the halosulfuron methyl applied as early post emergence herbicide followed by late post emergence application at 70 g ha^{-1} controlled purple nutsedge shoots up to 81 per cent. Molin *et al*. (1999) reported that sequential applications of halosulfuron reduced purple nutsedge tuber viability.

Low doses of test herbicides did not control all group of weeds completely especially grassy weeds which led to lower growth attributes, yield parameters, cane and sugar yield. Application of atrazine at 1.0 kg a.i. ha^{-1} proved its efficiency against broad leaved weeds but failed to register its efficacy in reducing the certain grasses and sedge weed density because of its ineffectiveness against sedge weeds. Hence, the field was dominated by broad leaved weeds, growth attributes, yield parameters, cane and sugar yield was comparable with the test herbicides at higher doses. Unweeded control exhibited higher total weed density at all the stages. Similar result was earlier reported by Srivastava (2003).

5.6.3. Relative weed density

Comparison of relative densities of grasses, sedge and broad leaved weeds on 30 and 60 DAP revealed that broad leaved weeds dominated over grasses and sedge during both the years of study. Dominance of broad leaved weeds was due to their faster growth and deep root system and thus promoted the absorption of soil moisture as reported by Janagarathinam (2004). Under atrazine herbicide treatment, the grassy and sedge weed density dominated over broad leaved weeds. This indicates that pre emergence application of atrazine effectively controlled broad leaved weeds and grassy weeds and sedges to some extent. As the crop growth advanced the relative density of broad leaved weeds and sedge declined, the relative density of broad leaved and sedge weeds were lower with application of halosulfuron methyl + chlorimuron ethyl at higher

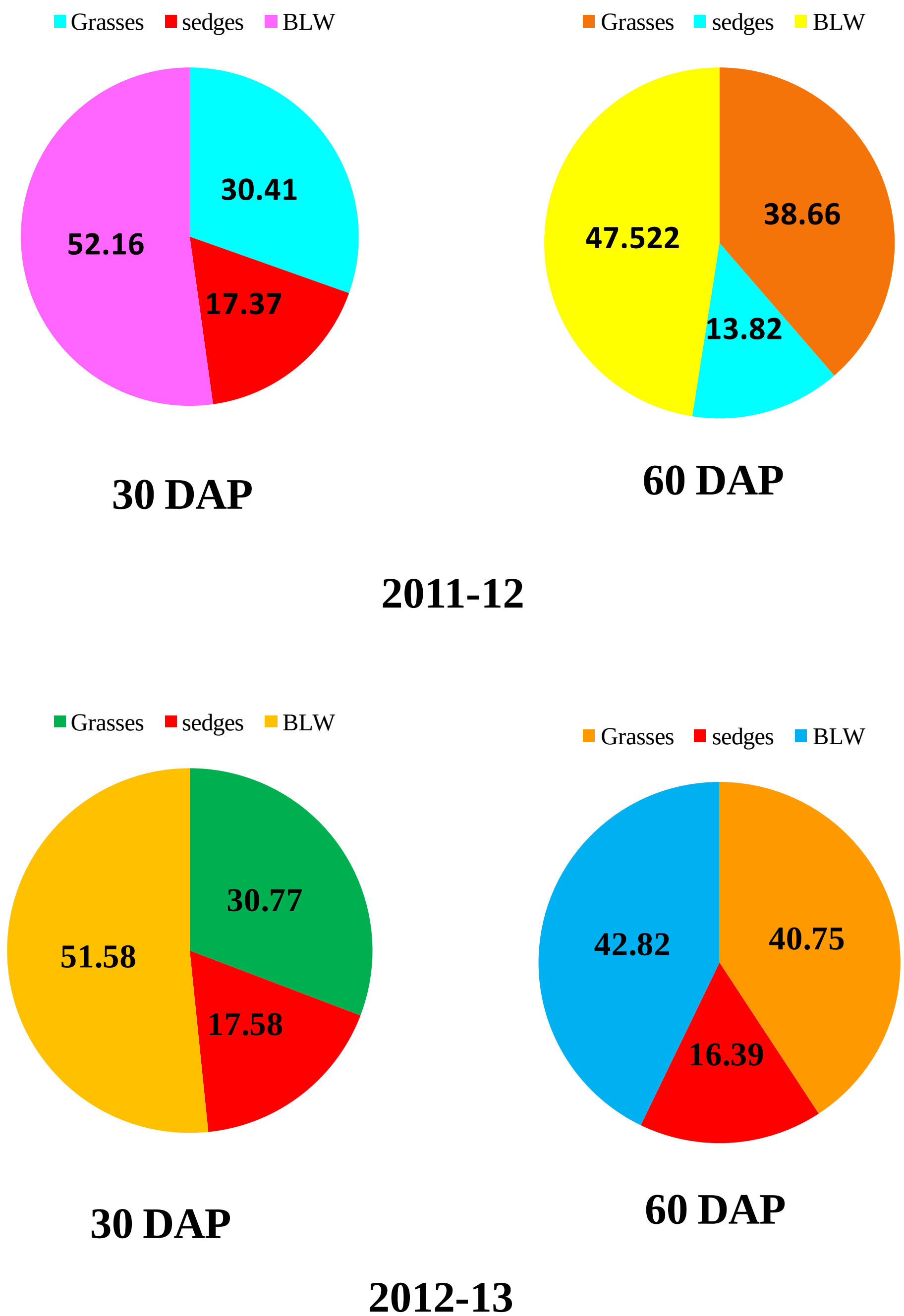

Fig. 12. Effect of different weed control treatments on relative density of weeds

doses (Fig. 12). Obviously, unweeded control resulted in higher grasses, sedge and broad leaved weed density due to unchecked weed growth at all the growth stages of the crop.

5.6.4. Dry weight of total weeds

The total weed dry weight is directly related to the weed density as well as relative density. The total weed dry weight showed significant differences among the different treatments from 30 to 120 DAP. Dry weight of total weeds exhibited similar trends as that of total weed density (Fig. 13 and 14). Reduction in the density of total weeds would have resulted in lower dry weight at all stages of observation during both the season of study. Weed dry weight is the most important parameter to assess the weed competitiveness for the crop growth and productivity. Sparse weeds with high biomass might be more competitive for crops than dense weeds with lesser dry matter. Considerable reduction in weed dry weight was observed with halosulfuron methyl + chlorimuron ethyl at 135.5 and 90 g a.i. ha^{-1}, chlorimuron ethyl at 48 and 72 g a.i. ha^{-1} and pre emergence application of atrazine at 1.0 kg a.i. ha^{-1} and hand weeding on 30 DAP registered the lower total weed dry weight.

Complete control of sedges by the application of halosulfuron methyl at 90 and 135.5 g a.i. ha^{-1} was earlier observed by Molin *et al.* (1999) and Blum *et al*. (2000). Halosulfuron methyl + chlorimuron ethyl (halosulfuron methyl + chlorimuron ethyl) proved to lower down the weed dry weight of sedges and broad leaved weeds.

Lower doses of test herbicides resulted in higher total weed dry weight and it was found to sub lethal dose to control the weeds at all the stages of observation. This results in, lower growth attributes, yield parameters, cane and sugar yield. Unweeded control treatment showed higher total weed dry weight at all the stages. This falls in line with Srivastava (2003).

