INTEGRATED WEED MANAGEMENT IN MENTHOL MINT (*Mentha arvensis* L.)

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CERTIFICATE

This is to certify that the thesis entitled "**INTEGRATED WEED MANAGEMENT IN MENTHOL MINT (*Mentha arvensis* L.)"** submitted by **Miss ASHA M. R. ID No. UHS16PGM715** for the degree of **MASTER OF SCIENCE (HORTICULTURE)** in **PLANTATION, SPICES, MEDICINAL AND AROMATIC CROPS** to the University of Horticultural Sciences, Bagalkot is a record of bonafide research work carried out by her during the period of her study at University of Horticultural Sciences, Bagalkot under my guidance, supervision and the thesis has not previously been formed the basis for the award of any other degree, diploma, associateship, fellowship or similar titles.

ARABHAVI
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Affectionately dedicated to

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My Guide

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LIST OF ABBREVIATIONS

Sl. No.	Abbreviations	
1.	a.i.	Active ingredient
2.	*et al.*	and others/associates/Co-workers
3.	*etc.*	And so on; and other people / things
4.	@	at the rate of
5.	Cm	Centimetre
6.	COC	Copper oxy chloride
7.	C: B	Cost: benefit ratio
8.	CD	Critical Difference
9.	DAP	Days after planting
10.	DAS	Days after sowing
11.	DI	Days intervals
12.	^{0}C	Degree centigrade
13.	EC	Emulsified concentrate
14.	FYM	Farm yard manure
15.	Fig.	Figure
16.	G	Gram
17.	HAS	Hours after spraying
18.	Km	Kilo meter
19.	Kg	Kilogram
20.	L	Litre
21.	Ml	Millilitre
22.	Mm	Millimetre
23.	MOP	Murate of potash

Contd….

Sl. No.	Abbreviations	
24.	Nm	Nanometre
25.	NPK	Nitrogen: Phosphorus: Potassium
26.	NS	Non significant
27.	( )	Parenthesis
28.	%	Per cent
29.	Ha	Per hectare
30.	POE	Post-emergent
31.	PE	Pre-emergent
32.	Q	Quintal
33.	RH	Relative humidity
34.	`	Rupee
35.	SSP	Single super phosphate
36.	m^2	Square meter
37.	v	Square root
38.	SE m±	Standard error of mean ±
39.	T	Tonne
40.	UV	Ultraviolet
41.	WP	Wettable powder

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1. INTRODUCTION

Mints are a group of perennial herbaceous plants, belonging to the family Lamiaceae, which yields essential oil on distillation (Harley and Brighton, 1977). The various species of mints which are commercially cultivated in different parts of the world are menthol mint or Japanese mint or corn mint or field mint (*Mentha arvensis* L.), pepper mint (*M. piperita* L.), spear mint or garden mint or lamb mint (*M. spicata* L.) and bergamot mint or orange mint (*M. citrate* L.).

Among various mint species, menthol mint is commercially cultivated in tropics and subtropics for its essential oil, which is a primary source of menthol and dementholized oil (Croteau *et al*., 2005). The fresh leaves contain 0.4-0.6 per cent oil. The main constituent of the oil is menthol (70-85%). The menthol content of oil varies, depending on climatic conditions. Generally, it is higher in tropical regions. Menthol mint is an important essential oil-bearing plant which is extensively used in flavoring of large number of pharmaceuticals, food and oral preparations and cosmetic industries (Ram *et al*., 2006). Menthol itself finds extensive use in medicine in treatment of ulcer, inflammatory diseases, as a carminative and an analgesic in the treatment of neuralgia and rheumatism.

Menthol mint is an important cash crop grown in India. It has become most popular among small holders. India is the largest producer and exporter of mentha oil. In India, the production of menthol oil is about 38,000 MT from an area of around 0.30 million hectares with an average productivity of around 120 kilograms per hectare (Anonymous, 2015). India dominates menthol production and supplies 80 per cent of global demand, followed by China and Japan. Tarai region of Uttar Pradesh (Nainital, Badayun, Bilaspur, Rampur, Moradabad and Bareilly), extending to part of Indo-Gangetic plains (Barabanki and Lucknow) accounts for around 90 per cent of mint production, with the remaining 10 per cent coming from smaller areas in the Punjab (Ludhiana and Jalandhar) and Rajasthan.

The continuous increase in mint cultivation is due to increasing internal consumption and demand for menthol and mint oil from USA, Germany, France, UK, Singapore, Australia and Japan. The development of improved technology pertaining to mentha cultivation though has helped to great extent in boosting its production, yet there are many problems that need serious attention. Among these production problems, weeds management is of major concern. As many as 37 species of weeds, both grassy and non-grassy weeds, were recorded to be growing in the field where menthol mint was under cultivation (Misra *et al*., 1973). Menthol mint shows delayed sprouting of about 10-30 days for complete emergence. It is very slow growing during initial stages which makes it a poor competitor with weeds and frequent irrigations provide congenial environment for sprouting, growth and development of weeds. The crop passes through summer and rainy seasons and is associated with both broad leaved and grassy weeds (Walia *et al*., 1980). Rapid weed emergence and crop growth leads to severe crop weed competition, which results in heavy reduction in growth and economic yield of the crop, leading to lower profitability. The weeds, if not controlled at critical period of crop-weed competition leads to reduction in fresh herb and essential oil. The oil yield reduction is about 60-80 per cent depending upon the density and type of weed flora (Gulati and Duhan, 1979; Randhawa *et al*., 1982; Singh, 1982).

Weeds also deteriorate the quality of crop produce as separating out weed plants from the crop produce during oil extraction is not possible. Weed menace in mentha fields are normally tackled by using manual or mechanical methods. Manual weeding being arduous, costly and time consuming is not possible on a large scale. Whereas, peak period of weed removal from mentha crop coincides with the harvesting period of many winter season crops, thus posing a serious problem of labour availability which delays the removal of weeds. Under such situation, use of herbicides for weed control holds a great promise. Application of straw mulch increased herb and essential oil yield of menthol mint (Patra *et al*., 1993) and reduces the weed density and weed biomass (Lal, 1974a). Whereas, sugarcane trash availability is abundant in Belgaum region can be used as organic mulch for the mint. Sugarcane trash mulch application reduced weed density and weed biomass and increased stolon population, mint dry matter accumulation, fresh herbage and mint oil yield (Singh and Saini, 2008). Similarly, application of various herbicides influenced plant height (Kaur, 1999), number of plantlets (Singh *et al*., 1995), fresh herbage yield, and essential oil yield of menthol mint (Kumar *et al*., 2001). The chemical method involving use of selective pre and post-emergent herbicides for weed control holds a great promise, effective, economical and the farmers are adopting this method extensively. Pre-emergence herbicides are controlling weeds in menthol mint which provide only short term control of weeds and post-emergent herbicide controls the weeds emerging later compete with the crop and reduce its productivity. Thus the use of integrated approach is recommended for long term control of weeds is desirable in this crop.

Moreover, to advise a cost effective weed management practices to the farmer, the present investigation was planned to study the integrated effect of manual weeding, inter-cultivation, mulching and pre and post-emergent application herbicides on weed dynamics and productivity of menthol mint. The crop comes up well in Arabhavi region which is situated in northern dry zone of Karnataka. There is a large scope for cultivation of this crop since, the research done on this crop in Karnataka state itself is meager, as these crops are uncommon to the growers and often lack of knowledge in their scientific cultivation and improper marketing channel.

In view of the above, it was felt necessary to provide scientific information on the effect of integrated use of pre and post-emergence herbicides along with sugarcane trash mulch, inter-cultivation and manual weeding on weed dynamics and crop productivity for Arabhavi, northern dry zone of Karnataka condition and to standardize the "Integrated weed management" protocol for Arabhavi region. Therefore, the present study on "Integrated weed management in menthol mint (*M. arvensis* L.)" has been undertaken with the following objectives:

Objectives:

1. To standardize the suitable weed management method for menthol mint.
2. To find out the effect of different weed management methods on growth, yield and quality of menthol mint.
3. To work out the economics.

2. REVIEW OF LITERATURE

Menthol mint is a group of aromatic herb of considerable economic importance. During *Kharif* season due to heavy rains and scarcity of labour, it is very difficult to manage the weeds by conventional, cultural and mechanical methods. Therefore, the study of integrated weed management practices assumes a greater importance in the cultivation of menthol mint. The infestation by a wide spectrum of weed flora including grasses, sedges and broad leaved weeds are one of the major causes for low yield of menthol mint. The work done on integrated weed management in menthol mint is very limited in northern dry zone of Karnataka. However, the available information on this various mint species and other related crops has been reviewed and presented under following heads:

2.1 Weed flora and losses caused by weeds in menthol mint

2.1.1 Weed flora

The weed species varies from place to place, from season to season, vary with soil conditions and cropping pattern. Generally, weeds are found in large numbers with great vigor, because of their wider adaptability even under extremities of climatic, edaphic and biotic stress. High persistence nature of weeds is attributed to their ability of high seed production and longer seed viability. The degree of damage caused by weeds is related to the type, species and density of weeds growing in a crop community. Mint being a widely spaced crop is infested with wide spectrum of weed flora.

Signh *et al*. (1995) reported that *Chenopodium album*, *Anagallis arvensis* and *Rumex aspera* are predominant weed species associated with menthol mint. *Medicago denticulata* was the major weed showing infestation of 35 per cent followed by *Spergula arvensis* (19 %) and *Melilotus indica* (15 %). Kaur (1999) reported that 25 weed species infested the mint field by reducing herb and oil yield of menthol mint.

Weed flora associated with mint crop comprised of 37 species represented by 33 genera and 15 families. Out of these, 11 genera belong to a single family *i.e.* Gramineae. Perennial grasses were found throughout the crop season consisting of *Cynodon dactylon*, *Cyperus rotundus* and *Halepense sp*. winter weeds highly infested the field in the month of March largely with dicots followed by annual and perennial grasses. Dominant weed species were *Coronopus didymus*, *Anagallis arvensis*, *Arenaria serpyllifolia* and *Poa annua*. After winter annuals, summer annuals infested the crop and are mostly dominated by *Eleusina indica*, *Eleusina aegyptiacum*, *Brachiaria ramose*, *Cynodon dactylon* and *Phyllanthus niruri* reported by Singh and Khosla (1989).

The dominating weed species of menthol mint are reported by Gulati and Duhan (1979) from Haldwani are *Cyperus rotundus*, *Cynodon dactylon, Blumea glomerata*, *Launia pinnatiloeia*, *Cannabis sp*., *Nicotiana plumbaginifolia*, *Sinapis alba*, *Amaranthus paniculatus*, *Rumex dentatus, Desmostachya bipinnata.* However, grassy weeds are dominated.

Mishra *et al*. (1973) noticed that about 37 species of weeds, both grassy and non-grassy, were recorded to be growing in the field where menthol mint was under cultivation. And the most important weed species involving in reducing the herb and oil yield of menthol mint are *Cyperus rotundus* (55%), *Cynodon dactylon* (20%), *Chinapodium alba* (8%), *Asphodelus tenuifolius* (6%), *Trianthema portulacastrum* (5%) and miscellaneous species (6%) respectively. *Mentha piperita* was infested with 30 weed species reported by Skender *et al*. (1997).

2.1.2 Losses caused by weeds

Weeds are the main causes for great losses in menthol mint which is depend upon type and density of weeds. High intensity of weeds leads to slow germination and initial growth, wider row spacing and slow lateral spread, which causes tremendous loss in productivity as well as quality.

Singh *et al*. (2009) reported that uncontrolled weed growth caused 78 and 81 per cent reduction in total (1^{st} and 2^{nd} harvest) herb and oil yield of menthol mint, respectively. The unrestricted weed growth caused 58 per cent of reduction in oil yield of menthol mint reported by Kothari and Singh (1994).

Kothari *et al.* (1991) reported that, unrestricted weed growth significantly reduced mint oil yield by 58 and 73 per cent, respectively in first and second harvests. About 50 per cent reduction in the herbage and about 75 per cent reduction in essential oil yield when compared with weed free treatment was recorded by Singh *et al*. (1982) due unrestricted weed growth.

The crop weed competition during critical period of crop growth reduces the herb and essential oil yield of mint. So, in order to obtain higher herb and oil yield, these weed plants should be controlled during critical period of crop-weed competition. Weeds cause up to 74 per cent yield losses reported by Walia *et al*. (2006).

Weeding between 4 to 14 weeks after planting of the menthol mint gave considerably higher yield of menthol mint reported by Singh (1991a). Weed free condition up to 75-95 days of crop growth of menthol mint was sufficient to get good yields of herb and oil which were almost same as obtained under weed free conditions reported by Gulati and Duhan (1979).

Singh (1982) revealed that, higher yield of menthol mint and peppermint obtained by keeping the crop weed free up to 105 days from date of planting. The critical period of weed interference is a specific minimum period of time during which the crop of menthol mint must be free from weeds in order to prevent loss in yield given by Nieto *et al*., 1968.

2.2 Influence of herbicides on weeds

2.2.1 Weed density

Kothari and Singh 1994 reported that, unrestricted weed growth significantly reduced mint oil yield by 58 and 73 per cent, respectively in the first and second harvests. PE applications of terbacil of 1.5 kg a.i./ha, pendimethalin of 1.0 kg a.i./ha or oxyfluorfen of 0.25 kg a.i./ha followed by application of fluazifopbutyl of 0.25 kg a.i./ha after first harvest were found to be highly effective in reducing weed density and dry weight and gave oil yield comparable to weed-free check. None of the herbicides impaired the quality of menthol mint oil measured in terms of menthol content. Successive weeding, hoeing and mulching (wheat straw @ 5 t/ha) also gave an oil yield equivalent to that of the weed-free control.

Walia *et al*. (2006) recorded that PE application of oxyfluorfen @ 145, 176, 206, 235 and 265 g/ha proved very effective for suppressing weed population of menthol mint and all these treatments found similar to recommended in the treatment *i.e*, pendimethalin @ 750 g /ha and also similar to two hand weeding treatment. Terbacil @ 2 kg and @ 3 kg, terbutryne @ 1 kg and @ 1.5 kg, diuron @ 0.75 kg, fluchloralin @ 0.9 kg, paraquat @ 0.3 kg and pendimenthalin @ 0.9 kg/ha were equally effective in controlling weeds and remained *on par* with two and three hand hoeings treatments reported by Randha *et al*. (1982).

Singh *et al*. (1995) found that PE application of metribuzin @ 0.8 kg and @ 1.2 kg/ha and alachlor @ 2.0 kg and @ 2.5 kg/ha proved ineffective in controlling weeds. PE application of prometyne @ 3 kg/ha, atrazine @ 2 kg + DCU @ 9 kg/ ha and simazine @ 2 kg + TCA @ 6 kg/ha in pepper mint gave 85 per cent control of annual dicotyledonous weeds population without much affecting the crop recorded by Kamennobrodskaya (1967).

2.2.2 Weed biomass

Weed dry matter accumulation will play a major role in herbage yield and essential oil yield of menthol mint. Karkanis *et al*. (2017) reported that, pendimethalin and oxyfluorfen were effective against annual weeds in both spearmint and peppermint crops, these herbicides should be included in integrated weed management systems for better weed management in mint crops.

Kaur *et al*. (2013) revealed that, application of oxyfluorfen @ 0.2 kg a.i/ha as PE recorded lowest weed density and dry matter of grass and broad leaved weeds and gave the highest menthol mint yield and oxyfluorfen @ 0.2 kg a.i/ha 10 DAP as a early POE herbicide also recorded the same result but further delayed spray of chemical recorded poor weed control and herb yield was significantly reduced.

Reduction of dry matter of weeds and increased herb yield of menthol mint with oxyfluorfen @ 0.3 kg a.i/ha was recorded by Jaidev *et al*. (1993). Highest weed control efficiency was observed in menthol mint due to isoproturon @ 0.75 kg/ ha and pendimethalin @ 1.0 kg and diuron + pendimethalin @ 0.3 kg + 0.375 kg/ha and two hand hoeing given by Kumar *et al*. (2001).

Singh *et al*. (2009) reported that, PE application of oxyfluorfen @ 0.205 kg/ha was found to be *on par* with pendimethalin @ 0.75 kg/ha in reduced weed dry matter accumulation in menthol mint. The reduced weed dry matter with the application of Diuron @ 0.4 kg and @ 0.6 kg/ha in menthol mint was reported by Singh and Saini (2008).

The dry matter of weeds under PE application of terbutryn (0.5 kg and 0.75 kg/ha) and diuron (0.6 kg/ha) were *on par* with each other and significantly superior to isoproturon (0.75 kg/ha), isoproturon + pendimethalin (0.37 kg + 0.37 kg/ha), ethalfluralin (0.3 kg and 0.4 kg/ha), pendimethalin (0.75 kg and 1.25 kg/ha) and two hand weeding in menthol mint. All the weed control treatments proved superior to un-weeded control in curtailing the dry matter production by weeds reported by Brar *et al*. (2000).

The PE application of diuron @ 0.8 kg/ha gave seven folds reduction in dry matter accumulation by weeds as compared with un-weeded control, but was found to be *on par* with pendimethalin @ 1.0 kg and @ 1.5 kg/ha, diuron @ 0.6 kg/ha and two hoeing given by Singh *et al*. (1995) in menthol mint.

In menthol mint application of herbicides significantly reduced the dry matter accumulation of weeds. Four hand hoeing proved superior over rest of the treatments. Increasing rates of both oxyfluorfen (0.1 kg, 0.2 kg and 0.3 kg/ha) and pendimethalin (0.5 kg, 1.0 kg and 1.5 kg/ha) resulted in less dry matter accumulation by weeds reported by Jaidev *et al*. (1993).

Kothari *et al*. (1991) reported that, more than 95 per cent of total dry matter accumulation before 75 DAP and weeds emerged after 75 DAP acquire negligible amount of dry matter. The PE application of terbacil @ 1.6 kg and 2.4 kg/ha in menthol mint proved very effective against weeds and caused significant reduction in dry matter accumulation by weeds than all other treatments but was found *on par* with two hand weeding given by Randhawa *et al*. (1984).

The PE application of terbacil @ 1.6 kg and 2.4 kg/ha, terbutryne @ 0.375 kg and 0.75 kg/ha, simazine @ 1.0 kg and 1.5 kg/ ha and higher dose of metoxuron 0.8 kg/ha significantly reduced weeds dry weight as compared with two hand hoeing and un-weeded control in menthol mint. They further reported that all the weed control treatments resulted in significant reduction in dry matter accumulation by weeds as compared with no weeding and were either *on par* or better than two hand hoeing in menthol mint. Diuron @ 0.8 kg and 1.2 kg/ha had 58.4 per cent and 63.8 per cent less dry matter accumulation than weedy check, respectively recorded by Walia *et al*. (1980).

In pepper mint the PE application of diuron @ 0.6 kg/ha, pendimethalin @ 0.75 kg/ha reduced dry weight of weeds by 99 per cent at 45 days after planting and 93 per cent at harvest, respectively as compared with un-weeded control given by Kaur *et al*.,(1999).

2.3 Influence of herbicides on chlorophyll content of mint

The chlorophyll content of leaf is strongly affected by numerous external factors. Agostinetto *et al.* (2017) conducted an experiment to evaluate herbicides effect from different mechanisms of action in photosynthetic and oxidative stress parameters, as well visual phyto-toxicity and wild radish control in wheat. Two trials were conducted where the first one evaluated the photosynthetic parameters on wheat plants in two seasons, following the application of herbicides bentazon, clodinafop, iodosulfuron, metribuzin, metsulfuron and 2,4-D; and the second one evaluated wild radish (*Raphanus sativus* L.) control, wheat phytotoxicity and yield due to bentazon, iodosulfuron, metribuzin, metsulfuron and 2,4-D herbicides application. Photosynthetic rate, stomatal conductance and transpiration were negatively affected by metribuzin (0.3 l/ha), metsulfuron and 2,4-D herbicides at 24 and 120 HAS, respectively compared to control.

2.4 Toxicity symptoms of herbicides

The lower plant height of the crop was observed in weed control treatments which were included with sulfosulfuron herbicide might be due to the phytotoxic effect of this herbicide on crop plants. The sulfosulfuron herbicide caused more reduction in crop plant height after 30 DAP to harvesting stage of crop. The higher plants height in un-weeded control as compared to metribuzin application might due to competition for sunlight between crop plants and taller weeds like *Rumex dentatus* and *Ageratum conyzoides* resulting in low light induced height increment and lanky growth. Menthol mint being openly grown plant require good quality sun light for photosynthesis process and hence grow taller in search of light reported by Singh (2012).

Ali *et al.* (2004) showed that herbicidal treatments of metribuzin and isoproturon + diflufenican produced smaller plants which can be due to their phytotoxic effect on wheat crop. Metribuzin and isoproturon+ carfentrazone treated plots resulted in lowest plant height as compared with other herbicides. Oxidative stress was also induced.

2.5 Influence of herbicides on crop

2.5.1 Plant height

Statistically no significant difference in plant height of menthol mint was recorded by Randhawa *et al*. (1984) by PE application of fluchloralin @ 1.64 kg a.i/ha, dinitramine (0.5 kg and 0.75 kg a.i/ha) and PE application of metoxuron (0.4 kg a.i/ha and 0.6 kg a.i. /ha), metribuzin (0.7 kg a.i/ha), terbacil (1.6 kg and 2.4 kg a.i/ ha), terbutryne (0.5 kg and 0.75 kg a.i/ha) and isoproturon (0.5 kg a.i/ha).

