

**“Efficacy of various weedicides on weed
management, growth, physiology and
productivity of winter sown Ashwagandha
(*Withania somnifera* (L.) Dunal.)”**

THESIS

Submitted to the

Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur

**In partial fulfilment of the requirements for
the Degree of**

MASTER OF SCIENCE

In

**AGRICULTURE
(PLANT PHYSIOLOGY)**

By

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2022

Document Information

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Submitted	6/28/2022 7:30:00 AM
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ACKNOWLEDGEMENT

First of all, I thank 'Almighty God' who has blessed me with the opportunity and strength to successfully complete this work.

It is a moment of great pleasure to put in record my heartfelt gratitude and indebtedness to honorable guide and chairman of my Advisory Committee **Dr. Gyanendra Tiwari**, Professor, Department of Plant Physiology, JNKVV, Jabalpur for his able magnificent guidance, inspiration, constructive criticisms and encouragement during the course of investigations and preparation of the thesis.

I express equal gratitude and indebtedness from bottom of my heart towards the member of my advisory committee **Dr. Radheshyam Sharma**, Scientist, Agricultural Biotechnology, JNKVV and **Dr. R. Shiv Ramakrishnan**, Professor, Department of Plant Physiology, JNKVV, Jabalpur for their helpful and constant guidance during the course of investigation.

I take the opportunity to thank **Dr. P.K. Bisen**, Hon'ble Vice Chancellor, JNKVV, **Dr. D. Khare**, Dean Faculty of Agriculture, JNKVV, Jabalpur, **Dr. G.K. Koutu**, Director, Research Services, JNKVV, Jabalpur, **Dr. D.P. Sharma**, DES, JNKVV, Jabalpur, **Dr. Abhishek Shukla**, Directorate of Instructions, JNKVV, Jabalpur and **Dr. A.K. Sarawgi**, Dean, College of Agriculture, Jabalpur for their exuberant interest for submission of piece of research work.

It is my proud privilege to express my deep sense of respect and heartfelt gratitude to **Dr. R. K. Samaiya**, Professor and Head, Department of Plant Physiology, JNKVV, Jabalpur, for their passionate and unreserved support, encouragement and sustained interest which contributed to the success of this work.

I also owe an everlasting debt of gratitude to all the members of Department of Plant Physiology **Dr. (Smt.) A. Upadhyay**, Professor, **Dr. Preeti Sagar Nayak**, Guest Faculty, and all the members of the department of Plant Physiology for their full cooperation and help during the course of investigation.

I feel wordless to express my heartiest feelings towards My father Shri Bholu Singh Mandloi and my mother Smt. Basanti Mandloi and my elder Sisters, Harshlata Mandloi and Jayshree Mandloi and also my Brother Vinay Mandloi for their unconditional love, care, blessings, appreciation and moral support.

Friends play a major role in one's life. Words are not enough too obvious my feelings. I would like to thank some of my friends: Yogesh Kumar, Prashant Namdeo, Samiksha Hote, Ramkrishna Birla, Pushpranjan Sahu, and Alok Gupta for encouraging and supporting me and making me strong and positive in myself during the tough times.

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(Rupesh Mandloi)

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LIST OF ABBREVIATIONS

Legends	:	Descriptions
%	:	Percentage
°C	:	Degree Celsius
ANOVA	:	Analysis of Variance
CCI	:	Chlorophyll Content Index
CD at 5%	:	Significant at 5% Level of Significance
CD	:	Critical Difference
CGR	:	Crop Growth Rate
cm	:	Centimeter
cm ²	:	Square centimeter
d.f.	:	Degrees of freedom
DAS	:	Days After Sowing
et al.	:	And others people
Eve.	:	Evening
Fig.	:	Figure
g	:	Gram
i.e.	:	That is
LAD	:	Leaf Area Duration
LAI	:	Leaf Area Index
m	:	Meter
m ²	:	Meter square
Morn.	:	Morning
MSS	:	Mean Sum of Squares
No.	:	Number
Plant ⁻¹	:	Per plant
RF	:	Rainfall
RGR	:	Relative Growth Rate
SCMR	:	SPAD chlorophyll meter
readingSEM±	:	Standard error of mean
Tem.max	:	Maximum temperature
Tem.min	:	Minimum temperature
Viz.	:	Namely

Chapter- I

INTRODUCTION

INTRODUCTION

Ashwagandha / Wintercherry (*Withania somnifera* (L) Dunal.) belongs to family Solanaceae is an important Ayurvedic medicinal plant that has been recognised for its pharmacological, chemical composition, and therapeutic efficiency. It is known in India by several names such as Amukkira (Tamil), Asgandh (Hindi), Tilli (Marathi), and Akshan (Punjabi) for more than 6000 years Ashwagandha has been used as a Rasayana. The root smells like horse ("ashwa"), that is why it is called Ashwagandha. The entire plant is used medicinally to treat a variety of human ailments, although the root and leaves are the most commonly utilised components. The species name *somnifera* means 'sleep-inducing' in Latin, indicating its sedating properties. It has been also used for sexual vitality and as an adaptogen.

Daily consumption of powdered root of this plant is assumed to delay the senescence, rejuvenate the muscle and reproductive organs and increase the fertility (Durg *et al.*, 2018). In folk medicine, it's used to treat cough, stress, nervous exhaustion, memory loss and muscular weakness (Sharma and Dash, 1998)

The plant is remarkable in phytochemical terms since it has the largest and most structurally diverse collection of withanolides (modified steroidal molecules with an ergostane backbone), which are named after it. Adaptogenic, anti-sedative, and anti-convulsion activities are among the ethnopharmacological qualities of the plant, and it has been used to treat neurological illnesses, geriatric debilities, arthritis, and stress and behaviour problems. Several recent molecular pharmacological studies have linked these medicinal properties to one or more withanolides found in the herb. In several places of India, the area planted with Ashwagandha is growing day by the day.

The presence of a variety of secondary metabolites in *W. somnifera* is thought to be responsible for its medicinal properties, including alkaloids (dl-isopelletierine, anaferine, anahygrine, tropine, psudotropine, hygrine, 3-trigloyloxytropine, cushohygrine, choline and withanosomine), flavanol glycosides [6,8-dihydroxykaempferol 3-rutinoside, quercetin and its 3-o-rutinoside and 3-rutinoside-7-glucoside], glycowithanolides [sitoindoside vii to x, steroidal lactones [withanolide a, withanolide d, withanone, withaferin a], sterols and phenolics. Leaves of ashwagandha contain steroidal lactones, withanolides along with somnital, glucose, withanone. Seeds have five withanolides viz., withasomnilide, withasomniferanalide,

somniferanolide, somniferawithanolide and somniwithanolide.

It is grown on more than 5000 hectares in Madhya Pradesh alone. The estimated yearly production of Ashwagandha roots in India is more than 1500 tonnes, with a demand of around 7000 tonnes, necessitating further cultivation and production. The plant is drought tolerant and is now grown as a rainfed crop in practically every section of the country due to its high value and export potential (Chandranath and Katti, 2010). This plant has ploidy levels that vary and a tetraploid majority; the chromosome number is $2n = 48$. (Iqbal and Dutta, 2007). It is a tiny, erect, evergreen shrub with woolly pubescence that grows to around 30-75 cm in height. Tuberous roots, 20-30 cm long, cylindrical, 1-2 cm diameter, and yellowish-brown skin are found in wastelands throughout India's drier regions.

Due to its wide range of pharmacological actions, *Withania somnifera* has attracted the attention of scientists all over the world. However, due to a number of factors, including a long gestation period between planting and harvesting, a limited genetic base, self-pollination, a low percentage of seed viability, germination and seedling survival, and infestation by various weeds and pathogens, its commercial cultivation is limited.

Due to its slow initial development, weak canopy cover, and deep root system as a late rainy and winter season crop, it is heavily infected by weeds at the early phases of its growth and often fails completely. The dominating weed flora that stunts crop growth and productivity varies depending on soil type, moisture conditions, and other climatic factors. Weed losses are for 45 percent more than losses from insects, pests, and diseases, which account for 30 and 20 percent, respectively (Rao, 1993). The coordinated management of weed populations with effective, dependable, and practicable management approaches that are both economically and environmentally sound in boosting and maintaining agricultural productivity is known as an integrated weed management system (Foy, 1993). This condition needs the development of an effective and cost-effective asgandh weed control strategy.

The early stages of growth are the most essential, as any stress has the greatest impact on economic output. During this phase, weed competition is a major source of stress. Furthermore, this time period corresponds with peak labour activity, resulting in a labour shortage for weeding. This raises the production costs. Due to competition for

light, nutrients, space, and moisture posed by weed diversity, crop productivity and quality suffer. Chemical weed control has been shown to be a more successful and cost-efficient weed control approach than hand weeding. and it is absolutely necessary to use herbicides to achieve optimal productivity.

The various weed-control methods each have their own set of advantages and disadvantages. The effectiveness and costs of any method will primarily determine its final decision. One of the most essential agronomic practises for better output in medicinal crops is timely weed management. In a tropical country like India, the abundance of sunshine and appropriate nutrients provided to the crop after transplanting encourage the growth of weeds in the crop fields. Herbicides hold promise for fast, effective, and efficient weed removal in areas where labour is scarce and expensive. The choice of herbicides for a particular situation will depend upon the climate, soil type, prevalent weed species, crop cultivar and method of propagation and management.

The herbicides when used in combination with one or two hand weedings, improves their efficiency and the post-emergent herbicides are beneficial to keep the crop weed free in the early stages During later stages, hand weeding helps to reduce the cost of weeding and keep the weed population below the economic threshold level throughout the crop growth period. Keeping all this in view, the present study was carried on **“Efficacy of various weedicides on weed management, growth, physiology and productivity of winter sown Ashwagandha. (*Withania somnifera* (L.) Dunal.)”** with the following objective:

1. To study the efficacy of weedicides application on phenology growth and physiology of ashwagandha (*Withania somnifera* (L) Dunal.).
2. To optimise the combination of effective weedicides on weed management and productivity.

Chapter- II

REVIEW OF LITERATURE

REVIEW OF LITERATURE

One of the limiting factors in good agricultural production is weed infestation. Weeds are plants that compete with cultivated plants or interfere in some other way with man's legal activity. Weeds are plants that are unwanted and undesirable, have a high profile, are persistent, competitive, and are damaging to the environment as a whole. Ashwagandha is a slow-growing crop. Weeds grew quickly during this time, posing a threat to Ashwagandha growth. As a result, Ashwagandha yield may be reduced, and the crop's productivity is highly dependent on weed-free conditions.

Work done in India and abroad related with diversity, density and weed management of ashwagandha and other related crop of family Solanaceae was reviewed and presented as below.

2.1 Weed flora

The type and density of weeds growing in a crop community determine the extent of weed damage. Season and cultivation type are known to affect weed species. Weed persistence is strongly influenced by edaphic (soil), biotic, and climatic conditions, all of which affect its presence, abundance, range and distribution.

Patro *et al.* (1970) observed that *Cyperus rotundus*, *Digitaria sanguinalis*, *Echinochloa colonum*, *Eleusine indica*, *Eleusine aegyptica*, *Acanthospermum hispidum*, *Amaranthus spp*, *Celoria argenticola* and *Commelina spp*. Were the important weed flora of potato field in Orissa.

Pritam (1978) reported that *Cyperus rotundus*, *Ageratum conyzoides*, *Echinochloa colonum*, *Digitaria sanguinalis* and *Commelina nudiflora* were the important weeds of tomato in Solan.

Saimbhi *et al.* (1994) stated that *Cyperus rotundus*, *Eleusine indica*, *Trianthema portulacastrum*, *Celostia argenta*, *Portulaca spp.* and *Amaranthus spp* were the predominant weeds of vegetable fields of Jalandhar in Punjab.

Nadagouda (1995) observed that the weed flora in onion field at Belawatagi (Dharwad) were *Cyperus rotundus*, *Cyanodon dactylon*, *Setaria glauca*, *Pennisetum*

spp., *Echinochloa crus-galli*, *Digitaria sanguinalis*, *Commelina bengalensis*, *Cynotis cristata* among monocots, *Parthenium hysterophorus*, *Phyllanthus niruri*, *Convolvus arvensis*, *Hibiscus*, *Ponduriformis*, *Chenopodium album*, *Trianthema monogyna*, *Eclipta alba*, *Amaranthus viridis*, *Euphorbia* spp., *Portulaca oleracea*, *Lactuca ranchinata*, *Lagasca mollis*, *Phyllanthus maderapatensis*.

Malik et al. (1998) observed that *Trianthema portulacastrum*, *Echinochloa colonum*, *Amaranthus viridis*, *Diguaria ciliaris*, *Phyllanthus niruri*, *Commelina benghalensis* *Dactyloctenium aegyptium*, *Cynodon dactylon*, *Cyperus rotundus* and *Orobanche Nicotiana* etc the important weed flora infesting vegetables in india.

Rao (1999) reported that *Dactyloctenium aegyptium*, *Cleome viscase*, *Euphorbia hirta*, *Phyllanthus niruri* and *Cyperus rotundus* were the important weeds of tomato.

Yadav (2001) observed that most dominant weed flora of the chilli (*Capsicum annum* L.) field were *Amaranthus viridis* L., *Trianthema portulacastrum* L., *Digitaria ciliaris* Retz., and *Dactyloctenium aegyptium* L.

Kulmi and Tiwari (2005) observed that the weed flora in ashwagandha field *Dinebra arabica* (49.9%), *Echinochloa crusgalli* (9.3%), *Physalis minima* (8.1 %), *Corchorus olerious* (7.5%), *Digera arvensis* (5.9%), *Acalypha indica* (4.8%) and *Xanthium strumarium* (4.5%). Other weeds (10%) such as *Dinebra retroflexa*, *Digitaria sanguinalis*, *Cyperus rotundus*, *Eclipta alba*, *Phyllanthus niruri* and *Commelina bengalensis* were low in density.

2.2 Crop weed competition

Crop-weed competition is complicated because various factors affect the extent to which it occurs. The total effect of the interference as reflected in crop growth and yield, results from competition for nutrients, moisture and sunlight (Rao, 2000).

Lawson (1972) stated that weeds left beyond the rapid growth of spring planted cabbage crop resulting in smaller marketable heads. Increase severe competition affected internal head quality, reduced the number of plants producing heads and resulted in death of proportion of the crop plants.

Sweet *et al.* (1974) reported that there was great variation in competitive ability of crop plants with and associated plants. Crop plants with quick start and better establishment and subsequent dense growth effectively suppressed the weed growth, whereas, slow growing ones tended to become infested weeds.

Gupta (1984) stated that A fundamental principle of plant ecology is that early occupants on a soil tend to exclude later ones and this holds good also in agriculture. The seeds that germinate either before or even at same time as the crop are the most successful competitors because they are capable of accumulating dry matter faster than the crop plants

John and Daniel (1985) demonstrated that transplanted tomatoes must be maintained free of weeds for at least five weeks to avoid significant yield reduction and by at least of seven weeks to achieve maximum yields consistently.

In brinjal, critical period for weed competition in so far as it affected yields was the two months after transplanting as reported by Nandal and Pandita (1990).

Qasem and Hill (1993) investigated the effect of weed competition. They observed severe reduction in the growth of cabbage, tomatoes and lettuce crops and the reduction increased as exposure time to the competition increased.

Muniyappa *et al.* (1995) reported that 35 days after transplanting/sowing was found to be the critical period of weed competition in tomatoes.

Pandey (2000) reported that weeds depleted crops environment of nutrients, water and light thus, yields of chilli was reduced considerably. In addition, weeds cause spread of several diseases and pests. The quality of produce is also reduced by weed infestation.

2.3 Critical period of crop weed competition

Shadbolt and Holm (1956) observed that the period from emergence to four weeks was the critical stage in the competition of weeds in row planted vegetable crops.

Paller *et al.* (1973) stated that the duration of weed competition in transplanted

onion and found that the presence of weeds for only two weeks reduced the yield by 42 per cent. They have concluded that weed free condition for seven weeks after transplanting gave the maximum yield.

Rajagopal and Sankaran (1979) reported that the crop weed competition in tomato and found that the critical weed free period for tomato was up to 30 days from transplanting.