5.6.5. Weed control efficiency

Early post emergence application of halosulfuron methyl + chlorimuron ethyl at 90 and 135.5 g a.i. ha^{-1} resulted in higher WCE over lower doses of halosulfuron methyl + chlorimuron ethyl, halosulfuron methyl and chlorimuron ethyl. Pre emergence application of atrazine and hand weeding treatments were also comparable with higher doses of test herbicides *viz.,* halosulfuron methyl + chlorimuron ethyl and chlorimuron ethyl (Fig. 13 and 14). Lesser weed competition achieved through the different doses of halosulfuron

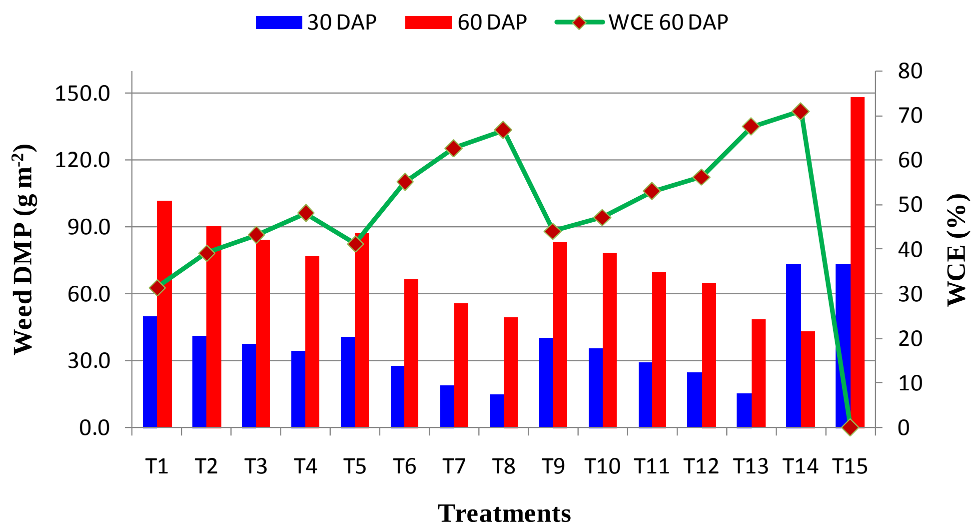

Fig. 13. Effect of different weed control treatments on total weed dry weight and weed control efficiency in sugarcane (2011-12)

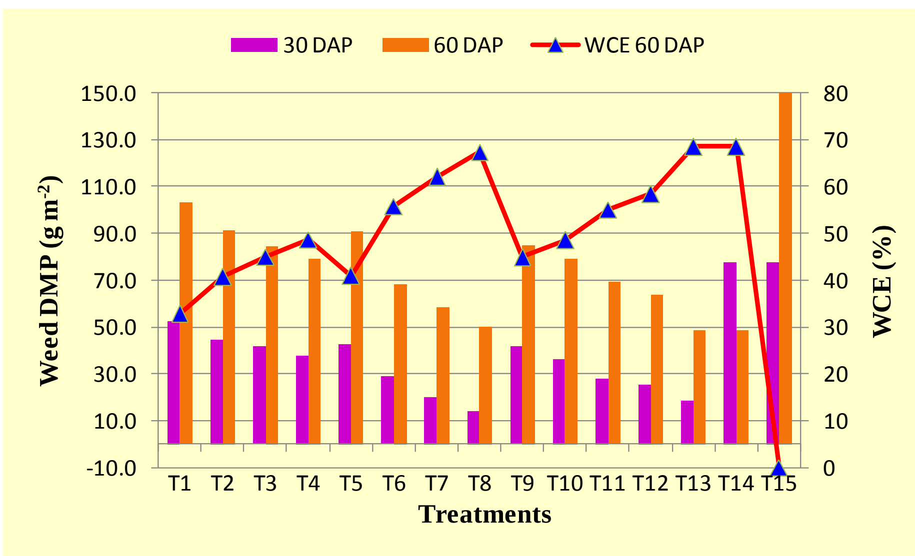

Fig. 14. Effect of different weed control treatments on total weed dry weight and weed control efficiency in sugarcane (2012-13)

methyl + chlorimuron ethyl and chlorimuron ethyl might have favoured the growth and development of sugarcane, there by higher weed control efficiency was obtained during early stages than other practices. This is in accordance with the findings of Zafar *et al*. (2010) and Singh *et al*. (2011) who have inferred that lower weed dry weight is a reflection of lesser density and biomass accumulation, which has further contributed for higher weed control efficiency. Unweeded control proved to be inferior which have lower WCE than the rest of the treatments.

5.7. Weed management methods on crop quality parameters

Sucrose content in cane is affected primarily by varieties, climatic conditions and relatively to a minor extent by the fertilizers applied. Weather factors prevailed during maturity stage play a major role on quality parameters of sugarcane. Weed management practices did not have any significant influence on the quality characters like brix, sucrose, purity, commercial cane sugars and reducing sugars during both the years of study. The results of the present study are also in corroboration with the findings obtained by Kanwar *et al*. (1992), Gouthaman (1997) and Singh *et al.* (2002).

The quality parameters did not differ significantly among the weed control treatments of sugarcane during both the crop seasons, since the quality is mainly dependent on the varietal character. Similar, results were obtained by Muhamed *et al*. (1990) and Sathyavelu (1998). They also observed that the quality of cane juice was not significantly affected by the weed infestation and the weed control methods (Singh *et al*., 2002). Different weed control treatments had little effect on sucrose per cent in juice and commercial cane sugar but mechanical weed control yielded 53 per cent more commercial cane sugar than weedy check (Singh *et al.*, 1995b). Similarly, Singh *et al.* (2002) observed that various weed control methods did not result in any significant difference in brix content, sucrose per cent, purity per cent, polarity per cent and commercial cane sugar per cent. Sathyavelu *et al*. (2002) reported that the quality of the cane was not affected significantly by the weed infestation. Zafer *et al.* (2010) reported that the quality parameters of sugarcane such as sucrose, brix, polarity, purity and CCS did not show any marked difference between weed control treatments.

5.8. Weed management methods on economics

EPOE application of halosulfuron methyl + chlorimuron ethyl at 135.5 g a.i. ha^{-1} had the highest net return of Rs. 1,44,878 and 1,62,128 for 2011-12 and 2012-13 and B:C of 1.52 and 1.62 over other treatments during both the seasons. EPOE application of halosulfuron methyl + chlorimuron ethyl at 90 g a.i ha^{-1}, chlorimuron ethyl at 18 g a.i. ha^{-1} and pre emergence application of atrazine at 1.0 kg a.i. ha^{-1}also had higher net return The reason attributed to the higher net return and B:C was effective weed management practices which reduced the weed density, dry weight and nutrient removal by weeds and positively influenced the growth attributes, yield parameters and yield of sugarcane during both the seasons of study (Fig. 15 and 16). The weed free environment lead to increased availability of resources to the crop with better utilization leading to good growth ultimately resulted in increased crop yield attributes and yield. The higher economic return as well as B:C for the use of different herbicides in weed management in sugarcane were also obtained by Chinnusamy (1990), Rao *et al.* (1995), Afghan (1996), Vasuki (2005), Patel *et al*. (2007) and Zafer *et al.* (2010).