Walia *et al*. (1980) observed the maximum plant height of menthol mint under un-weeded control (49 cm) which was followed by 2 hand hoeing and application of terbacil @ 1.6 kg/ha treatments whereas, diuron at both the rates *i.e.* 0.8 kg and 1.2 kg/ha significantly reduced plant height.

Zheljiazkov *et al*. (1996) reported that, highest growth indices, fresh herbage and essential oil yield from *Mentha piperita* and *Mentha arvesnsis* var. *piperences* were obtained when mechanical or combined (mechanical and chemical) weed control is used. The significantly higher plant height was recorded in weedy check (44.4 cm) followed by diuron @ 0.6 kg a.i/ha followed by hoeing reported by Singh (1991a).

2.5.2 Plant spread

PE application of pendimethalin @ 0.750 kg a.i./ha followed by one hand weeding at 30 DAP, oxyfluorfen @ 0.100 kg a.i/ha followed by one hand weeding at 30 DAS and one hoeing at 15 DAP followed by hand weeding at 30 DAS recorded maximum plant spread at harvest in menthol mint (Singh *et al*., 1995).

2.5.3 Leaf to stem ratio

Kothari *et al.* (1991) reported that, uncontrolled weed growth causes significant reduction in leaf to stem ratio (0.61), herb yield (64.4 q/ ha), oil content (0.55 %) and oil yield (35.4 kg/ha).

2.5.4 Leaf area

Thankamani (2016) reported that paddy straw mulch recorded maximum leaf area (647.47 cm^2) than the control in ginger crop. Better performance of ginger in beds under paddy straw mulch due to increasing yield attributing traits, the optimized soil temperature, controlled evaporation losses, increased soil moisture conservation, due suppression of weeds and uptake of major, secondary and micro nutrients.

2.5.5 Fresh herb yield

PE and POE application of herbicides help in controlling weed flora associated with menthol mint and improve the green herbage yield by reducing weed density and weed biomass. Singh and Saini (2008) reported that, PE application of diuron @ 0.4 kg and 0.6 kg/ha increased crop dry matter accumulation and menthol mint oil yield over weedy check. But results found were similar at both the concentration of diuron spray.

The herb yield was found to be *on par* with PE application of oxyfluorfen applied @ 0.205 kg, 0.235 kg and 0.265 kg/ha and pendimethalin @ 0.75 kg/ha treated plots and this parameter was recorded to be significantly superior to un-weeded control treatment reported by Singh *et al*. (2009). The oxyfluorfen @ 0.35 kg/ha produced higher herb yields as compared with pendimethalin @ 0.75 kg, isoproturon @ 0.75 kg/ha and 2 hand weeding reported by Sing (2003).

PE application of oxyfluorfen @ 206, 235 and 265 g/ha and pendimethalin @ 750 g/ha resulted in 59.3, 64.3, 67.2 and 68.2 per cent higher herb yield than un-weeded control. The same result has also been reported by Jaidev *et al*. (1993). PE application of isoproturon @ 0.75 kg/ha produced the highest herb yield (341 q/ha) which was 29.1 per cent higher than un-weeded control but was *on par* with diuron @ 0.4 kg, pendimethalin @ 0.75 kg, oxyfluorfen @ 0.35 kg, diuron @ 0.4 kg followed by one hand hoeing, oxyfluorfen @ 0.23 kg followed by one hand hoeing and isoproturon @ 0.5 kg/ha recorded by Kaur (1999) in pepper mint.

The maximum green herb yield of 154.9 q/ha was recorded in menthol mint under PE application of diuron @ 0.6 kg followed by one hoeing which was *on par* with diuron @ 0.4 kg and 0.6 kg, pendimethalin @ 1.0 kg followed by one hand hoeing, pendimethalin @ 1.0 kg/ha and 2 hand hoeing recorded by Singh (1991b).

Walia *et al*. (1980) reported the maximum herb yield of 82 q/ha was recorded menthol mint with PE application of terbacil @ 1.6 kg/ha and it was significantly better than diuron @ 0.8 kg and 1.2 kg/ha.

2.5.6 Essential oil yield

Oil content of crop is the functional factor for determining the essential oil yield. Kaur *et al*. (2013) reported that, highest oil yield was recorded with PE application of oxyfluorfen @ 0.2 kg/ha in menthol mint.

Kumar *et al*. (2001) discovered that, the highest average oil yield (189 kg/ha) of menthol mint under pendimethalin + isoproturon (0.5kg + 0.5 kg/ha) treatment combination which was 3.3, 15.2, 81.7 per cent more in comparison to PE application of diuron (0.6 kg /ha), two hand hoeing and un-weeded control treatments, respectively. However, in case of pepper mint, isoproturon @ 0.75 kg/ha recorded the highest oil yield of 97 kg/ha which was 11.5, 12.8 and 49.2 per cent more than of diuron @ 0.6 kg/ha, two hand hoeing and weedy treatments respectively. The maximum pepper mint essential oil yield was recorded under PE application of isoproturon @ 0.75 kg/ha and it was 3.4 times higher than un-weeded control (29.01 kg/ha) revealed by Kaur (1999).

Jaidev *et al*. (1993) showed that, the maximum oil yield of menthol mint was noticed in weed free treatment which was *on par* with four hand weeding, pendimethalin @ 1.5 kg and 1.0 kg /ha. The maximum menthol mint oil of 93.01 kg/ha was obtained with PE application of diuron @ 0.6 kg/ha followed by one hoeing but was *on par* with diuron @ 0.6 kg, pendimethalin @ 1.0 kg/ha followed by two hoeing at 6th and 9th week after planting recorded by Singh (1991b).

Highest menthol mint oil yield was recorded under terbacil @ 3.0 kg/ha and three hand hoeing treatment, which were *on par* with terbacil @ 2 kg, terbutryne @ 1.5 kg, diuron @ 0.75 kg, pendimethalin @ 0.9 kg/ha and 2 hand weeding reported by Randhawa *et al.* (1982).

The maximum oil yield (63 kg/ha) of menthol mint recorded under PE application of terbacil @ 1.6 kg/ha treatment which was significantly higher than terbacil @ 1.2 kg/ha, diuron @ 0.8 kg and 1.2 kg/ha and two hand weeding. Diuron at both the doses produced significantly lower oil yield than two hand weeding reported by Walia *et al.* (1980).

2.5.7 Essential oil content

Jaidev *et al.* (1993) reported that the maximum oil yield (124.5 kg/ha) was obtained in weed free treatment which was *on par* with four hand weeding, combined with application of pendimenthalin @ 1.5 kg and 1.0 kg/ha.

Singh *et al.* (1995) revealed that different herbicidal treatments did not affect the oil content of menthol mint significantly. Similar results were also recorded by Kumar *et al.* (2001).

Kaur (1999) observed that PE application of isoproturon @ 0.75 kg/ha produced the highest herb yield (341 q/ha) which was 29.1 per cent higher than un-weeded control but was *on par* with diuron 2 0.4 kg, pendimenthalin @ 0.75 kg, oxyfluorfen @ 0.35 kg, diuron @ 0.4 kg followed by one hand hoeing, oxyfluorfen @ 0.23 kg followed by one hand hoeing and isoproturon @ 0.5 kg/ha in menthol mint

2.5.8 Essential oil quality

Gulati and Bhan (1971) conducted the experiment during the analysis of chemical properties of menthol mint oil obtained from terbacil @ 1.0 kg, 1.5 kg and 2.0 kg/ha treated plots showed that PE application of terbacil did not affect the quality of oil as indicated by menthol, methyl acetate content of oil when compared with weed free control.

Kothari and Singh (1994) revealed that PE application of herbicides [Terbacil @ 1.5 kg a.i/ ha, pendimethalin @ 1.0 kg a.i/ ha or oxyfluorfen @ 0.25 kg a.i/ ha followed by application of fluzifopbutyl @ 0.25 kg a.i/ha] did not affect the quality of menthol mint oil measured inters of menthol. No effect of any herbicide on quality of menthol mint oil was reported by Jaidev *et al*. (1993).

Singh and Aggarwal (1988) tested menthol mint oil and did not get residue of simazine @ 0.5 kg and 1.0 kg/ha, fusillade @ 0.15 kg/ha and paraquat @ 0.4 kg/ha in oil. Nagy (1977) observed that terbacil @ 2 to 5 kg/ha or propyzamide (30 per cent) + diuron (32 per cent) @ 6 kg to 9 kg/ha both applied before sprouting and oxadiazon @ 3 to 5 kg/ha applied 2 to 6 weeks before harvest were safe to peppermint.

Zheljiazkov *et al*. (1996) reported that, the quality of essential oil of pepper mint and menthol mint did not influenced by tillage followed application of Sinbar NP80 @ 2/kg ha.

Application of diuron @ 0.4 kg and 0.6 kg/ ha, oxyfluorfen @ 0.23 kg and 0.35 kg/ha, isoproturon @ 0.5 kg and 0.75 kg/ha and pendimenthalin @ 0.5 kg and 0.75 kg/ha alone or in combination with hand weeding did not significantly affect most of the essential oil quality parameters of peppermint (Kaur, 1999).

2.6 Influence of mulch on crop and weeds

The principle aim of mulching is to cut off the light to the weeds and to suppress their growth. Since every type of the mulch covers the soil surface and performs physical pressure to the weeds. Mulch applied on soil surface checks evaporation, protects soil from erosion, reduces the soil temperature, suppresses the weeds, enhances soil microbial activities and ultimately improves soil structure after decomposition.

2.6.1 Influence of mulch on weeds

The organic mulch application reduced the weed density and weed biomass by suppressing the emerging weeds. Singh and Saini (2008) reported that, straw mulch application reduced weed density and weed biomass.

Reduction of weed density with straw mulch application was due to one or a combination of reasons, including mechanical hindrance or direct suppression of the emerging weeds reported by Dyck and Liebman (1994) in lambsquater and sweet corn; effect of light transmittance, soil moisture and soil temperature (Teasdale *et al*., 1993); secretion of allele-chemicals by decomposition of straw mulch (Liebman and Davis, 2000; Weston., 1966).

Application of straw mulch reduced the weed growth both in terms of dry matter and density reported by Ghorai and Bera (1988), Lal (1974a) and Chakraborty (1971).

2.6.2 Influence of mulch on crop

Ram *et al*. (2006) reported that application of sugarcane trash as mulch significantly improved the herbage production than no mulch treatment at first, second and total of both the harvests. Rice straw mulch and citronella distillation waste increased the herb yield of menthol mint by 17 and 31 per cent, respectively and essential oil yield also increased significantly reported by Patra *et al*. (1993).

Singh and Saini (2008) noticed that, menthol mint responds positively to mulch application @ 6 t/ha improves the crop vegetation by reducing weed density and weed biomass and also creates conducive soil temperature and soil moisture conditions for sprouting and growth of menthol seedlings and increased stolons population, mint dry matter accumulation, fresh herbage and mint oil yield.

Lal (1974b) observed in maize that, an increased dry matter accumulation was obtained under straw mulch application. The increase in number of stolons and dry matter accumulation could be due to low weed density and weed dry biomass (Lal, 1974a) and favorable soil temperature (Walker, 1969).

2.7 Influence of integrated weed management methods on menthol mint

Integrated weed management is a long term management approach, using several weed management techniques. It is a system for managing weeds over the long term and minimization of herbicide resistance.

Straw mulch application @ 6 t /ha in combination with herbicides *viz*., trifluralin @ 1.2 kg, pendimethalin @ 0.75 kg, oxyfluorfen @ 0.35 kg and isoproturon

@ 0.75 kg/ha increased menthol herb yield significantly as compared with respective herbicide alone reported by Bhullar *et al*. (2009).

The reduced weed growth and increased fresh herb and oil yield were obtained under organic mulch application with paddy straw @ 6 t/ha integrated with both the levels of diuron @ 0.4 kg and 0.6 kg/ ha recorded by Singh (2003).

Kothari and Singh (1994) revealed that PE application of terbacil (1.5 kg a.i./ha), pendimethalin (1.0 kg a.i./ha) or oxyfluorfen (0.25 kg a.i./ha) followed by application of fluzifopbutyl (0.25 kg a.i./ha) and successive weeding, hoeing and mulching (wheat straw mulch 5 t/ha) gave an oil yield equivalent to that of weed-free control.

PE application of diuron @ 0.6 kg/ha integrated with one hoeing given after first harvest maintained weed free condition till the completion of crop and produced maximum total fresh herb yield (240.3 q/ha) which was 65.2 and 15.3 per cent higher than un-weeded control and two hand hoeing respectively, recorded by Singh (1991b).

Mahey *et al*. (1973) observed that, effective control of weeds in menthol mint was noticed under two hand weeding, 40 and 60 days after planting integrated with two inter-row shielded application of paraquat @ 0.5 kg/ha @ 83 and 95 DAP, respectively.

Karkanis *et al*. (2017) revealed that, the PE application of pendimethalin and oxyfluorfen provided better control of annual weeds resulting in higher crop yield by concluding that pendimethalin and oxyfluorfen were effective against annual weeds in both spearmint and pepper mint crops, these herbicides should be included in integrated weed management systems for better weed control in mint crops.

Zheljiazkov *et al*. (1996) reported that, three tillage followed by application of Sinbar NP80 @ 2 kg/ha gave the highest growth indices, fresh herbage and essential oil yield in *Mentha piperita* and *Mentha arvesnsis* var. *piperences* species respectively.

2.8 Economics of different weed management methods on menthol mint

Ratnam *et al*. (2012) reported that among the weed management treatments, the higher net return of ` 1,21,73/ha and B:C ratio of 0.61 was recorded with PE application of oxyfluorfen 0.25 kg/ha followed by quizalofop ethyl 0.05 kg/ha at 30 DAS supplemented with hand weeding at 60 and 90 DAS in turmeric.

Kamble *et al*. (2005) discovered that the most economical and effective menthod of weed control in miaze is PE application of atrazine + one hoeing + one weeding at 20 days after planting gives the highest cost : benefit ratio of 1:3.6.

Maximum net returns of ` 19358/ha and cost: benefit ratio of 2.06 with atrazine 0.25 kg/ha followed by one hand weeding at 40 days after planting reported by Ramesh and Nadanaasbabady (2005) in maize.

3. MATERIAL AND METHODS

The field experiment entitled, "Integrated weed management in menthol mint (*Mentha arvensis* L.)" was conducted in the Department of Plantation, Spices, Medicinal and Aromatic Crops, Kittur Rani Channamma College of Horticulture, Arabhavi, University of Horticultural Sciences, Bagalkot during 2017-18. The details of materials used and methods followed for conduct of this study have been presented in this chapter under the following heads:

3.1 Geographical location of the experimental site

Arabhavi is situated at $16^0$15? North latitude and 74° 45? East longitudes, at an altitude of about 612 m above sea level. It is situated in northern dry zone of Karnataka (Zone-3, Region-2 of agro-climatic zones of Karnataka).

3.2 Climate condition of experimental site

Arabhavi is considered to have the benefit of both south-west and north-east monsoons. The mean annual rainfall of this area is 359.6 mm, distributed over a period of six to seven months from April to November. The command area receives water from Ghataprabha Left Bank Canal from mid-October to mid-March. The monthly mean maximum temperature goes up to 26.15°C (July 2017) and monthly mean minimum temperature drops down to 22.10°C (December 2017). The mean relative humidity ranges between 91.10 per cent (July 2017) and 78.00 per cent (December 2017). The meteorological data for the period of experimentation was recorded at the meteorological observatory of the Agricultural Research Station, Arabhavi, which is situated at 2 Km from the college campus (Appendix I).

3.3 Soil characteristics of experimental site

The soil of experimental site is sandy clay loam (vertisols) with neutral pH (8.79). Soil samples were collected from a depth of 0-15 cm from the experimental site adopting the standard procedure and the composite samples were used for analysis of physico-chemical properties (Appendix II).

3.4 Experimental details

3.4.1 Design and layout (Fig. 1)

The investigation of ‘Integrated weed management in menthol mint (*Mentha arvensis* L.)’ was laid out in Randomized Complete Block Design, replicated three times with twelve treatments. Each plot was of 4.5 m x 3.6 m (16.2 m^2) size. The plan of layout is given in Fig. 1.

1	Location	Dept. of PMA, KRCCH, Arabhavi
2	Plot size: Gross	4.5 m x 3.6 m (16.2 m^2)
3	Net plot	700 m^2
4	Type of mulch	Sugarcane trash @ 5 t/ha
5	Season	*Kharif* 2017
6	Spacing	45 cm x 30 cm
7	Seed rate	400 kg/ha (stolons)
8	Date of sowing	08th July, 2017
9	Variety	Kosi

3.4.1.a Characteristics of menthol mint variety (Kosi):

The stem is hairy, green and having erect growth. The leaves are petiolated with serrated margins. It grows to a height of 65 cm in 120 days. It contains 0.71 per cent essential oil on fresh weight basis having 75-80 per cent menthol content. Oil yield varies from 200 to 250 kg per hectare.

3.5 Details of pre and post-emergent herbicides

3.5.1 Oxyfluorfen

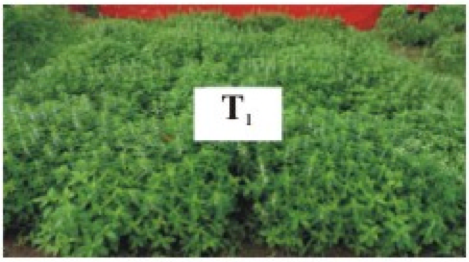
Trade name: Goal, RH2615

Group: Nitrodiphenyl Ether Herbicide

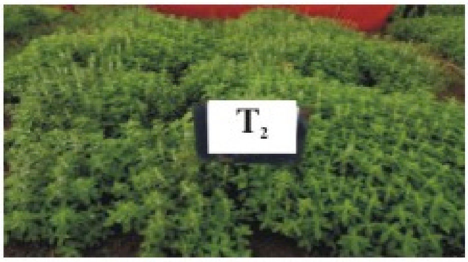
Chemical name: 2 chloro-1-(3-ethoxy-4-nitrophenolxy) 4 (trifluoromethyl)- benzene

Table 1: Treatment details

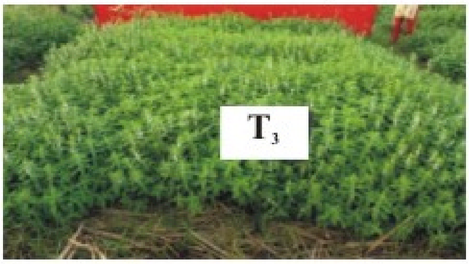
Treatments		Dosage (a. i. kg/ha)	Time of application of Herbicides /Sugarcane trash mulch /Intercultivation (Days after planting)		
			Herbicide	Sugarcane trash mulch (t/ha)	Inter-cultivation
T_1	Hand weeding	-	-	-	15 DI
T_2	Intercultivation	-	-	-	15, 30 and 45
T_3	Organic mulch	-	-	@ 5 t/ha	30
T_4	Metribuzin 70 WP (PE)	0.70	2-3	-	-
T_5	Oxyfluorfen 23.5 EC (PE)	0.25	2-3	-	-
T_6	Oxyfluorfen 23.5EC (PE) + Metribuzin 70 WP	0.25 + 0.7	2-3 and 30	-	-
T_7	Metribuzi 70 WP (PE) + Quizalofop-ethyl 5EC (POE)	0.7 + 0.05	2-3 and 30	-	-
T_8	Oxyfluorfen 23.5 EC (PE) + Quizalofop-ethyl 5EC 50g (POE)	0.25 + 0.05	2-3 and 30	-	-
T_9	Oxyfluorfen 23.5 EC (PE) + Metribuzin 70 WP (POE) + Quizalofop-ethyl 5EC (POE)	0.25 + 0.70 + 0.05	2-3 and 30	-	-
T_{10}	Oxyfluorfen 23.5 EC (PE) + Inter-cultivation	0.25	2-3	-	45
T_{11}	Metribuzin 70 WP 0.7 kg (PE) + Inter-cultivation	0.70	2-3	-	45
T_{12}	Unweeded (control)	-	-	-	-