The critical stages of crop weed competition was 15 - 30 days for okra was reported by Singh *et al.* (1982)

Nandal and Pandita (1988) reported that brinjal crop kept free from weeds between 20 to 40 days of transplanting, yielded equivalent to weed free condition and reduced the cost of weeding.

In a field experiment at Kanpur in transplanted chilli, keeping the field free of weeds between 15 and 60 days after transplanting appeared to be optimum for obtaining economic yield reported by Anon (1996).

2.4 Losses due to weeds

Weeds in ashwagandha crop can cause a considerable reduction in crop yield by suppressing the growth of crop due to slow growth habit and short stature of the later. Weeds are the potential competitors with crop plants as a result of which they cause marked reduction in the ashwagandha crop yield. The losses depend upon the density of weeds, duration of weeds, types of weed species and crop competing ability.

William and Warren (1975) observed that Nut sedge reduced the yield of transplanted tomatoes by about 53 per cent during one season in Brazil.

Schroder (1992) reported that *Amaranthus blitoides* and *Physalis wrightii* weeds reduced the pepper yield by 33 per cent in untreated plots, whereas, *Amaranthus palmeri* and *Chenopodium album* reduces the yield by 61 and 76 per cent, respectively.

Singh *et al.* (1993) reviewed that the yield losses caused by weeds in vegetable

crops and reported it to be ranging from 6 to 82 per cent. He also reported that the yield losses in tomato ranged from 42-71 percent.

Gonzalez *et al.* (1996) reported that black night shade competed for light and nutrients from the beginning of tomato flowering and reduced tomato fruit yield by 36.5 percent.

Liberman *et al.* (1996) reported that average loss of US No. 1 potato tuber due to weed interference was 12 per cent with mould board plough compared with 43 per cent with the chisel plough.

Jaiswal and Lal (1996) reported that weeds reduced the yield of potato Cv. Kufri Jyothi by 42 per cent.

Ved Prakash *et al.* (2003) reported that weed infestation is the major limiting factor in realizing potential yield of Capsicum, resulting in heavy reduction in the yield as high as 78 per cent.

Patel *et al.* (2004) reported that chili fruit yield losses range between 60 to 70 percent depending upon the weed flora and intensity of weeds.

Kulmi and Tiwari (2005) reported that Unchecked weed growth caused 57.2% loss in dry root yield and 53.6% loss in seed yield of asgandh. Higher doses of isoproturon (0.75 kg ha^{-1}) and glyphosate (1.5 kg ha^{-1}) gave 8.6 and 13.4% phytotoxicity tel asgandh crop, respectively.

Khokhar *et al.* (2006) reported that compared to weed free condition, weed-crop competition caused 30.1 and 46.4 percent reduction in the fruit yield during the first and second year in chili.

2.5 Effect of herbicides on weed

Petrov *et al.* (1976) reported that trifluralin at 30-35 liters product ha^{-1} resulted in control of annual monocotyledonous and some dicotyledonous weeds in brinjal crop. Application of metalochlor at 2-3 litres formulated product has applied before transplanting produced better results.

The study conducted by Rajagopal *et al.* (1976) on chilli revealed that alachlor

1.0, 2.0 and 2.5 kg ha⁻¹ resulted in early weed control of annual weeds.

Singh *et al.* (1985) reported that pendimethalin, fluchloralin and oxadiazon at 1.0 kg ha⁻¹ controlled the weed effectively and increased the growth and yield of chilli.

Kumar and Dixit (2004) recorded that the effects of different weed management practices in brinjal and observed that pendimethalin @ 0.50 kg a.i ha⁻¹ one hand weeding resulted the best weed control and the highest fruit yield (328 q ha⁻¹).

Kolar and Dhingra (1986) found that application of 1.5 litres basalin (fluchloralin) ha⁻¹ (presowing) gave effective weed control until 30-40 DAS resulting in yields of 1.1 t ha⁻¹ compared with 0.99 t with two handweedings and 0.59 tonnes without weed control in mungbean. Basalin gave effective control of grasses and broad-leaved weeds but not the perennial weeds such as *Trianthemamonogyna*, *Cyperus rotundus* and *Cynodon dactylon*.

Ziemniaka and Ochrony (1990) observed that Field trials conducted in 1984-89 revealed that 250-375 g ha⁻¹ haloxyfop-ethoxyethyl gave excellent *Elymus repens* control in potatoes. Tank mixtures containing 187.5-260 g of this herbicide plus 350 g metribuzin controlled both grasses and broadleaved weeds; however, the mixture was phytotoxic to potato cultivars sensitive to metribuzin.

Semidey *et al.* (1990) noted that in brinjal field the application of quizalofop at 0.28 - 0.56 kg ha⁻¹ resulted in 90 per cent control of grasses for ten weeks after transplanting.

Leela (1993) reported that alachlor, butachlor and oxyfluorfen controlled the dominant *monocotyledonous weeds* such as *Cyperus rotundus*, *C. iris* and *Cynodon dactylon* for 60 days in tomato, while dominant *dicotyledonous weeds* such as *Acanthospermum hispidum*, *Euphorbia spp.* and *Portulaca oleracea* were controlled for 60-65 day. One herbicide application provided good weed control in short-duration crops.

Ram *et al.* (1994) reported that the highest yield was recorded under weed free condition followed by two weeding at 15 and 45 days after transplanting. Among the

treatment in which the chemicals were used, the highest yield, lowest weed population, dry matter of weeds, weed index (%) and highest weed control efficiency (%) were obtained with alachlor (PE) @ 2.0 kg ha⁻¹ + hand weeding (hoeing) 45 DAT. This treatment also showed the maximum cost benefit ratio.

Joshi *et al.* (1995) reported that application of alachlor @ 1.25 kg a.i. ha⁻¹ or pendimethalin @ 0.75 kg a.i. ha⁻¹. As pre-emergence suppressed the weeds significantly and also recorded higher chilli Yield.

Singh *et al.* (1995) reported that oxyfluorfen 0.3 kg ha⁻¹ significantly reduced the weed density compared with fluchloralin @ 1.0 g ha⁻¹, oxyfluorfen @ 0.1 kg ha⁻¹ and metolachlor @ 0.5 and 0.75 kg ha⁻¹. Oxyfluorfen pendimethalin and fluchloralin at all the levels controlled the wild amaranth and horse purslane significantly compared with the weedy control. The lowest number of these weeds was recorded by oxyfluorfen @ 0.3kg ha⁻¹; thus showing 98.9 and 99.0 per cent control: respectively. It was followed by oxyfluorfen @ 0.2kg ha⁻¹. Application of oxyfluorfen at all levels was found effective in controlling fly roost leaf flower recording 1.3 weeds m⁻² at 0.3 kg ha⁻¹ compared with 22.6 m⁻² recorded under the weedy control. Other herbicides could not control this weed significantly. Thus, oxyfluorfen @ 0.3 kg ha⁻¹ was found the most effective against all the weeds (95.2%). recording the lowest number of total weeds (10.3 m⁻² followed by oxyfluorfen @ 0.2 kg ha⁻¹ (86.8%).

Ackley *et al.* (1997) revealed that the rimsulfuron at 26 and 35 g ha⁻¹, sequentially at 26 g ha⁻¹, at 26 g ha⁻¹ plus metribuzin at 280 g ha⁻¹, and metribuzin at 280 g ha⁻¹ were evaluated post-emergence for weed control in transplanted tomatoes cv. Agriset. Common lambsquarters (*Chenopodium album*) was controlled by rimsulfuron at 35 g/ha. Rimsulfuron plus metribuzin gave consistent control of common ragweed (*Ambrosia artemisiifolia*). But jimsonweed (*Datura stramonium*) control was inconsistent and goose grass (*Eteusine indica*) control was generally low. Rimsulfuron treatments cause slight (<12%) temporary injury to new terminal growth of tomatoes. In greenhouse studies, giant foxtail (*Solaria faberi*) and large crabgrass (*Digilaria sanguinalis*) control by rimsulfuron was above 95 and 85%, respectively, but goose grass was not controlled.

Pratap *et al.* (1997) reported that a field experiment was conducted to compare

17 weed control measures in tomato fields (cv. Pusa Early Dwarf). The best weed control was achieved with hand weeding (after 15, 30 and 45 days), greatly reducing the number of weeds and dry weight m^2 and increasing crop yield. Total yield losses in both years due to weeds were estimated at 84.7 and 86.4%. Pre- and post-emergence applications of metribuzin ($0.35 + 0.50 \text{ kg ha}^{-1}$ or $0.50 + 0.35 \text{ kg ha}^{-1}$) reduced the weed population and weed dry weight, but not as much as hand weeding 3 times. However, metribuzin or hand weeding twice decreased yield losses and were useful alternatives.

Pandey and Padhiar (1998) found that the efficacy of metribuzin, pendimethalin, oxadiazon, fluchloralin and sethoxydim for the control of weeds (mainly *Echinochloa spp.*, *Cyperus spp.*, *Physalis spp.* and *Enicostema spp.*) in tomatoes. In general, herbicide application + one hand weeding increased weed control efficacy compared with herbicide application alone.

Birader *et al.* (1999) observed that in chili crop the weed population and weed dry weight were greatly reduced with post-emergence application of glufosinate ammonium @ $1.20 \text{ kg a.i. ha}^{-1}$ both in combination with inter culture (IC) at 40 and 60 DAT + hand weeding at 45 and 75 DAT.

Singh and Bhan (1999) found that application of metribuzin (0.75 kg ha^{-1}) was most effective and yielded at par with hand weeding twice, herbicides reduced the population and dry matter production of weeds and produced significantly higher tuber yield was recorded under hand weeding at 20 and 40 days after planting (DAP).

Prakash *et al.* (1999) revealed that the effects of various weed control treatments on density and dry weight of weeds in a tomato crop, yield of tomato, weed index and weed control efficiency and various economic measures. The weed control treatments caused significant reductions in weed density and weed biomass production, resulting in significant yield increases compared with an un-weeded control. The highest yield (511 kg ha^{-1}) and weed control efficiency (98.6%) were recorded under the weed free treatment. However-Pendimethalin treatment at 1.0 kg ha^{-1} followed by hand weeding 45 days after transplanting (DAT) was on a par with the weed-free treatment. This treatment also recorded the lowest weed density (115.6 weeds/m^2), weed biomass (100.1 g/m^2), weed Index (8.3) and gave a mean weed

control efficiency 73.7% Season-long weed competition with the crop reduced the fruit yield by 72.3%, compared to the weed-free plot.

Narasalgi (1999) reported that alachlor 1.5 kg ha⁻¹ and fluchloralin 1.0 kg ha⁻¹ were effective in controlling. *Commelinabenghalensis*, *Amaranthusviridis* and *Physalis minima* in directed seeded chilli crop.

Reddy CN *et al* (2000) reported that Fruit yield of brinjal in the plots treated with butachlor, pendimethalin, metolachlor, alachlor, each 1.0 kg ha⁻¹ or oxyfluorfen @0.10 kg ha⁻¹ fb HW at 40 DAP was at par with weed free check and was significantly higher as compared to application of herbicides at higher levels.

Carciu *et al.* (2001) reported that the research was conducted during 1999-2000 with tomato cv. Unirea using different combinations of herbicides. The predominant weeds in 1999 were *Amaranthus retrollexus* and *Chenopodium album*, while *Convolvulus arvensis* dominated in 2000. Dual 500 EC [metolachlor] (4 litres ha⁻¹) + Sencor70WP (metribuzin) (0.3 kg ha⁻¹) + Fusilade Super [fluazifop-P] (1.5 litres ha⁻¹) provided the greatest weed control: 84.94% in 1999 and 82.12% in 2000.

Singh *et al.* (2002) reported that Field experiment was conducted during winter seasons of 1996–97 and 1997–98 to assess the effect of clodinafop-propargyl on weeds and wheat yield. Results revealed that *Phalaris minor* was controlled effectively due to application of clodinafop-propargyl at 50 and 60 g ha⁻¹. Tank mixture of clodinafop-propargyl and isoproturon caused reduction in the density of *Chenopodium album* and *Melilotus alba*, but mixing of isoproturon with clodinafoppropargyl at 500 g ha⁻¹ was less effective than at 750 g ha⁻¹. Clodinafop-propargyl at 50 and 60 g ha⁻¹ yielded more than at 40 g ha⁻¹.

Erdal Elkoca *et al.* (2004) found that weed control applications significantly decreased intensity and dry weight of weeds and increased yield and all yield parameters compared with the unweeded control excepting 1000-grain weight, corresponding increases in yield by 48.3% (metribuzin+quizalofop-p-ethyl) and 74.5% (metribuzin+fluazifop-p-butyl) with significant benefits with chemical herbicides.

Kumar and Dixit (2004) recorded that the effects of different weed management practices in brinjal and observed that pendimethalin @ 0.50 kg a.i. ha⁻¹

one hand weeding resulted the best weed control and the highest fruit yield (328 q ha⁻¹).

Shaikh (2005) reported that weed control efficiency (>80%) was recorded in hand weeding. oxyfluorfen at 0.10 kg ha⁻¹ and pendimethalin at 0.75 kg ha⁻¹ supplemented with hand weeding at 45 DAT. The mean Chilli yield was higher in pendimethalin (9.62 t ha⁻¹) @ 0.75 kg ha⁻¹ fb weeding at 45 DAT and oxyfluorfen 0.10 kg ha⁻¹. Drill sown chilli yield was higher (298.30 kg ha⁻¹) with pendimethalin 1.0 kg ha⁻¹ as pre-emergence spray + hand weeding and was on par with oxadiargyl 0.09 kg ha⁻¹ + hand-weeding in the findings of Agasmanl and Channappagoudar 2005.

Kundu *et al* (2009) reported that the maximum reduction of weed population, weed dry weight and the highest weed control efficiency vis-a-vis crop yield, and maximum benefit: cost ratio was obtained in the treatment receiving quizalofop-p-ethyl 50 g a.i. ha⁻¹ at 21 days after emergence (DAE) + hand weeding (HW) at 28 DAE. This was closely followed by the treatment with quizalofop-p-ethyl 50 g a.i. ha⁻¹ at 14 DAE + HW at 21 DAE. Weedy check treatment produced lowest yield of mungbean.

Birgani *et al.* (2010) revealed that the efficacy of select. Herbicides on weeds a. yield of direct seeded tomato. Treatments were: pre-emergence application of metribuzin at 0.53 and 0.7 kg a.i./ha. Post emergence application of metribuzin at 0.53 and 0.7 kg ai ha⁻¹ at 4-leaf stage of tomato. pre plant and pre-emergence application of oxyfluorfen each at 0.48 kg ai ha⁻¹ pre plant application of napropamide al 0.6 and 1.8 kg ai ha⁻¹ respectively, weedy and weed free checks Compared to the weedy check. Average numbers of weeds were reduced by application of: metribuzin pre and post was 82 and 69%, respectively.

Dixit *et al.* (2012) found that Quizalofop-ethyl (MS and SS) at 50 g ha⁻¹ resulted into significantly less population of grassy weeds over rest of the herbicidal treatments.

Kalhapure (2013) found that due to the decreased competition of weed with crop for space, water, air, nutrients and sunlight because of their effective control as a result of application of different pre and post-emergence herbicides. It provides

better environment and other resources in sufficient quantity for the proper growth and development of crop.

Banjare *et al.* (2013) observed that Application of pendimethalin (extra) (0.64 kg ha^{-1}) pre-transplanting + one hand weeding at 40 DAT + pendimethalin (extra) (0.64 kg ha^{-1}) at 45 DAT as post-emergence effectively controlled the weeds and increased the fruit yield of brinjal followed by Pendimethalin (1.0 kg ha^{-1}) pre-transplanting + one hand weeding at 45 DAT.

Singh *et al.* (2017). Reported that best weed index (9.36 %) was recorded by the treatment combination of pendimethalin (T1) followed by quizalofop-p-ethyl (T7) and it was equally good with hand weeding twice (T10) with respect to tuber yield. Significant highest net return (115226 ha^{-1}) was recorded by T7 than all other treatments but was found on par with T10 (111826 ha^{-1}). B: C ratio recorded by T7 (3.60) was significantly superior than the other treatments. Highest weed population, weed dry matter, weed index and lowest tuber yield, net return and B: C ratio were recorded under control treatment.