The use of lower doses of halosulfuron methyl + chlorimuron ethyl and chlorimuron ethyl application reduced the cost spent on weeding, which resulted in lesser cost of cultivation, but weed control was not effective due to improper removal of weeds especially grassy weeds and eventually ended with lower net return and B:C. Unweeded control had negative values over the other treatments, which might have favoured regeneration and establishment of many weeds with higher weed dry weight and lower weed control efficiency.

5.9. Residual effect of herbicides on soil environment and succeeding crops

5.9.1. Residual effect of herbicides on soil microorganisms

Herbicides applied in crop fields for weed control are likely to have effects of the microorganisms in the rhizosphere of crops, weed and in soil (Lewis *et al*., 1988). Application of herbicides in agriculture may have side effects on biological equilibrium following the changes in soil environment.

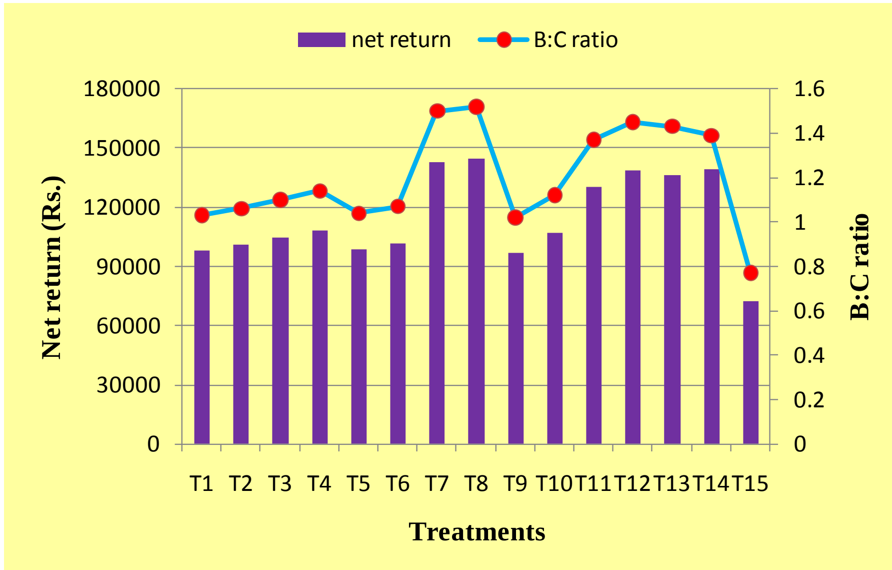

Fig.15. Effect of different weed control treatments on economics (2011-12)

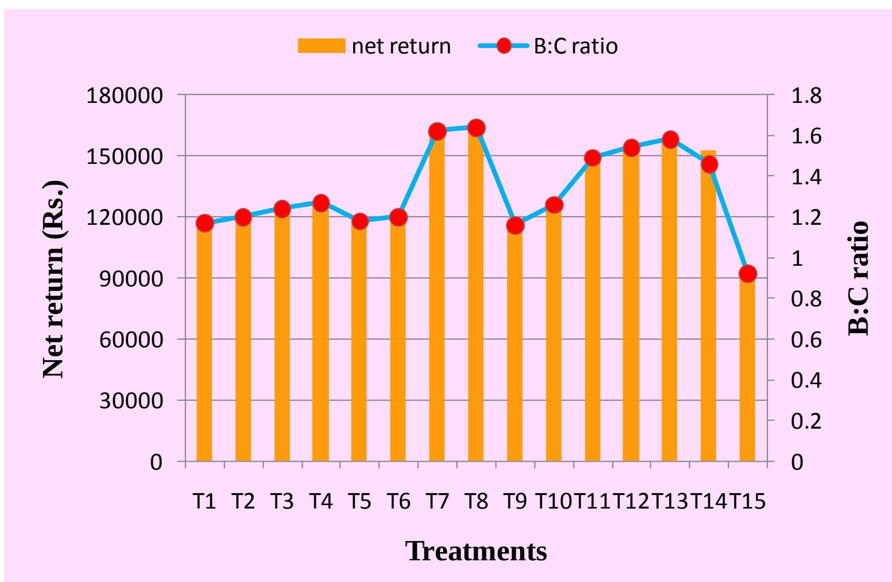

Fig.16. Effect of different weed control treatments on economics (2012-13)

Gonzalez *et al.* (1999) studied that soybean nodulation and consequently on yield was not affected by chlorimuron ethyl. This indicated that herbicides had only minimal effect on the soil microorganisms. Initial reduction in microbial counts was observed at higher doses of halosulfuron methyl + chlorimuron ethyl due to inhibitory effect of herbicides. At later stage of spray, these herbicides in sugarcane lost their potency, probably due to degradation in soil. Hence, it may be concluded that the herbicides do not leave any adverse effect on the soil microflora after few days or months of their application. The similar result was reported by Ohmes *et al.* (2000)

5.9.2. Residual effect of herbicides on weed seed bank

Seed bank is an indicator of weed population in soil and also "memory" of a weed community. It consists of new seeds recently shed by a weeds as well as older seeds that have persisted in the soil for several years (Thompson, 1997). Management of weeds in a particular area would require prior information regarding the kind of weed species infesting a field and also their density. Usage of herbicides also influences the species composition of the seed bank and may increase or decrease, it depending on the chemicals used and they can also cause species shifting (Roberts and Neilson, 1981). There was a variation on different doses of halosulfuron methyl + chlorimuron ethyl treatments in terms of herbicidal effect on seed bank potential of weeds. The reduction on weed seed bank potential resulted from the reduction on seeding capacity of weeds due to herbicide application. The emergence of grasses, broad leaved weeds and sedges was higher in unweeded control as compared to other treatments. Emergence of sedge was more in atrazine treated plot compared to halosulfuron methyl + chlorimuron ethyl. This was due to sedge weeds that were not effectively controlled by atrazine as compared to broad leaved weeds. A decline in weed density as affected by herbicides used in sugarcane and evidenced by seed bank study was earlier reported by Ball (1992).

5.9.3. Residual effect of herbicides on succeeding crops

The agricultural soil is the final destination of a large number of herbicides, either when they are applied directly to the soil or on the foliage of vegetation (Walker, 1987). When the herbicides reach the ground and interacting with the environment, their fate is governed by three general types of processes: physical (sorption-desorption, volatilization, leaching by water erosion and transportation along the ground by wind and water); chemicals (photodecomposition, sorption, chemical reactions with the soil constituents) and biological (represented by the microbial decomposition of the molecule and removal of soil by plants).

Halosulfuron methyl provides soil residual activity on perennial weeds like *Cyperus* species with control often extending for four months after applications. Similar observations were also made by Chinnusamy *et al.* (2012) and Walters *et al*. (2005). Chlorimuron ethyl provided greater than 95 per cent foliar control of volunteer horse radish which was also observed by Rundle *et al*. (2007). Since Combi is combination of halosulfuron methyl and chlorimuron ethyl, it controlled the sedges and broad leaved weeds effectively in sugarcane. The results revealed that the germination of succeeding crop pearl millet and sunflower recorded at 10 DAS was not significantly affected due to residual effect of herbicide.

The crop stand of pearl millet ranged from 84 to 87 per cent, sunflower ranged from 91 to 96 per cent under all the treatments at 10 DAS. This indicated that the residual amount of herbicides which remains in soil had no adverse effect on germination of succeeding crops. This result is in line with the outcome of Hareesh *et al*. (2012) who reported that application of sulfonyl urea herbicides had no adverse effect on residual crop.