T_1: Hand weeding

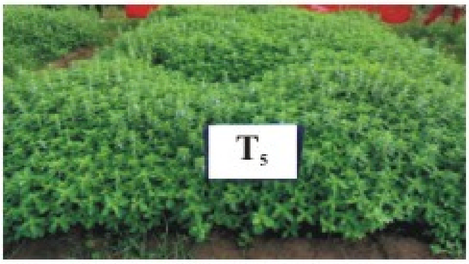


T_2: Inter-cultivation

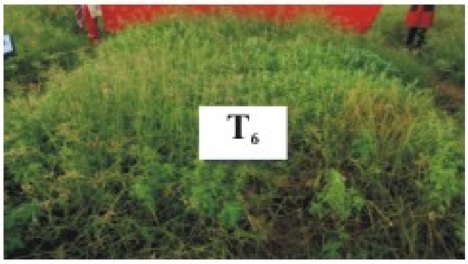


T_3: Sugarcane trash mulch

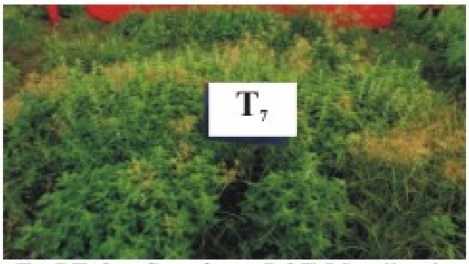
T_4: PE Metribuzin @ 0.7 kg a.i./ha



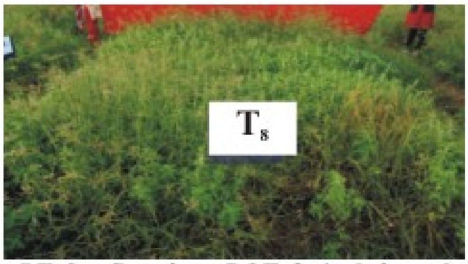
T_5: PE Oxyflourfen @ 0.25 kg a.i./ha



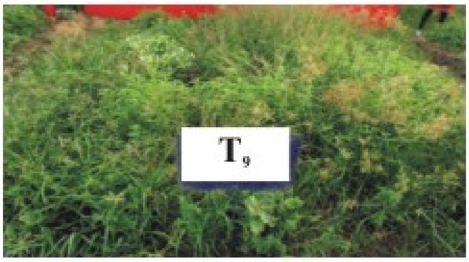
T_6: PE Oxyflourfen + POE Metribuzin



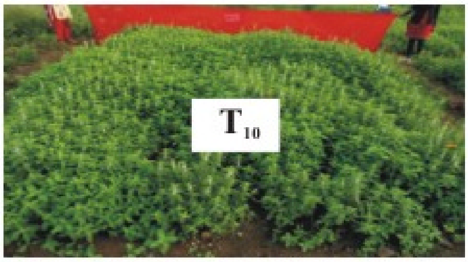
T_7: PE Oxyflourfen + POE Metribuzin



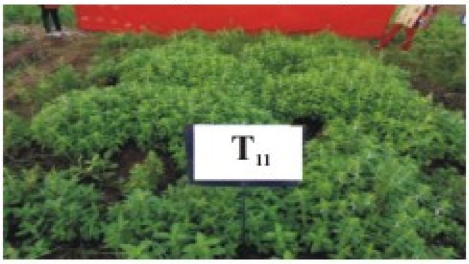
T_8: PE Oxyfluorfen + POE Quizalofop-ethyl



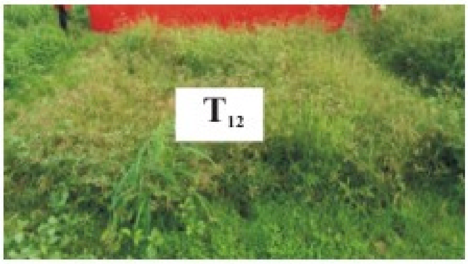
T_9: PE Oxyfluorfen + PE Metribuzi + POE Quizalofop-ethyl



T_{10}: PE Oxyfluorfen + Inter-cultivation



T_{11}: PE Metribuzin + Inter-cultivation



T_{12}: Un-weeded (control)

Plate 1: Treatment details of different weed management methods at 90 DAP

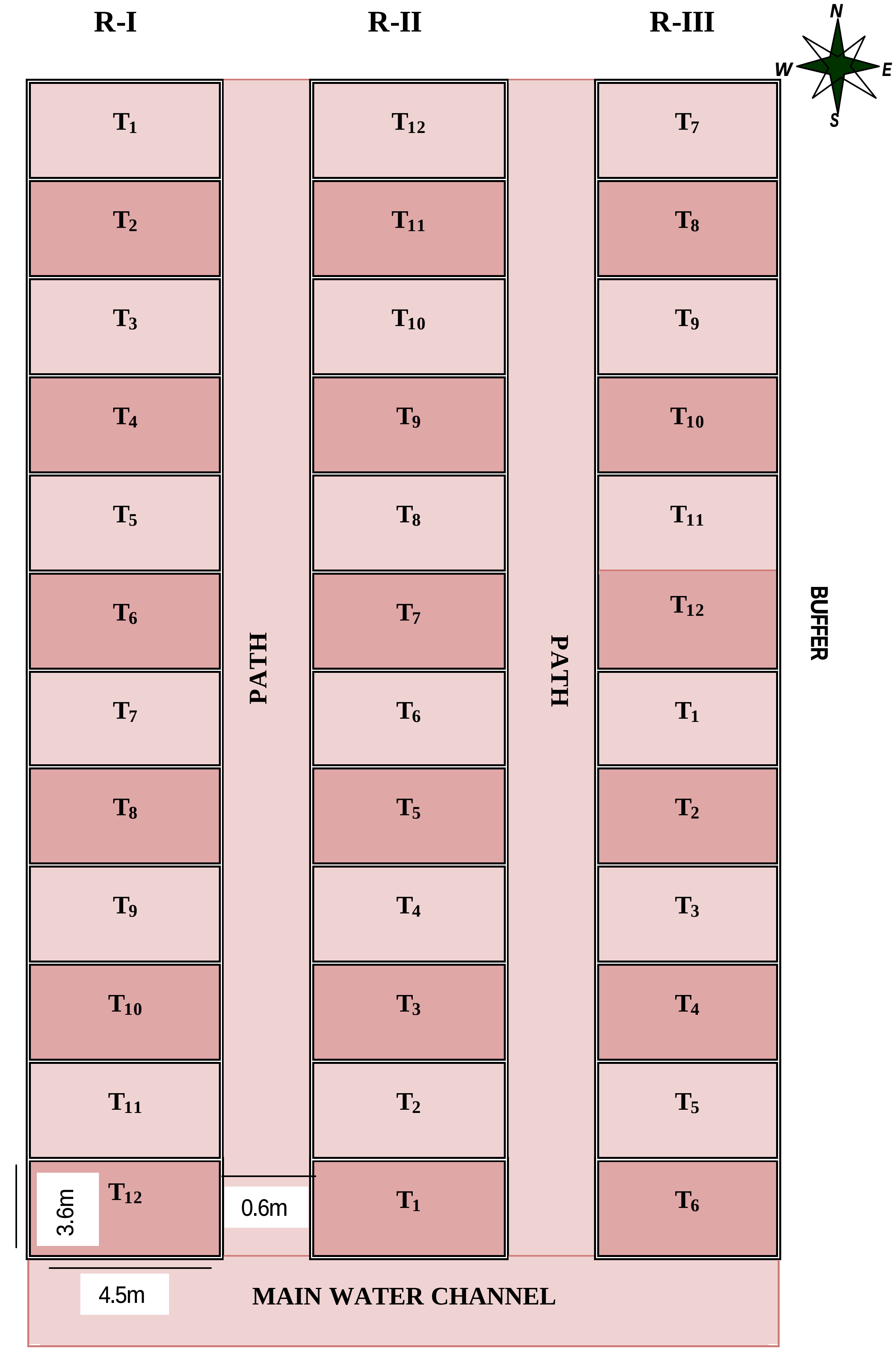


Fig. 1: Plan and layout of an experimental site

Plate 2: General view of experimental plot at harvest

Formulation: Emulsifiable concentrate

Mode of action: This herbicide can be absorbed by both leaves and roots but these are not translocated extensively. The mode of action of this herbicide includes light dependent action which involves inhibition of chloroplast, energy transfer and photosynthetic electron transport leading to free radical formation, lipid peroxidation and membrane disruption (Walia, 2009).

Uses: Selective herbicide for pre-emergence or early post emergence control of certain annual broad leaf and grassy weeds.

3.5.2 Metribuzin

Trade name: Sencor, Lexone, Metri, Metribuzin, Tricor

Group name: Triazonone

Chemical name: 4-amino-6-tert-butyl-3-methylsulfanyl-1,2,4-triazin5-one (IUPAC)

Formulation: Wettable powder

Mode of action: It acts by inhibiting photosystem II of photosynthesis by disrupting electron transfer. This results in death due to starvation in the target plant. Selectivity is due to differing metabolism of the compound within the plant.

Uses: pre-emergent and early post emergent herbicide.

3.5.3 Quizalofop-ethyl

Trade name: Turger Super, Assure II, Pilot Super and Targa D^+

Group: Aryloxyphenoxy-propionates

Chemical name: ethyl 2-[4-(6-chloroquinoxalin-2-yl) oxyphenooxy] proponate

Formulation: Emulsifiable concentrate (EC)

Mode of action: Selective and systemic herbicide of Aryloxyphenoxy-propionates group used to control grass weeds in broad leaf crops. The products quickly absorbed and translocated in the weeds, and up to 5 days after application, visible symptoms of poisoning are occurred. Up to 10 days after application, the weeds are completely killed.

Uses: Pre-emergent and post emergent herbicide.

3.6 Experimental preparations

The details of experimental preparations and cultural operations performed during the experimentation are presented here under:

3.6.1 Field preparation and cultural operations

The experimental site was brought to fine tilth by ploughing deeply with tractor drawn reversible double mouldboard plough followed by passing rigid tyne cultivator and rotovator for clod crushing and weed removal. Then the plots of 3.6 m width and 4.5 m length were laid out and separated by bunds of 60 cm width as per the plan making provision for irrigation channels.

3.6.2 Planting material and its preparation

The plants were uprooted and white stolons of uniform thickness were separated. They were cut into of 7.0 to 10.0 cm long cuttings having 2-3 nodes and dipped in 0.3 per cent COC for 5-10 minutes before planting.

3.6.3 Method of planting

The furrows were opened at 45 cm interval in each plot. Prepared stolons were placed horizontally in mid of furrows at 30 cm spacing, at a depth of 2.5 to 4.0 cm and later covered with soil. The seed rate followed was 400 kg of stolons per hectare.

3.6.4 Spray of herbicides

Oxyfluorfen and metribuzin was sprayed as pre-emergence (2 DAP) on 10th July, 2017 and metribuzin and quizalofop-ethyl was sprayed as post-emergence (30 DAP) on 08th August, 2017. The spraying was done with knapsack sprayer fitted with flood-jet type nozzle. The quantity of water used was 1000 litres per hectare.

3.6.5 Mulch application

The organic mulch of sugarcane trash (5 t/ha) was applied to plots according to treatments 30 days after planting.

3.6.6 Application of manures and fertilizers

The experimental plots were provided with the calculated quantity of fertilizers. FYM was applied (32.40 kg/plot) during land preparation. Phosphorous and potassium fertilizers at the rate of 60 kg each per hectare in the form of SSP and MOP respectively were uniformly applied to all the plots as basal dose. Nitrogen fertilizer at the rate of 150 kg per hectare in the form of urea top dressed in three split doses at 30, 60 and 90 days after planting. The fertilizer mixture was applied by broadcasting uniformly in rows to individual plots and mixed thoroughly in to the soil.

3.6.7 Irrigation and aftercare

Irrigation was given immediately after planting and subsequent irrigations were given at eight to ten days intervals depending on the rainfall and soil moisture.

3.6.8 Hand Weeding

Hand weeding was done at an interval of 15 days intervals from planting to harvest.

3.6.9 Inter-cultivation:

Inter-cultivation is done manually at 15 days intervals up to 45 days.

3.6.10 Plant Protection

Incidence of few insect pests like hadda betel, chafer betel and sucking pests were observed in the initial stages of crop growth. The intensity of incidence was not serious. The pest was controlled by spraying indoxicarb (1 ml/L).

3.6.11 Harvesting

The crop was harvested at 120 days after planting in *kharif*, when the crop was at fifty per cent flowering. The plants were cut 1 to 4 cm from the ground level by using sharpe sickle in the late morning to get more percentage of oil in the leaves.

3.7 Observations

3.7.1 Weed parameter

3.7.1.1 Weed flora

The different weed species are observed in the experimental plot by visually. The dominant weeds species present in menthol mint plot are presented in table 2.

3.7.1.2 Weed density (number/m^2)

The species-wise number of weeds were counted from two randomly selected spots (100 cm × 100 cm quadrets) in each plot. Count were taken before first hand weeding (30 DAP), 45, 60, 90 days after planting and at harvest.

3.7.1.3 Weed biomass (g/m^2)

For fresh weight and dry matter accumulation, weed samples were taken at 30, 45, 60, 90 days after planting and at harvest from two randomly selected spots (100 cm × 100 cm quadrets) in each plot. The weed samples were collected in separate bags and were weighed for fresh weight and then dried in oven at 60^{o}C till constant weight.

3.7.2 Growth parameters

Observations on growth parameters were recorded on five randomly selected plants in each replication of different treatments at 30, 45, 60, 90 days after planting and at harvest.

3.7.2.1 Plant height (cm)

Plant height was measured from the ground level to the growing tip of the main stem and expressed in centimeter.

3.7.2.2 Plant spread (cm)

The plant spread was taken in N-S and E-W direction from five tagged plants at 30, 45, 60, 90 days after planting and at harvest. The mean value of five selected plants was considered as plant spread and expressed in centimeter.

3.7.2.3 Number of branches (number/plant)

Branches arising from main stem from five randomly selected plants were counted at 30, 45, 60, 90 days after planting and at harvest and mean was expressed as number of branches per plant.

3.7.3 Physiological parameters

3.7.3.1 Leaf to stem ratio

Observations on leaf to stem ratio were recorded on five randomly selected plants in each replication of different treatments at harvest. Leaves and stems were separated manually. Weight of leaves and stems were taken separately after drying under sun and then in oven at 60°C temperature till a constant weight achieved. The leaf to stem ratio was calculated on dry weight basis as given below:

$$\text{Leaf to stem ratio} = \frac{\text{Leaf weight (g)}}{\text{Stem weight (g)}}$$

3.7.3.2 Leaf area (cm^2)

The leaf area was calculated on five randomly selected plants by using Biovis instrument at harvest. The average was expressed as leaf area in cm^2.

3.7.3.3 Total dry matter accumulation at harvest (g/plant)

The selected five plants were uprooted from soil and the different plant parts like leaves, stem and roots were separated and dried in oven for 15 hours at 60°C. The average weight of leaves, stem and roots per plant was weighed on balance and expressed in grams.

3.7.4 Biochemical parameter

3.7.4.1 Estimation of chlorophyll content (mg/g)

Total chlorophyll, chlorophyll “a” and chlorophyll “b” content were determined by following DMSO method at 3 days after pre and post emergent herbicidal sprays. Third fully expanded leaf from the top was brought in polyethylene bags from the field and was cut in to small pieces. The known weight of leaves kept in test tube containing 7.0 ml of dimethyl sulphoxide (DMSO). The test tube incubated at 65°C for 30 minutes. Later leaf residue was removed by decanting the solution and final volume was made in 10 ml with DMSO. The absorbance of the extract was measured at 645, 663 and 440 nm in a UV- visible spectrophotometer (Elico, SL - 159) and a blank was run using DMSO. The total chlorophyll, chlorophyll “a” and chlorophyll “b” contents were calculated by using the following formula and expressed in mg per g fresh weight.

Calculation:

The amount of chlorophyll present in the extract (mg chlorophyll content per gram tissue) was calculated by using the equations given by Arnon (1949).

$$\text{mg chlorophyll a per g tissue} = 12.7\,(A663) - 2.69\,(A645) \times \frac{v}{1000 \times w \times a}$$

$$\text{mg chlorophyll b per g tissue} = 22.9\,(A645) - 4.68\,(A663) \times \frac{v}{1000 \times w \times a}$$

$$\text{mg total chlorophyll per g tissue} = 20.2\,(A645) + 8.02\,(A663) \times \frac{v}{1000 \times w \times a}$$

Whereas,

A = absorbance at specific wavelengths

v = final volume of chlorophyll extracted (ml)

w = fresh weight of the sample (mg)

a = path length of light (1 cm)

3.7.5 Recording the toxicity symptom

The data on toxicity symptoms of herbicides were recorded based on visivual observation after both pre and post emergent herbicidal sprays.

3.7.6 Yield parameters

3.7.6.1 Fresh herbage yield (g/plant)

Five labeled plants were selected for recording fresh yield at the time of harvest and their fresh weight was recorded and means weight was calculated and expressed in grams.

3.7.6.2 Fresh herbage yield (kg/plot)

All the plants from net plot area were cut at the ground level and weighed to calculate fresh herbage yield and expressed in kilograms per plot.

3.7.6.3 Fresh herbage yield (t/ha)

The fresh herbage yield was recorded in each plot at the time of harvest. Then fresh yield per hectare was calculated on the basis of fresh herbage yield per plot. The fresh herbage yield per hectare was expressed in tonnes.

3.7.6.4 Shade dried herbage yield (g/plant)

The plants used for fresh herb per plant yield at harvest were dried in shade for 3-4 hours. The sample dry herb weights were recorded and summed up to arrive at mean shade herbage yield per plant and expressed in grams.

3.7.6.5 Shade dried herbage yield (kg/plot)

The fresh herb at harvest from net plot was cut close to ground and dried in shade for 3-4 hours. The shade dried herbage weight recorded was expressed in kilograms.

3.7.6.6 Shade dried herbage yield (t/ha)

The shade dried herbage yield was recorded in each net plot at the time of harvest. Then shade dried yield per hectare was calculated on the basis of shade dried herbage yield per plot and was expressed in tonnes

3.7.7 Quality parameters

3.7.7.1 Essential oil yield (kg/ha) and oil content (%)

Known weight of fresh herbage from each plot was taken and withered for few hours in shade. The plant material was chopped into small pieces and essential oil extraction was done by hydro-steam distillation method using essential oil extraction unit of 10 kg capacity (CSIR – Institute of Himalayan Bioresource Technology patented technology). Essential oil content was estimated on fresh weight basis by using following formula and expressed in per cent.

$$\text{Oil content (\%)} = \frac{\text{Weight of oil/plot (g)}}{\text{Weight of fresh herb/plot (g)}} \times 100$$

3.7.7.2 Menthol content (%)

Menthol content was estimated by using gas chromatography and expressed in percentage.

3.8 Soil analysis

3.8.1 Soil pH

The pH of the soil was recorded by using combined electrode pH meter as suggested by Jackson (1967). The soil and water ratio of 1:2.5 was used for pH measurement.

3.8.2 Electrical conductivity

Electrical conductivity was measured in soil and water suspension (1:2.5) with the help of salt bridge or solo bridge (conductivity meter) following the method given by Jackson (1973) and expressed in dS/m^2.

3.8.3 Organic carbon

Organic carbon percentage in the soil was estimated by Walkley and Black wet oxidation method described by Jackson (1973) and expressed in percentage.

3.8.4 Available nitrogen

The available nitrogen in the soil was determined by Modified Kjeldal's method as suggested by Subbaiah and Asija (1956) and expressed in kilogram per hectare.

3.8.5 Available phosphorus

The method suggested by Muhr *et al*. (1963) was employed for determination of available phosphorus and expressed in kilogram per hectare.

3.8.6 Available potassium

This was extracted with neutral normal ammonium acetate and the quality was determined by using Flame photometer as suggested by Muhr *et al*. (1963) and expressed in kilogram per hectare.

3.9 Economics

3.9.1 Cost of cultivation (` /ha)

The price of the inputs that were prevailing during July 2017 to November 2017 was considered for working out the economics of the different weed management practices. Cost of cultivation was computed as per treatments.

3.9.1 Gross returns (` /ha)

Gross returns were worked out based on the market price of the produce multiplied by oil yield per hectare.

3.9.2 Net returns (` /ha)

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

Net returns = Gross returns – Cost of cultivation

3.9.3 Cost: benefit ratio

The Cost: benefit ratio was worked out by using the formula:

$$C: B = \frac{\text{Gross returns (` /ha)}}{\text{Cost of cultivation (` /ha)}}$$

3.10 Statistical analysis of data

Fisher method of analysis of variance as given by Panse and Sukhatme (1967) was applied for analysis and interpretation of data. The level of significance used in ‘F’ test was at P = 0.05 and critical difference (CD) values were worked out wherever ‘F’ test was significant.

3.10.a Transformation of data

Data on weed density, weed fresh and dry weight have shown high degree of variation. A relationship between the means and variance was observed. Therefore, the data on these weed parameters were subjected to square root transformation (vx+0.5). Transformation to make analysis of variance more valid as suggested by Chandel (1984).

4. EXPERIMENTAL RESULTS

The investigation on "Integrated weed management in menthol mint (*Mentha arvensis* L.)" was undertaken during *kharif* 2017 at Department of Plantation, Spices, Medicinal and Aromatic Crops, Kittur Rani Channamma College of Horticulture, Arabhavi. The results obtained during the investigation are presented in this chapter.

4.1 Weed parameters

4.1.1 Weed flora

The important weeds belonging to grasses, sedges and broad-leaved groups observed in experimental area at different stages of crop are given in Table 2. The important grasses are (*Cynodon dactylon*, *Digitaria marginata*, *Digitaria sanguinalis*, *Eleusina indica*), sedges (*Cyperus rotundus*) and broad leaved (*Ageratum conyzoides*, *Amaranthus viridis*, *Euphorbia hirta*, *Malvastrum coromondelianum*, *Parthenium hysterophorus*, *Rumex denticulate* and *Melilotus alba*) weed species were observed in menthol mint. Most of the *kharif* season weeds were observes in the experimental area. Among the different weeds, *Cyperus rotundus*, *Parthenium hysterophorus*, *Cynodon dactylon* and *Digitaria marginata* were dominant.

4.1.2 Weed Density (number/m^2)

The data on weed density as influenced by different weed management practices in menthol mint are presented in table 3.

At all the stages of crop growth the weed density differs significantly. At 30, 45, 60, 90 DAP and at harvest, the significantly lowest weed density (5.66, 16.33, 33.66, 32.00 and 31.33/m^2, respectively) were recorded in PE application of oxyfluorfen @ 0.25 kg a.i./ha (T_5). PE application of oxyfluorfen @ 0.25 kg a.i./ha followed by inter-cultivation (T_{10}) (6.00, 18.66, 37.00, 34.33 and 32.33/m^2, respectively) and organic mulch with sugarcane trash @ 5 t/ha (T_3) (6.33, 20.33, 39.33, 35.00 and 34.33/m^2, respectively) were *on par* with PE application of oxyfluorfen @ 0.25 kg a.i./ha (T_5) and significantly highest weed density (90.00, 111.66, 157.00, 168.66 and 172.66/m^2, respectively) were recorded in un-weeded treatment (T_{12}).