Chethan *et al.* (2019) reported that the application of metribuzin at 0.75 kg ha^{-1} as PE effectively controlled the weeds and obtained a weed density of 2.43 and 2.04 Weeds/m^2 and weed dry biomass of 1.35 and 1.64 g/m^2 respectively at 25 and 55 DAP. By application of the metribuzin as PE and paraquat as early-postemergence (PoE), the tuber yield was increased from 9-16.5 % the sprout-eye orientation has significant effect on tuber yield.

2.6 Toxic Effect of herbicide on crop

Wax *et al.* (1976) stated that Metribuzin [4-amino-6-*tert*-butyl-3-(methylthio)-s-triazin-5(4H) one] controls several species of troublesome annual broadleaf weeds in soybeans [*Glycine max* (L.) Merr.] but it sometimes causes excessive crop injury. To determine the extent to which this injury is caused by differential sensitivity of cultivars to metribuzin, we evaluated the response of approximately 250 soybean cultivars to soil-incorporated metribuzin in field experiments in 1973 and 1974. Most cultivars were relatively tolerant of metribuzin at 0.56 kg ha^{-1} . At 0.84 and 1.7 kg ha^{-1} , many entries were severely injured or killed. Some of the most sensitive cultivars were 'Altona,' 'Hurrelbrink,' 'Norman,' 'Portage,' 'Semmes,' 'Tracy,' and 'Vansoy.' These

cultivars, and possibly others with only moderate resistance to metribuzin, should probably be avoided when metribuzin is to be used for weed control.

Moshier and Russ. (1981) reported that Metribuzin was applied at 0.6 or 1.1 kg/ha and incorporated prior to soybean planting in very fine sandy loam (coarse-silty, mixed, calcareous, mesic Typic Udifluent) with pH of 7.9 and 0.7% organic matter content in 1978 and 1979. Visual injury of 4-week-old plants was less in 1978 but more in 1979 when metribuzin was applied 3 weeks before planting rather than immediately before planting. Injury in 7-week-old plants was not significantly affected by time of metribuzin applications in 1978 but was greater from applications immediately before planting compared to applications 3 weeks prior to planting in 1979. Injury differences were attributed to rainfall quantity and pattern. The metribuzin applications at 0.6 or 1.1 kg ha^{-1} 3 weeks prior to planting did not affect soybean yields either year even though the higher rate reduced plant stands and plant height. Yields were reduced only when metribuzin was applied at the higher rate immediately before planting. Cultivation at 3 and 7 weeks after soybean planting did not significantly affect soybean tolerance either year.

Sajjapongse *et al* (1983) examine that alachlor, metribuzin and oxyfluorfen were studied in more detail. Tomato plant growth was significantly suppressed by the herbicides. Phytotoxicity was severe with oxyfluorfen, moderate with alachlor and absent with metribuzin. The degree of severity increased with higher application rates, significantly reducing tomato yields. Yield from the oxyfluorfen treatment was the lowest as the result of severe phytotoxicity at the early growth stage. Yield from the alachlor treatment was significantly less than that of the weed-free treatment. Yield from the metribuzin treatment was as high as the weed-free treatment. Only metribuzin and oxyfluorfen were used in the third trial. Yields from the metribuzin treatments were the highest whereas those of oxyfluorfen were not different from the weedy check.

Sajjapongse and Roan (1987) revealed that the tomatoes cv. Peto86 kept weed-free for 42 days after transplanting (DAT) or weeded from 28 DAT gave the same yield as those kept weed-free throughout the season. A single weeding between 28 and 42 DAT was sufficient to prevent yield loss. The major weeds were *Echinochloa colonum*, *Eleusine indica*, *Amaranthus vindis*, *Portulaca oleracea* and

Chenopodium licifolium Metribuzin at 0.5-1.0 kg ha⁻¹ was effective pre-emergence but caused crop-injury if applied post-transplanting, crop injury being higher with higher doses and later applications.

Nishimoto (1993) demonstrated that Six field experiments were conducted to determine the tolerance of young papaya to oxyfluorfen weed control in young papaya. Papaya trees tolerated oxyfluorfen at rates of up to 4.5 kg ha⁻¹ if the trees were at least 120 cm tall when oxyfluorfen was first applied; applications to shorter papaya trees often caused injury or death. Papaya trees recovered from oxyfluorfen injury if the initial injury was not too severe.

Onofri *et al.* (1995) revealed that the greenhouse experiments were conducted to assess the effects of 0-1000 g ha⁻¹ rimsulfuron and/or metribuzin on tomatoes at the 6- to 8-leaf stage and *Solanum nigrum* at the cotyledon to 6-leaf stage. Results indicated that efficacy against *S. nigrum* varied with plant age and herbicide dose. Rimsulfuron was most effective at the cotyledon stage and at 7-8 g. However, its efficacy at the 4-leaf stage was enhanced by application at 10-15 g in combination with metribuzin at 150 g. *S. nigrum* was not adequately controlled beyond the 6-leaf stage. Tomatoes were tolerant of ≤600 g rimsulfuron at the 6- to 8-leaf stage, but >100 g metribuzin caused significant phytotoxicity when applied alone or in combination.

Walter *et al.* (1996) found that Metribuzin is the herbicide of choice by potato (*Solanum tuberosum* L.) growers and they need information on the response of newly released cultivars to this herbicide. This study was conducted to determine the response of three new potato cultivars 'AC Novachip', 'Belmont', and 'Russet Norkotah' to metribuzin. The effects of metribuzin applied at 0.89 lb/acre pre- or postemergence, on plant injury and tuber yield were compared to a hand-weeded check. Yields of Belmont were not affected by metribuzin applications. Pre- and post-application of metribuzin reduced both Canada no. 1 and total yields of Russet Norkotah in 1990. Total yields of AC Novachip were reduced in some years with metribuzin applied postemergence. The results suggest that metribuzin can safely be applied pre and postemergence to Belmont.

Sathya Priya *et al.* (2017) demonstrated that Pre-emergence (PE) application

of oxyfluorfen (23.5% EC) at 250 g a.i. ha⁻¹ can keep the weed density and dry weight below the economic threshold level and increased the rice grain yield. Plant injury symptoms of oxyfluorfen was complete recovery of affected rice plants could be observed only after 30 days after herbicide application (DAHA) and the phytotoxicity was not evident thereafter in rice crop. Carryover effect and plant injury from oxyfluorfen herbicide applied in transplanted rice.

Fortino and Splittstoesser (2017) demonstrated that Metribuzin selective post emergence activity in the field but in glasshouse studies tomato cultivars had a wide range of tolerance to metribuzin applied to the foliage. Tomatoes were more susceptible to injury when they were less than 10-cm tall. Metribuzin was more effective in controlling broadleaf weeds than grass weeds, but grass control was acceptable with higher rates.

Ladlie *et al.* (2017) found that In field trials, soybeans [*Glycine max* (L.) Merr.] treated with trifluralin [α, α, α -trifluoro-2,6-dinitro-*N, N*-dipropyl-*p*-toluidine] at 0.56 and 0.84 kg ha⁻¹ were protected from injury by metribuzin [4-amino-6-*tert*-butyl-3-(methylthio)-s-triazine-5(4*H*) one] at 0.28 to 1.12 kg ha⁻¹. Soybean injury from metribuzin at high soil pH values was reduced by applying it in combination with trifluralin. Trifluralin also protected soybeans from injury caused by low rates of atrazine [2-chloro-4-(ethyl amino)-6-(isopropyl amino)-s-triazine] greenhouse studies.

2.7 Yield and yield attribute

Rajagopal *et al.* (1976) on chilli revealed that higher yield was recorded in pre-emergence application of alachlor 1.5 kg ha⁻¹ + one hand weeding at 30 OAT compared to pendimethalin application alone.

Nandal and Pandita (1988) reported that the use of fluchloralin at the rate of 1.25 kg a.i. ha⁻¹ in brinjal yielded higher than two hands weeding and remained at par with weed free treatment.

Singh *et al.* (1991) evaluated the effect of per-plant incorporated fluchloralin and glyphosate each at 1.25 kg ha⁻¹ as a protective spray alone or followed by hand weeding in rows for the control of weeds in brinjal glyphosate applied through a rope

wick applicator followed by manual weeding resulted in maximum plant height and (62.2 cm), fruit yield (4.67t ha⁻¹).

Kumar *et al.* (1999) observed that application of herbicide pendimethalin at 1.0 kg a.i ha⁻¹ coupled with mulching paddy straw recorded significantly highest number of fruits plant, higher average fruit weight and fruit yield in tomato. Therefore, the combination of both herbicides (pendimethalin 1.0 kg a.i. ha⁻¹) and mechanical operation (paddy straw mulch) proved to be very effective in control of seed in tomato cultivation

Adigun (2001) opined that selective weed control with consequent high chilli pepper fruit yields were comparable to the hoe-weeded control with pre-emergence application of oxadizon + prometryn; metolachlor of CGA and pendimethalin + metribuzin each at 1.5 + 1.0 kg a.i. ha⁻¹ in wet season.

Kumar *et al.* (2013) reported that experiment during late Kharif, 2009-11 to assess the effect of integrated nutrient management on growth and yield of ashwagandha (*Withania somnifera* Dunal) The treatments consist of 100% recommended dose of NPK (RDF) at 40:60:20 kg, 50% RDF at 20:30:10 kg, vermicompost @ 2, 4, 6 t, Jatropa cake @ 1, 2 and 3 t ha⁻¹, respectively along with PSB @ 2 kg+ Azospirillum @ 2 kg ha⁻¹. Simultaneously, 50% RDF also tested with aforesaid doses. For comparison two treatment viz. biofertilizer PSB @ 2 kg/ha+ Azospirillum @ 2 kg ha⁻¹ and absolute control were also taken. The results of the present investigation revealed that among the various traits viz. the highest plant height (49.9 cm), shoot fresh weight (32.09 g plant⁻¹), shoot dry weight (10.41 g plant⁻¹), leaf fresh weight (64.91 g/plant), leaf dry weight (13.84 g plant⁻¹), leaf area (1193.1 cm²), root length (24.5 cm), root fresh and dry weight (11.38 and 4.68 g plant⁻¹), fresh and dry root yield (2.36 and 0.78 t ha⁻¹), respectively were found after application of Jatropa cake at 3 t/ha+50% RDF+PSB at 2 kg/ha+ Azospirillum at 2 kg ha⁻¹ followed by vermicompost @ 6 t/ha+50% RDF+PSB at 2 kg ha⁻¹+Azospirillum at 2 kg ha⁻¹.

Karad *et al.* (2003) found that an experiment was undertaken with a view to study the effect of plant density and fertilizer levels on the growth, seed yield, quality and yield-contributing characters in Ashwagandha with three replications by using three different spacing S₁ (30×10 cm), S₂ (30×20 cm) and S₃ (30×30 cm) and four

different fertilizers levels. The wider spacing of 30×30 cm recorded early flowering, higher number of branches and berries per plant. While plant count at harvest, seed and root yield per hectare were maximum with the closer spacing of 30×10 cm. Fertilizer application of 10 t FYM with 80:40:20 kg NPK/ha recorded significant effect on early flowering, number of branches⁻¹, number of berries⁻¹, plant height, seed yield⁻¹ and per hectare, 1000 grain weight and germination percentage. While root yield⁻¹ and per hectare were maximum with the fertilizer level of 10 t FYM with 60:30:15 kg NPK/ha. The number branches⁻¹, number of berries⁻¹ and seed yield⁻¹ was highest due to S₃F₃, S₃F₃ and S₃F₃, interaction, respectively.

Syriac and Geetha (2007) studied that the relative efficacy of four pre-emergence herbicides and soil solarization treatment in reducing weed infestation and in enhancing the yield of brinjal. Season-long crop-weed competition reduced the yield of brinjal by 51 and 49% during 1998-99 and 1999-2000, respectively. Soil solarization for one month registered the highest fruit yield during both the years (18.92 and 18.12 t ha⁻¹, respectively). The pre-emergence herbicides alachlor (2.0 and 2.5 kg a.i. ha⁻¹), oxadiazon (0.5 and 0.75 kg a.i. ha⁻¹) and pendimethalin (2.0 kg a.i. ha⁻¹) and hand weeding twice treatments recorded fruit yields comparable to that of soil solarization. As far as weed dry weight is concerned. Alachlor (2.0 and 2.5 kg a.i. ha⁻¹) recorded excellent weed control comparable to weed free check at 30 and 60 DAT.

Mekki *et al.* (2010) stated that the higher yield may be attributed to lower dry matter accumulation by weeds and decrease in their population that helped in increasing the yield attributes which ultimately led to higher yield

Ali *et al.* (2011) demonstrated that A field experiment was conducted during rainy season of 2009 on sandy loam soil to study the influence of weeds on yield of rainy season greengram (*Vigna radiata* L. Wilczek). Application of imazethapyr 100 g/ha at 15–20 days after sowing was found most effective in reducing population and dry weight of weeds and maximum yield of green gram Quizalofop-p-ethyl 100 g ha⁻¹ applied at 15–20 DAS was also equally effective.

Goel *et al.* (2011) demonstrated that Application of 25 mg N/kg soil and FYM 12.5 t ha⁻¹ significantly increased the mean height of ashwagandha to the tune of 41.6

and 8.1%, respectively, over control. Combined use of 25 mg N/kg soil and FYM @ 12.5 t ha⁻¹ produced significantly taller plants (47.7 cm) in comparison to other treatments over control (31.7 cm). Application of 25 mg N/kg soil produced average number of primary branches (2.7) over control (1.5). Application of FYM @ 12.5 and 25 t/ha increased the average number of primary branches significantly from 2.0 to 2.3 and 2.6 over control.

Shehzad *et al.* (2012) stated that Weeds infestation is one of the major threats to crop growth and yield. The efficacy of various post emergence herbicides was evaluated on the basis of *P. minor*, *A. fatua* and *E. spinosa* population reduction and yield attributes in wheat (*Triticum aestivum* L.) crop. Results showed that clodinafop propargyl increased wheat grain per spike, 1000-grain weight, straw yield and grain yield up to 92%, 80%, 107% and 59%, respectively as compared to control, while fenoxaprop-p-ethyl showed the lowest response. Reduction in weed density and dry masses was found parallel to the yield, which was higher for clodinafop propargyl and lowest for fenoxaprop-p-ethyl. The maximum rate of benefit (Rs. 147781/1679 US\$) ha⁻¹ and marginal rate of return (47%) was observed against clodinafop propargyl (0.12 kg a.i. ha⁻¹) followed by bromoxynil + MCPA and efficacy of clodinafop propargyl support its use in wheat crop for effective weed control and better yield.

Pedde *et al.* (2013) reported that in a study on chickpea at Parbhani, two hand weeding resulted in the highest plant height, plant spread, branches, root nodules and dry matter followed by one hoeing + 2 hand weeding, pendimethalin 0.75 kg ha⁻¹ as pre-emergence, and quizalofop-p-ethyl 40 g ha⁻¹ as post emergence. Among the herbicidal treatments, the pre-emergence application of pendimethalin 0.75 kg ha⁻¹ was effect five in recording higher growth parameters followed by quizalofop-p-ethyl 40 g ha⁻¹ as post-emergence. The highest grain and straw yields were recorded with one hoeing + two hand weeding, followed by 2 hand weeding.

Pratap *et al.* (2014) revealed that that application of quizalofop-ethyl 5% EC (SS) at 50 g ha⁻¹ resulted in significantly higher kernel yield (0.98 t ha⁻¹) which was at par with its market sample applied at the same dose. Density and dry matter accumulation of weeds was also minimum by the application of these herbicides. However, the highest kernel yield of ground nut.

Singh *et al.* (2016) found that the experiment involved nine treatments replicated thrice in randomized block design. Significantly lower density and dry matter of weeds were recorded with weed free followed by oxyflurofen 0.30 kg ha before planting fb one hand weeding of 40-60 DATS after transplanting and combined application of oxyflurofen at 0.30 kg ha⁻¹ before planting + quizalofop-p-ethyl 0.05 kg/ha at 30 days after transplanting. The average bulb weight, plant height, marketable bulb and total bulb yield were also highest in weed free while it was at par to oxyflurofen at 0.30 kg ha⁻¹ before planting fb one hand weeding of 40-60 days after transplanting and oxyflurofen at 0.30 kg/ha + quizalofop-p-ethyl 0.05 kg ha⁻¹ at before planting and 30 days after transplanting. The maximum B: C ratio of 2.31 was obtained in combined spray of oxyfluorfen and quizalofop-p-ethyl at before planting and 30 days after transplanting of crop.