Sulfonyl urea herbicides are widely applied in the control of most broad-leaved weeds and annual grasses in a variety of agricultural crops due to their low application rates (3 to 40 g ha^{-1}), low mammalian toxicity and unprecedented herbicidal activity (Battaglin *et al*., 2000; Cessna *et al*., 2006). In the soil, halosulfuron-methyl was dissipated faster with increasing temperature and lowering of soil pH. However, increasing moisture contents increased the dissipation rate of halosulfuron-methyl (Kuwatsuka and Yamamoto, 1997). They also reported that halosulfuron sorption was highly correlated with soil organic content and inversely correlated with soil pH.

Further, plant height and dry weight of plants recorded at 30, 60 and 90 DAS were also unaffected due to residual effect of different doses of halosulfuron methyl + chlorimuron ethyl applied in sugarcane. Sharma *et al.* (1988) also observed that there was no adverse effect with the application of atrazine + alachlor in cereals on succeeding *Rabi* crops. Yield of pearl millet and sunflower showed no distinct variation due to different dose of halosulfuron methyl + chlorimuron ethyl. It showed that new formulation of halosulfuron methyl + chlorimuron ethyl with different doses, could be very effective against most of the broad leaved weeds and sedges in sugarcane.

The outcome of the present study clearly indicated that weed free environment created either by manual hand weeding or through integrated weed management practices encouraged sugarcane to utilize resources at optimum level and to produce more yield. The production of high biomass which is a major determinant of yield coupled with enhanced yield attributes resulted in high productivity. But, the labour intensive manual weeding escalates the cost of cultivation due to high wages and non availability of manual labour. In the present agricultural scenario, early post emergence application of halosulfuron methyl + chlorimuron ethyl at 90 g a.i. ha^{-1} is the best option in sugarcane which proved to be the best in combating the weed menace. From the above study it could be inferred that sugarcane being a long duration crop, herbicide residue could not persist in the soil beyond the season.

Summary and Conclusion

CHAPTER VI

SUMMARY AND CONCLUSION

Sugarcane is the most adaptable crop under varied ecological conditions. In tropical agriculture, weeds are the major threat in crop production which affect the crop yields considerably. The crop faces severe competition during early stages of crop growth with weeds for light, space and nutrients. Risk in labour cost and availability, warrant for alternate effective and economic weed control practices. Hence, development of economically viable weed management practice as a component technology is an essential tool for increasing the productivity of sugarcane. To achieve the objective, field experiments were conducted at Eastern Block farms, Department of Farm management, Tamil Nadu Agricultural University, during main and late seasons of 2011 and 2012, respectively.

The experiment was laid out in a randomised block design with three replications. The treatments included four doses of halosulfuron methyl (45, 67.5, 90, 135.5 g a.i. ha^{-1}) chlorimuron ethyl (6, 9, 12 and 18 g a.i. ha^{-1}) and halosulfuron methyl+chlorimuron ethyl (45, 67.5, 90, 135.5 g a.i. ha^{-1}) compared with atrazine at 1.0 kg a.i. ha^{-1}, hand weeding and unweeded control. The treatments were replicated thrice. Weed control treatments were imposed as per the treatmental schedule in both the seasons.

Observations on weeds density and dry weight, crop growth parameters *viz*., plant height, number of tillers, leaf area, DMP, physiological characters like CGR, RGR, the yield attributing characters like number of millable canes, cane length, internode length, number of internodes, cane girth, individual cane weight, cane yield and sugar yield nutrient uptake by crops, nutrient removal by weeds, microbial dynamics, quality parameter, herbicide residue in soil and residual effect of test herbicides on succeeding crops were recorded. Correlation and economic return were computed. The Summary of the experimental findings and the conclusion drawn are presented here under.

The weed flora of the experimental field consisted of 11species of weeds. Major broad leaved weeds of the experimental fields were *Trianthema portulacastrum*, *Digera arvensis, Amaranthus viridis, Cleome gynandra, Partheneium hysterophorus* and *Datura fastuosa*. Predominant grassy weeds found in the experimental site were *Dactyloctenium* *aegyptium, Echinochloa colonum, Setaria verticillata* and *Dinebra retroflexa. Cyperus rotundus* was the only predominant sedge weed observed in the experimental fields.

In both the years of study, at all the stages, broad leaved weeds dominated the weed flora in terms of relative density followed by grasses and sedges. During special and main seasons 2011 and 2012, sedge weed density was lower in the plots applied with haloslfuron methyl at 135.5 and 90 g a.i. ha^{-1}. Similarly, broad leaved weed density was lower with atrazine at 1.0 kg a.i. ha^{-1} and chlorimuron ethyl at 12 and 18 g a.i. ha^{-1} compared to other test herbicides. The relative density of sedges and BLW was lower with the herbicide combination of halosulfuron methyl + chlorimuron ethyl at 135.5 and 90 g a.i. ha^{-1}.

At all the stages of crop growth, early post emergence application of halosulfuron methyl + chlorimuron ethyl (combi) at 135.5 and 90 g a.i. ha^{-1} was effective in reducing the weed population. The trend was same in the late season also. Chlorimuron ethyl at 18 g a.i. ha^{-1}, atrazine at 1.0 kg a.i. ha^{-1} and hand weeding on 30 DAP also recorded lesser weed population comparable with higher doses of halosulfuron methyl + chlorimuron ethyl (135.5 and 90 g a.i. ha^{-1}).

In both the seasons, minimum weed dry weight was recorded with halosulfuron methyl + chlorimuron ethyl at 135.5 g a.i. ha^{-1} followed by the same combination of halosulfuron methyl + chlorimuron ethyl at 90 g a.i. ha^{-1}. Hand weeding at 30 DAP also recorded lower weed dry weight and was comparable with atrazine at 1.0 kg a.i. ha^{-1} and chlorimuron ethyl at 18 g a.i. ha^{-1}. The dry weight of weeds was markedly less by virtue of effective suppression of weed growth, as evident from high weed control efficiency by the herbicides.

Maximum WCE and minimum dry weight of weeds were recorded with halosulfuron methyl + chlorimuron ethyl at 135.5 g a.i. ha^{-1}. The above treatment not only restricted the weed dry matter accumulation, but also, considerably reduced the nutrient depletion by weeds, thereby, enhanced the nutrient availability to crop during both the years of study.

Lower doses of halosulfuron methyl + chlorimuron ethyl (45, 67.5 g a.i. ha^{-1}) and chlorimuron ethyl (6, 9 g a.i. ha^{-1}) and unweeded control registered higher weed density and dry weight thereby the WCE was minimum under these treatments. There was no visual phytotoxic symptoms observed in sugarcane with application of halosulfuron methyl, halosulfuron methyl + chlorimuron ethyl and chlorimuron ethyl even at higher doses.

Significant enhancement in plant height was noticed with EPOE application of halosulfuron methyl + chlorimuron ethyl at 135.5 g a.i. ha^{-1} and hand weeding on 30 DAP followed by halosulfuron methyl + chlorimuron ethyl at 90 g a.i. ha^{-1} and atrazine at 1.0 kg a.i. ha^{-1}. Tiller production was also higher with halosulfuron methyl + chlorimuron ethyl at 135.5 g a.i. ha^{-1} followed by hand weeding on 30 DAP and halosulfuron methyl + chlorimuron ethyl at 90 g a.i. ha^{-1}, resulting in enhanced growth rate of the crop. Due to improvement in cane height, number of tillers and crop growth rate, leaf area index, the crop dry matter production was also higher with halosulfuron methyl + chlorimuron ethyl at 135.5 and 90 g a.i. ha^{-1}.