Table 2: The common weeds noticed in the experimental site.

Sl. No.	WEED SPECIES	FAMILY
A Grassy weeds		
1	*Cynodon dactylon*	Poaceae
2	*Digitaria marginata*	Poaceae
3	*Digitaria sanguinalis*	Poaceae
4	*Eleusine indica*	Poaceae
B Sedges		
5	*Cyperus rotundus*	Cyperaceae
C Broad leaved weeds		
6	*Abutilon indicum*	*Malvaceae*
7	*Acanthospermum hispidum*	Compositae
8	*Ageratum conyzoides*	Asteraceae
9	Alternanthera sessilis	Compositae
10	*Amaranthus viridis*	Amaranthaceae
11	Anagallis arvensis	Primulaceae
12	*Chenopodium album*	Amaranthaceae
13	*Digera arvensis*	Amaranthaceae
14	*Euphorbia hirta*	Euphorbiaceae
15	*Euphorbia thymipholia*	Euphorbiaceae
16	*Helicabamum cardiospurmum*	Sapindaceae
17	*Ipomea spp.*	Convolvulaceae
18	*Malvastrum coromondelianum*	Malvaceae
19	*Melilotus alba*	Fabaceae
20	*Mimosa pudica*	Fabaceae
21	*Parthenium hysterophorus*	Asteraceae
22	*Phyllanthus urinaria*	Euphorbiaceae
23	*Portulaca oleraceae*	Portulaceae
24	*Psoralea corylifolia*	Fabaceae
25	*Rumex denticulate*	Polygonaceae
26	*Scarlet pimpernel*	Primulaceae
27	*Sida acuta*	Fabaceae
28	*Solanum nigrum*	Solanaceae
29	*Triumfetta rhomboidea*	Tiliaceae
30	*Verbascum nicotinifolia*	Scrophularaceae
31	*Vernonia cinerea*	Compositae
32	*Xanthium strumarium*	Compositae

Table 3: Weed density (number/m^2) of menthol mint as influenced by different weed management practices

Treatments	Dose (kg a.i./ha)	Weed density (Days after planting)				
		30	45	60	90	At harvest
T_1: Hand weeding	15 days intervals	12.66 (3.55)	22.66 (4.75)	42.66 (6.53)	43.00 (6.55)	41.660 (6.45)
T_2: Inter-cultivation	15 days intervals	14.33 (3.77)	23.00 (4.79)	41.33 (6.42)	42.33 (6.50)	41.330 (6.42)
T_3: Sugarcane trash mulch	5 t/ha (30 DAP)	06.33 (2.50)	20.33 (4.50)	39.33 (6.27)	35.00 (5.90)	34.330 (5.84)
T_4: Metribuzin (PE)	0.70	39.33 (6.24)	70.33 (8.37)	91.66 (9.57)	97.66 (9.88)	105.66 (10.26)
T_5: Oxyfluorfen (PE)	0.25	05.66 (2.35)	16.33 (4.00)	33.66 (5.79)	32.00 (5.64)	31.330 (5.58)
T_6: Oxyfluorfen (Pre) + Metribuzin (POE)	0.25 and 0.70	14.00 (3.74)	29.66 (5.44)	59.00 (7.67)	50.66 (7.11)	48.660 (6.97)
T_7: Metribuzi (PE) + Quizalofop-ethyl (POE)	0.70 and 0.05	27.00 (5.19)	63.66 (7.97)	86.66 (9.30)	89.66 (9.46)	94.000 (9.69)
T_8: Oxyfluorfen (PE) + Quizalofop-ethyl (POE)	0.25 and 0.05	16.66 (4.07)	27.66 (5.24)	63.00 (7.93)	60.00 (7.74)	58.660 (7.65)
T_9: Oxyfluorfen (PE) + Metribuzin (POE) + Quizalofop-ethyl (POE)	0.25, 0.70 and 0.05	20.33 (4.48)	40.00 (6.32)	65.33 (8.08)	63.33 (7.95)	62.660 (7.91)
T_{10}: Oxyfluorfen (PE) + Inter-cultivation	0.25 + At 45 DAP	06.00 (2.44)	18.66 (4.31)	37.00 (6.08)	34.33 (5.85)	32.330 (5.68)
T_{11}: Metribuzin (PE) + Inter-cultivation	0.70 + At 45 DAP	19.00 (4.35)	46.33 (6.80)	78.66 (8.86)	81.33 (9.01)	80.660 (8.96)
T_{12}: Un-weeded (control)	-	90.00 (9.48)	111.66 (10.56)	157.00 (12.47)	168.66(12.93)	172.66 (13.09)
S.Em ±		**02.27 (0.21)**	**02.50 (0.19)**	**06.64 (0.28)**	**06.83 (0.28)**	**07.100 (0.30)**
CD at 5%		**06.66 (0.63)**	**07.34 (0.58)**	**19.48 (0.84)**	**20.00 (0.85)**	**20.830 (0.90)**

PE- Pre-emergent (2DAP) POE- Post-emergent (30 DAP)
Figures in parenthesis are indicating transformed values (vx+1).

4.1.3 Fresh weight of weeds (g/m^2)

The data on fresh weight of weeds as influenced by different weed management practices in menthol mint are presented in table 4.

The data on fresh weight of weeds differs significantly at 30, 45 and 60 DAP. Among all the weed management treatments, PE application of oxyfluorfen @ 0.25 kg a.i./ha (T_5) was recorded significantly minimum weed fresh weight (23.33, 35.66, and 60.00 g/m^2, respectively) which was significantly superior than all other weed control treatments. PE application of oxyfluorfen @ 0.25 kg a.i./ha followed by inter-cultivation (T_{10}) (25.66, 41.66 and 62.00 g/m^2, respectively), organic mulch with sugarcane trash @ 5 t/ha (T_3) (27.33, 42.66 and 69.66 g/m^2, respectively), hand weeding (T_2) (34.00, 43.33 and 87.66 g/m^2, respectively) and inter-cultivation (T_1) (34.66, 44.00 and 77.00 g/m^2, respectively) were recorded on par with (T_5). Un-weeded control (T_{12}) was recorded significantly highest weed fresh weight (201.66, 220.00 and 317.66 g/m^2, respectively).

Similarly at 90 DAP and at harvest significantly lowest weed fresh weight (58.66 and 58.33 g/m^2, respectively) was recorded in PE application of oxyfluorfen @ 0.25 kg a.i./ha (T_5) which was *on par* with PE application of oxyfluorfen @ 0.25 kg a.i./ha followed by inter-cultivation (T_{10}) (60.00 and 59.00 g/m^2, respectively), organic mulch with sugarcane trash @ 5 t/ha (T_3) (67.66 and 67.33 g/m^2, respectively), inter-cultivation (T_2) (75.00 and 74.00 g/m^2, respectively), hand weeding (T_1) (83.00 and 81.66 g/m^2, respectively) and PE application of oxyfluorfen @ 0.25 kg/ha followed by POE application of metribuzin 0.70 kg a.i./ha (T_6) (99.0 and 94.66 g/m^2, respectively) as compared to other different weed management practices. Un-weeded control (T_{12}) was recorded significantly highest weed fresh weight (621.00 and 1031.33 g/m^2, respectively).

4.1.4 Dry weight of weeds (g/m^2)

The dry weight of weeds as influenced by different weed management practices in menthol mint indicated that significant differences at all the stages of crop growth are presented in table 5.

Table 4: Fresh weight of weeds (g/m^2) of menthol mint as influenced by different weed management practices

Treatments	Dose (kg a.i./ha)	Weed fresh weight (Days after planting)				
		30	**45**	**60**	**90**	**At harvest**
T_1: Hand weeding	15 days intervals	34.00 (5.82)	43.33 (6.58)	87.66 (9.35)	83.00 (9.10)	81.66 (9.02)
T_2: Inter-cultivation	15 days intervals	34.66 (5.87)	44.00 (6.63)	77.00 (8.77)	75.00 (8.66)	74.00 (8.60)
T_3: Sugarcane trash mulch	5 t/ha (30 DAP)	27.33 (5.22)	42.66 (6.52)	69.66 (8.34)	67.66 (8.22)	67.33 (8.20)
T_4: Metribuzin (PE)	0.70	131.00 (11.43)	152.66 (12.35)	189.66 (13.77)	430.33 (20.74)	623.66 (24.91)
T_5: Oxyfluorfen (PE)	0.25	23.33 (4.81)	35.66 (5.92)	60.00 (7.74)	58.66 (7.65)	58.33 (7.62)
T_6: Oxyfluorfen (Pre) + Metribuzin (POE)	0.25 and 0.70	38.00 (6.16)	56.66 (7.52)	100.00 (9.99)	99.00 (9.94)	94.66 (9.72)
T_7: Metribuzi(PE) + Quizalofop-ethyl (POE)	0.70 and 0.05	101.66 (10.06)	126.33 (11.23)	175.66 (13.25)	319.33 (17.86)	453.33 (21.28)
T_8: Oxyfluorfen (PE) + Quizalofop-ethyl (POE)	0.25 and 0.05	37.33 (6.10)	63.33 (7.95)	133.33 (11.54)	129.66 (11.38)	126.66 (11.25)
T_9: Oxyfluorfen (PE) + Metribuzin (POE) + Quizalofop-ethyl (POE)	0.25, 0.70 and 0.05	42.33 (6.50)	81.33 (9.01)	118.33 (10.87)	115.66 (10.75)	115.33 (10.73)
T_{10}: Oxyfluorfen (PE) + Intercultivation	0.25 + At 45 DAP	25.66 (5.06)	41.66 (6.44)	62.00 (7.87)	60.00 (7.74)	59.00 (7.67)
T_{11}: Metribuzin (PE) + Inter-cultivation	0.70 + At 45 DAP	47.66 (6.90)	98.33 (9.91)	161.33 (12.69)	295.33 (17.17)	155.66 (12.22)
T_{12}: Un-weeded (control)	-	201.66 (14.19)	220.00 (14.8)	317.66 (17.74)	621.00 (24.85)	1031.33 (32.09)
S.Em ±		**4.56 (0.22)**	**5.86 (0.25)**	**12.10 (0.33)**	**19.07 (0.40)**	**26.93 (0.65)**
CD at 5%		**13.32 (0.66)**	**17.19 (0.74)**	**35.50 (0.98)**	**55.95 (1.19)**	**79.00 (1.92)**

PE- Pre-emergent (2DAP) POE- Post-emergent (30 DAP)
Figures in parenthesis are indicating transformed values (vx+1).

Table 5: Dry weight of weeds (g/m^2) of menthol mint as influenced by different weed management practices

Treatments	Dose (kg a.i./ha)	Weed dry weight (Days after planting)				
		30	**45**	**60**	**90**	**At harvest**
T_1: Hand weeding	15 days intervals	14.77 (2.54)	15.33 (3.91)	25.66 (5.06)	24.33 (4.93)	22.00 (4.68)
T_2: Inter-cultivation	15 days intervals	15.14 (2.60)	23.00 (4.78)	27.66 (5.25)	25.66 (5.06)	24.00 (4.89)
T_3: Sugarcane trash mulch	5 t/ha (30 DAP)	10.76 (1.86)	12.33 (3.51)	25.00 (4.98)	22.66 (4.76)	22.00 (4.68)
T_4: Metribuzin (PE)	0.70	29.52 (4.92)	49.33 (7.02)	68.66 (8.28)	85.66 (9.25)	87.33 (9.33)
$T_{5:}$ Oxyfluorfen (PE)	0.25	7.94 (1.38)	5.66 (2.37)	23.66 (4.85)	20.00 (4.47)	19.00 (4.35)
T_6: Oxyfluorfen (Pre) + Metribuzin (POE)	0.25 and 0.70	12.28 (2.12)	16.33 (4.03)	31.00 (5.56)	29.66 (5.44)	28.33 (5.32)
T_7: Metribuzi (PE) + Quizalofop-ethyl (POE)	0.70 and 0.05	25.09 (4.24)	44.66 (6.67)	57.33 (7.56)	57.66 (7.58)	60.66 (7.78)
T_8: Oxyfluorfen (PE) + Quizalofop-ethyl (POE)	0.25 and 0.05	16.02 (2.75)	24.33 (4.93)	33.00 (5.73)	31.33 (5.59)	30.66 (5.52)
T_9: Oxyfluorfen (PE) + Metribuzin (POE) + Quizalofop-ethyl (POE)	0.25, 0.70 and 0.05	17.44 (2.99)	40.00 (6.31)	38.00 (6.15)	34.33 (5.84)	33.33 (5.75)
T_{10}: Oxyfluorfen (PE) + Intercultivation	0.25 + At 45 DAP	9.35 (1.62)	11.33 (3.36)	24.66 (4.95)	21.00 (4.58)	20.00 (4.47)
T_{11}: Metribuzin (PE) + Inter-cultivation	0.70 + At 45 DAP	21.96 (3.74)	43.33 (6.57)	45.66 (6.75)	45.00 (6.70)	43.00 (6.55)
T_{12}: Un-weeded (control)	-	36.85 (5.99)	64.0 (7.98)	109.66 (10.45)	124.66 (11.14)	140.33 (11.81)
S.Em ±		**1.15 (0.18)**	**2.17 (0.17)**	**3.05 (0.18)**	**13.17 (0.178)**	**4.41 (0.22)**
CD at 5%		**3.38 (0.55)**	**6.36 (0.48)**	**8.96 (0.53)**	**9.70 (0.53)**	**12.94 (0.66)**

PE- Pre-emergent (2DAP) POE- Post-emergent (30 DAP)
Figures in parenthesis are indicating transformed values (vx+1).

At 30 and 45 DAP, PE application of oxyfluorfen @ 0.25 kg a.i./ha (T_5) (7.94 and 5.66 g/m^2, respectively) was recorded significantly lowest weed dry weight and which was *on par* with PE application of oxyfluorfen @ 0.25 kg a.i./ha followed by inter-cultivation (T_{10}) (9.35 and 11.33 g/m^2, respectively) and organic mulch with sugarcane trash @ 5 t/ha (T_3) (10.76 and 12.33 g/m^2, respectively). Un-weeded control (T_{12}) recorded significantly highest weed dry weight (36.85 and 64.99 g/m^2, respectively).

At 60, 90 DAP and at harvest, PE application of oxyfluorfen @ 0.25 kg a.i./ha (T_5) (23.66, 20.00 and 19.00 g/m^2, respectively) recorded significantly the lowest weed dry weight and which was *on par* with PE application of oxyfluorfen @ 0.25 kg a.i./ha integrated with inter-cultivation (T_{10}) (24.66, 21.00 and 20.00 g/m^2, respectively), organic mulch with sugarcane trash @ 5 t/ha (T_3) (25.00, 22.66 and 22.00 g/m^2, respectively), inter-cultivation (T_2) (27.66, 25.66 and 24.00 g/m^2, respectively), hand weeding (T_1) (25.66, 24.33 and 22.00 g/m^2, respectively) as compared to un-weeded control (T_{12}) which recorded significantly highest weed dry weight (109.66, 124.66 and 140.33 g/m^2, respectively).

4.2 Growth parameters of menthol mint

4.2.1 Plant heights (cm)

The data recorded on plant height at 30, 45, 60, 90 DAP and at harvest as presented in table 6 revealed that different weed management practices had shown significant variation in plant height when observed at 90 days after planting (DAP) and at harvesting stage.

Significantly the highest plant height of 63.66 and 68.80 cm was recorded in organic mulch with sugarcane trash @ 5 t/ha (T_3) which was *on par* with PE application of oxyfluorfen @ 0.25 kg a.i./ha (T_5) (62.33 and 68.00 cm, respectively), PE application of oxyfluorfen @ 0.25 kg a.i./ha followed by inter-cultivation (T_{10}) (61.33 and 67.06 cm, respectively), un-weeded (T_{12}) (60.33 and 64.33 cm, respectively) and hand weeding (T_1) (57.33 and 61.68 cm, respectively) compared other different weed management practices. The significantly lowest plant height of

Table 6: Plant height (cm) of menthol mint as influenced by different weed management practices

Treatments	Dose (kg a.i./ha)	Plant height (Days after planting)				
		30	45	60	90	At harvest
T_1: Hand weeding	15 days intervals	22.53	37.13	51.57	57.33	61.68
T_2: Inter-cultivation	15 days intervals	20.43	36.33	54.24	61.00	63.84
T_3: Sugarcane trash mulch	5 t/ha (30 DAP)	19.33	36.66	53.11	63.66	68.80
T_4: Metribuzin (PE)	0.70	17.03	37.66	50.00	51.66	61.66
T_5: Oxyfluorfen (PE)	0.25	20.00	37.66	55.06	62.33	68.00
T_6: Oxyfluorfen (Pre) + Metribuzin (POE)	0.25 and 0.70	17.40	35.33	50.80	58.00	64.75
T_7: Metribuzi(PE) + Quizalofop-ethyl (POE)	0.70 and 0.05	15.53	35.02	51.35	57.33	64.66
T_8: Oxyfluorfen (PE) + Quizalofop-ethyl (POE)	0.25 and 0.05	17.73	35.53	52.02	55.00	62.33
T_9: Oxyfluorfen (PE) + Metribuzin (POE) + Quizalofop-ethyl (POE)	0.25, 0.70 and 0.05	17.46	36.66	47.68	58.33	63.97
T_{10}: Oxyfluorfen (PE) + Intercultivation	0.25 + At 45 DAP	18.66	35.33	57.86	61.33	67.06
T_{11}: Metribuzin (PE) + Inter-cultivation	0.70 + At 45 DAP	15.46	35.66	50.57	49.00	61.2
T_{12}: Un-weeded (control)	-	20.06	37.66	54.64	60.33	64.33
S.Em ±		**1.05**	**1.63**	**1.41**	**2.60**	**1.53**
CD at 5%		**NS**	**NS**	**NS**	**7.64**	**4.51**

PE- Pre-emergent (2DAP) POE- Post-emergent (30 DAP)

49.00 and 61.20 cm was recorded in PE application of metribuzin 0.70 kg a.i./ha followed by inter-cultivation (T_{11}) compared to un-weeded control (T_{12}).

4.2.2 Number of branches per plant

The data pertaining to the number of branches per plant at different stages of crop growth as influenced by different weed management practices are presented in table 7. When the observations were taken at 30 DAP, the differences in number of branches were found to be non-significant under the influence of all the weed management practices.

Number of branches differs significantly at 45, 60, 90 DAP and at harvest. The maximum numbers of branches per plant were recorded in PE application of oxyfluorfen @ 0.25 kg a.i./ha (T_5) (24.48, 48.68, 50.66 and 55.33/plant, respectively) followed by hand weeding (T_1) (21.28, 40.13, 41.66 and 51.33/plant, respectively) and organic mulch with sugarcane trash @ 5 t/ha (T_3) (19.28, 38.58, 39.83 and 45.66/plant, respectively). The significantly minimum numbers of branches were recorded in un-weeded control (T_{12}) (13.81, 28.4, 27.33 and 26.0/plant, respectively).

4.2.3 Plant spread (NS-EW) (cm)

The data pertaining to the plant spread (NE-EW) at different stages of crop growth as influenced by different weed management practices are presented in table 8. The plant spread varies significantly with different weed management practices at all the stages of crop growth.

At 30, 45, 60, 90 DAP and at harvest, significantly the maximum plant spread was observed in PE application of oxyfluorfen @ 0.25 kg a.i./ha (T_5) (33.29, 41.4, 66.96, 75.28 and 77.5 cm, respectively) which was followed by PE application of oxyfluorfen @ 0.25 kg a.i./ha followed by inter-cultivation (T_{10}) (25.52, 36.0, 58.66, 63.5 and 67.16 cm, respectively) and organic mulch with sugarcane trash @ 5 t/ha (T_3) (25.33, 35.56, 58.33, 62.83 and 66.66 cm, respectively). Significantly minimum plant spread was recorded in un-weeded control (T_{12}) (18.03, 21.20, 48.03, 33.33 and 33.66 cm, respectively).