Hoogar *et al* (2017) reported that, among different herbicides, lower sedge density and dry weight was recorded by Metribuzin 500 g *a.i.* ha⁻¹ as pre-emergent (20.5 m⁻² and 9.0 g m⁻², respectively). Whereas application of Fenoxaprop–p-ethyl 54 gm *a.i.* ha⁻¹ as early post emergent at 20 DAP recorded significantly lower grasses, broad leaved and total weed density (15.3, 24.7 and 62.0 m⁻², respectively), weed dry weight (7.9, 10.3 and 28.1 g m⁻², respectively), lower weed index (5.9 %), higher weed control efficiency (73.3 %). This treatment registered significantly higher tuber yield (19.77 t ha⁻¹) which was on par with Quizalofop–p-ethyl (18.93 t ha⁻¹) and significantly lower tuber yield was recorded in weedy check (14.00 t ha⁻¹). Effect of Weed Management Practices on Weed Density, Weed Control Efficiency, Weed Index and Yield of Potato (*Solanum tuberosum* L.)

Poornima S. *et al* (2018) reported that field experiment was conducted during the rainy season, 2015 at Hyderabad, Telangana, on sandy-loam soil, to study the bio-efficacy of new-generation herbicidal combinations for weed management and their impact on weed flora, yield and economics of green gram [*Vigna radiata* (L.) Hepper]. A medium-duration variety 'MGG 295' was used for the study. The results revealed that combinations of haloxyfop-p-methyl @ 135 g ha⁻¹ + imazethapyr @ 75 g ha⁻¹ at 12–15 days after sowing (DAS) and quizalofop ethyl @ 50 g ha⁻¹ + imazethapyr @ 75 g ha⁻¹ at 12–15 DAS as early post-emergence were found promising for Southern Zone of Telangana for getting higher productivity and

profitability.

Chavan *et al.* (2019) stated that Maximum Plant height plant⁻¹ (33.87 cm) at harvest were recorded with the weed free treatment (T6) which was found at par with the Pendimethalin 30% EC @ 1.0 kg a.i. ha⁻¹ (PE) (T1), treatment Pendimethalin 30% EC @1.0 kg a.i. ha⁻¹ (PE) + One hoeing at 30 DAS (T3) and Quizalofop-p-ethyl 5% EC @ 100 g a.i. ha⁻¹ at 20 DAS + one hoeing at 30DAS (T4). Maximum mean number of branches plant⁻¹(10.10), Mean plant spread plant⁻¹ (46.23 cm) were recorded with the weed free treatment (T6) which was found at par with the Pendimethalin 30% EC @1.0 kg a.i. ha⁻¹ (PE) + One hoeing at 30 DAS (T3) and Quizalofop-p-ethyl 5% EC @ 100 g a.i. ha⁻¹ at 20 DAS + one hoeing at 30DAS (T4). While, maximum total dry matter accumulation at harvest plant-1(17.27g), were recorded with the weed free treatment (T6) which was closely followed by the Pendimethalin 30% EC @1.0 kg a.i. ha⁻¹ (PE) + One hoeing at 30 DAS (T3) and Quizalofop-p-ethyl 5% EC @ 100 g a.i. ha⁻¹ at 20 DAS + one hoeing at 30DAS (T4)

Mudalagiriappa *et al.* (2021) stated that field experiments were conducted to evaluate the bio-efficacy and phytotoxicity of sodium acifluorfen 16.5% + clodinafop-propargyl 8% EC as postemergence against weed flora in groundnut during Kharif (rainy season) 2015 and summer 2016 at UAS, GKVK, Bengaluru, Karnataka. Different postemergence herbicides were applied at 22 days after sowing (DAS) and compared with two rounds of hand weeding at 20 and 45 DAS. The results revealed that sodium acifluorfen 16.5% + clodinafop-propargyl 8% EC (206.25 + 80 g ha⁻¹) recorded higher pod (1.44 and 1.65 t/ha) and haulm yield (1.59 and 1.89 t ha⁻¹) in 2015 and 2016. Higher economic yield under this treatment was attributed to the reduced weed density, weed dry weight, weed index and higher weed control efficiency and higher herbicide efficiency index. Post-emergence application of sodium acifluorfen 16.5% + clodinafop-propargyl 8% EC was found non-phytotoxic to groundnut as well as succeeding crop.

2.8 Physiological parameter and biophysical trait

Nichiporovich (1970) postulated that 3-4 LAI was needed for higher productivity.

Kubsad *et al* (2009) reported that to study the effect of spacings and fertilizer

levels on physiological parameters in relation to productivity of ashwagandha. The higher fertilizer level of 24 kg N and 48 kg P ha⁻¹ increased the leaf area index (3.918).

Welbank *et al* (1988) reported that the ratio of grain yield to LAD increased with increase in daily radiation during grain filling.

Sahoo and Guru (1998) observed that positive association of LAD with grain yield.

Kubsad *et al* (2009) reported that the higher fertilizer level of 24 kg N and 48 kg P/ha increased the net assimilation rate (0.359 g/dm²/day).

Shekhar (1974) found that CGR reached a maximum level on 82nd day after transplanting onion. During *kharif* season, CGR at 67th and 97th day was significantly higher than at other periods except on 82nd day.

Brewster (1977) found that the NAR of onion seedlings was 0.54g per m² per day. In his later studies, Brewster (1979) found that between 100C and 190C temperature, NAR increased and between 190C and 270C and increase in LAR was compensated for by decrease in NAR with the result that relative growth rate (RGR) showed little difference.

Sahoo and Guru (1998) observed that the positive association of SLA with grain yield.

Asana (1968) noted that during early stages of growth, RGR increase with increased light intensity.

Karimi *et al.* (1991) reported that the modern wheat cultivars were characterized by a greater RGR during the vegetative phase.

Deshmukh and Patil (1995) observed that RGR and LAI were highly heritability associated. High genetic RGR is a basic component of growth analysis is defined at any instant of time.

Bonner (1952) observed that the chloroplast accounts for 25% of total dry matter production and 40% of the total nitrogen of leaves.

Kongika and Mathis (1995) observed that the chlorophyll a/b was found to be correlated with the photosynthetic efficiency of a crop.

Choudhary *et al* (1994) found that the grain development was accompanied by decreases in chlorophyll contents of the leaf as a result of ageing.

Dong *et al.* (2001) stated that specific Leaf Area can be used as an indirect measure of several basic leaf processes, such as leaf-water relations, photosynthetic capacity and growth potential.

Evans (1972), and Cruz *et al.* (2004) concluded that SLW represents leaf thickness and gives an estimative of the proportion between the assimilatory surface and the veins that sustain those leaf tissues.

2.9 Proximate analysis

Ash %

Kumari and Gupta (2016) reported in ashwagandha root powder the ash content was 4.41 %

Crude fibre (%)

Kumari and Gupta (2016) reported in ashwagandha root powder the crude fiber content was 32.3%.

Protein (%)

Kumari and Gupta (2016) reported in ashwagandha root powder the protein content was 3.9%.

Fat (%)

Kumari and Gupta (2016) reported in ashwagandha root powder the fat content was 0.3%.

Moisture (%)

Kumari and Gupta (2016) reported in ashwagandha root powder the moisture content was 7.45 %.

Withanolide content (%)

Kubsad *et al.* (2009) reported that the crop harvested at 180 DAS had significantly higher total Withanolide content in roots of Ashwagandha (0.560%) compared to others harvested at 120 DAS (0.468%) and 150 DAS (0.498%).

Thakur (2014) stated that investigations on effect of tree-crop combinations and nitrogen levels on growth, yield and withanolides content and yield of *Withania somnifera*. Withanolide content in roots varied from 0.73 to 0.79 per cent but was not affected due to different tree crop combinations and nitrogen doses.

Chapter- III

MATERIALS AND METHODS

MATERIALS AND METHODS

The present investigation entitled “**Efficacy of various weedicides on weed management, growth, physiology and productivity of winter sown Ashwagandha. (*Withania somnifera* (L.) Dunal.)**” was conducted during *Kharif* season of the year 2021-22 at Research Farm of Botanical Garden, Department of Plant Physiology, College of Agriculture, JNKVV, Jabalpur (M.P.).

Different materials and methodologies were used during the course of evaluation. Estimation of biochemical constituent was done in the laboratory of the Department of Plant Physiology, JNKVV, Jabalpur.

3.1 Experimental Site

A field experiment was conducted at Research Farm of Botanical Garden, JNKVV, Jabalpur (MP). All physical facilities viz., labourers, agrochemicals, equipments and irrigation etc. were adequately supplied as per need.

3.2 Climate

The climate of Jabalpur is sub-tropical with summer followed by cold winter. It comes under the Narmada Valley in central part of Madhya Pradesh and situated in Kymore Plateau. It is situated in 23°09' North latitude and 79°58' East longitude. The altitude is 411.78 meters above mean sea level.

The annual rainfall of Jabalpur region ranges between 1000 to 1500 mm and nearly 90% of the total annual rainfall is mainly received during the period between end June to end September. The rainfall is often erratic and non-uniform distribution along with an occasional long dry spells or frequent heavy rainy days during rainy season. The maximum and minimum temperature ranged between 33.26°C to 20.79°C and 24.69°C to 14.7°C respectively during the current year. The relative humidity varies from season to season. It ranges between 80 to 90% during rainy season which reduces as 60 to 70% and 30 to 40% during winter and summer seasons, respectively.

3.2.1 Weather Conditions

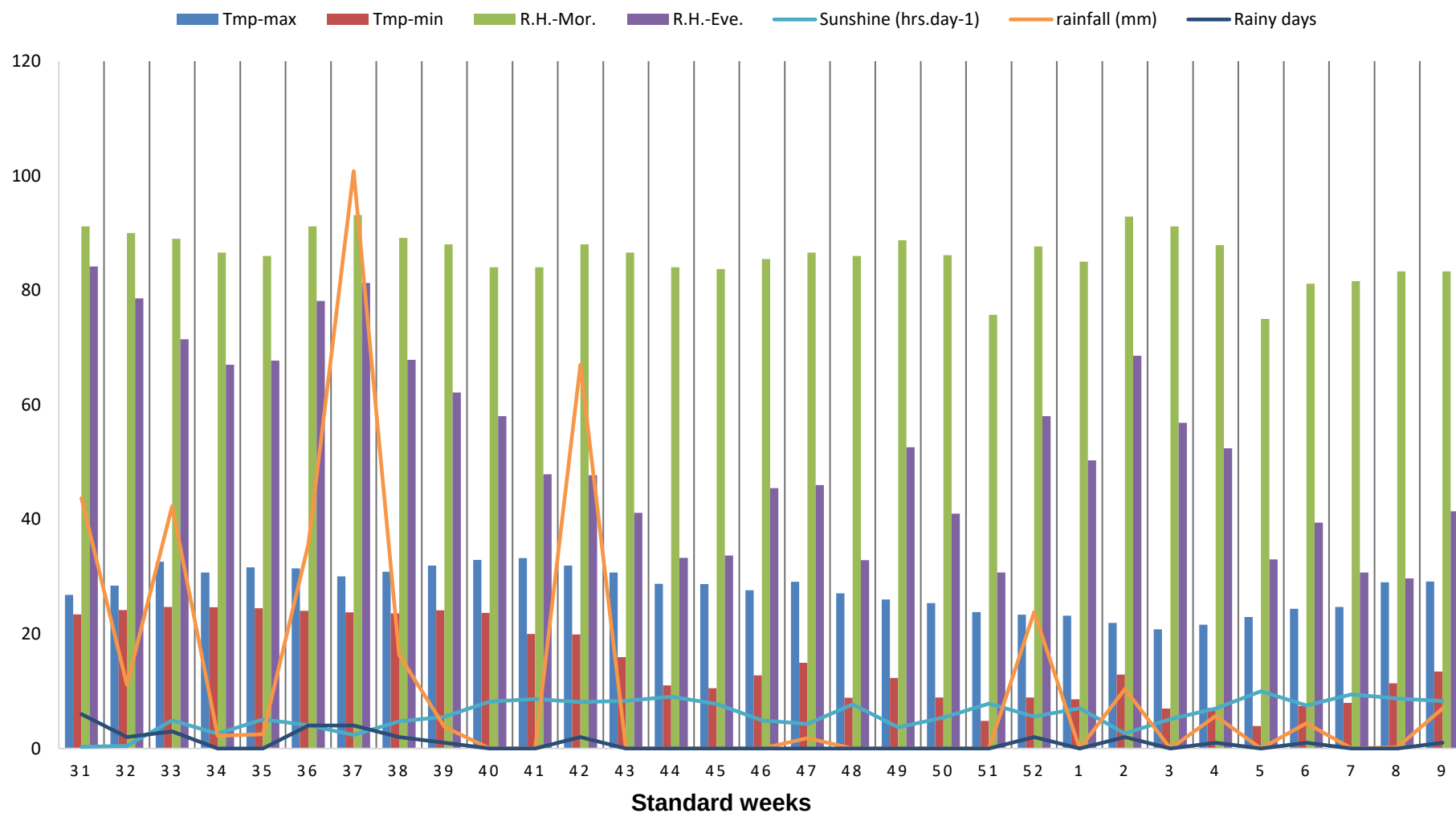
The different weather parameters prevailed during the entire crop growth season were recorded from the Meteorological Observatory, College of Agricultural Engineering, JNKVV, Jabalpur. Data on these weather parameters are given in Table

3.1, Fig.3.1.

Table 3.1 Weekly Meteorological data during the Late *kharif* season 2021-22

Months	Meto. Week (#)	Temp (°C)		R.H. (%)		Wind Velocity (m/s)	Sunshine (hrs.day ⁻¹)	Rainfall (mm)	No. of Rainy Days
		Max.	Min.	Mor.	Eve.				
AUG.	31.00	26.84	23.41	91.14	84.14	7.96	0.30	43.70	6.00
	32.00	28.46	24.16	90.00	78.57	6.19	0.47	11.10	2.00
	33.00	32.60	24.69	89.00	71.43	3.29	4.90	42.30	3.00
	34.00	30.74	24.67	86.57	67.00	4.26	2.57	2.20	0.00
	35.00	31.61	24.49	86.00	67.71	3.37	5.10	2.50	0.00
SEP.	36.00	31.43	24.06	91.14	78.14	3.50	4.07	35.70	4.00
	37.00	30.04	23.79	93.14	81.29	3.01	2.34	100.80	4.00
	38.00	30.87	23.59	89.14	67.86	3.11	4.73	16.30	2.00
	39.00	31.94	24.11	88.00	62.14	3.26	5.56	3.80	1.00
OCT.	40.00	32.91	23.70	84.00	58.00	2.29	8.19	0.00	0.00
	41.00	33.26	20.00	84.00	47.86	1.51	8.63	0.00	0.00
	42.00	31.93	19.89	88.00	47.71	2.79	8.11	67.00	2.00
	43.00	30.71	15.97	86.57	41.14	1.43	8.31	0.00	0.00
NOV.	44.00	28.73	11.04	84.00	33.29	1.40	9.04	0.00	0.00
	45.00	28.70	10.54	83.71	33.71	1.23	7.79	0.00	0.00
	46.00	27.64	12.76	85.43	45.43	2.36	4.90	0.00	0.00
	47.00	29.13	14.96	86.57	46.00	1.57	4.30	1.80	0.00
	48.00	27.10	8.86	86.00	32.86	1.67	7.70	0.00	0.00
DEC.	49.00	26.01	12.34	88.71	52.57	2.33	3.70	0.00	0.00
	50.00	25.40	8.89	86.14	41.00	1.83	5.39	0.00	0.00
	51.00	23.83	4.81	75.71	30.71	2.17	7.84	0.00	0.00
	52.00	23.35	8.93	87.63	58.00	1.88	5.58	23.80	2.00
JAN.	1.00	23.20	8.59	85.00	50.29	2.41	7.04	0.00	0.00
	2.00	21.93	12.90	92.86	68.57	3.76	2.61	10.40	2.00
	3.00	20.79	6.99	91.14	56.86	2.51	5.16	0.00	0.00
	4.00	21.63	7.13	87.86	52.43	2.54	6.96	5.70	1.00
	5.00	22.97	3.93	75.00	33.00	1.80	10.00	0.00	0.00
FEB.	6.00	24.41	7.41	81.14	39.43	2.60	7.53	4.40	1.00
	7.00	24.71	7.96	81.57	30.71	2.79	9.47	0.00	0.00
	8.00	29.00	11.37	83.29	29.71	3.01	8.71	0.20	0.00
	9.00	29.14	13.44	83.29	41.43	3.30	8.29	7.00	1.00

Fig. 3.1 : Weekly meteorological parameters during the crop season August 2021 to February 2022



3.3 Soil characteristics

The soils adjoining Jabalpur are classified as “vertisol” per US classification of soil. The soils of the region have medium to deep depth and black colour with sandy clay-loam texture and neutral soil reaction. It swells by wetting and shrinks by drying. Therefore, deep and wide cracks develop during winter season.