The yield components like number of internodes, internode length, cane length, cane girth and number of millable cane were higher with halosulfuron methyl + chlorimuron ethyl at 135.5 g a.i. ha^{-1} and hand weeding on 30 DAP, and they were comparable with halosulfuron methyl + chlorimuron ethyl at 90 g a.i. ha^{-1}, atrazine at 1.0 kg a.i. ha^{-1} and chlorimuron ethyl at 18 g a.i. ha^{-1}. The positive effect of these treatments on cane growth and development was due to effective suppression of weeds resulting in reduced dry weight and nutrient depletion by weeds and enhanced nutrient availability and uptake by the crop.

Nutrient removal by weeds was considerably reduced with the application of halosulfuron methyl + chlorimuron ethyl at 135.5 g a.i. ha^{-1} and this was comparable with halosulfuron methyl + chlorimuron ethyl at 90 g a.i. ha^{-1}, atrazine at 1.0 kg a.i. ha^{-1}, chlorimuron ethyl at 18 g a.i. ha^{-1} and hand weeding on 30 DAP. Nutrient uptake by the crop was higher with halosulfuron methyl + chlorimuron ethyl at 135.5 g a.i. ha^{-1}. This was followed by halosulfuron methyl + chlorimuron ethyl at 90 g a.i. ha^{-1}, atrazine at 1.0 kg a.i. ha^{-1}, chlorimuron ethyl at 18 g a.i. ha^{-1} and hand weeding on 30 DAP. This favoured the cane growth which resulted in increased yield parameters and finally the cane yield.

During both the seasons, higher cane and sugar yields were realized with halosulfuron methyl + chlorimuron ethyl at 135.5 g a.i. ha^{-1}, hand weeding on 30 DAP and halosulfuron methyl + chlorimuron ethyl at 90 g a.i. ha^{-1}, atrazine at 1.0 kg a.i. ha^{-1} and chlorimuron ethyl at 18 and 12 g a.i. ha^{-1}. Lower doses of halosulfuron methyl + chlorimuron ethyl(45, 67.5 g a.i. ha^{-1})and chlorimuron ethyl(6, 9 g a.i. ha^{-1}) registered considerable yield reduction in special and main seasons respectively, due to severe competition by weed with the crop.

Further Growth component and yield components were positively correlated with yield. Thus, better control of weeds and limited crop-weed competition for resources might be the reason for increased growth and yield parameters, which ultimately reflected on the final yield of the crop.

Weed management practices did not have any significant effect on the quality characters like brix percentage, sucrose percentage, purity coefficient and commercial cane sugar percentage during both the years of study.

The test herbicides at higher doses showed a significant detrimental effect on soil bacteria, fungi and actinomycetes and reduced the microbial population in herbicide treated plots at 1, 15, 30 and 60 DAHS. Microbial density started to recover slowly with the test herbicides like halosulfuron methyl, chlorimuron ethyl and halosulfuron methyl + chlorimuron ethyl and atrazine applied plots after 60 days of their application. The plots that were not applied with the herbicides (hand weeding and unweeded check), the microbial density increased continuously. Lower doses of test herbicides did not have any effect on the population of bacteria, fungi and actinomycetes. The trend of microbial population was similar in both the years of study.

All other treatments, except the highest dose of halosulfuron methyl, halosulfuron methyl + chlorimuron ethyl and chlorimuron ethyl recorded the terminal residues Below Detectable Levels(BDL)in post harvest soil. Highest dose of halosulfuron methyl, halosulfuron methyl + chlorimuron ethyl and chlorimuron ethyl registered minimum residues in post harvest soil and there was no residue build up in soil.

Plot applied with halosulfuron methyl + chlorimuron ethyl (combi) at 135.5 and 90 g a.i. ha^{-1} recorded lower density of total weeds at a depth of 0-15 cm and 15-30 cm and this was comparable with of atrazine at 1.0 kg a.i. ha^{-1}, chlorimuron ethyl at 12 and 18 g a.i. ha^{-1} and hand weeding at 30 DAP. Invariably, unweeded control recorded higher density of total weeds in both the seasons of experimentation. Between the two depths studied, the top layer of soil recorded higher number of weeds as compared to bottom layer of the soil.

The study on the residual effect of test herbicides applied to preceding crop of sugarcane on the succeeding crops of pearl millet and sunflower indicated that the succeeding crops were not affected by the residue of test herbicides even at higher doses. However, weed density of succeeding crops were highly reduced under the treatments that received halosulfuron methyl + chlorimuron ethyl for weed control when compared to test herbicides at lower doses.

Highest net return was realised with halosulfuron methyl + chlorimuron ethyl (combi) at 135.5 g a.i. ha^{-1}. This was followed by halosulfuron methyl + chlorimuron ethyl at 90 g a.i. ha^{-1}, atrazine at 1.0 kg a.i. ha^{-1}, chlorimuron ethyl at 18 and 12 g a.i. ha^{-1}. Higher B:C ratio was obtained with halosulfuron methyl + chlorimuron ethyl at 135.5 and 90 g a.i. ha^{-1} due to low cost of herbicidal treatment. This was comparable with atrazine at 1.0 kg a.i. ha^{-1}, chlorimuron ethyl at 18 g a.i. ha^{-1}. Eventhough hand weeding treatment recorded higher net income, B:C was comparatively less due to higher cost of cultivation. Unweeded control recorded lowest net income and B:C ratio in both the seasons.

Conclusions

The following conclusions are drawn from the results of the field experiments.

- ✓ Early post emergence application of halosulfuron methyl + chlorimuron ethyl (combi) at 135.5 and 90 g a.i. ha^{-1}, chlorimuron ethyl at 18 g a.i. ha^{-1} and atrazine at 1.0 kg a.i. ha^{-1} and hand weeding on 30 DAP significantly reduced the weed density and dry weight with higher weed control efficiency and lower weed index in sugarcane.
- ✓ Among the different weed control treatments, the herbicide combination of halosulfuron methyl + chlorimuron ethyl at 135.5 and 90 g a.i. ha^{-1}, chlorimuron ethyl at 18and 12 g a.i. ha^{-1} and atrazine at 1.0 kg a.i. ha^{-1} and hand weeding on 30 DAP significantly registered lesser nutrient depletion by weeds.
- ✓ Growth parameters like plant height, LAI, DMP, CGR and RGR of sugarcane were significantly higher with halosulfuron methyl + chlorimuron ethyl (combi) at 135.5

and 90 g a.i. ha^{-1} which was comparable with chlorimuron ethyl at 18 g a.i. ha^{-1} and atrazine at 1.0 kg a.i. ha^{-1} and hand weeding on 30 DAP.