Table 7: Number of branches of menthol mint as influenced by different weed management practices

Treatments	Dose (kg a.i./ha)	Number of branches (Days after planting)				
		30	45	60	90	At harvest
T_1: Hand weeding	15 days intervals	3.70	21.28	40.13	41.66	51.33
T_2: Inter-cultivation	15 days intervals	3.33	17.66	35.63	36.00	43.00
T_3: Sugarcane trash mulch	5 t / ha (30 DAP)	4.80	19.28	38.58	39.83	45.66
T_4: Metribuzin (PE)	0.70	3.36	15.93	29.61	29.00	28.00
T_5: Oxyfluorfen (PE)	0.25	4.83	24.48	48.68	50.66	55.33
T_6: Oxyfluorfen (Pre) + Metribuzin (POE)	0.25 and 0.70	4.90	18.33	34.28	33.00	32.00
T_7: Metribuzi (PE) + Quizalofop-ethyl (POE)	0.70 and 0.05	3.63	16.95	30.55	30.00	29.16
T_8: Oxyfluorfen (PE) + Quizalofop-ethyl (POE)	0.25 and 0.05	4.56	17.66	33.93	32.00	31.00
T_9: Oxyfluorfen (PE) + Metribuzin (POE) + Quizalofop-ethyl (POE)	0.25, 0.70 and 0.05	4.80	17.40	34.95	32.66	32.16
T_{10}: Oxyfluorfen (PE) + Intercultivation	0.25 + At 45 DAP	4.36	18.28	36.28	37.66	43.66
T_{11}: Metribuzin (PE) + Inter-cultivation	0.70 + At 45 DAP	4.60	17.33	32.00	31.00	30.33
T_{12}: Un-weeded (control)	-	3.93	13.81	28.40	27.33	26.00
S.Em ±		**0.24**	**0.49**	**1.30**	**1.95**	**1.31**
CD at 5%		**NS**	**1.46**	**3.81**	**5.726**	**3.84**

PE- Pre-emergent (2DAP) POE- Post-emergent (30 DAP)

Table 8: Plant spread (NS-EW in cm) of menthol mint as influenced by different weed management practices

Treatments	Dose (kg a.i./ha)	Plant spread (Days after planting)				
		30	45	60	90	At harvest
T_1: Hand weeding	15 days intervals	25.09	34.60	57.55	62.50	64.50
T_2: Inter-cultivation	15 days intervals	23.26	33.00	55.80	56.83	59.33
T_3: Sugarcane trash mulch	5 t/ha (30 DAP)	25.33	35.56	58.33	62.83	66.66
T_4: Metribuzin (PE)	0.70	21.34	21.96	48.46	36.16	37.25
$T_{5:}$ Oxyfluorfen (PE)	0.25	33.29	41.40	66.96	75.28	77.50
T_6: Oxyfluorfen (Pre) + Metribuzin (POE)	0.25 and 0.70	22.99	30.10	55.13	54.58	48.50
T_7: Metribuzi (PE) + Quizalofop-ethyl (POE)	0.70 and 0.05	19.61	24.06	51.73	39.75	40.16
T_8: Oxyfluorfen (PE) + Quizalofop-ethyl (POE)	0.25 and 0.05	21.46	28.16	55.10	53.58	47.33
T_9: Oxyfluorfen (PE) + Metribuzin (POE) + Quizalofop-ethyl (POE)	0.25, 0.70 and 0.05	22.73	29.33	53.16	52.60	52.50
T_{10}: Oxyfluorfen (PE) + Intercultivation	0.25 + At 45 DAP	25.52	36.00	58.66	63.50	67.16
T_{11}: Metribuzin (PE) + Inter-cultivation	0.70 + At 45 DAP	19.43	26.06	52.20	41.33	40.90
T_{12}: Un-weeded (control)	-	18.03	21.20	48.03	33.33	33.66
S.Em ±		**1.10**	**1.23**	**1.87**	**1.76**	**2.75**
CD at 5%		**3.22**	**3.62**	**5.51**	**5.16**	**8.07**

PE- Pre-emergent (2DAP) POE- Post-emergent (30 DAP)

4.3 Physiological parameters

4.3.1 Leaf to stem ratio

Data on leaf to stem ratio of menthol mint due to different management practices are furnished in table 9. The leaf to stem ratio of menthol mint at harvest did not showed any significant difference with respect to different weed management practices.

4.3.2 Total Leaf area (cm^2)

The observation on leaf area of menthol mint as influenced by different weed management practices are presented in the table 9. The total leaf area differs significantly at harvest. Significantly the maximum leaf area was recorded in PE application of oxyfluorfen @ 0.25 kg a.i./ha (T_5) (5279.54 cm^2) which was *on par* with PE application of oxyfluorfen @ 0.25 kg a.i./ha followed by inter-cultivation (T_{10}) (4629.35 cm^2) and organic mulch with sugarcane trash @ 5 t/ha (T3) (4532.29 cm^2). The significantly minimum total leaf area (1769.14 cm^2) was recorded in un-weeded control (T_{12}).

4.3.3 Dry matter accumulation (g/plant)

The effect of different weed management practices had significant difference on dry matter accumulation of menthol mint at harvest and presented in table 9. PE application of oxyfluorfen @ 0.25 kg a.i./ha (T_5) recorded significantly the higher dry matter accumulation (54.78 g/plant) which was *on par* with PE application of oxyfluorfen @ 0.25 kg a.i./ha followed by inter-cultivation (T_{10}) (51.18 g/plant) and organic mulch with sugarcane trash @ 5 t/ha (T_3) (51.0 g/plant). The significantly minimum dry matter accumulation was recorded in un-weeded control (T_{12}) (30.42 g/plant).

4.4 Biochemical parameters

4.4 Chlorophyll content (mg/g of tissue)

The data on chlorophyll content recorded at 3 days after PE and POE herbicidal sprays are presented in table 10. The chlorophyll b content did not vary significantly with different weed management practices.

Table 9: Leaf to stem ratio, leaf area and dry matter accumulation of menthol mint as influenced by different weed management practices

Treatments	Dose (kg a.i./ha)	Leaf to stem ratio	Leaf area in (cm^2)	Dry matter accumulation (g)
		(At harvest)		
T_1: Hand weeding	15 days intervals	0.99	4502.85	48.31
T_2: Inter-cultivation	15 days intervals	0.98	4264.75	50.33
T_3: Sugarcane trash mulch	5 t/ha (30 DAP)	0.97	4532.29	51.00
T_4: Metribuzin (PE)	0.70	1.05	2069.62	35.04
T_5: Oxyfluorfen (PE)	0.25	1.00	5279.54	54.78
T_6: Oxyfluorfen (Pre) + Metribuzin (POE)	0.25 and 0.70	0.99	4233.65	40.91
T_7: Metribuzi(PE) + Quizalofop-ethyl (POE)	0.70 and 0.05	1.03	3373.20	36.13
T_8: Oxyfluorfen (PE) + Quizalofop-ethyl (POE)	0.25 and 0.05	0.96	4220.44	43.57
T_9: Oxyfluorfen (PE) + Metribuzin (POE) + Quizalofop-ethyl (POE)	0.25, 0.70 and 0.05	0.99	4198.60	39.20
T_{10}: Oxyfluorfen (PE) + Intercultivation	0.25 + At 45 DAP	1.06	4629.35	51.18
T_{11}: Metribuzin (PE) + Inter-cultivation	0.70 + At 45 DAP	0.94	3119.67	40.97
T_{12}: Un-weeded (control)	-	0.99	1769.14	30.42
S.Em ±		**0.04**	**441.98**	**3.80**
CD at 5%		**NS**	**1296.38**	**11.15**

PE- Pre-emergent (2DAP) POE- Post-emergent (30 DAP)

Table 10: Chlorophyll content (mg/g) of menthol mint as influenced by different weed management practices

Treatments	Dose (kg a.i./ha)	Chlorophyll content					
		3 Days after pre-emergent herbicidal spray			3 Days after post-emergent herbicidal spray		
		Chl.a	Chl.b	Total Chl. content	Chl.a	Chl.b	Total Chl. Content
		(mg/g of tissue)					
T_1: Hand weeding	15 days intervals	2.123	0.710	2.662	3.326	1.510	4.416
T_2: Inter-cultivation	15 days intervals	2.166	0.670	2.672	3.340	1.170	4.449
T_3: Sugarcane trash mulch	5 t/ha (30 DAP)	2.173	0.760	2.767	3.423	1.213	4.490
T_4: Metribuzin (PE)	0.70	1.013	0.690	1.604	2.103	1.190	3.055
$T_{5:}$ Oxyfluorfen (PE)	0.25	1.956	0.660	2.467	3.193	1.160	4.037
T_6: Oxyfluorfen (Pre) + Metribuzin (POE)	0.25 and 0.70	1.653	0.620	2.118	2.280	1.120	3.256
T_7: Metribuzi (PE) + Quizalofop-ethyl (POE)	0.70 and 0.05	1.590	0.690	2.158	2.106	1.190	3.052
T_8: Oxyfluorfen (PE) + Quizalofop-ethyl (POE)	0.25 and 0.05	1.693	0.740	2.291	2.426	1.206	3.366
T_9: Oxyfluorfen (PE) + Metribuzin (POE) + Quizalofop-ethyl (POE)	0.25, 0.70 and 0.05	1.763	0.730	2.357	2.656	1.196	3.565
T_{10}: Oxyfluorfen (PE) + Intercultivation	0.25 + At 45 DAP	1.836	0.690	2.388	3.253	1.190	4.111
T_{11}: Metribuzin (PE) + Inter-cultivation	0.70 + At 45 DAP	1.056	0.720	1.673	2.226	1.183	3.150
T_{12}: Un-weeded (control)	-	2.030	0.720	2.591	3.010	1.220	3.918
S.Em ±		**0.065**	**0.070**	**0.0516**	**0.101**	**0.108**	**0.057**
CD at 5%		**0.179**	**NS**	**0.040**	**0.339**	**NS**	**0.182**

PE- Pre-emergent (2DAP) POE- Post-emergent (30 DAP)
Chl.a- Chlorophyll a Chl.b- Chlorophyll b Total Chl- Total chlorophyll

Chlorophyll-a and total chlorophyll content differs significantly with the different weed management practices. Significantly the highest chlorophyll-a and total chlorophyll content of 2.173 and 2.767 mg per gram of tissue were recorded in organic mulch with sugarcane trash @ 5 t/ha (T_3) which were *on par* with inter-cultivation (T_2) (2.166 and 2.672 mg/g, respectively), hand weeding (T_1) (2.123 and 2.662 mg/g, respectively) and significantly lowest were recorded in PE application of metribuzin @ 0.7 kg a.i./ha (T_4) (1.013 and 1.604 mg/g, respectively).

The data on chlorophyll content recorded at 3 days after post-emergent herbicidal spray are presented in table 10. Significantly the highest chlorophyll-a and total chlorophyll content of 3.423 and 4.490 mg per gram of tissue were recorded in organic mulch with sugarcane trash @ 5 t/ha (T_3) which were *on par* with inter-cultivation (T_2) (3.340 and 4.449 mg/g, respectively), hand weeding (T_1) (3.326 and 4.416 mg/g, respectively) and significantly lowest were recorded in PE application of metribuzin @ 0.7 kg a.i./ha (T_4) (2.103 and 3.055 mg/g, respectively).

4.5 Yield parameters

4.5.1 Fresh herbage yield (g/plant, kg/plot and t/ha)

The observation on fresh herbage yield of menthol mint as influenced by different weed management practices are presented in the table 11 and fig. 5.

The effect of different weed management practices had significant effect on fresh herbage yield of menthol mint at harvest. PE application of oxyfluorfen @ 0.25 kg a.i./ha (T_5) recorded significantly the higher fresh herbage yield (402.56 g/plant, 18.63 kg/plot and 17.69 t/ ha, respectively) which were *on par* with PE application of oxyfluorfen @ 0.25 kg a.i./ha followed by inter-cultivation (T_{10}) (401.47 g/plant, 14.41 kg/plot and 13.68 t/ha, respectively) and organic mulch application of sugarcane trash @ 5 t/ha (T_3) (377.81 g/plant, 14.12 kg/plot and 13.40 t/ha, respectively). Significantly minimum fresh herbage yield were recorded in un-weeded control (T_{12}) (120.85 g/plant, 6.23 kg/plot and 5.95 t/ha, respectively).

Table 11: Fresh herbage yield of menthol mint as influenced by different weed management practices

Treatments	Dose (kg a.i./ha)	Fresh herbage yield (At harvest)		
		g/plant	kg/plot	t/ha
T_1: Hand weeding	15 days intervals	286.00	12.72	12.08
T_2: Inter-cultivation	15 days intervals	282.66	12.83	12.18
T_3: Sugarcane trash mulch	5 t/ha (30 DAP)	377.81	14.12	13.40
T_4: Metribuzin (PE)	0.70	155.06	8.05	7.64
T_5: Oxyfluorfen (PE)	0.25	402.56	18.63	17.69
T_6: Oxyfluorfen (Pre) + Metribuzin (POE)	0.25 and 0.70	258.33	8.68	8.24
T_7: Metribuzi (PE) + Quizalofop-ethyl (POE)	0.70 and 0.05	175.39	8.23	7.81
T_8: Oxyfluorfen (PE) + Quizalofop-ethyl (POE)	0.25 and 0.05	203.00	9.12	8.65
T_9: Oxyfluorfen (PE) + Metribuzin (POE) + Quizalofop-ethyl (POE)	0.25, 0.70 and 0.05	196.66	9.20	8.73
T_{10}: Oxyfluorfen (PE) + Intercultivation	0.25 + At 45 DAP	401.47	14.41	13.68
T_{11}: Metribuzin (PE) + Inter-cultivation	0.70 + At 45 DAP	185.82	8.54	8.10
T_{12}: Un-weeded (control)	-	120.85	6.23	5.95
S.Em ±		**18.66**	**1.22**	**1.16**
CD at 5%		**54.75**	**3.59**	**3.41**

PE- Pre-emergent (2DAP) POE- Post-emergent (30 DAP)

4.5.2 Shade dried herbage yield (g/plant, kg/plot and t/ha)

The observation on shade dried herbage yield of menthol mint as influenced by different weed management practices are presented in the table 12.

The effect of different management practices had significant effect on shade dried herbage yield at harvest. PE application of oxyfluorfen @ 0.25 kg a.i./ha (T_5) recorded significantly the higher fresh herbage yield (118.33 g/plant, 15.53 kg/plot and 14.63 t/ha, respectively) which were *on par* with PE application of oxyfluorfen @ 0.25 kg a.i./ha followed by inter-cultivation (T_{10}) (95.66 g/plant, 12.43 kg/plot and 11.80 t/ha, respectively) and organic mulch application of sugarcane trash @ 5 t/ha (T_3) (94.33 g/plant, 11.11 kg/plot and 10.55 t/ha, respectively). Significantly minimum fresh herbage yield were recorded in un-weeded control (T_{12}) (34.00 g/plant, 4.38 kg/plot and 4.16 t/ha, respectively).

4.5.3 Essential oil yield (g/plot and kg/ha)

The essential oil yield differs significantly with respect to different weed management practices are presented in table 13.

PE application of oxyfluorfen @ 0.25 kg a.i./ha (T_5) recorded significantly the higher essential oil yield (113.33 g/plot and 107.62 kg/ha, respectively) which were *on par* with PE application of oxyfluorfen @ 0.25 kg a.i./ha followed by inter-cultivation (T_{10}) (110.00 g/plot and 104.46 kg/ha, respectively) and organic mulch application of sugarcane trash @ 5 t/ha (T3) (95.00 g/plot and 90.21 kg/ha, respectively) as compared to un-weeded control. Significantly lower essential oil yield were recorded in un-weeded control (T_{12}) (41.03 g/plot and 38.99 kg/ha, respectively).

4.6 Quality parameter

4.6.1 Essential oil content (%)

The data on essential oil content of menthol mint with respect to different weed managemnt treatments are presented in the table 13. The essential oil content of menthol mint was recorded at harvest are calculated on fresh weight basis (%). The different weed management practices found non-significant with respect to essential

Table 12: Shade dried herbage yield of menthol mint as influenced by different weed management practices

Treatments	Dose (kg a.i./ha)	Shade dried herbage yield (At harvest)		
		g/plant	kg/plot	t/ha
T_1: Hand weeding	15 days intervals	93.33	8.91	8.46
T_2: Inter-cultivation	15 days intervals	87.0	9.38	8.90
T_3: Sugarcane trash mulch	5 t/ha (30 DAP)	94.33	11.11	10.55
T_4: Metribuzin (PE)	0.70	55.66	5.86	5.56
$T_{5:}$ Oxyfluorfen (PE)	0.25	118.33	15.53	14.63
T_6: Oxyfluorfen (Pre) + Metribuzin (POE)	0.25 and 0.70	72.66	7.78	7.38
T_7: Metribuzi (PE) + Quizalofop-ethyl (POE)	0.70 and 0.05	66.66	6.11	5.78
T_8: Oxyfluorfen (PE) + Quizalofop-ethyl (POE)	0.25 and 0.05	75.66	8.18	7.76
T_9: Oxyfluorfen (PE) + Metribuzin (POE) + Quizalofop-ethyl (POE)	0.25, 0.70 and 0.05	69.66	7.56	7.17
T_{10}: Oxyfluorfen (PE) + Intercultivation	0.25 + At 45 DAP	95.66	12.43	11.80
T_{11}: Metribuzin (PE) + Inter-cultivation	0.70 + At 45 DAP	68.33	6.80	6.45
T_{12}: Un-weeded (control)	-	34.0	4.38	4.16
S.Em ±		**6.03**	**0.86**	**0.80**
CD at 5%		**17.71**	**2.52**	**2.36**

PE- Pre-emergent (2DAP) POE- Post-emergent (30 DAP)

Table 13: Essential oil content, oil yield and menthol content of menthol mint as influenced by different weed management practices

Treatments	Dose (kg a.i./ha)	Oil content (%)	Oil yield (g/plot)	Oil yield (kg/ha)	Menthol content (%)
T_1: Hand weeding	15 days intervals	0.69	83.33	79.13	72.270
T_2: Inter-cultivation	15 days intervals	0.70	86.66	82.30	70.553
T_3: Sugarcane trash mulch	5 t/ha (30 DAP)	0.65	95.00	90.21	70.916
T_4: Metribuzin (PE)	0.70	0.61	50.00	47.48	72.270
T_5: Oxyfluorfen (PE)	0.25	0.60	113.33	107.62	70.553
T_6: Oxyfluorfen (Pre) + Metribuzin (POE)	0.25 and 0.70	0.72	60.00	56.97	70.916
T_7: Metribuzi (PE) + Quizalofop-ethyl (POE)	0.70 and 0.05	0.72	56.66	53.81	72.270
T_8: Oxyfluorfen (PE) + Quizalofop-ethyl (POE)	0.25 and 0.05	0.70	60.00	56.97	70.553
T_9: Oxyfluorfen (PE) + Metribuzin (POE) + Quizalofop-ethyl (POE)	0.25, 0.70 and 0.05	0.69	61.66	58.55	70.916
T_{10}: Oxyfluorfen (PE) + Intercultivation	0.25 + At 45 DAP	0.76	110.00	104.46	72.270
T_{11}: Metribuzin (PE) + Inter-cultivation	0.70 + At 45 DAP	0.68	58.33	55.39	70.553
T_{12}: Un-weeded (control)	-	0.63	41.03	38.99	70.916
S.Em ±		**0.04**	**7.23**	**6.86**	**1.06**
CD at 5%		**NS**	**21.20**	**20.14**	**NS**

PE- Pre-emergent (2DAP) POE- Post-emergent (30 DAP)

oil content. The result revealed that, the range of essential oil content of menthol mint is 0.61 to 0.76 %.

4.6.2 Menthol content (%)

The menthol content of menthol mint did not showed any significant difference as influenced by different weed management practices presented in table 13.

4.7 Economics

The data on the cost of cultivation, gross returns net return and cost: benefit ratio as influenced by different weed management practices are presented in table 14 and economic details are provided in appendix III.

4.7.1 Cost of cultivation (`/ha)

The highest cost of cultivation was recorded in hand weeding (T_1) (` 68,092/ha) as compared to other different weed management practices such as PE application of oxyflourfen @ 0.25 kg a.i./ha followed by inter-cultivation ($T_{10}$) (` 45,872/ha), PE application of oxyflourfen @ 0.25 kg a.i./ha (T_5) (` 45,682/ha) and sugarcane trash mulch @ 5 t/ha ($T_3$) (` 71,320/ha), whereas lowest cost of cultivation was recorded in un-weeded treatment (T_{12}) (` 29,962/ha).

4.7.2 Gross return (`/ha)

The maximum gross returns was recorded in PE application of oxyflourfen @ 0.25 kg a.i./ha (T_5) (` 1,29,144/ha) followed by PE application of oxyflourfen @ 0.25 kg a.i./ha followed by inter-cultivation ($T_{10}$) (` 1,25,352/ha) and organic mulch application of sugarcane trash @ 5 t/ha (T_3) (` 1,08,252/ha) and minimum gross returns were recorded in un-weeded control ($T_{12}$) (` 46,788 /ha).

4.7.3 Net returns (`/ha)

The maximum net returns was recorded in PE application of oxyflourfen @ 0.25 kg a.i./ha (T_5) (` 83,461/ha) followed by pre-application of oxyflourfen @ 0.25 kg a.i./ha followed by inter-cultivation ($T_{10}$) (` 79,479.78/ha) and organic mulch

Table 14: Economics of menthol mint as influenced by different weed management practices

Treatments	Dose (kg a.i./ha)	Cost of Cultivation (` /ha)	Gross return (` /ha)	Net return (` /ha)	Cost: Benefit ratio
T_1: Hand weeding	15 days intervals	68,092	94,956	26,864	1: 1.39
T_2: Inter-cultivation	15 days intervals	39,792	98,760	58,968	1: 2.48
T_3: Sugarcane trash mulch	5 t/ha (30 DAP)	43,699	1,08,252	64,554	1: 2.48
T_4: Metribuzin (PE)	0.70	34,318	56,976	22,659	1: 1.66
T_5: Oxyfluorfen (PE)	0.25	45,682	1,29,144	83,462	1: 2.82
T_6: Oxyfluorfen (Pre) + Metribuzin (POE)	0.25 and 0.70	38,898	68,364	29,4667	1: 1.75
T_7: Metribuzi (PE) + Quizalofop-ethyl (POE)	0.70 and 0.05	37,285	64,572	27,287	1: 1.73
T_8: Oxyfluorfen (PE) + Quizalofop-ethyl (POE)	0.25 and 0.05	39,439	68,364	28,925	1: 1.73
T_9: Oxyfluorfen (PE) + Metribuzin (POE) + Quizalofop-ethyl (POE)	0.25, 0.70 and 0.05	41,985	70,260	28,275	1: 1.67
T_{10}: Oxyfluorfen (PE) + Intercultivation	0.25 + At 45 DAP	45,872	1,25,352	79,479	1: 2.73
T_{11}: Metribuzin (PE) + Inter-cultivation	0.70 + At 45 DAP	34,978	66,468	31,491	1: 1.90
T_{12}: Un-weeded (control)	-	29,962	46,788	16,826	1: 1.56

PE- Pre-emergent (2DAP) POE- Post-emergent (30 DAP)

application of sugarcane trash @ 5 t/ha (T_3) (` 64,553/ha) and minimum net returns was recorded in un-weeded control ($T_{12}$) (` 16,825/ha.)