3.4 Land preparation

In order to get a good tilth for sowing of ashwagandha in the present experimental field, one summer ploughing followed by one pass of tractor driven cultivator and two pass of disc harrow were made and then the field was finally leveled before sowing of the ashwagandha crop in the experimental field.

3.5 Layout of the experiment

The Nine weed control treatments were laid out in Randomized Block Design with three replications. The different treatments were randomized within each replication using random table. The layout plan of the present experiment has been graphically illustrated through the Figure 3.2.

3.6 Experimental details: -

Season	:	winter 2021-22
Expt. Design	:	Randomized Block Design (RBD)
Replications	:	3
Treatments	:	9 viz;

3.6.1 Treatment Details

T ₁	:	Control(untreated)
T ₂	:	Control (Handweeding)
T ₃	:	Quizalofop p-ethyl <i>a.i</i> 50 gm ha ⁻¹
T ₄	:	Haloxypop R.methyl <i>a.i</i> 750 gm ha ⁻¹
T ₅	:	Clodinafop propagyl <i>a.i</i> 60 gm ha ⁻¹
T ₆	:	Quizalofop p-ethyl+Haloxypop R.methyl
T ₇	:	Quizalofop p-ethyl+Haloxypop R.methyl + Clodinafop propagyl
T ₈	:	Oxyflourfen <i>a.i</i> 100 gm ha ⁻¹
T ₉	:	Metribuzin <i>a.i</i> 525 gm ha ⁻¹
Gross plot size	:	2.8 m x 3.0 m (8.4 m ²)

Net plot size	: 1.2 m x 2.0 m
Distance between rows	: 0.40m
Distance between plot	: 0.60 m
Distance between replication	: 1.0 m
Total experimental area	: 11.0 m x 30.0m (330 m ²)
No. of rows plot ⁻¹	: 7
No. of plots	: 27
Seed rate	: 10 kg ha ⁻¹
Variety	: JA 20
Spray schedule	: At 40, 80 days after sowing
Date of sowing	: 06-08-2021
Date of harvesting	: 21-02-2022

3.2 Different treatments with different dose.

S.NO	TREATMENT	NAME OF HERBICIDE	DOSES
1	T ₁	Control (untreated)	Water spray
2	T ₂	Control (Hand weeding)	40,80 Days
3	T ₃	Quizalofop-p-ethyl	50 g ha ⁻¹
4	T ₄	Haloxifopr.methyl	750 g ha ⁻¹
5	T ₅	Clodinofoppropargyl	60 g ha ⁻¹
6	T ₆	Quizalofop+Haloxifop	50+750 g ha ⁻¹
7	T ₇	Quizalofop+Haloxifop+Clodinofof	50+750+60 g ha ⁻¹
8	T ₈	Oxyflourfen	100 g ha ⁻¹
9	T ₉	Metribuzin	525 g ha ⁻¹

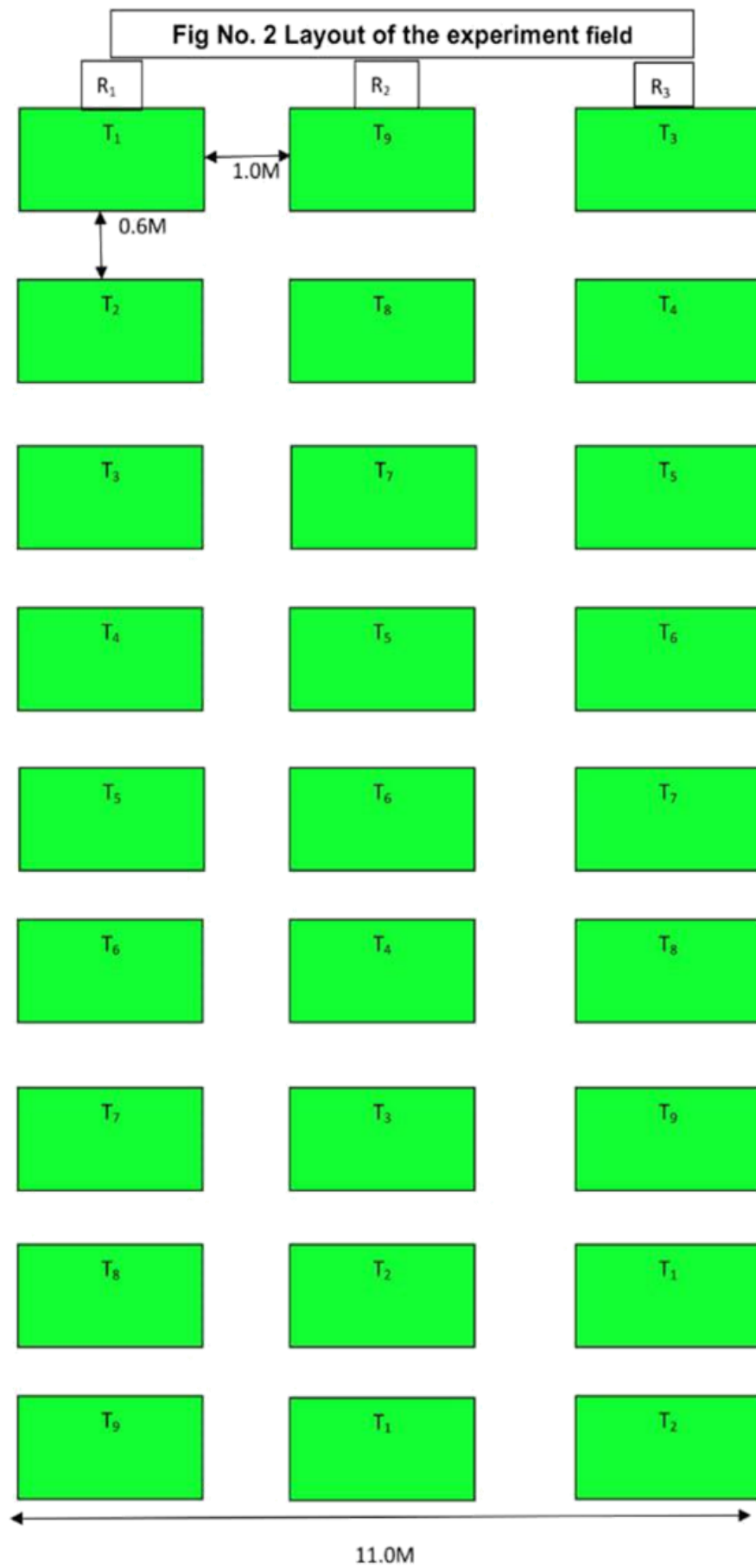


Fig 3.2 Layout Plan of Experimental Design



Field view

3.7 Seed sowing:

The pure healthy disease and insect free vigorous and good quality seeds of Ashwagandha (*Withania somnifera* (L.) Dunal.) were used for sowing. The seeds of Ashwagandha (JA-20) were sown in the field @ 10 kg/ha by hand dibbling at a depth of 5 cm in open furrows. crop was done on 06/08/2021.

3.8 Intercultural practices:

FYM @ 10-ton ha⁻¹ was uniformly mixed with the experimental plots before planting of *Withania somnifera* (L.) Dunal. Three irrigations were done at an interval of 40 days.

3.9 Sampling:

Five plants were randomly selected from each treatment for determining various growth analytical parameters, biophysical traits and yield and yield attributes at the interval of 60,90,120,150 (at harvest).

Observation recorded:

The observations were subdivided into following groups and recorded during the crop season recorded for obtaining the root yield at maturity.

3.10 Weed population management and crop survival

- 1 Diversity and number of weeds before treatment
- 2 Diversity and number of weeds after treatment
- 3 Survival percentage of ashwagandha

3.11 Phenological observation

1. Days of primary branches initiation.
2. Days of secondary branches initiation
3. Days of floral initiation.
4. Days of 50% flowering.
5. Days to fruit initiation.
6. Days to capsule formation.
7. Days to physiological maturity.
8. Days to physical maturity.

3.12 Growth analytical parameters and biophysical traits

1. LAI (Leaf Area Index) (Gardner *et al.*,1985)
2. LAD (Leaf Area Duration) (cm² days) (Watson,1952)
3. SLA (Specific Leaf Area) (cm² g⁻¹) (Gardner *et al.*,1985)
4. SLW (Specific Leaf Weight) (g cm⁻²) (Pearce *et al.*,1968)
5. CGR (Crop Growth Rate) (g cm⁻² day⁻¹) (Watson,1952)
6. RGR (Relative Growth Rate) (g g⁻¹ day⁻¹) (Watson,1952)
7. BMD (Biomass Duration) (g days) (Kvet,1962)
8. Chlorophyll Content Index (SPAD 502)

3.12.1 Leaf area index (LAI)

LAI expresses the ratio of leaf surface (one side only) to the ground area occupied by the plant or a crop stand worked out as per specifications of Gardner *et al.* (1985).

$$\text{LAI} = \frac{\text{Total leaf area}}{\text{Land area}} \quad \text{LAI} = \frac{(\text{LA}_2 + \text{LA}_1)}{2p}$$

Where LA₁ and LA₂ represents leaf area during two consecutive intervals and 'P' ground area.

3.12.2 Leaf area duration (LAD)

Leaf area duration expresses the magnitude and persistence of leaf area or leafiness during the period of crop growth. It reflects the extent of seasonal integral of light interaction and correlated with yield. LAD was computed as follows (Watson, 1952):

$$\text{LAD} = \frac{(\text{LA}_2 + \text{LA}_1)}{2} \times (t_2 - t_1) \text{ (cm}^2 \text{ days)}$$

Where LA₁ and LA₂ represents the leaf area at two successive time intervals (t₁ and t₂).

3.12.3 Specific leaf area (SLA)

The specific leaf area expresses the ratio between the leaf area (LA) and leaf dry weight (LW) (Gardner et al., 1985).

$$SLA = \frac{(LA_2/LW_2 + LA_1/LW_1)}{2} \text{ (cm}^2\text{g}^{-1}\text{)}$$

Specific leaf weight (SLW)

It is the ratio between the leaf dry weight (LW) and the leaf area (LA) it indicates the leaf thickness on the weight basis (Gardner *et al.*, 1985).

$$SLW = \frac{(LW_2/LA_2 + LW_1 / LA_1)}{2} \text{ (g cm}^{-2}\text{)}$$

3.12.4 Crop growth rate (CGR)

The daily increment in plant biomass is termed as crop growth rate (Watson, 1952) or rate of dry matter production. It was determined as per the following formula suggested by Watson, 1952.

$$CGR = \frac{W_2 - W_1}{p (t_2 - t_1)} \text{ (g cm}^{-2}\text{ days}^{-1}\text{)}$$

Where,

p = ground area (cm²)

W₁ = dry weight per unit area at t₁

W₂ = dry weight per unit area at t₂

t₁ = first sampling and

t₂ = second sampling

3.12.5 Net Assimilation Ratio (g cm⁻²day⁻¹)

The term NAR was used by Williams (1946). NAR is defined as dry matter increment per unit leaf area or per unit leaf dry weight per unit of time. The NAR is a measure of the average photosynthetic efficiency of leaves in a crop community.

$$NAR = \frac{(W_2 - W_1)}{(t_2 - t_1)} \times \frac{(\text{Log } L_2 - \text{Log } L_1)}{(L_2 - L_1)} \text{ (g cm}^{-2}\text{ day}^{-1}\text{)}$$

Where, W_1 and W_2 is dry weight of whole plant at time t_1 and t_2 respectively L_1 and L_2 are leaf weights or leaf area at t_1 and t_2 respectively $t_2 - t_1$ are time interval in days.

3.12.6 Relative growth rate (RGR)

The Relative growth rate expresses the dry weight increase in time interval in relation to initial weight. In practical situations, the mean relative growth rate is calculated from measurements at t_1 and t_2 . It was calculated as per formula given by (Watson, 1952).

$$RGR = \frac{\ln W_2 - \ln W_1}{t_2 - t_1} \text{ (g g}^{-1}\text{day}^{-1}\text{)}$$

Ln represents natural log

3.12.7 Biomass Duration (BMD)

This is the parameter which represents dry weight losses or gains during a unit time period (Kvet, 1962).

$$BMD = \frac{W_2 - W_1}{(\ln W_2 - \ln W_1)} (t_2 - t_1) \text{ (g days)}$$

3.12.8 Chlorophyll Content Index

Chlorophyll content index was determined in the 4th leaf of five weeks old plant using a non-destructive method that uses an optical instrument called chlorophyll meter (SPAD 512).

3.13 Yield and yield attributing traits

3.13.1 Plant height (cm)

Plant height was recorded at harvest from the soil surface to the tip of uppermost node.

3.13.2 Number of branches plant⁻¹

The number of branches plant⁻¹ was calculated by tagging five plants at maturity.

3.13.3 Number of leaves plant⁻¹

The number of leaves plant⁻¹ was calculated by tagging five plants at maturity.

3.13.4 Number of capsule plant⁻¹

The number of capsule plant⁻¹ was recorded from five tagged plants at maturity.

3.13.5 Seed Index (1000 seed weight) (g)

1000 seed were taken manually from the produce of each plot and their weight was recorded by electronic balance.

3.13.6 Seed yield (g plant⁻¹ and kg ha⁻¹)

The Seed yield g plant⁻¹ and kg ha⁻¹ was recorded after threshing, cleaning and drying the capsule. It is also known as economical yield.

3.13.7 Root yield (g plant⁻¹ and kg ha⁻¹)

The Seed yield g plant⁻¹ and kg ha⁻¹ was recorded after uprooting, cleaning and drying the roots. It is also known as economical yield.

3.13.8 leaf yield (g plant⁻¹ and kg ha⁻¹)

The leaf yield g plant⁻¹ and kg ha⁻¹ was recorded after drying leaves in electric oven.

3.13.9 Harvest index

Harvest index is the ratio of economic yield to the total biological yield expressed in percentage. It represents the efficiency of photosynthates translocation to economic parts (Synder and Carlson, 1984).

$$HI = \frac{\text{Economic yield}}{\text{Biological yield}} \times 100$$

While calculating the biological yield only the above ground parts were taken into consideration.

3.14 Proximate analysis

The ashwagandha root powder were analyzed for the biochemical constituents as follows:

3.14.1 Total ash (%)

The ash content in the seed sample was estimated according to AOAC (1980). The details of procedure used are given below:

Procedure

Two gram of sample was weighed accurately into a weighed porcelain crucible

(which had precise been heated to about 600°C and cooled). The crucible was heated first over a low flame till all material was completely charred, followed by heating in a muffle furnace for about 600°C. It was then cooled in desiccators and weighed. The crucible was again heated in the muffle furnace for 1-2 hours then cooled and weighed. This was repeated till two consecutive weights were same and then ash was almost white or grayish white in color.

$$\text{Ash (\%)} = \frac{\text{Weight of ash}}{\text{Weight of sample}} \times 100$$

3.14.2 Determination of Moisture percentage

The moisture percentage in the sample was estimated as given below (A.O.A.C., 1980)

Procedure

5 gm of sample was weighed in a pre-weighed moisture box. dried at 105°C for 8 hrs. in a hot air oven, cooled in a desiccator and weight. The difference in weight of moisture box represented the moisture content of the sample.

$$\text{Moisture (\%)} = \frac{\text{Differences in weight}}{\text{Weight of sample}} \times 100$$

3.14.3 Total crude fiber (%)

Materials

1. Sulphuric acid solution: 12.5 ml of conc. sulphuric acid was diluted to 1 liter distilled water.
2. Sodium hydroxide solution: 12.5 g of sodium hydroxide was dissolved in 1 liter distilled water.