- ✓ Among the different treatments, increased nutrient uptake by sugarcane in both the seasons was observed with the herbicides combination of halosulfuron methyl + chlorimuron ethyl at 135.5 and 90 g a.i. ha^{-1}, chlorimuron ethyl at 18 g a.i. ha^{-1} and atrazine at 1.0 kg a.i. ha^{-1} and hand weeding on 30 DAP
- ✓ Higher yield parameters such as cane height, individual cane weight, cane length, cane girth, cane and sugar yields were recorded with halosulfuron methyl + chlorimuron ethyl (combi) at 135.5 and 90 g a.i. ha^{-1} which was comparable with chlorimuron ethyl at 18 g a.i. ha^{-1} and atrazine at 1.0 kg a.i. ha^{-1} and hand weeding on 30 DAP. The quality parameters of sugarcane did not differ significantly due to weed control treatments during both the experimental seasons.
- ✓ Test herbicides applied at lower doses to sugarcane did not affect bacteria, fungi and actinomycetes population. Whereas, at higher doses initial reduction of microbial population was observed and it recovered within 60 days after herbicides application
- ✓ Halosulfuron methyl + chlorimuron ethyl (combi) at 135.5 and 90 g a.i. ha^{-1}, chlorimuron ethyl at 18 g a.i. ha^{-1} and atrazine at 1.0 kg a.i. ha^{-1} and hand weeding on 30 DAP plots recorded lesser density of total weeds at a depth of 0-15 cm and 15-30 cm when compared with un weeded control.
- ✓ Succeeding crops like pearl millet and sunflower sown immediately after the harvest of sugarcane were not affected by the residue of test herbicides at higher doses applied to the preceding crop of sugarcane.
- ✓ Halosulfuron methyl + chlorimuron ethyl (combi) at 135.5 and 90 g a.i. ha^{-1} recorded higher gross and net returns and B:C ratio. This was comparable with chlorimuron ethyl at 18 g a.i. ha^{-1} , atrazine at 1.0 kg a.i. ha^{-1}. Unweeded control recorded negative values per rupee invested.

Recommendations

From the results of the field experiments, it could be recommended that,

- ❖ Atrazine is the commonly used pre emergence herbicide for chemical weed management in sugarcane. Alternatively, the new formulation of halosulfuron methyl and chlorimuron ethyl combination is suggested as promising herbicides for early post emergence application (2-3 leaf stages of weeds).
- ❖ Pre emergence application of atrazine at 1.0 kg a.i. ha^{-1} or early post emergence application of chlorimuron ethyl at 12 g a.i. ha^{-1} is suggested for weed control in cane fields dominated by broad leaved weeds.
- ❖ In a situation where the sugarcane fields are infested predominantly by sedges, halosulfuron methyl at 90 g a.i. ha^{-1} as EPOE is found to be effective.
- ❖ Halosulfuron methyl + chlorimuron ethyl at 90 g a.i. ha^{-1} is found to be a sound chemical weed management practice for sugarcane to achieve effective control of sedges and broad leaved weeds besides realising higher yields and economic returns.

Future line of work

- ❖ The new molecule evaluated with present investigation need to be evaluated in sugarcane under intercropped situation
- ❖ Herbicide molecule effective for grassy weed control shall have to be tested

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Appendices

APPENDIX I

Weather data during the cropping period of 2011-12

Standard week	Mean Temperature (°C)		Mean R.H. (%)		Rainfall (mm)	Rainy days	Sunshine hours
	Max.	Min.	0722 Hrs	1422 Hrs			
2011-42	31.6	22.6	95	60	111.4	4	6.4
43	29.7	22.6	91	68	39.0	5	4.0
44	27.7	21.9	95	79	150.0	6	3.4
45	28.9	19.5	93	55	74.0	3	7.0
46	30.2	20.8	89	47	0.0	0	8.0
47	29.1	21.1	81	57	0.0	0	6.4
48	27.3	22.1	94	75	102.5	4	1.4
49	29.2	20.9	90	56	0.0	0	5.9
50	29.7	21.6	89	58	1.8	0	7.7
51	28.2	18.3	88	53	0.0	0	6.5
52	30.5	15.2	89	40	9.8	1	6.9
2012- 1	29.0	19.8	89	52	0.5	0	7.1
2	30.6	21.5	89	48	0.0	0	6.8
3	29.8	15.4	87	44	0.0	0	9.8
4	29.6	16.1	89	50	0.0	0	8.8
5	29.5	19.4	88	45	0.5	0	7.6
6	31.6	21.3	87	44	0.0	0	7.7
7	32.1	20.9	88	46	0.0	0	7.7
8	33.6	17.3	79	25	0.0	0	8.7
9	34.8	19.1	80	29	0.0	0	9.5
10	34.5	21.6	86	40	0.0	0	7.3
11	34.1	23.8	83	35	0.0	0	7.9
12	35.8	22.2	80	29	0.0	0	9.2
13	35.2	23.2	80	37	5.4	1	8.4
14	35.4	22.8	85	32	0.0	0	8.9
15	36.1	24.6	81	37	0.0	0	9.0
16	35.7	26.2	87	47	0.6	0	6.6
17	33.6	23.6	91	51	73.6	1	4.7
18	34.0	24	89	52	0.0	0	8.0

Standard week	Mean Temperature (°C)		Mean R.H. (%)		Rainfall (mm)	Rainy days	Sunshine hours
	Max.	Min.	0722 Hrs	1422 Hrs			
19	34.7	23.7	88	55	18.2	1	7.1
20	35.0	24.4	88	48	0.0	0	9.0
21	34.4	23.9	86	47	7.4	1	7.4
22	34.9	24.4	84	42	0.0	0	7.6
23	33.1	24.8	71	47	0.5	0	6.2
24	32.6	24.0	75	50	0.0	1	6.7
25	30.4	23.2	76	50	10.6	0	4.8
26	32.5	22.9	84	54	0.2	0	3.0
27	31.5	23.2	76	48	2.1	0	7.3
28	32.2	22.9	90	54	3.5	1	6.2
29	30.9	24.4	79	55	21.7	2	3.0
30	31.3	23.7	74	52	0.0	0	4.4
31	31.7	24.1	70	44	0.5	0	6.8
32	30.2	23.0	85	59	6.8	1	2.6
33	31.5	22.7	89	54	1.0	0	4.6
34	32.8	22.5	86	54	13.4	1	8.4
35	29.7	23.1	82	59	6.6	2	2.5
36	31.3	23.3	82	53	0.6	0	4.5
37	32.1	22.7	81	48	0.4	0	6.7
38	33.3	21.5	85	45	0.0	0	9.2
39	33.3	22.6	86	50	5.1	1	7.6
40	33.0	21.6	75	43	0.0	0	9.7
41	32.6	21.6	89	54	74.6	2	5.1
42	29.4	23.1	94	69	83.8	2	4.4
43	28.0	22.4	91	66	5.8	0	4.0
44	28.5	22.5	85	64	13.0	1	4.3
45	31.1	21.5	91	53	1.0	1	8.3
46	31.0	22.4	89	42	0.0	0	8.4