4.7.4 Cost benefit ratio (C: B)

The maximum cost: benefit ratio (1:2.82) was recorded in PE application of oxyflourfen @ 0.25 kg a.i./ha (T_5) which is followed by PE application of oxyflourfen @ 0.25 kg a.i./ha (T_{10}) followed by inter-cultivation (1:2.73) and organic mulch application of sugarcane trash @ 5 t/ha (T_3) (1:2.48) and minimum cost: benefit ratio recorded in un-weeded control (T_{12}) (1: 1.56).

5. DISCUSSION

The field experiment on "Integrated weed management in menthol mint (*Mentha arvensis* L.)" was carried out during 2017-2018 in the Department of Plantation, Spices, Medicinal and Aromatic Crops, Kittur Rani Channamma College of Horticulture, Arabhavi, University of Horticultural Sciences, Bagalkot. The result obtained in the investigation is discussed in this chapter by making an attempt to reason out differential behaviour of different weed management practices compared with un-weeded control and in relationship with yield of the menthol mint.

5.1 Weed parameters

5.1.1 Weed flora

The weed flora associated with menthol mint in the experimental site comprised of grasses, sedges and broad leaved weeds (Table 2). The important grassy weeds observed were *Cynodon dactylon*, *Digitaria marginata*, *Digitaria sanguinalis* and *Eleusina indica*, while, *Cyperus rotundus* was the only sedge found. *Ageratum conyzoides*, *Amaranthus viridis*, *Euphorbia hirta*, *Malvastrum coromondelianum*, *Parthenium hysterophorus*, *Rumex denticulate* and *Melilotus alba* were the dominating broad leaved weed species. Apart from these there were many other less common weeds totalling to 34 different species indicating high weed diversity. The diversity of weed in the experimental site was high as it is located in command area of Ghatprabha left bank canal and irrigated at least eight months in a year. As the field was irrigated with canal water, weeds particularly *Parthenium hysterophorus* was recurring as fresh flushes after irrigation. The similar result was observed by Singh and Khosla (1989) who recorded 37 species belonging to 33 genera representing 15 families, out of these, 11 genera belong to a single family *i.e.* Gramineae.

5.1.2 Weed density (number/m^2)

The minimum weed density was recorded at 30 DAP in PE application of oxyflourfen @ 0.25 kg a.i./ha (Fig. 2) as compared to un-weeded control. The observation recorded that *Cyperus rotundus* was a major weed at this stage. None of the weed control treatments were effective against the menace. At 30 DAP as the crop was not fully developed and was not able to compete with weeds, so role of herbicides

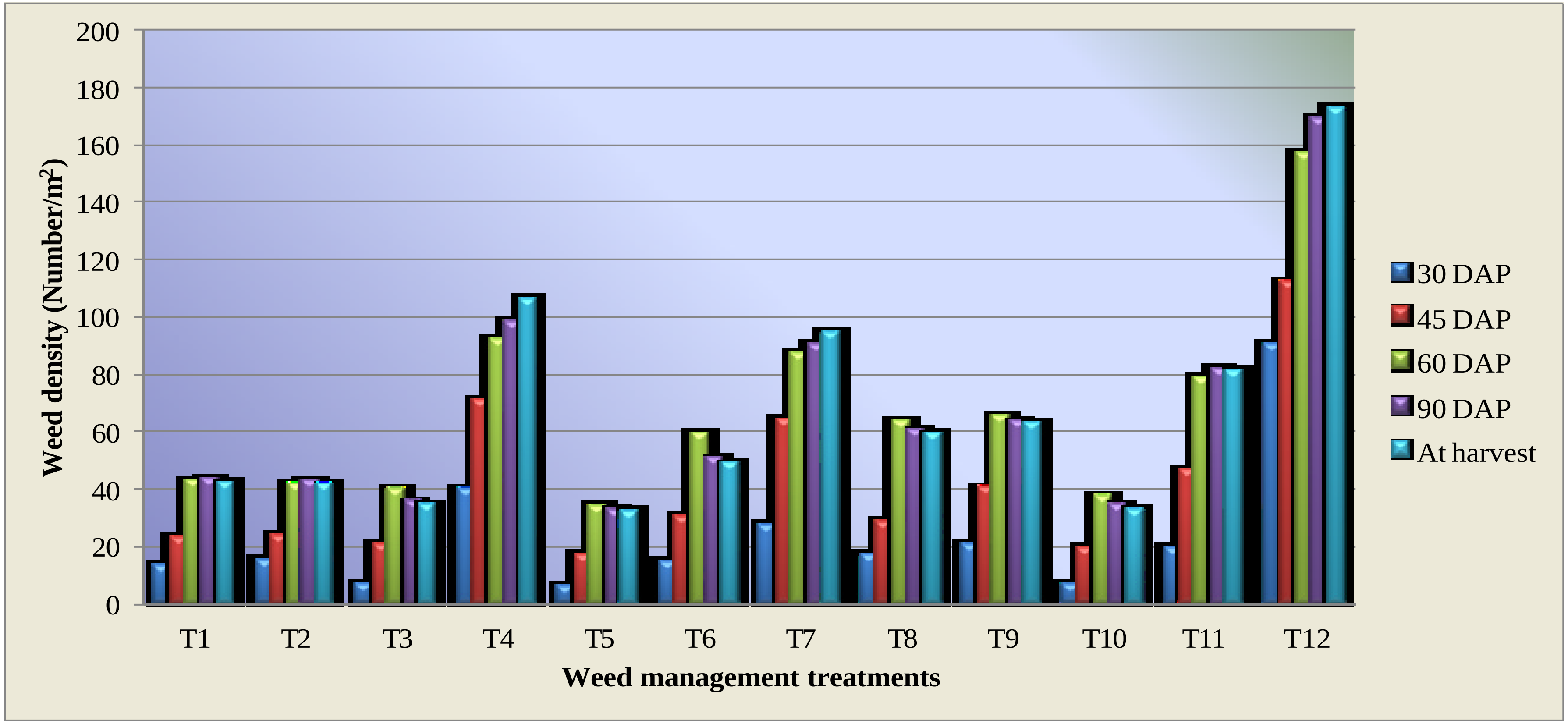


Fig. 2: Weed density (number/m^2) of menthol mint as influenced by different weed management practices

PE- Pre-emergent (2DAP) POE- Post-emergent (30 DAP)

T_1: Hand Weeding	T_7: PE metribuzi + POE quizalofop-ethyl
T_2: Inter-cultivation	T_8: PE oxyfluorfen + POE quizalofop-ethyl
T_3: Sugarcane trash mulch	T_9: PE oxyfluorfen + POE metribuzin + POE quizalofop-ethyl
T_4: PE Metribuzin	T_{10}:PE oxyfluorfen + Intercultivation
T_5: PE oxyflourfen	T_{11}: PE metribuzin + Inter-cultivation
T_6: PE oxyfluorfen + POE metribuzin	T_{12}: Un-weeded (control)

was critical to overcome competition posed by weeds the similar findings were observed by Kothari and Singh (1994) in menthol mint.

The weed densities increased from 30 to 90 DAP and then declined due to smothering effect of crop. Un-weeded treatment recorded significantly higher number of weeds per square meter at 30, 45, 60, 90 DAP and at harvest (90.00, 111.66, 157.00, 168.66 and 172.66/m^2, respectively). The lowest weed density was recorded in PE application of oxyflourfen @ 0.25 kg a.i./ha (05.66, 16.33, 33.66, 32.00 and 31.33/m^2, respectively) due to reduced weed germination, weed growth and their photosynthetic activity that was found *on par* with PE application of oxyflourfen @ 0.25 kg a.i./ha followed by inter-cultivation (06.00, 18.66, 37.00, 34.33 and 32.33/m^2, respectively) which involved in loosening of soil favouring the crop growth. Similar result was recorded by Walia *et al*., (2006) in menthol mint.

Organic mulch of sugarcane trash (06.33, 20.33, 39.33, 35.00 and 34.33/m^2, respectively) also reduced the weed density owing to mechanical hindrance for weed emergence by restricting solar radiations reaching below. Similar observation was recorded by Dyck and Liebman (1994).

5.1.3 Weed biomass

5.1.3.1 Fresh and dry weight of weeds (g/m^2)

The data on fresh and dry weights of weeds (Fig. 3 and 4, respectively) shows significant reduction in weed fresh and dry weights as compared with un-weeded control at all the stages of crop growth.

Minimum weed fresh weights (7.94, 5.66, 23.66, 20.00 and 19.00g/m^2 at 30, 45, 60, 90 DAP and at harvest, respectively) and dry weights (7.94, 5.66, 23.66, 20.00 and 19.00g/m^2, respectively) were observed in PE application of oxyflourfen @ 0.25 kg a.i./ha due to reduced weed density and persistent effect of herbicide apart from reduced photosynthetic activity of different weed species. Mulch helps in suppressing weeds to a greater extent. Mulching with sugarcane thrash at 5t/ha reduced weed density and weed biomass. A very little weed growth occurred under the sugarcane trash as the mulches prevent penetration of light facilitated better stolen production, crop dry matter accumulation, fresh herbage and mint oil yield. The results are in line with the findings of Singh and Saini (2008) in menthol mint.

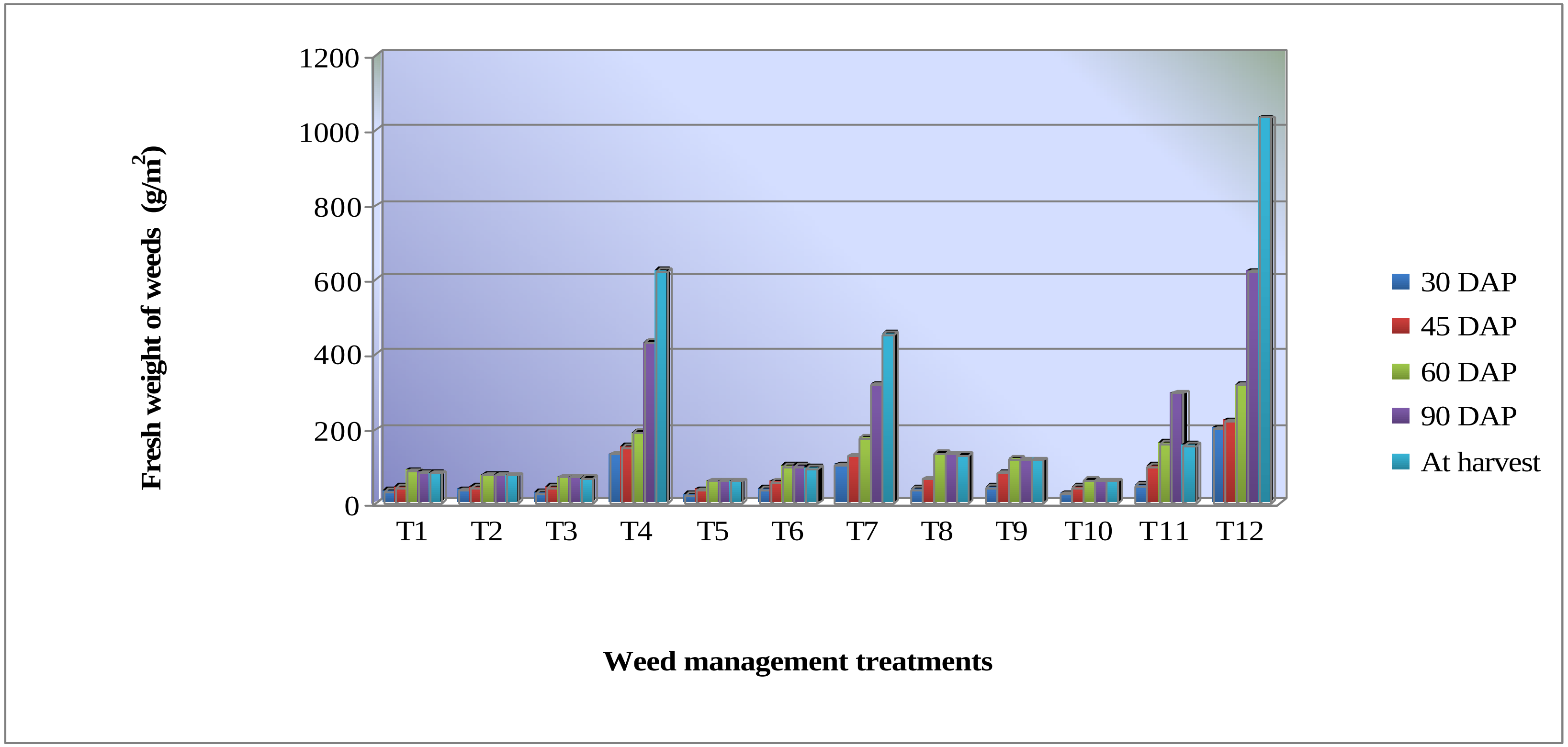


Fig. 3: Fresh weight of weeds (g/m^2) of menthol mint as influenced by different weed management practices

PE- Pre-emergent (2DAP) POE- Post-emergent (30 DAP)

T_1: Hand Weeding	T_7: PE metribuzi + POE quizalofop-ethyl
T_2: Inter-cultivation	T_8: PE oxyfluorfen + POE quizalofop-ethyl
T_3: Sugarcane trash mulch	T_9: PE oxyfluorfen + POE metribuzin + POE quizalofop-ethyl
T_4: PE Metribuzin	T_{10}:PE oxyfluorfen + Intercultivation
T_5: PE oxyflourfen	T_{11}: PE metribuzin + Inter-cultivation
T_6: PE oxyfluorfen + POE metribuzin	T_{12}: Un-weeded (control)

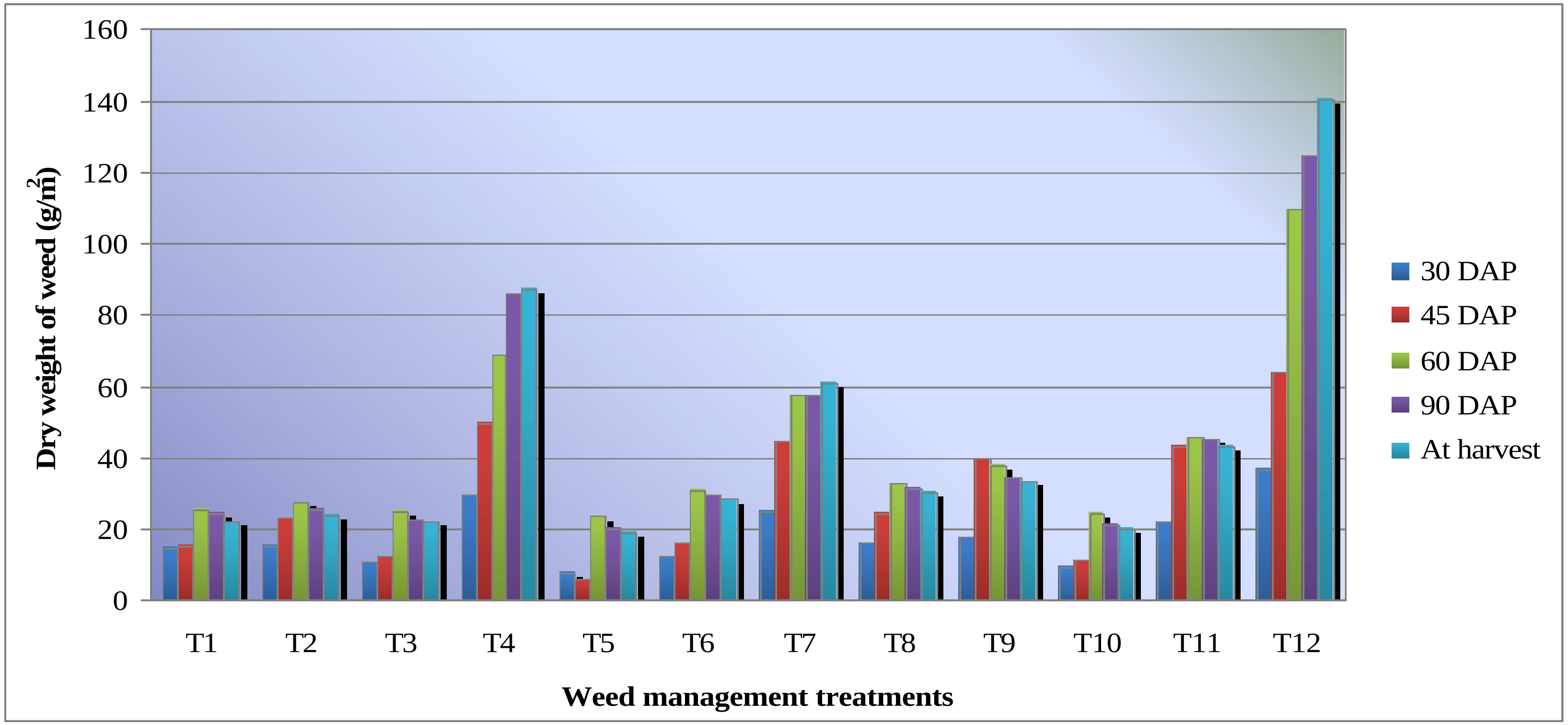


Fig. 4: Dry weight of weeds (g/m^2) of menthol mint as influenced by different weed management practices

PE- Pre-emergent (2DAP) POE- Post-emergent (30 DAP)

T_1: Hand Weeding T_2: Inter-cultivation T_3: Sugarcane trash mulch T_4: PE Metribuzin T_5: PE oxyflourfen T_6: PE oxyfluorfen + POE metribuzin	T_7: PE metribuzi + POE quizalofop-ethyl T_8: PE oxyfluorfen + POE quizalofop-ethyl T_9: PE oxyfluorfen + POE metribuzin + POE quizalofop-ethyl T_{10}:PE oxyfluorfen + Intercultivation T_{11}: PE metribuzin + Inter-cultivation T_{12}: Un-weeded (control)

The most rapid increase in fresh and dry weights of weeds were noted at 30 and 45 DAP indicating planting to 45 days as the most crucial time for weed management in menthol mint owing to non competition from the crop, hence favouring the weed growth. However, maintaining the crop weed-free up to the first 45 days could not suppress weeds that emerged thereafter. During later stages the crop covered sufficient surface area and the late-emerging weeds failed to compete with the crop. Since there was no such increment in weed growth after 90 DAP in all the weed control treatments except in metribuzin treatments.

5.1.4 Herbicidal toxicity on crop

The toxicity related observations, like burning and drying of leaves from margin and petiole were recorded at 3 days after herbicidal spray. Initially the upper leaves dryed, later followed by lower leaves in case of metribuzin application as a post-emergent @ 0.7 kg a.i./ha. Evethough some plants turned yellow and showed drying with PE application of oxyflourfen @ 0.25 kg a.i./ha recovered later on indicating non persistant low phytotoxic effect on menthol mint. Spray of quizalofop-ethyl @ 0.05 kg a.i./ha did not show any toxicity symptoms except slight yellowing. The use of herbicides, even in tolerant crops, can cause stress evidenced by increased phyto-toxicity affecting growth and development as noticed by Agostinetto *et al.* (2016) in wheat.

5.2 Growth parameters of menthol mint

5.2.1 Plant heights (cm)

The height is one of the major morphological traits related to growth and as such has a great bearing on fresh herbage and oil yield. The plant height of menthol mint increased with age up to the harvestable maturity irrespective of the treatments. However, being determinate plant, after reaching flowering stage the height increment decreased, which would stop at reaching senescence.

Significantly highest plant height at 90 DAP and at harvest (Table 6) was recorded in organic mulch with sugarcane trash (63.66 and 68.8 cm, respectively) which was *on par* with PE application of oxyfluorfen @ 0.25 kg a.i./ha (62.33 and 68.0 cm) and PE application of oxyfluorfen @ 0.25 kg a.i./ha followed by inter-cultivation (61.33 and 67.06 cm, respectively) this may due to reduced weed density and weed biomass and addition of organic carbon to the soil, increase in availability of nutrients and more moisture supply, improved microbial activity in soil.

The Significantly lowest plant height was recorded in PE application of metribuzin @ 0.7 kg a.i./ha followed by inter-cultivation (49.0 and 61.2 cm, respectively) and followed by PE application metribuzin @ 0.7 kg a.i./ha (51.66 and 61.66 cm, respectively) as compared to un-weeded control (60.33 and 64.33 cm, respectively) at 90 DAP and at harvest which may be due to the phytotoxic effect of metribuzin as rightly observed by Ali *et al.* (2004) in wheat. The higher plant height in un-weeded control as compared to metribuzin application due to competition for sunlight between crop plants and taller weeds like *Rumex dentatus* and *Ageratum conyzoides* resulting in low light induced height increment and lanky growth was reported by Gurwinder Singh (2012).