Procedure

1. Extracted 2g of ground sample with petroleum ether to remove fat (initial boiling temperature 35⁰-38⁰C and final temperature, 52⁰C.
2. After extraction with petroleum ether, boiled 2g of dried material with 200ml of H₂SO₄ acid for 30 mins with bumping chips.

3. Filtered through muslin cloth and washed with boiling water until washings were no longer acidic.
4. Boiled with 200ml of NaOH solution for 30min.
5. Again, filtered through muslin cloth and washed with boiling water until washings were no longer basic.
6. Removed residue and transferred to ashing dish (pre-weighed dish W_1)
7. Dried the residue for 2hrs at $130 \pm 2^\circ\text{C}$. Cooled the dish in a desiccator and weighed (W_2)
8. Ignited the samples at $600 \pm 15^\circ\text{C}$
9. Cooled in a desiccator and reweighed (W_3).

$$\text{Crude fiber \%} = \frac{\text{Loss in weight on ignition} \times (W_2 - W_1) - (W_3 - W_1) \times 100}{\text{Weight of sample}}$$

3.14.4 Estimation of protein % in root

The nitrogen content was estimated by micro Kjeldahl method (A.O.A.C., 1980).

Reagents:

1. 40% NaOH
2. Boric acid indicator (4% solution)
3. Dissolved 0.2g of Methyl red in 100ml of 95% ethanol and 0.2g of Bromocresol green in 100ml of 95% ethanol.
4. Standard HCL acid 0.1N or H_2SO_4 acid 0.1N
5. Catalyst mixture: Potassium sulphate and copper sulphate in the ratio of 5:2 (3g per sample).

Procedure:

1. Weighed 100mg of the sample (containing 1 to 3mg Nitrogen) and transferred to a 30ml digestion flask.
2. Digested with concentrated Sulphuric acid (10ml) after adding catalyst mixture (3g per sample) and digestion had done for about 3hrs till the liquid became colorless. The digestion tube was allowed to cool and the content carefully diluted to 100ml with distilled water.
3. The solution was then transferred quantitatively to a distillation apparatus. 40ml of 40% of Sodium Hydroxide was added and the liberating ammonia was collected in a flask containing 25ml of 2% Boric acid with 2 drops of mixed indicator (bromocresol green+ methyl red)
4. Distillation was continued for 5mins appearance of green colour to ensure the complete evaluation of ammonia. After distillation solution was titrated with 0.1N H₂SO₄.

Nitrogen and protein percent was calculated by the following formula:

$$\text{Nitrogen} = \frac{(\text{Sample-Blank}) \times \text{Normality of H}_2\text{SO}_4 \times 14.01 \times 100}{\text{weight of sample (mg)}}$$

Protein percent in the sample was estimated multiplying nitrogen percent of sample by factor 6.25.

$$\text{Protein (\%)} = \text{Nitrogen \%} \times 6.25$$

3.14.5 Determination of fat percentage

The fat content in the sample was estimated by pelican equipment socs plus based on principle of Soxhlet's extraction method as described in AOAC (1980). The extract method used for this purpose is given below:

Procedure

1 g of sample was weighed accurately into a thimble and plugged with fat free cotton. Weighed the extraction flask (A). Fat content was determined by extracting the

sample with solvent, petroleum ether A.R. grade 60-80⁰ fraction, for 6 hours by Soxhlet's extraction procedure. After extraction excess of ether is evaporated until no colour of ether remained. Cooled at room temperature and weighed the flask (B). The percent of fat was calculated by using following formula.

$$\text{Fat (\%)} \text{ in ground sample} = \frac{\text{Wt. of flask (B)} - \text{Wt. of flask (A)}}{\text{Weight of sample}} \times 100$$

3.14.6 Estimation of Withanolides

Sample preparation

One gram of the finely powdered plant material or commercial product was extracted three times with 3.0 ml of MeOH by sonication for 10 min. After centrifugation (5 min at 3000 rev./min). The extract was combined in a 10 ml volumetric flask and adjusted to the final volume with MeOH. The liquid samples were diluted 1:1 with MeOH. Prior to use, all samples were filtered through a 0.45 µm Nalaf 10 membrane filter from Gelmon (Ann Arbor, mi, USA). Every sample solution was made in triplicate, R.S.D. were below 2.0% for all experiments.

Calibration

Two milligrams of each standard compound were placed in one 5 ml volumetric flask and dissolved in MeOH (stock solution). Five additional calibration levels were prepared by diluting this solution with MeOH. Standard solutions were stored at 4°C and were stable for at least 30 days (confirmed by re-assaying the solution). Within the range of concentrations injected (400.0-16 µg/ml). The detector response was linear. All data were recorded and processed by Empower Software DC from waters.

Analytical method

HPLC analysis was performed on a waters HPLC system equipped with a 2996 photodiode array detector (Waters Pvt. Ltd.). For all separations a x Bridge™ C₁₈ column (4.6 mm x 250 mm, 5.0 µm particle size) from was used. The mobile phase consisted of water (A) and an acetonitrile (B), which were applied in the following gradient elution: from 80 A/20B in 5 minutes to 65 A/35 B in 20 minutes then 30 A/70 B in 45 minutes and 80 A/20 B in 50 minutes. The separation temperature was kept

constant at 50°C, flow rate and sample volume were monitored at 230 nm peaks were assigned by spiking the sample with authentic samples and comparison of the UV-spectra and retention times.

$$\text{Withanolides \%} = \frac{\text{Area of sample} \times \text{wt. of std.} \times \text{Dilution}}{\text{Area of standard} \times \text{dilution} \times \text{wt. of sam.}} \times \text{purity}$$

3.15 Statistical analysis

Analysis of observations taken on different variables was carried out to know the degree of variation among all the treatments. The data was statistically analyzed through randomized block design (Fisher, 1963). The results obtained through analysis of variance are given in appendix and the skeleton of analysis of variance table is given below:

Table no. 3.3 Analysis of variance (ANOVA)

S.No.	Source of variance	Degree of freedom (d.f.)	Sum of square (SS)	Mean sum of square (MSS)	Calculated F. value	Table value (5%)
1.	Replications	(r-1) = 2				
2.	Treatments	(t-1) = 8				
3.	Error	(r-1) (t-1) = 16				
	Total	(Rt-1) = 26				

$$\text{SEm} \pm = \sqrt{EMS / r}$$

$$\text{SEd} \pm = \sqrt{2EMS / r}$$

$$\text{CD} = \text{SEd} \pm \times t \text{ at } 5\%$$

Where,

r = No. of replications

EMS = Error mean square

$SEm_{\pm}$ = Standard error of treatment mean

$SEd_{\pm}$ = Standard error of difference to two treatment mean

CD = Critical difference to two treatments mean

Chapter- IV

RESULTS

RESULTS

The present investigations were carried out on different post-emergence herbicides in ashwagandha in a completely randomized block design under the experiment entitled **“Efficacy of various weedicides on weed management, growth, physiology and productivity of winter sown Ashwagandha. (*Withania somnifera* (L.) Dunal.)”** The data were statistically analyzed and the experimental results of the present investigations have been presented under following subheads:

4.1 Weed Population before treatment.

4.1.1 Diversity and number of weeds before the first spray of herbicide at 40 DAS

Result revealed that there were 9 species of weeds found in *Withania somnifera* (Table 4.1) These species were *Ageratum houstonianum*, *Euphorbia hirta*, *Cynodon dactylon*, *Tridax procumbens*, *Parthenium hysterophorus*, *Alternanthera sessilis*, *Cloris barbata*, *Commelina benghalensis* and *Cyperus rotundus*. Out of these weeds *Ageratum houstonianum* was the dominant weed in all the plots (average population 64.25 per plot), followed by *Cyperus rotundus* (average population 45.7 per plot), *Cynodon dactylon* (average population 43.4 per plot.), *Alternanthera sessilis* (average population 29.6 per plot), *Tridax procumbens* (average population 22.7 per plot), *Commelina benghalensis* (average population 16.3 per plot), *Parthenium hysterophorus* (average population 15.3 per plot), *Cloris barbata* (average population 15.2 per plot), the minimum population weed (average population 12.6 per plot) was recorded by *Euphorbia hirta* in Late Kharif season crop *Withania somnifera* (L.) Dunal.

Table 4.1 Diversity and number of weeds before the first spray of weedicide

Weed population / Plot											
S.N.	Weed species diversity	Plot 1	Plot 2	Plot 3	Plot 4	Plot 5	Plot 6	Plot 7	Plot 8	Plot 9	Average weed / plot
1	<i>Ageratum</i>	66	57	65	66	62	74	52	68	68	64.25
2	<i>Euphorbia</i>	12	15	10	14	12	11	16	13	11	12.62
3	<i>Cynodon</i>	47	43	48	38	39	44	49	43	41	43.48
4	<i>Tridax</i>	23	25	23	25	29	18	20	23	19	22.76
5	<i>Parthenium</i>	15	14	15	14	18	14	17	16	15	15.34
6	<i>Alternanthera</i>	28	34	25	36	26	27	29	32	30	29.64
7	<i>Cloris</i>	13	13	15	17	17	18	14	14	14	15.24
8	<i>Commelina</i>	17	16	17	18	15	14	15	18	18	16.34
9	<i>Cyperus</i>	45	48	48	45	52	40	49	41	44	45.74

4.1.2 Effect of first spray of herbicide on diversity and number of weed at 50 DAS

50 DAS number of weeds (per treatment) were significantly affected due to spray of weedicides (Table 4.2). The least population of *Ageratum houstonianum* (0) was recorded with T₂ significantly followed by T₈ (10), T₉ (22), T₇(37), T₅(51), T₆(54), T₃(55) and T₄(60). The maximum population (66) was recorded with control T₁.

Population of *Euphorbia hirta* was affected significantly with spray of weedicides (Table 4.2). The least population of *Euphorbia hirta* (0) was recorded with T₂ significantly followed by T₈ (2), T₉ (3), T₃(8), T₄(9), T₅(10), T₄(11) and T₇(12). However, T₈ and T₉ were at par with each other. The maximum population (12) was recorded with control T₁.

Population of *Cynodon dactylon* was affected significantly with the spray of weedicides (Table 4.2). The least population of *Cynodon dactylon* (0) was recorded with T₂ significantly followed by T₈(3), T₉(5), T₇(16), T₆(22), T₅(26), T₄(26) and T₃(27).

However, T₈ and T₉ were at par with each other. The maximum population (47) was recorded with control T₁.

Spray of Weedicides (Table 4.2) Population of *Tridax procumbens* was significantly affected. The least population of *Tridax procumbens* (0) was recorded with T₂ significantly followed by T₈(4), T₉(5), T₇(13), T₆(14) T₃(19), T₄(19) and T₅(23). However, T₈ and T₉ were at par with each other. The maximum population (23) was recorded with control T₁.

Population of *Parthenium hysterophorus* was affected significantly with spray of weedicides (Table 4.2). The least population of *Parthenium hysterophorus* (0) was recorded with T₂ significantly followed by T₈ (3), T₉ (5), T₆(11), T₃(12), T₄(12), T₇ (13) and T₅(15). The maximum population (15) was recorded with control T₁. Whereas T₈ and T₉ were at par with each other.

Spray of Weedicides (Table 4.2) population of *Cloris barbata* was significantly affected. The least population of *Cloris barbata* (0) was recorded with T₂ significantly followed by T₈(5), T₇(5), T₉ (6), T₃(8) T₆(10), T₄(11) and T₅(13). However T₈ and T₇ were at par with each other. The higher population (13) was recorded with control T₁.

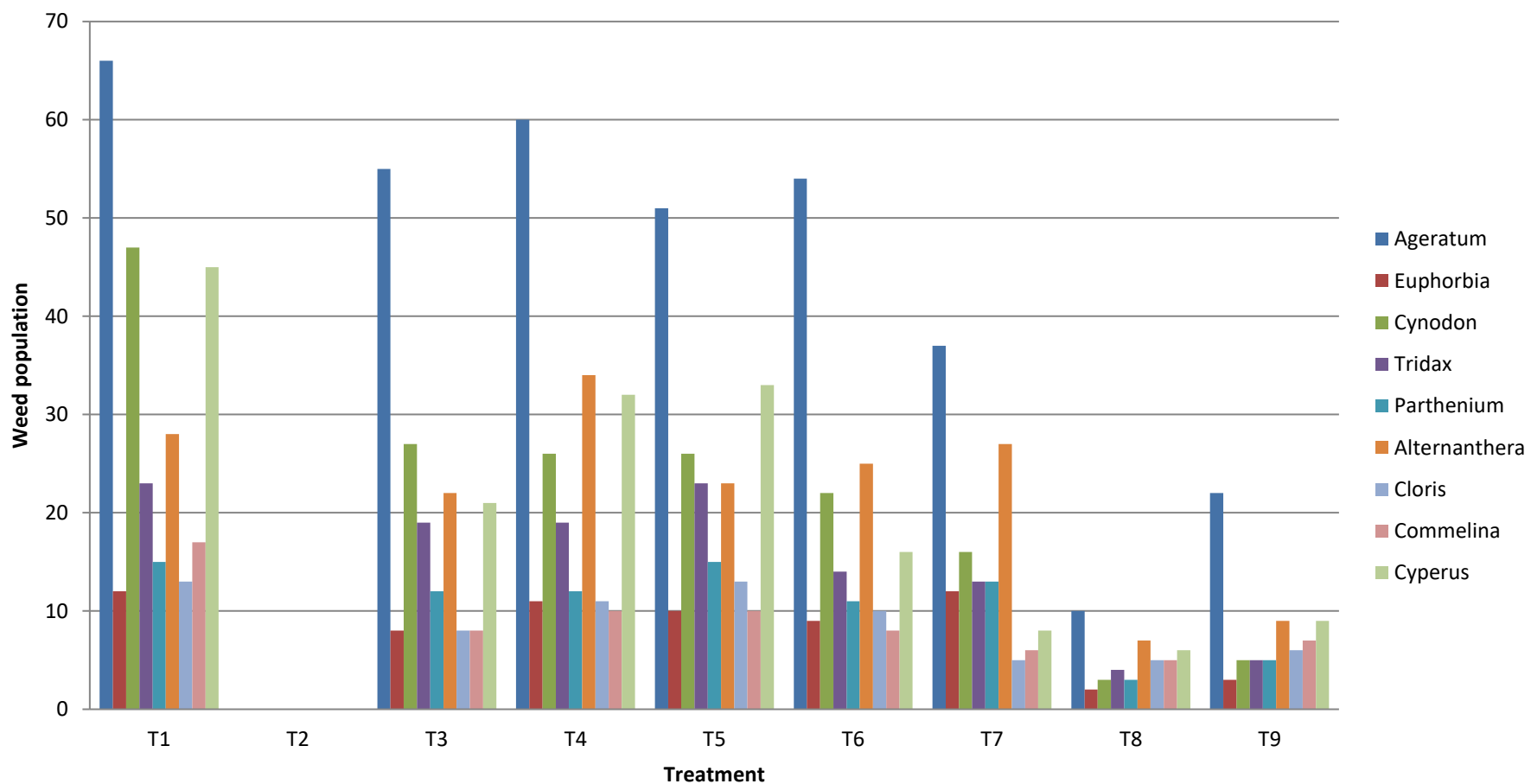
Population of *Commelina benghalensis* was affected significantly with spray of weedicides (Table 4.2). The least population of *Commelina benghalensis* (0) was recorded with T₂ significantly followed by T₈ (5), T₇ (6), T₉ (7), T₃(8), T₆(8), T₄(10), and T₅(10). Whereas T₈ and T₇ were at par with each other. The higher population (17) was recorded with control T₁.