APPENDIX II

Weather data during the cropping period of 2012-13

Standard week	Mean Temperature (°C)		Mean R.H. (%)		Rainfall (mm)	Rainy days	Sunshine hours
	Max.	Min.	0722 Hrs	1422 Hrs			
2012 -17	33.6	23.6	91	51	73.6	1	4.7
18	34.0	24.2	89	52	0.0	0	8.0
19	34.7	23.7	88	55	18.2	1	7.1
20	35.0	24.4	88	48	0.0	1	9.0
21	34.4	23.9	86	47	7.4	1	7.4
22	34.9	24.4	84	42	0	0	7.6
23	33.1	24.8	71	47	0.5	1	6.2
24	32.6	24.0	75	50	0	0	6.7
25	30.4	23.2	76	50	10.6	1	4.8
26	32.5	22.9	84	54	0.2	0	3.0
27	31.5	23.2	76	48	2.1	0	7.3
28	32.2	22.9	90	54	3.5	1	6.2
29	30.9	24.4	79	55	21.7	2	3.0
30	31.3	23.7	74	52	0	0	4.4
31	31.7	24.1	70	44	0.5	0	6.8
32	30.2	23.0	85	59	6.8	1	2.6
33	31.5	22.7	89	54	1.0	0	4.6
34	32.8	22.5	86	54	13.4	1	8.4
35	29.7	23.1	82	59	6.6	2	2.5
36	31.3	23.3	82	53	0.6	0	4.5
37	32.1	22.7	81	48	0.4	0	6.7
38	33.3	21.5	85	45	0	0	9.2
39	33.3	22.6	86	50	5.1	1	7.6
40	33.0	21.6	75	43	0	0	9.7

Standard week	Temperature (°C)		R.H. (%)		Rainfall (mm)	Rainy days	Sunshine hours
	Max.	Min.	0722 Hrs	1422 Hrs			
41	32.6	21.6	89	54	74.6	2	5.1
42	29.4	23.1	94	69	83.8	2	4.4
43	28.0	22.4	91	66	5.8	0	4.0
44	28.5	22.5	85	64	13	1	4.3
45	31.1	21.5	91	53	1	0	8.3
46	31.0	22.4	89	42	0	0	8.4
47	31.7	18.4	91	50	9.4	1	5.4
48	30.9	21.0	89	37	0	0	8.8
49	30.8	21.5	87	49	2.5	1	7.2
50	31.2	18.9	86	37	0	0	9.1
51	29.4	19.9	81	42	0	0	4.5
52	30.4	21.7	85	48	4.4	1	5.8
2013-1	32.4	20.2	87	35	0	0	8.0
2	31.6	18.8	87	34	0	0	6.9
3	30.7	18.5	85	41	0	0	9.1
4	31.5	17.7	85	28	0	0	9.7
5	31.2	19.5	84	37	0	0	8.1
6	32.5	22.0	82	39	0	0	7.8
7	32.5	22.9	77	43	0	0	5.8
8	31.1	20.4	90	43	99.8	1	7.5
9	33.5	17.1	75	21	0	0	9.7
10	32.6	24.0	82	51	0	0	5.9
11	33.9	22.6	75	34	0	0	8.8
12	35.0	23.6	77	30	0	0	9.4
13	35.5	24.1	86	44	0	0	8.3

APPENDIX III

Herbicide name	Trade name	Formulation	Group	Chemical name	Mode of action	selectivity	Spectrum	persistence
Atrazine	Atrataf	50 % WP	Traizine	2-Chloro-4-ethylamino-6-isopropylamino -1,3,5-triazine	Inhibition of photosystem	selective	Broad leaved weeds and grasses	Half life is 60 days
Halosulfuron methyl	New form	75 % WDG	Sulfonyl urea	Methyl 5-[((4,6-dimethoxy-2pyrimidinyl)amino) carbonylaminosulfonyl] -3-chloro-1- methyl-1H-pyrazole-4-carboxylate	Inhibits acetolactate synthesis ALS	selective	Sedges and Broad leaved weeds	Half life is 55 days
Chlorimuron ethyl	kloben	25% WP	Sulfonyl urea	Ethyl 2-[[[[(4-chloro-6-methoxypyrimidin-2-yl) amino] carbonyl]amino]sulfonyl]benzoate	Inhibits acetolactate synthesis ALS	selective	Broad leaved weeds	Half life is 45 days

APPENDIX IV

Media to assess the population dynamics of different microbial communities

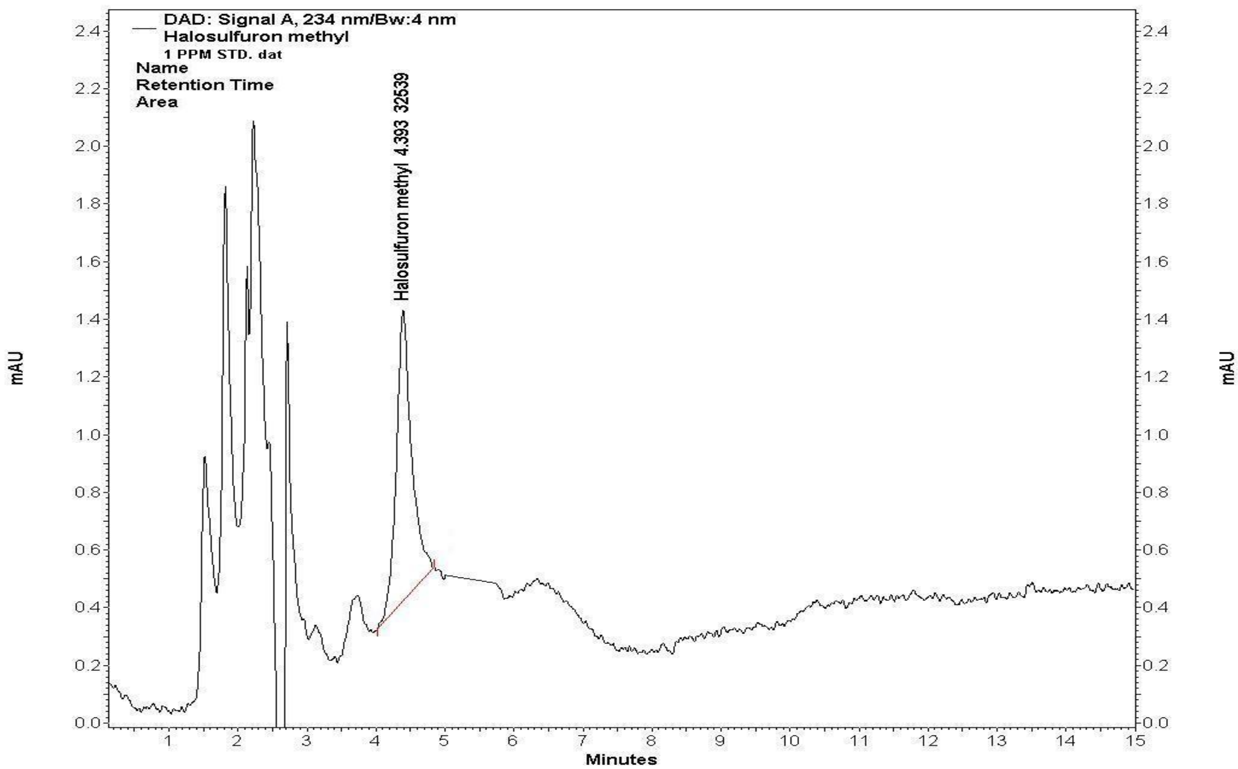
1. Nutrient agar medium (Manual, 1957)		
Glucose	:	5.0g
Beef extract	:	3.0g
Sodium chloride	:	5.0g
Agar	:	15-20g
Distilled water	:	1000 ml
pH	:	7.0
2. Martin's Rose Bengal Agar medium (Martin, 1950)		
Glucose	:	10.0 g
Peptone	:	5.0g
Potassium di hydrogen phosphate	:	l.0g
Magnesium sulphate	:	0.5 g
Rose bengal	:	33.0mg
Streptomycin sulphate (10% solution)*	:	3.0ml
Agar	:	15.0g
Distilled water	:	1000ml
3. Kenight's Agar medium – Actinomycetes (Allen, 1953)		
Glucose	:	1.0ml
Magnesium sulphate	:	0.1 g
Potassium di hydrogen phosphate	:	0.1g
Potassium chloride	:	0.1g
Di ammonium sulphate	:	0.1 g
Agar	:	15 g
Distilled water	:	1000ml

* After autoclaving at 121°C for 15 min, cooled and streptomycin sulphate was added.