5.2.2 Number of branches per plant

Significant differences in number of branches per plant were observed at all the stages of crop growth except at 30 DAP (Table 7). The maximum number of branches per plant were recorded with PE application of oxyfluorfen @ 0.25 kg a.i./ha (24.48, 48.68, 50.66 and 55.33 at 45, 60, 90 DAP and at harvest, respectively) due to less weed infestation and luxuriant crop growth. This was followed by hand weeding (21.28, 40.13, 41.66 and 51.33, respectively) due to reduced the weed density by frequent weed removal and organic mulch with sugarcane trash @ 5 t/ha (19.28, 38.58, 39.83 and 45.66, respectively).

5.2.3 Plant spread (NS-EW in cm)

The plant spread varied significantly among the different weed control treatments at all the stages of crop growth (Table 8). Significantly maximum plant spread was observed in PE application of oxyflourfen @ 0.25 kg a.i./ha (33.29, 41.4, 66.96, 75.28 and 77.5 cm respectively, at 30, 45, 60 and 90 DAP at harvest) as the treatment also recorded higher plant growth and maximum number of branches due to reduced weed growth and weed biomass. Significantly minimum plant spread recorded in un-weeded control (18.03, 21.2, 48.03, 33.33 and 33.66 cm, respectively) as the vigorous weed growth might have restricted the crop growth and reduced photosynthesis by shading on crop finally leading to lower plant spread. The current result is in line with that of Singh *et al*. (1995) in menthol mint.

5.3 Physiological parameters

5.3.1 Total leaf area (cm^2/plant)

The observation on total leaf area differed significantly at harvest. The significantly maximum leaf area was recorded in PE application of oxyfluorfen @ 0.25 kg a.i./ha (5279.54 cm^2), which was *on par* with PE application oxyfluorfen followed by inter-cultivation (4629.35 cm^2). The result might be due to better performance of mint in field due to less competition due to less weed. Performance of organic mulch with sugarcane trash (4532.29 cm^2) was also *on par* with the best treatment due to increasing yield attributing traits, optimized soil temperature, controlled evaporation losses, increased soil moisture conservation, suppression of weeds and uptake of major, secondary and micro nutrients. Similar result was also reported by Thankamani (2016) in ginger crop.

5.3.2 Dry matter accumulation (g/plant)

The leaf area and crop dry matter accumulation are dependable variables, as the leaf area increases the crop dry matter accumulation also increases in plant. Greater the leaf area greater will be the crop dry matter accumulation and is a good growth index to express the photosynthetic efficiency of plants under different treatments and it indicates the progressive growth and development of the crop.

The effect of different weed management treatments had significant difference on average dry matter accumulation at harvest (Table 9). PE application oxyfluorfen @ 0.25 kg a.i./ha recorded significantly highest crop dry matter accumulation (54.78 g/plant), which can be attributed to improved vegetative growth of crop plants due to less weed competition up to harvest resulting in better plant height, number of branches, plant spread and maximum leaf area due to better utilization of growth resources and similar observation was made by Singh (2003). The treatment was *on par* with PE application of oxyfluorfen @ 0.25 kg a.i./ha followed by inter-cultivation (51.18 g/plant) owing to higher leaf area recorded less weed population and loosening of soil helping the plants to grow and spread more as compared to un-weeded control.

The organic mulch with sugarcane trash also recorded *on par* value (51.0 g/plant) due better stolon production under mulch resulting in better dry matter accumulation. Similar observations were made by Singh and Saini (2008) with application of oxyflourfen 0.35 kg/ha produced higher dry matter accumulation. Significantly lower dry matter accumulation recorded in un-weeded plot (30.42 g/plant) due to maximum weed density and weed dry weight leading higher weed competition restricting the crop growth and development.

5.4 Biochemical parameters

5.4.1 Chlorophyll content of menthol mint (mg/g)

The chlorophyll content of leaf is strongly influenced by numerous external factors. Chlorophylls of different forms play an important role as a part of the photosynthetic apparatus of all phototrophic organisms. Higher plants contain chlorophyll a, the major yellow green pigment and chlorophyll b, the blue-green pigment in different ratios

Chlorophyll-a and total chlorophyll content differs significantly with the different weed management treatments after PE herbicidal spray (Table 10). The organic mulch application of sugarcane trash recorded maximum chlorophyll-a (2.173 mg/g) and total chlorophyll content (2.767 mg/g). The reduced chlorophyll-a (1.013 mg/g) and total chlorophyll content (1.604 mg/g) noticed in PE application of metribuzin spray which was followed by PE application of metribuzin followed by inter-cultivation (1.056 mg/g and 1.673 mg, respectively). The phyto-toxic effect of metribuzin was due to its action on photo-system II reducing the photosynthetic activity. Herbicides are known to cause stress even in tolerant crops as evidenced by Agostinetto *et al*. (2016) in wheat.

Pre emergent application of oxyfluorfen did not show prolonged toxicity symptoms on menthol mint and it recorded chlorophyll-a (1.956 mg/g) and total chlorophyll content (2.467 mg/g) respectively. Even though both oxyfluorfen and metribuzin reduced weed growth and development, plants in the oxyfluorfen treatment were recovered but not in the metribuzin treatment.

The data on chlorophyll content recorded after 3 days of post-emergent herbicidal spray differ significantly (Table 10).

The significantly highest chlorophyll-a and total chlorophyll content of 3.423 and 4.490 mg per gram of tissue were recorded in organic mulch with sugarcane trash @ 5 t/ha which were *on par* with inter-cultivation (3.340 and 4.449 mg/g respectively) and significantly lowest were recorded in PE application of metribuzin @ 0.7 kg a.i./ha (2.103 and 3.055 mg/g, respectively) may due to phyto-toxicity of herbicide. The quizalofop-ethyl had no toxic effect on menthol mint. The pre and post-emergent spray of metribuzin not only reduced weed density and weed biomass, but also reduced the crop dry weight due to reduction in chlorophyll content. Agostinetto *et al.* (2016) reported negative effect of metribuzin on photosynthetic rate, stomatal conductance and transpiration from similar study on wheat.

5.5 Yield parameters

5.5.1 Fresh herbage and dry herbage yield (t/ha)

In mentha, fresh and dry herbage yield is the most important parameter which decide essential oil yield (Fig. 5). PE application of oxyflourfen @ 0.25 kg a.i./ha was significantly superior in terms of fresh herb yield (17.69 t/ha) and shade dried herb yield (14.63 t/ha). This may be due to increased plant height, number of branches, plant spread and higher dry matter accumulation per plant as a result of suppressed weed growth and development. Similar result was obtained by Kaur (1999) in pepper mint. whereas, significantly minimum fresh herbage yield (5.95 t/ha) and shade dried herbage yield (4.16 t/ha) were recorded in un-weeded control due to luxuriant weed growth competing with mint crop for soil moisture, nutrient, light and space leading to lower fresh and dry herbage yield as reported by Singh (2009) in menthol mint.

5.5.2 Essential oil yield (Kg/ha)

The data regarding essential oil yield on fresh weight basis are influenced by different weed management practices (Table 13). PE application of oxyfluorfen @ 0.25 kg a.i./ha recorded significantly higher essential oil yield (107.62 kg/ha) which was *on par* with PE application of oxyfluorfen followed by with inter-cultivation (104.46 kg/ha) and organic mulch with sugarcane trash (90.21 kg/ha). The higher oil

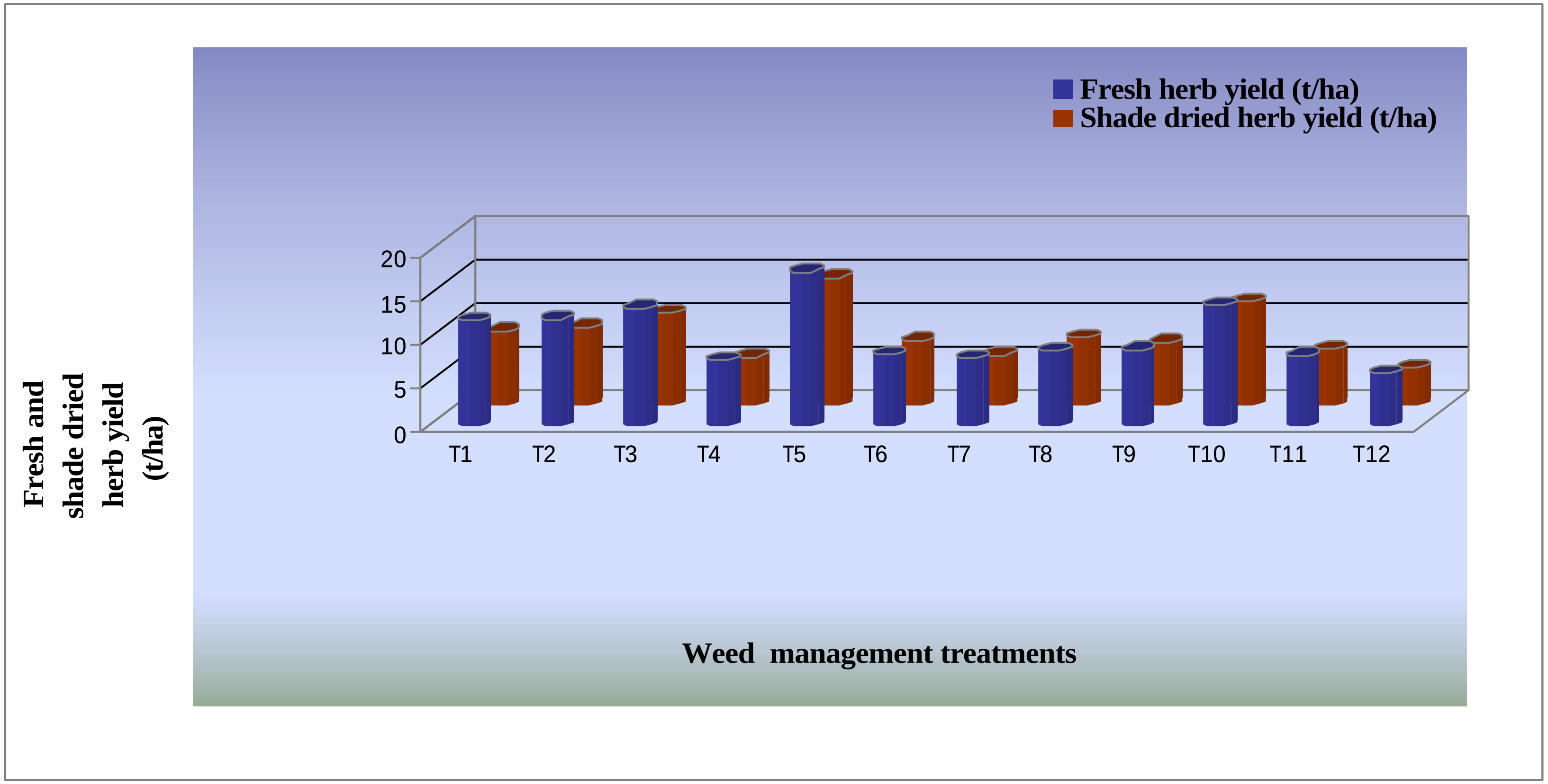


Fig. 5: Fresh and shade dried herbage yield of menthol mint as influenced by different weed management practices

PE- Pre-emergent (2DAP) POE- Post-emergent (30 DAP)

T_1: Hand Weeding	T_7: PE metribuzi + POE quizalofop-ethyl
T_2: Inter-cultivation	T_8: PE oxyfluorfen + POE quizalofop-ethyl
T_3: Sugarcane trash mulch	T_9: PE oxyfluorfen + POE metribuzin + POE quizalofop-ethyl
T_4: PE Metribuzin	T_{10}:PE oxyfluorfen + Intercultivation
T_5: PE oxyflourfen	T_{11}: PE metribuzin + Inter-cultivation
T_6: PE oxyfluorfen + POE metribuzin	T_{12}: Un-weeded (control)

Plate 3: Best treatment (T_5: PE oxyflourfen) at harvest

Plate 4: Control (T_{12}: Un-weeded) at harvest

yield was due to better fresh & dry herbage yield and essential oil content of different weed management treatments and the similar results were obtained by Walia *et al.* (1980) and Jaidev *et al*. (1993) in menthol mint. Lower essential oil yield recorded in un-weeded control (38.99 kg / ha) due to reduced fresh and dry herbage yield of crop.

5.5.3 Essential oil content (%)

The essential oil content of menthol mint was recorded at harvest are calculated on fresh weight basis (%). The data on essential oil content of menthol mint with respect to different weed management practices did not showed any significant differences. The range of essential oil content is 0.61 to 0.76 per cent respectively.

5.5.4 Menthol content (%)

The data on menthol content of menthol mint did not differ significantly as influenced by different weed management practices.

5.6 Economics of different weed management practices

The data on economics of different weed management practices are presented in table 13 and fig. 6. Among the different weed management treatments maximum gross returns (`1,29,144 /ha), net returns (`83,461/ha) and cost: benefit ratio (1: 2.8) were recorded in PE spray of oxyfluorfen due to 66.33, 71.56 and 63.77 per cent increases in fresh, shade dried herbage yield and essential oil yield respectively as compared to un-weeded control which recorded minimum of gross return, net return and cost: benefit ratio (`46,788/ha, ` 16,825/ha and 1:1.5 respectively) due to increased cost of cultivation, reduced herbage and oil yield. Similar result was obtained by Ratnam *et al*. (2012) in turmeric.

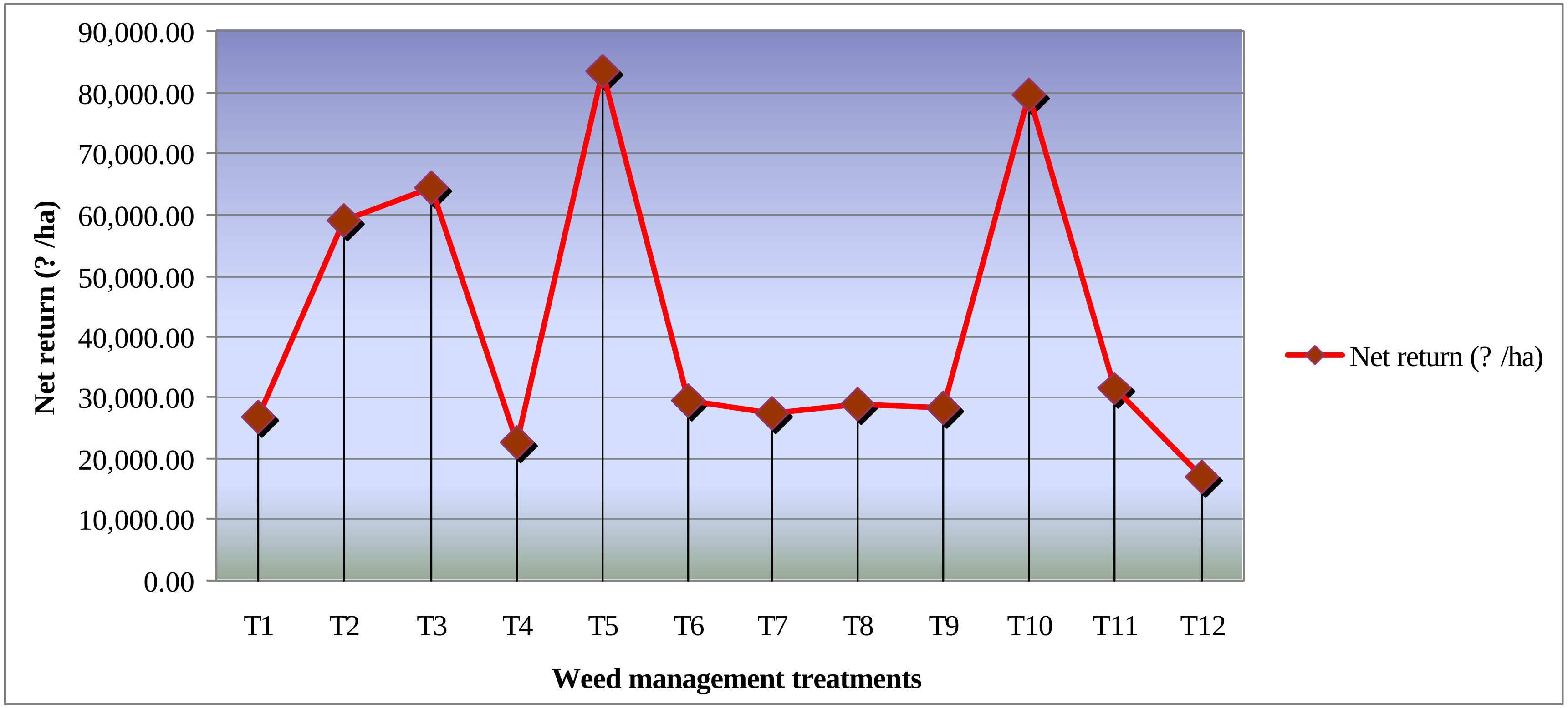


Fig. 6: Net return of menthol mint as influenced by different weed management practices

PE- Pre-emergent (2DAP) POE- Post-emergent (30 DAP)

T_1: Hand Weeding	T_7: PE metribuzi + POE quizalofop-ethyl
T_2: Inter-cultivation	T_8: PE oxyfluorfen + POE quizalofop-ethyl
T_3: Sugarcane trash mulch	T_9: PE oxyfluorfen + POE metribuzin + POE quizalofop-ethyl
T_4: PE Metribuzin	T_{10}:PE oxyfluorfen + Intercultivation
T_5: PE oxyflourfen	T_{11}: PE metribuzin + Inter-cultivation
T_6: PE oxyfluorfen + POE metribuzin	T_{12}: Un-weeded (control)

6. SUMMARY AND CONCLUSIONS

The present investigation entitled "Integrated weed management in menthol mint (*Mentha arvensis* L.)" was carried out at the Department of Plantation, Spices, Medicinal and Aromatic Crops, Kittur Rani Channamma College of Horticulture, Arabhavi, University of Horticultural Sciences, Bagalkot during 2017-18. Salient findings of the investigation are summarized as under:

Effect on weeds

During the cropping period, the PE application of oxyfluorfen @ 0.25 kg a.i./ha (T_5), PE application of oxyfluorfen @ 0.25 kg a.i./ha followed by inter-cultivation (T_{10}) and organic mulch with sugarcane trash @ 5 t/ha (T_3) were recorded lower number of weeds (31.33, 32.33 and 34.33/m^2 @ 30 DAP, respectively), fresh weight (58.33, 59.0 and 67.33 g/m^2 @ 30 DAP, respectively) and dry weight of weeds (19.0, 20.0 and 22.0 g/m^2 @ 30 DAP, respectively).

The PE application of alone oxyfluorfen @ 0.25 kg a.i./ha (T_5) and followed by inter-cultivation at 45 days after planting (T_{10}) and sugarcane trash mulch @ 5 t/ha (T_3) gave better control of the competitive weeds, *i.e. Cynodon dactylon*, *Cyperus rotundus* and *Digitaria sanguinalis* and POE application of metribuzin and quizalofop-ethyl controls broad leaved weeds *Amaranthus viridis*, *Ageratum conyzoides*, *Parthenium hysterophorus*. The grassy weeds did not appear extensively under sugarcane trash mulch, oxyfluorfen herbicide and their combinations treatments due to the better crop spread as compared with metribuzin sprayed treatments and their combinations.

Effect on menthol mint

Among all the weed management treatments, the performance of the menthol mint was good with PE application of oxyfluorfen @ 0.25 kg a.i./ha (T_5), PE application of oxyfluorfen @ 0.25 kg a.i./ha followed by inter-cultivation (T_{10}) and organic mulch with sugarcane trash @ 5 t/ha (T_3).

PE application of oxyfluorfen @ 0.25 kg a.i./ha (T_5) recorded maximum number of branches (55.33/plant), plant spread (77.50 cm), leaf area (5279.54 cm^2) and dry matter accumulation (54.78 g)

The maximum plant height of 68.80 cm and total chlorophyll content recorded in organic mulch with sugarcane trash @ 5 t/ha (T_3) which were *on par* with PE application of oxyfluorfen @ 0.25 kg a.i./ha (T_5).

The highest fresh (17.69, 13.68 and 13.4 t/ha, respectively), dry herbage (14.63, 11.80 and 10.55/ha, respectively) and essential oil yield (107.62, 104.46 and 90.21 kg/ha, respectively) were obtained in PE application of oxyfluorfen @ 0.25 kg/ha (T_5), which was *on par* with PE application of oxyfluorfen @ 0.25 kg/h followed by inter-cultivation (T_{10}) and organic mulch with sugarcane trash @ 5 t/ha (T_3). Un-weeded situation caused 66.36 per cent reduction in fresh herbage, 71.56 per cent in dry herbage and 68.63 per cent in essential oil yield. The sugarcane mulch @ 5 t/ha (T_3) increased fresh herbage yield by 55.59 per cent than un-weeded control.

The essential oil content in fresh herbage remained unaffected due to different weed management treatments.

PE application of oxyfluorfen @ 0.25 kg a.i./h (T_5) recorded maximum gross returns (` 1,29,144/ha), net returns (` 83,46/ha) and cost: benefit ratio (1: 2.8) while minimum values recorded in un-weeded control (T_{12}) (` 34,317/ha, ` 46,788/ha, 16,825/ha and 1:1.56, respectively).