Population of *Cyperus rotundus* was affected significantly with spray of weedicides (Table 4.2). The least population of *Cyperus rotundus* (0) was recorded with T₂ significantly followed by T₈(6), T₇ (8), T₉(9), T₆ (16), T₃(21), T₄(32), and T₅(33). The maximum population (45) was recorded with control T₁.

Table 4.2 Effect of first spray of herbicides on diversity and number of weeds at 50 DAS

Population of Weed Species									
Treatment	<i>Ageratum</i>	<i>Euphorbia</i>	<i>Cynodon</i>	<i>Tridax</i>	<i>Parthenium</i>	<i>Alternanthera</i>	<i>Cloris</i>	<i>Commelina</i>	<i>Cyperus</i>
T₁	66 (8.13)	12 (3.48)	47 (6.90)	23 (4.72)	15 (3.93)	28 (5.33)	13 (3.72)	17 (4.41)	45 (6.76)
T₂	0 (0.71)	0 (0.71)	0 (0.71)	0 (0.71)	0 (0.71)	0 (0.71)	0 (0.71)	0 (0.71)	0 (0.71)
T₃	55 (7.45)	8 (2.96)	27 (5.23)	19 (4.36)	12 (3.58)	22 (4.74)	8 (2.97)	8 (2.85)	21 (4.63)
T₄	60 (7.78)	11 (3.42)	26 (5.08)	19 (4.41)	12 (3.46)	34 (5.84)	11 (3.38)	10 (3.19)	32 (5.70)
T₅	51 (7.20)	10 (3.14)	26 (5.05)	23 (4.83)	15 (3.89)	23 (4.85)	13 (3.61)	10 (3.27)	33 (5.77)
T₆	54 (7.40)	9 (2.93)	22 (4.77)	14 (3.71)	11 (3.44)	25 (4.97)	10 (3.24)	8 (2.97)	16 (4.05)
T₇	37 (6.75)	12 (3.54)	16 (4.06)	13 (3.59)	13 (3.62)	27 (5.19)	5 (2.41)	6 (2.54)	8 (2.96)
T₈	10 (3.24)	2 (1.64)	3 (1.78)	4 (2.04)	3 (1.95)	7 (2.68)	5 (2.26)	5 (2.34)	6 (2.52)
T₉	22 (4.78)	3 (1.93)	5 (2.25)	5 (2.44)	5 (2.34)	9 (3.08)	6 (2.59)	7 (2.73)	9 (3.02)
SEm±	0.10	0.16	0.22	0.19	0.09	0.13	0.10	0.09	0.11
C.d. 5%	0.31	0.48	0.63	0.57	0.27	0.39	0.30	0.26	0.32

Fig. 4.1 Effect of first spray herbicides on diversity and no of weeds



4.1.3 Effect of first spray of herbicide on density of weeds in treatments (plant m⁻²) at 50 DAS

Weed density of *Ageratum houstonianum* was affected significantly with spray of weedicides (Table 4.3). The minimum weed density of *Ageratum houstonianum* (0) was noted with T₂ significantly followed by T₈ (1.20 m⁻²), T₉ (2.67 m⁻²), T₇ (4.44 m⁻²), T₅ (6.21 m⁻²), T₆ (6.48 m⁻²), T₃ (6.56 m⁻²) and T₄ (7.16 m⁻²). The maximum weed density (7.82 m⁻²) was noted with T₁.

Spray of Weedicides (Table 4.3) weed density of *Euphorbia hirta* was significantly affected. The lowest weed density of *Euphorbia hirta* (0) was noted with T₂ significantly followed by T₈ (0.28 m⁻²), T₉ (0.40 m⁻²), T₃ (0.99 m⁻²), T₆ (1.03 m⁻²), T₅ (1.15 m⁻²), T₅ (1.35 m⁻²) and T₁ (1.39 m⁻²). The highest weed density was recorded with T₇ (1.43).

Weed density of *Cynodon dactylon* was affected significantly with spray of weedicides (Table 4.3). The minimum weed density of *Cynodon dactylon* (0) was noted with T₂ significantly followed T₈ (0.32 m⁻²), T₉ (0.56 m⁻²), T₇ (1.56 m⁻²), T₆ (2.66 m⁻²), T₅ (3.06 m⁻²), T₄ (3.10 m⁻²) and T₃ (3.25 m⁻²). Whereas T₈ and T₉ were at par each other. The maximum weed density (5.64 m⁻²) was recorded with control T₁.

Spray of Weedicides (Table 4.3) weed density of *Tridax procumbens* was significantly affected. The lowest weed density of *Tridax procumbens* (0) was noted with T₂ significantly followed by T₈ (0.44 m⁻²), T₉ (0.65 m⁻²), T₇ (1.52 m⁻²), T₆ (1.62 m⁻²), T₃ (2.26 m⁻²) and T₄ (2.30 m⁻²). However T₈ and T₉ were at par each other. The maximum weed density was recorded with control T₁ (2.70 m⁻²) and T₅ (2.74 m⁻²).

Weed density of *Parthenium hysterophorus* was affected significantly with spray of weedicides (Table 4.3). The lowest weed density of *Parthenium hysterophorus* (0) was noted with T₂ significantly followed by T₈ (0.40 m⁻²), T₉ (0.60 m⁻²), T₆ (1.35 m⁻²), T₄ (1.39 m⁻²), T₃ (1.47 m⁻²), T₇ (1.51 m⁻²) and T₅ (1.75 m⁻²). The maximum weed density (1.79 m⁻²) was recorded with T₁.

Spray Weedicides (Table 4.3) weed density of *Alternanthera sessilis* was significantly affected. The minimum weed density of *Alternanthera sessilis* (0) was

noted with T₂ significantly followed by T₈(0.79 m⁻²), T₉ (1.07 m⁻²), T₃(2.62 m⁻²), T₅(2.74 m⁻²) T₆(2.94 m⁻²) and T₇(3.17 m⁻²). However T₈ and T₉ were at par each other. The maximum weed density was noted with control T₁ (3.33 m⁻²) and T₄(4.01 m⁻²).

Weed density of *Cloris barbata* was affected significantly with spray of weedicides (Table 4.3). The minimum weed density of *Cloris barbata* (0) was noted with T₂ significantly followed by T₈(0.56 m⁻²), T₇(0.63 m⁻²), T₉ (0.75 m⁻²), T₃(0.99 m⁻²) T₆(1.19 m⁻²), T₄(1.31 m⁻²) and T₅(1.51 m⁻²). The maximum weed density (1.59 m⁻²) was recorded with T₁.

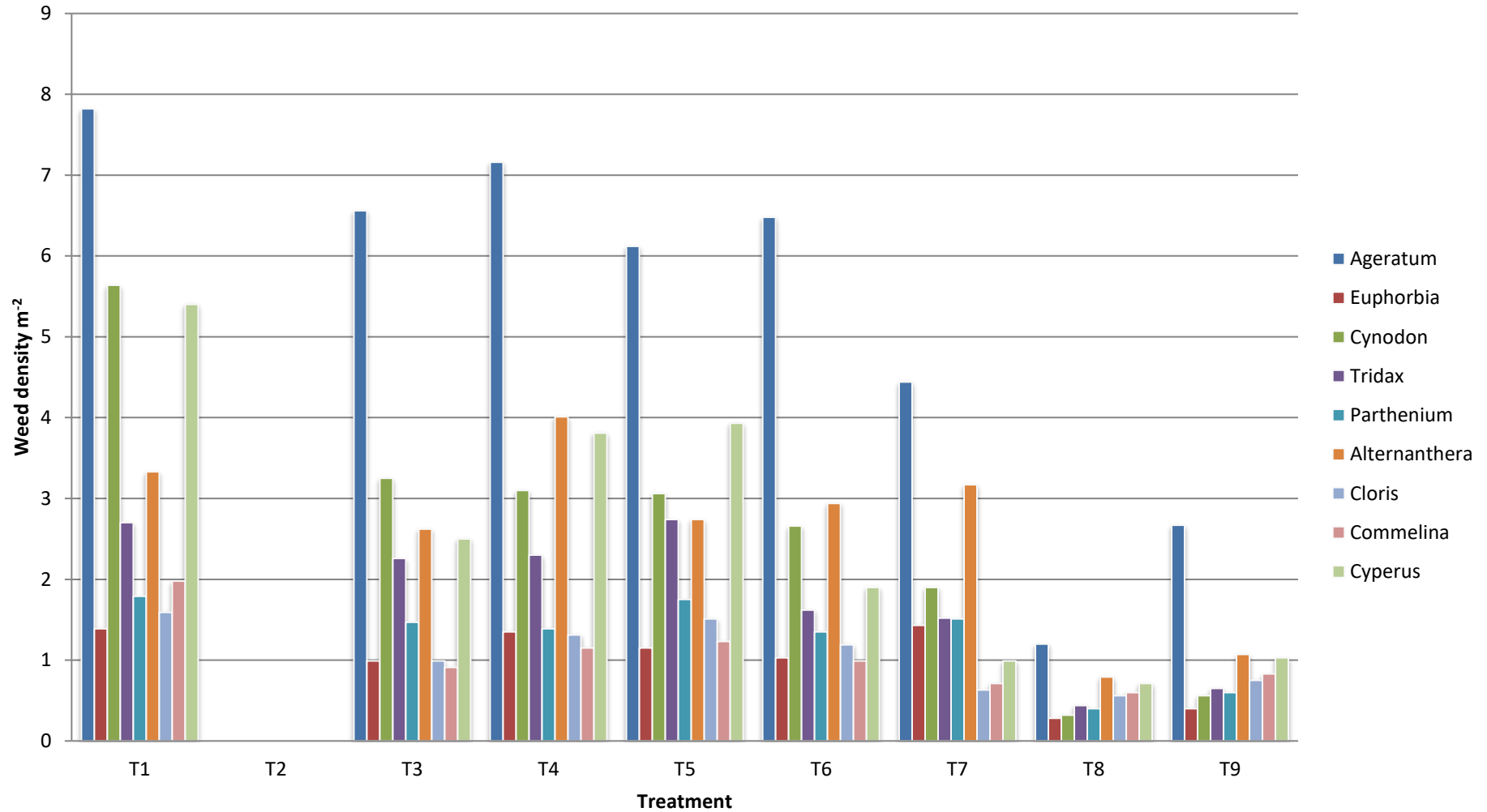
Weed density of *Commelina benghalensis* was affected significantly with spray of weedicides (Table 4.3). The minimum weed density of *Commelina benghalensis* (0) was noted with T₂ significantly followed by T₈ (0.60 m⁻²), T₇ (0.71 m⁻²), T₉ (0.83 m⁻²), T₃(0.91 m⁻²), T₆(0.99 m⁻²), T₄(1.15 m⁻²) and T₅(1.23 m⁻²). Whereas T₈ and T₇ were at par each other. The maximum plant density (1.98 m⁻²) was recorded with control T₁.

Weed density of *Cyperus rotundus* was affected significantly with spray of weedicides (Table 4.3). The minimum weed density of *Cyperus rotundus* (0) was noted with T₂ significantly followed by T₈(0.71 m⁻²), T₇ (0.99 m⁻²), T₉(1.03 m⁻²), T₆ (1.90 m⁻²), T₃(2.50 m⁻²), T₄(3.81 m⁻²), and T₅(3.93 m⁻²). The maximum plant density was recorded with control T₁ (5.40).

Table 4.3 Effect of first spray of herbicide on weed density (m⁻²) at 50 DAS

Density of weed species									
Treatment	<i>Ageratum</i>	<i>Euphorbia</i>	<i>Cynodon</i>	<i>Tridax</i>	<i>Parthenium</i>	<i>Alternanthera</i>	<i>Cloris</i>	<i>Commelina</i>	<i>Cyperus</i>
T ₁	7.82 (2.88)	1.39 (1.37)	5.64 (2.47)	2.70 (1.76)	1.79 (1.51)	3.33 (1.96)	1.59 (1.44)	1.98 (1.57)	5.40 (2.42)
T ₂	0.00 (0.71)	0.00 (0.71)	0.00 (0.71)	0.00 (0.71)	0.00 (0.71)	0.00 (0.71)	0.00 (0.71)	0.00 (0.71)	0.00 (0.71)
T ₃	6.56 (2.66)	0.99 (1.22)	3.25 (1.92)	2.26 (1.65)	1.47 (1.40)	2.62 (1.77)	0.99 (1.22)	0.91 (1.19)	2.50 (1.73)
T ₄	7.16 (2.77)	1.35 (1.36)	3.10 (1.88)	2.30 (1.66)	1.39 (1.37)	4.01 (2.21)	1.31 (1.34)	1.15 (1.28)	3.81 (2.08)
T ₅	6.12 (2.57)	1.15 (1.27)	3.06 (1.78)	2.74 (1.79)	1.75 (1.50)	2.74 (1.89)	1.51 (1.41)	1.23 (1.31)	3.93 (2.10)
T ₆	6.48 (2.64)	1.03 (1.22)	2.66 (1.78)	1.62 (1.45)	1.35 (1.36)	2.94 (1.84)	1.19 (1.30)	0.99 (1.22)	1.90 (1.55)
T ₇	4.44 (2.22)	1.43 (1.39)	1.90 (1.55)	1.52 (1.41)	1.51 (1.41)	3.17 (1.91)	0.63 (1.07)	0.71 (1.10)	0.99 (1.22)
T ₈	1.20 (1.30)	0.28 (0.88)	0.32 (0.91)	0.44 (0.97)	0.40 (0.95)	0.79 (1.41)	0.56 (1.02)	0.60 (1.05)	0.71 (1.10)
T ₉	2.67 (1.78)	0.40 (0.94)	0.56 (1.03)	0.65 (1.07)	0.60 (1.05)	1.07 (1.25)	0.75 (1.12)	0.83 (1.15)	1.03 (1.24)
SEm±	0.03	0.05	0.07	0.06	0.03	0.04	0.03	0.03	0.03
C.D. 5%	0.10	0.14	0.20	0.18	0.08	0.13	0.08	0.07	0.010

Fig. 4.2 Effect of first spray of herbicide on weed density



4.1.4 Effect of first spray of herbicides on drymatter production of weeds in *withania somnifera*

Weed biomass of *Ageratum houstonianum* was affected significantly with spray of weedicides (Table No. 4.4). T₈ was recorded minimum weed drymatter (127 g plot⁻¹) of *Ageratum houstonianum* which was at par with T₉ (178 g plot⁻¹) significantly followed by T₆ (419 g plot⁻¹), T₇ (437 g plot⁻¹), T₃ (535 g plot⁻¹), T₅ (624 g plot⁻¹) and T₂ (642 g plot⁻¹). The maximum weed biomass (657 g plot⁻¹) was recorded with T₄.

Weed biomass (Table No. 4.4) of *Euphorbia hirta* was affected significantly with spray of weedicides T₈ recorded minimum weed dry matter (4 g plot⁻¹) of *Euphorbia hirta* which was significantly followed by T₇ (8 g plot⁻¹), T₃ (9 g plot⁻¹), T₄ (11 g plot⁻¹), T₅ (12 g plot⁻¹) and T₆ (12 g plot⁻¹). The maximum weed biomass (13 g plot⁻¹) was recorded with T₂.

Spray of Weedicides (Table No. 4.4) T₈ was recorded minimum Weed biomass (38 g plot⁻¹) of *Cynodon dactylon* which was at par with T₇ (63 g plot⁻¹) and T₉ (65 g plot⁻¹) followed by T₄ (88 g plot⁻¹), T₆ (105 g plot⁻¹), T₂ (110 g plot⁻¹) and T₃ (120 g plot⁻¹). The maximum Weed biomass was recorded T₅ (123 g plot⁻¹).

Spray of Weedicides (Table No. 4.4) T₈ recorded minimum Weed biomass (67 g plot⁻¹) of *Parthenium hysterophorus* which was at par with T₉ (110 g plot⁻¹) followed by T₂ (185 g plot⁻¹), T₆ (186 g plot⁻¹), T₇ (202 g plot⁻¹), T₅ (229 g plot⁻¹) and T₃ (230 g plot⁻¹). The maximum Weed biomass (327 g plot⁻¹) was recorded with T₄.