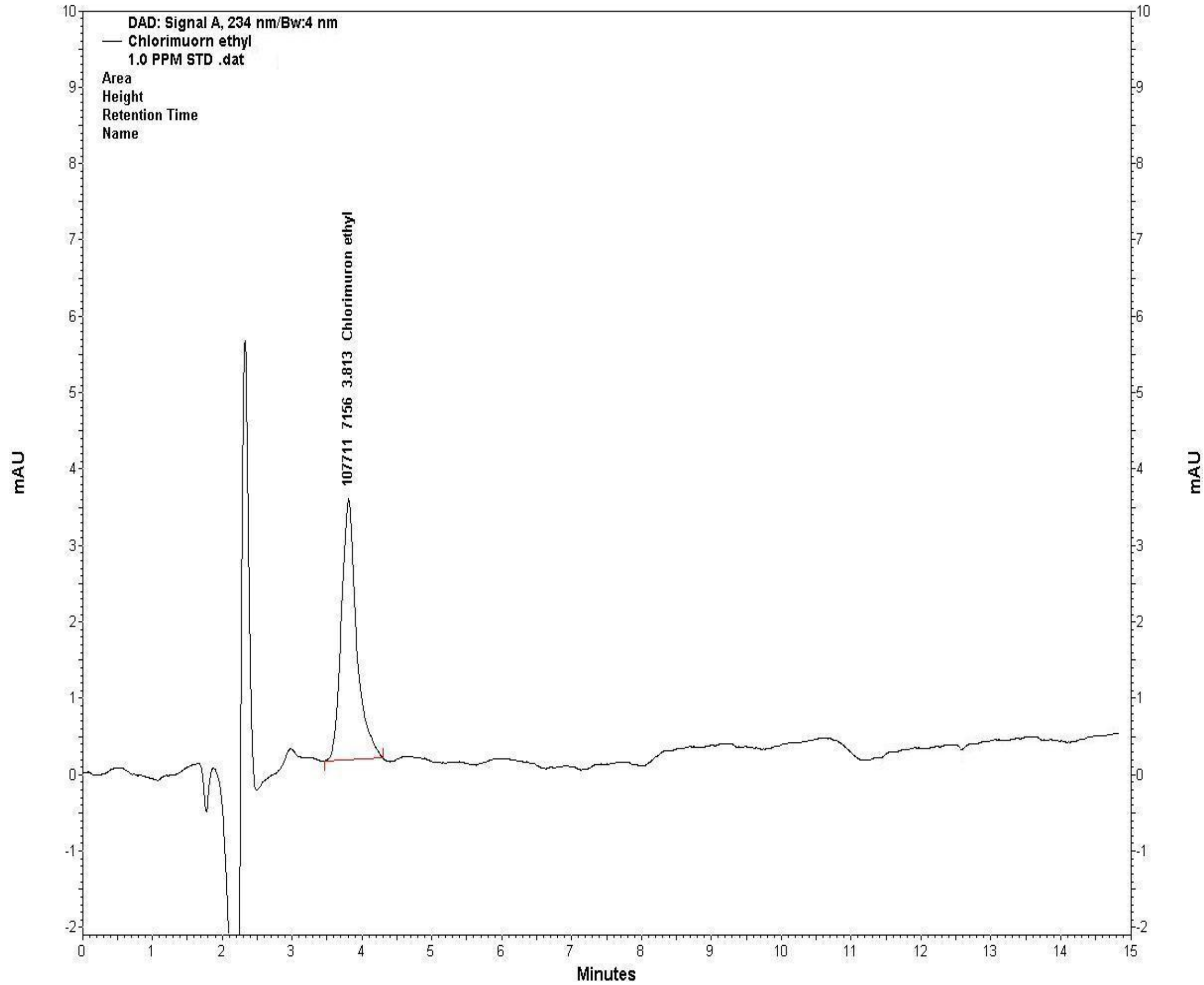
APPENDIX V

Unit cost of inputs and produce (in Rs.)

S. No.	Particulars	Unit	Cost (Rs.)
Input			
1.	Setts (75,000 two budded)	1000 setts	425.0
2.	Carbendazim	150 g	84.0
3.	Urea	kg	5.52
4.	DAP	kg	11.00
5.	MOP	kg	4.86
6.	$ZnSO_4$	kg	36.75
7.	Fe SO_4	kg	4.60
8.	Chlorpyriphos	lit	152
9.	Carbofuron (Furadon 3 G)	kg	52.96
10.	Bavistin	kg	298
11.	Atrazine	kg	260
12.	Halosulfuron methyl	kg	390
13.	Chlorimuron ethyl	kg	390
14.	Halosulfuron methyl + chlorimuron ethyl	kg	390
15.	*Azospirillum*	200 g	8.00
16.	Phosphobacteria	200 g	8.00
17.	Men labour wages	Man day	171.0
18.	Women labour wages	Man day	171.0
19.	Bullock pair	1 pair	150.0
20.	Harvesting charges	tonne	550
Produce			
1.	Cane	tonnes	2000



Appendix VI. Standard chromatogram of Halosulfuron methyl at 1.0 ppm



Appendix VII. Standard chromatogram of Chlorimuron ethyl at 1.0 ppm

Plates

Plate 1. General view of experimental field

Treatment imposing

Unweeded control

***EPOE – Combi 180 g ha^{-1} (30 DAP)**

***EPOE – Combi 180 g ha^{-1} (60 DAP)**

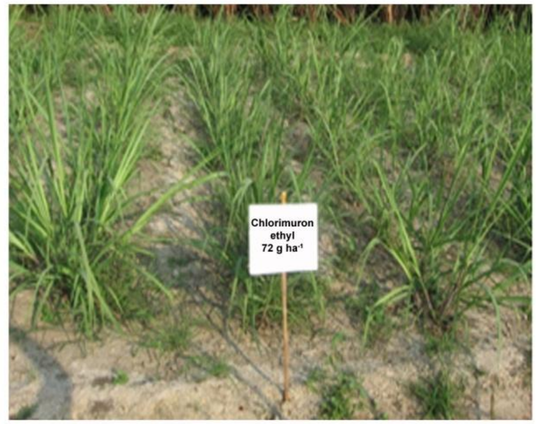
***EPOE – Combi 120 g ha^{-1} (30 DAP)**

***EPOE – Combi 120 g ha^{-1} (60 DAP)**

*** EPOE- early post emergence**

Plate 2. Efficiency of different herbicide weed management in sugarcane

PE – Atrazine @1.0 kg ha^{-1}



*EPOE – Chlorimuron ethyl 72 g ha^{-1}

* EPOE- early post emergence

Plate 3. Sugarcane tiller production under herbicides treated plot

Sunflower

Pearlmillet

Pot culture

Sunflower

Pearlmillet

Plate 4. Residual effect of herbicide on succeeding crops