Conclusion

The experiment was conducted to identify the suitable and economically viable cost effective integrated weed management practices for menthol mint to increase yield and quality of essential oil. The study indicated that among the different weed management practices the PE application of oxyfluorfen @ 0.25 kg a.i./ha proved effective in controlling most of the weed species and recorded significantly higher fresh herbage, dry herbage and essential oil yield. The oil quality was also not affected due to above treatment. The next best treatments are PE application of oxyfluorfen @ 0.25 kg a.i./ha followed by inter-cultivation and organic mulch with sugarcane trash @ 5 t/ha. The treatment PE application of oxyfluorfen @ 0.25 kg a.i./ha followed by inter-cultivation can be adopted by the farmers as a integrated method of weed management in menthol mint. The treatment organic mulch with sugarcane trash @ 5 t/ha recorded significantly reduced weed density, weed dry weight and recorded good herbage and oil yield and this treatment can be adopted by the farmers as a non-chemical method of weed management in menthol mint.

The experimental results may concluded that the above three treatments can be adopted by the farmers as a weed management practice in menthol mint for northern dry zone of Karnataka. Whereas, PE and POE application of metribuzin @ 0.07 kg a.i./ha having adverse effect on crop therefore, this should not be adopted as a weed management practice in menthol mint. The oil quality was not affected due to any of the weed management treatments.

Future line of work

Based on the work done and results obtained, aspects which need further investigation in menthol mint are as follows:

- Long term studies are required on chemical method of weed management in menthol mint.
- Studies on photo-blastic behavior of different local weeds species are required for chemical weed management.
- Studies on effect of quizalofop-ethyl at higher concentration in menthol mint

REFERENCES

Agostinetto, D., Perboni, L. T., Langaro, A. C., Gomes, J., Fraga, D. S., and Franco, J. J., 2017, Changes in photosynthesis and oxidative stress in wheat plants submmited to herbicides application. *Planta daninha*, **34**(1).

Ali, M., Sabir, S. and Mohy-ud-din, Q., 2004, Efficacy and economics of different herbicides against narrow leaved weeds in wheat. *Intl. J. Agri. Bio.*, **6**(6): 47–51.

Anonymous, 2015, Current data and market activity. *Multi Commodity Exchange Limited*.

Arnon, D. I., 1949, copper enzyme in isolated chloroplasts polyphenol oxidase in *Beta vulgaris*, *Plant physiol*., **24**: 1-15.

Bhullar, M. S., Saini, S. S., Uppal, S. K. and Kumar, R., 2009, Weed control in spring sugarcane (*Saccharum sp*.) + mentha (*Mentha arvensis*) intercropping system. National Workshop on Spices and Aromatic plants, held during February 4-5 at PAU, Ludhiana.

Brar, L. S., Walia, S. S. and Walia, U. S., 2000, Bio-efficacy of herbicides against weeds and Japanese mint (*Mentha arvensis* Linn.). *Indian J. weed Sci*., **32**(2):72-79.

Chakraborty, T., 1971, Different methods of weed control in medicinal and aromatic crops. *Int. J. Med. Arom. Pl*., **1**(2): 51-56.

Chandel, S. R. S., 1984. Analysis of variance. A hand book of Agricultural Statistics, 7th Ed., Pp. 358- 359.

Croteau, R., Davis, E. M., Ringer, K. L. and Wildung, M. R., 2005, Menthol biosynthesis and molecular genetics. *Naturwiss*, **92**(5): 62-77.

Dyck, E. and Liebman, M., 1994, Soil fertility management as a factor in weed control: the effects of crimson clover residue, synthetic nitrogen fertilizer and their interactions on emergence and early growth of lambsquater and sweet corn. *Pl. Soil*, **67**(2): 27-37.

Ghorai, A. K. and Bera, P. S., 1988, Weed control through organic mulching in pointed gourd (*Trichosanthes diocia* Linn.). *Indian J. Weed Sci.*, **30**(1): 14-17.

Gulati, B. C. and Bhan, V. M., 1971, Effect of pre-emergence application of terbacil on control of weeds in Japanese mint. *Indian Perfumer*, **15**(3): 53-59.

Gulati, B. C. and Duhan, S. P. S., 1979, Effect of time of weed removal and period of weed free condition on the yield of herb oil and quality of oil of *Mentha arvensis* Linn. *Indian Perfumer*, **23**(2): 87-90.

Harley, R. M. and Brighton, C. A., 1977, Chromosome numbers in the genus *Mentha arvensis* L. *Bot. J. Linn. Soc.*, **74**(3): 71–96.

Jackson, M. L., 1973, *Soil Chemical Analysis*. Prentice Hall of India (P) Ltd., New Delhi.

Jcakson, M. L. 1967, Soil Chemical Analysis. Prentice Hall of India Private Limited, New Delhi, Pp. 111-192.

Jaidev, Singh, J. N. and Singh, G. 1993, Chemical weed control in menthol mint (*Mentha arvensis* Linn.). *Indian J. Weed Sci.*, **25**(1): 50 -54.

Kamble, T. C., Kakade, S. U., Nemade, S. U., Pawar, R. V. and Apotikar, V. A., 2005, A integrated weed management in hybrid maize in Hisar. *Crop Res.*, **29**(3): 396-400.

Kamennobrodskaya, V. G., 1967, Effects of herbicides on the yield and quality of essential oil bearing crops. *Khimiya Sel' Khoz.*, **5**(2): 49-52.

Karkanis, A., Lykas, C., Liava, V., Bezou, A., Petropoulos, S. and Tsiropoulos, N., 2017, Weed interference with peppermint (*Mentha piperita* L.) and spearmint (*Mentha spicata* L.). *J. Sci. Food Agri.*, **98**(1): 43-50.

Kaur, M., 1999, Studies on weed management in peppermint (*Mentha piperita* Linn.). *M.Sc. Thesis*, *Punjab Agric. Univ.*, Ludhiana, India. 82.

Kaur, T., Singh, M. S., Bhullar, S. S., Shergill, S. L. and Kaur, R., 2013, Effect of planting methods and weed control on productivity of Japanese mint (*Mentha arvensis* L.). *Indian J. Agri. Res*., **47**(3): 243-247.

Kothari, S. K. and Singh, K., 1994, Chemical weed control in menthol mint (*Mentha arvensis* Linn.). *J. Essential Oils Res*., **6**(3): 45-55.

Kothari, S. K. Singh, D. V. and Singh, K., 1991, Critical periods of weed interference in Japanese mint (*Mentha aruensis* L.). *Trop. Pest Manage*., **37**(2):85-90.

Kumar, K., Walia, U. S. and Brar, L. S., 2001, Bio-efficacy of herbicides in *Mentha arvensis* Linn. and *Mentha piperita* Linn. *Indian J. Weed Sci*., **33**(4): 22-25.

Lal, R., 1974a, Soil temperature, soil moisture and maize from mulch and unmulched soils. *Pl. and Soil*, **40**(1): 29-43.

Lal, R., 1974b, Effects of constant and fluctuating soil temperature on growth, development and nutrient uptake of maize seedlings. *J. Pl. nd Soil*, **40**(1): 589-606.

Liebman, M. and Davis, A. S., 2000, Integration of soil, crop, weed management in low external input farming systems. *J. Weed Res*., **40**(11): 27-47.

Mahey, S. C., Hundal, J. S., Pande, P. N. and Mittra, M. K., 1973, Paraquat for inter-row weed control in sugarcane, maize and Japanese mint (*Mentha arvensis* Linn.) grown in Tarai. *Indian J. Weed Sci*., **5**(1): 20-28.

Mishra, L. P., Kapoor, L. D. and Choudhri, R. S., 1973, Studies on efficacy of some herbicides on the control of weeds in Japanese mint. *Indian J. Agron*., **18**(1): 10-19.

Muhr, G. R., Dutia, N. P., Sankar, S. H., Dever, R. F., Leley, V. K. and Dohalur, R. L., 1963, Methods of Analysis Soil Testing in India. United States Agency for International Development Mission to India, New Delhi. Pp. 37-39.

Nagy, F., 1977, Current weed control programmes for large scale production of lavender peppermint, tarragon and chamonite. *Novenyvedelen*, **13**: 399-408.

Nieto, J. N., Brondo, M. A. and Gonzalez, J. T., 1968, Critical periods of the crop growth cycle for competition from weeds. *J. Med. Arom. Pl. Sci.*, **22**(2): 15-26.

Panse, V. G. and Sukhatme, P. V., 1967, Statistical methods for agricultural workers, ICAR, Publication New Delhi. Pp. 359.

Patra, D. D., Rani, M., Singh, D. V. and Ram, M., 1993, Effect of straw mulching on fertilizer nitrogen use efficiency, moisture conservation and herb and essential oil yield in menthol mint (*Mentha arvensis* Linn.). *Fert. Res.*, **34**(1): 35-39.

Ram, D., Ram, M. and Singh, R., 2006, Optimization of water and nitrogen application to menthol mint (*Mentha arvensis* Linn.) through sugarcane trash mulch in a sandy loam soil of semi-arid subtropical climate. *Bioresource Tech.*, **97**(8): 86-93.

Ramesh, G. and Nadanassababady, T., 2005, Impact of herbicides on weeds and soil ecosystem of rainfed maize (Zea mays L.). *Indian J. Agric. Res.*, **39**(1): 31-36.

Randhawa, G. S., Saini, S. S., Walia, U. S., Mahey, R. K. and Sidhu, B. S., 1982, Weed control in the first and second cutting of menthol mint (*Mentha arvensis* Linn.). *Indian Perfumer*, **26**(1): 07 -11.

Randhawa, G. S., Walia, U. S., Saini, S. S. and Sidhu, B. S., 1984, Studies on comparative performance of herbicide in Japanese mint (*Mentha arvensis* Linn.) and their residual effects on the proceeding crops of Wheat, Oats, Raya and Potato. *Agric. Res. Commun.*, **3**(1): 43-48.

Ratnam, M., Rao, A.S. and Reddy, T.Y., 2012, Integrated weed management in turmeric (*Curcuma longa*). *Indian J. Agron.*, **57**(1): 82 –84.

Singh, J. N., Kewala, N. and Singh, G., 1982, Chemical weed control in Japanese mint. *Indian J. Weed Sci.*, **14**(1): 31-34.

Singh, G., 2012, Integrated weed management in menthol mint (*Mentha arvensis* L.). *MS.c Thesis*, *Punjab Agric*. *Univ*., Ludhiana.

Singh, K. and Aggarwal, S. G., 1988, Chemical weed control in Japanese mint and residual studies. *Indian Perfumer*, **32**: 341-346.

Singh, K. and Khosla, S. N., 1989, Weed control in Japanese mint: Part 1: Phytosociological aspects of weeds. *Indian Perfumer*, **33**(2): 01-06.

Singh, K., 1991a, Chemical weed control in Japanese mint: Part 2: Critical Period of weed pressure. *Indian Perfumer,* **35(**1): 22-24.

Singh, M. K. and Saini, S. S., 2008, Planting date, mulch, and herbicide rate effects on the growth, yield, and physicochemical properties of menthol mint (*Mentha arvensis* Linn.). *Weed Tech*., **22**(6): 91-98.

Singh, M. K., 2003, Studies on combined performance of herbicides, mulching and date of planting in *Mentha species*. *PhD. Thesis, Punjab Agri. Univ*., Ludhiana, India.

Singh, P., 1991b, Integrated weed control in Japanese mint (*Mentha arvensis* Linn.). *M.Sc Thesis, Punjab Agri. Univ*., Ludhiana, India.

Singh, P., Brar, L. S., and Randhawa, G. S., 1995, Efficacy of different herbicides for weed control in menthol mint (*Mentha arvensis* Linn.). *Indian Perfumer*, **39**(3): 72-75.

Singh, S., Walia, U. S. and Nayyar, S., 2009, Performance of oxyfluorfen (Goal 23.5 EC) for the control of weeds in Japanese Mint (*Mentha arvensis*). Proc. *National Workshop on Spices and Aromatic plants*, held at Kerala.

Skender, A., Mikrut, L., Lantiovic, Z. and Eichenberger, M., 1997. Weed flora in true chamoline and peppermint production condition. *Agronomski Glasmik*., **59**(2): 35-46.

Subbaiah, B. B. and Asija, G. L., 1956, A rapid procedure for estimation of available nitrogen in soils. *Current Sci*., 25(8): 259-260. Jackson, M. L., 1973, Soil chemical analysis. *Prentice Hall of India Pvt. Ltd.*, New Delhi, Pp. 183-192.

Teasdale, J. R., Beste, C. E. and Potts, W. E., 1993, Response of weeds to tillage and cover crop residue. *Weed Sci*., **39(**1): 95-99.

Thankamani, C. K., 2016, Effect of mulches on weed suppression and yield of ginger (*Zingiber officinale* R.). *Scientia Horticulturae*., **20(**7): 125-130.

Walia, U. S., 2009, Weed Management. Pp. 176 and 188 Kalyani publishers, New Delhi.

Walia, U. S., Brar, L. S. and Singh, B., 2006, Recommendations for weed control in field crops. Research Bulletin. *Department of Agronomy, PAU*, Ludhiana, **32**(1): 72-75.

Walia, U. S., Sandhu, K. S., Saini, S. S. and Samra, J. S., 1980, Studies on chemical weed control in menthol mint (*Mentha arvensis* Linn.). *Indian J. Weed Sci*., **12**(1): 81-85.

Walker, J. M., 1969, One degree increments in soil temperature effects maize seedlings behavior. *Proc. Soil Sci. Soc. Am*., **33**(2): 729-736.

Weston, L. A., 1966, Utilization of allelopathy for weed management in Agro-ecosystems. *Agron. J*., **88**(8): 60-66.

Zheljazkov, V., Yankov, B. and Topalov, V., 1996, Effect of mechanical and chemical weed control on the growth, development and productivity of *Mentha piperita* and *M. arvensis* var. *piperascens* grown for planting material. *J. Essent Oil Res*., **2**(8): 171–176.

Appendix I

Meteorological data recorded during the period of experimentation (2017-2018) from Agriculture research station, Arabhavi

Month	Temperature (°C)			Relative humidity (%)	Rainfall (mm)	EVP (mm)
	Maximum	Minimum	Average			
January 2017	31.40	9.90	20.65	88.90	0.00	1.90
February 2017	33.80	11.30	22.55	89.60	0.00	4.00
March 2017	41.20	19.50	30.35	85.10	0.00	4.40
April 2017	38.80	20.10	29.45	85.50	0.00	7.40
May 2017	39.40	22.80	31.10	84.80	10.20	6.80
June 2017	32.40	22.60	27.50	86.00	15.00	5.00
July 2017	31.00	21.30	26.15	91.10	37.20	3.50
August 2017	32.90	20.50	26.70	88.90	40.40	3.90
September 2017	33.10	19.40	26.25	93.60	179.40	3.70
October 2017	33.30	19.10	26.20	88.70	91.20	5.00
November 2017	33.40	12.40	22.90	78.00	8.20	4.10
December 2017	33.70	10.50	22.10	78.00	3.20	3.80
January 2018	32.30	8.20	20.25	80.80	0.00	4.20

Appendix II

Physical and chemical properties of soil of the experimental site

Sl. No.	Particulars	Characterization	Method employed
1.	**Physical properties** I. Soil structure		Hydrometer method (Piper, 1966)
	a. Silt (%) b. Clay (%) c. Sand (%)	17.50 32.00 49.50	
	II. Soil texture	Sandy clay loam	
	III. Soil colour	Black	-
	IV. Bulk density (g/cc)	2 g/cc	-
2.	**Chemical properties**		
	pH (1: 2.5 soil: water)	8.79	Potentiometric method (Jackson, 1967)
	Electrical conductivity (dS/m)	0.285	Conductometric method (Jackson, 1973)
	Organic carbon (%)	0.285	Walkley and Black wet oxidation method (Jackson, 1973)
	Available Nitrogen (kg/ha)	210	Modified Kjeldal's method (Subbaiah and Asija, 1956)
	Available phosphorus (kg/ha)	7.16	Olsen'smethod (Muhr *et al*., 1963)
	Available Potassium (kg/ha)	73.23	Flame photometer method (Muhr *et al*., 1963)

Appendix III

Prices of inputs and outputs

Sl. No.	Input	Units	Rate (`/unit))
1	FYM	t	1500.00
2	Stolan cost	kg	30.00
3	Urea	kg	5.52
4	SSP	kg	7.24
5	MOP	kg	16.05
6	Oxyfluorfen	kg	2100.00
7	Metribuzin	kg	1712.00
8	Quizalofop-ethyl	kg	481.00
9	Labrour charges	Man day	200.00
10	Distillation charges	t	1000.00
Output			
11	Essential oil price	kg	1200.00

Appendix IV

Cost of production (`/ha) as influenced by different weed management practices in menthol mint.

Treatments	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	T_9	T_{10}	T_{11}	T_{12}
FYM	1200	1200	1200	1200	1200	1200	1200	1200	1200	1200	1200	1200
Land preaparation	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000
Fertilizers	2225	2225	2225	2225	2225	2225	2225	2225	2225	2225	2225	2225
Stolons/ha	8000	8000	8000	8000	8000	8000	8000	8000	8000	8000	8000	8000
Irrigation	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000
Hand weeding	32000	0	0	0	0	0	0	0	0	0	0	0
Inter-cultivation	0	3600	0	0	0	0	0	0	0	0	0	0
Sugarcane trash mulch	0	0	6286	0	0	0	0	0	0	0	0	0
Herbicides	0	0	0	2665	3980	6645	5463	6777	9243	4180	2865	0
Plant protection	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000
Harvesting	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000
Distillation	12080	12180	13400	7640	17690	8240	7810	8650	8730	13680	8100	5950
Miscellaneous	1587	1587	1587	1587	1587	1587	1587	1587	1587	1587	1587	1587
Total	**68092**	**39792**	**43699**	**34317**	**45682**	**38897**	**37285**	**39440**	**41985**	**41872**	**34978**	**29962**

PE- Pre-emergent (2DAP) POE- Post-emergent (30 DAP)

T_1: Hand Weeding
T_2: Inter-cultivation
T_3: Sugarcane trash mulch
T_4: PE Metribuzin
T_5: PE oxyflourfen
T_6: PE oxyfluorfen + POE metribuzin
T_7: PE metribuzi + POE quizalofop-ethyl
T_8: PE oxyfluorfen + POE quizalofop-ethyl
T_9: PE oxyfluorfen + POE metribuzin + POE quizalofop-ethyl
T_{10}: PE oxyfluorfen + Intercultivation
T_{11}: PE metribuzin + Inter-cultivation
T_{12}: Un-weeded (control)

INTEGRATED WEED MANAGEMENT IN MENTHOL MINT (*Mentha arvensis* L.)

ASHA M. R. **2018** **Dr. I. B. BIRADAR**
Major Advisor

ABSTRACT

A Field experiment was conducted during 2017 to study the effect of different weed management methods on menthol mint in northern dry zone of Karnataka. The experiment was laid out in randomized block design having three replications with 12 treatments. The objective of the experiment is to identify the suitable and economically viable cost effective integrated weed management practices for menthol mint to increase yield and quality of essential oil.

The weed density, fresh weight of weeds and dry weight of weeds at 30 DAP were recorded significantly minimum in pre-emergent application of oxyflourfen @ 0.25 kg a.i./ha (05.66/m^2, 23.33 g/m^2 and 7.94 g/m^2, respectively) and maximum were recorded in un-weeded control (90.00/m^2, 201.66 g/m^2 and 36.85 g/m^2, respectively). Among the different weed management treatments pre-emergent application of oxyfluorfen 23.5 EC 0.25 kg a.i./ha recorded significantly maximum fresh herb (17.69 t/ha), shade dried herb (14.63 t/ha), essential oil yield (107.62 kg/ha), net returns (` 83,461.78/ha) and cost: benefit ratio (1: 2.82), respectively, whereas minimum of these values were recorded in un-weeded control (5.95 t/ha, 4.16 t/ha, 38.99 kg/ha, ` 16,825.78/ha and 1: 1.56).

Among the different weed management practices the pre-emergent application of oxyfluorfen @ 0.25 kg a.i./ha proved effective in controlling most of the weed species and recorded significantly higher fresh herbage, dry herbage and essential oil yield. The oil quality was also not affected due to any of the treatment.

The treatment pre-emergent application of oxyfluorfen @ 0.25 kg a.i./ha followed by inter-cultivation can be adopted by the farmers as a integrated method of weed management in menthol mint. The treatment organic mulch with sugarcane trash @ 5 t/ha recorded significantly reduced weed density, weed biomass and recorded good herbage and oil yield and this treatment can be adopted by the farmers as a non-chemical method of weed management in menthol mint.

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ªÀÄn§ÄÖf£ï 70% q§Æ¦ 0.7 Pf QÀææiÁvÀP WIPÁA± ªÄÃxÁ¯ï ¥ÃÀ¢Ã£Áz ªÄÃ¯ «µPÁj ¥juÁªÄ ©ÃgÀvz. P©£ gË¢ ºÆ¢P ªiÁqÀªÀzjAz®Æ ¸º GvªÄ P¼ ¤gðªºuAiiÁVzÀ PAqÀÄ§A¢zÀ gÁ¸ÁAiÀÄ¤P g»v P¼ ¤gðªºuAiÀÄ° §¼¸§ºÄzÁVz. CzÁåAiÀÄ£ ªiÁq¯Áz AiiÁªÀz G¥ZZÁgU¼ÀÄ ¸ÀÄUAz vÈ®z UÀÄtªÀÄlz ªÄÃ¯ ¥juÁªÄ ©Ãg°®.