Weed biomass of *Tridax procumbens* was affected significantly with spray of weedicides (Table No. 4.4). T₈ was recorded minimum weed drymatter (3 g plot⁻¹) of *Tridax procumbens* which was significantly followed by T₉ (10 g plot⁻¹) T₇ (12 g plot⁻¹), T₃ (14 g plot⁻¹), T₄ (15 g plot⁻¹), T₅ (15 g plot⁻¹) and T₂ (18 g plot⁻¹). The maximum weed biomass (20 g plot⁻¹) was recorded with T₆.

Weed biomass of *Alternanthera sessilis* was affected significantly with spray of weedicides (Table No. 4.4). T₈ recorded minimum weed drymatter (99 g plot⁻¹) of *Alternanthera sessilis* which was significantly followed by T₂ (172 g plot⁻¹), T₉ (182 g plot⁻¹), T₇ (208 g plot⁻¹), T₆ (229 g plot⁻¹), T₄ (311 g plot⁻¹) and T₅ (334 g plot⁻¹). The maximum weed biomass (378 g plot⁻¹) was recorded with T₃.

Spray of Weedicides (Table No. 4.4) T₉ was recorded minimum Weed biomass (7 g plot⁻¹) of *Commelina benghalensis* which was at par with T₈(8 g plot⁻¹) and T₇(10 g plot⁻¹) followed by T₅(12 g plot⁻¹), T₄(14 g plot⁻¹), T₆(17 g plot⁻¹) and T₃(19 g plot⁻¹). The maximum Weed biomass (26 g plot⁻¹) was recorded T₂.

Spray of Weedicides (Table No. 4.4) T₈ was recorded minimum Weed biomass (14 g plot⁻¹) of *Cloris barbata* which was at par with T₇(17 g plot⁻¹) and T₉(18 g plot⁻¹) followed by T₆(22 g plot⁻¹), T₃(27 g plot⁻¹), T₅(32 g plot⁻¹) and T₂(32 g plot⁻¹). The maximum Weed biomass (34 g plot⁻¹) was recorded T₄.

Weed biomass of *Cyperus rotundus* was affected significantly with spray of weedicides (Table No. 4.4). T₈ recorded minimum weed drymatter (4 g plot⁻¹) of *Cyperus rotundus* which was significantly followed by T₉(13 g plot⁻¹), T₇(14g plot⁻¹), T₂(16 g plot⁻¹), T₆(20 g plot⁻¹), T₄(20 g plot⁻¹) and T₃(23 g plot⁻¹). The maximum weed biomass (24 g plot⁻¹) was recorded with T₅.

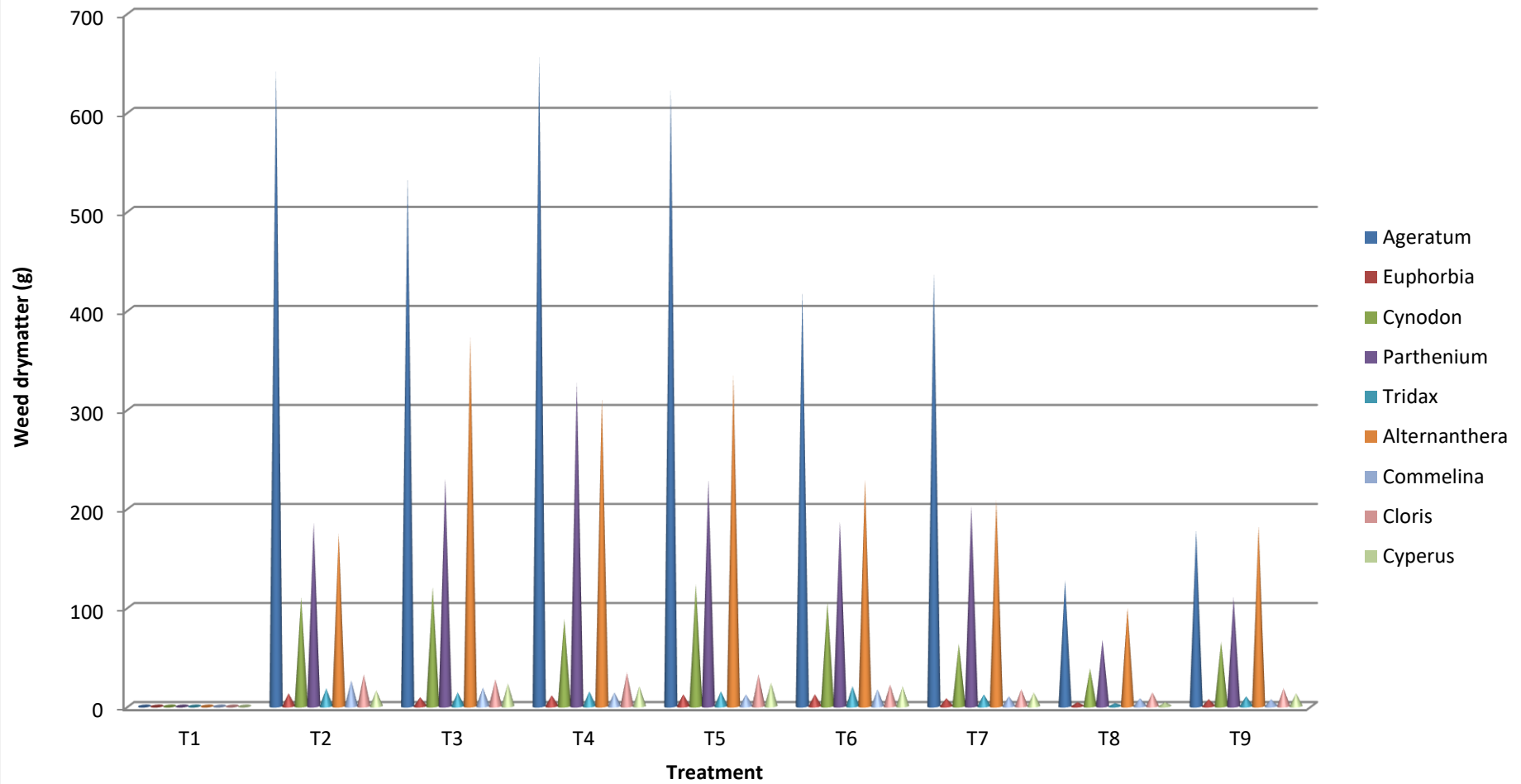
Total weed biomass (g plot⁻¹)

Weed biomass was affected significantly with spray of weedicides (Table No. 4.4). The minimum weed drymatter (364 g plot⁻¹) of weed was recorded with T₈ which was significantly followed by T₉(590 g plot⁻¹), T₇(970 g plot⁻¹), T₆(1030 g plot⁻¹), T₂(1216 g plot⁻¹), T₃(1350 g plot⁻¹) and T₅(1405 g plot⁻¹). The maximum weed biomass (1477 g plot⁻¹) was recorded with T₄.

Table 4.4 Effect of first spray of herbicide on weed biomass at 50 DAS

Weed biomass per treatment										
Treatment	<i>Ageratum</i>	<i>Euphorbia</i>	<i>Cynodon</i>	<i>Parthenium</i>	<i>Tridax</i>	<i>Alternanthera</i>	<i>Commelina</i>	<i>Cloris</i>	<i>Cyperus</i>	Total weed biomass
T ₁	0 (0.71)	0 (0.71)	0 (0.71)	0 (0.71)	0 (0.71)	0 (0.71)	0 (0.71)	0 (0.71)	0 (0.71)	0
T ₂	642 (25.32)	13 (3.67)	110 (10.51)	185 (13.27)	18 (4.30)	174 (12.89)	26 (5.10)	32 (5.71)	16 (4.06)	1216
T ₃	535 (23.13)	9 (3.11)	120 (10.62)	230 (15.17)	14 (3.84)	373 (19.26)	19 (4.44)	27 (5.16)	23 (4.84)	1350
T ₄	657 (25.48)	11 (3.40)	88 (9.24)	327 (17.28)	15 (3.94)	311 (17.31)	14 (3.75)	34 (5.86)	20 (4.32)	1477
T ₅	624 (24.98)	12 (3.53)	123 (11.11)	229 (14.74)	15 (3.91)	334 (18.28)	12 (3.58)	32 (5.68)	24 (4.85)	1405
T ₆	419 (20.07)	12 (3.45)	105 (9.91)	186 (13.56)	20 (4.60)	229 (14.68)	17 (4.22)	22 (4.75)	20 (4.06)	1030
T ₇	437 (20.46)	8 (2.89)	63 (7.95)	202 (14.21)	12 (3.56)	208 (14.41)	10 (3.15)	17 (4.06)	14 (3.85)	970
T ₈	127 (11.24)	4 (2.20)	38 (6.05)	67 (8.10)	3 (1.84)	99 (9.96)	8 (2.89)	14 (3.86)	4 (2.18)	364
T ₉	178 (13.36)	7 (2.80)	65 (8.00)	110 (10.46)	10 (3.13)	182 (13.42)	7 (2.60)	18 (4.10)	13 (3.65)	590
SEm ±	0.81	0.15	0.67	1.00	0.14	0.92	0.20	0.24	0.25	189
CD 5%	2.38	0.45	1.99	2.94	0.42	2.72	0.59	0.72	0.73	566

Fig 4.3 Effect of herbicide on drymatter production of weeds



4.2.1 Diversity and number of weeds before the second spray of herbicide at 80 DAS

Result revealed that there were 6 species of weeds found in Withania (Table 4.5). these species are *Ageratum houstonianum*, *Cynodon dactylon*, *Parthenium hysterophorus*, *Alternanthera sessilis*, *Lactuca serriola* and *Cyperus rotundus*. Out of these weeds *Ageratum houstonianum* was the dominant weed in all the plot (average population 56.04 per plot), followed by *Cyperus rotundus* (average population 21.3 per plot), *Cynodon dactylon* (average population 12.81 per plot), *Alternanthera sessilis* (average population 15.4 per plot), *Parthenium hysterophorus* (average population 12.58 per plot), the minimum population weed (average population 10.5 per plot) was recorded by *Lactuca serriola* in late *kharif* season crop.

Table 4.5 Diversity and number of weeds before the second spray of weedicide at 80 DAS

Weed population / Plot											
S. N.	Weed species diversity	Plot 1	Plot 2	Plot 3	Plot 4	Plot 5	Plot 6	Plot 7	Plot 8	Plot 9	Average weed /plot
1	<i>Ageratum</i>	57	51	57	58	53	57	60	58	53	56.04
2	<i>Cynodon</i>	13	10	14	15	15	12	11	14	12	12.81
3	<i>Parthenium</i>	13	12	13	11	14	10	11	16	14	12.58
4	<i>Alternanthera</i>	16	13	15	17	16	14	15	16	16	15.44
5	<i>Lactuca</i>	10	8	10	9	12	9	12	11	12	10.56
6	<i>Cyperus</i>	20	22	23	29	23	19	17	19	20	21.33

4.2.2 Effect of second spray of herbicide on diversity and Number of weeds in treatment 90 DAS

90 Days after application of weedicides population of weeds (per treatment) was significantly affected (Table 4.6). The least population of *Ageratum houstonianum*

(0) was recorded with T₂ significantly followed by T₈ (12), T₉ (17), T₇(43), T₃(45), T₆(45), T₅(46) and T₄(49). The minimum population (57) was recorded with control T₁.

Population of *Cynodon dactylon* was affected significantly with spray of weedicides (Table 4.6). The least population of *Ageratum houstonianum* (0) was recorded with T₂ significantly followed by T₈(3), T₇ (4), T₉(4), T₆(5), T₃(8), T₄(9) and T₅(11). However T₈, T₇ and T₉ at par with each other. The maximum population (13) was recorded with T₁.

Population of *Parthenium hysterophorus* was affected significantly with spray of weedicides (Table 4.6). The least population of *Parthenium hysterophorus* (0) was recorded with T₂ significantly followed by T₈(2), T₉(4), T₆(7), T₇(8), T₄(8), T₅ (10) and T₃(12). However T₈ and T₉ at par with each other. The maximum population (13) was recorded with control (13).

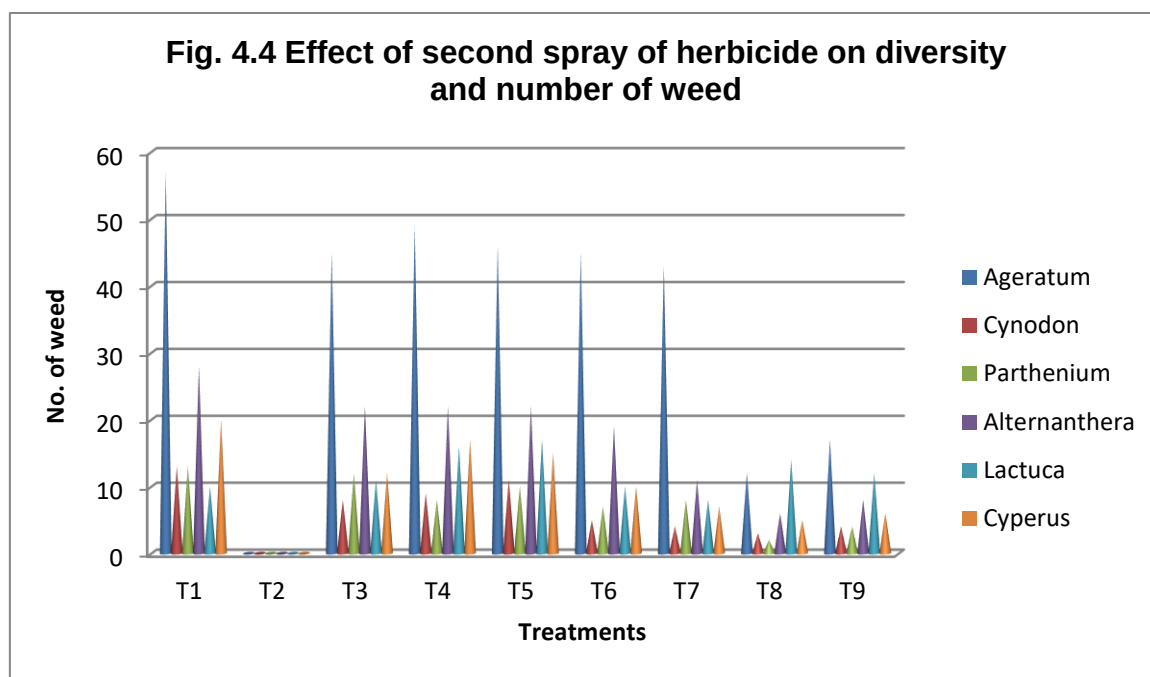
The least population (Table 4.6) of *Alternanthera sessilis* (0) was recorded with T₂ significantly followed by T₈(6), T₉ (6), T₇(11), T₆(12) T₄(12), T₃(15) and T₉(16). The maximum population (17) was recorded with control.

Population of *Cyperus rotundus* was affected significantly with spray of weedicides (Table 4.6). The least population of *Cyperus rotundus* (0) was recorded with T₂ significantly followed by T₈(5), T₉(7), T₇ (6), T₆ (10), T₃(12), T₅(15), and T₄(17) The highest population (20) was recorded with control T₁.

The least population (Table 4.6) of *Lactuca serriola* (0) was recorded with T₂ significantly followed by T₇ (8), T₆ (10), T₁ (10), T₃(11), T₉(12), T₈(14), T₄(16) and T₇(17) was recorded.

Table 4.6 Effect of second spray of herbicide on diversity and number of weed at 90 DAS

Population of weed species						
Treatment	<i>Ageratum</i>	<i>Cynodon</i>	<i>Parthenium</i>	<i>Alternanthera</i>	<i>Lactuca</i>	<i>Cyperus</i>
T₁	57 (7.58)	13 (3.66)	13 (3.66)	28 (4.18)	10 (3.21)	20 (4.48)
T₂	0 (0.71)	0 (0.71)	0 (0.71)	0 (0.71)	0 (0.71)	0 (0.71)
T₃	45 (6.76)	8 (2.97)	12 (3.50)	22 (3.88)	11 (3.42)	12 (3.57)
T₄	49 (7.05)	9 (3.02)	8 (2.93)	22 (3.52)	16 (4.03)	17 (4.17)
T₅	46 (6.81)	11 (3.34)	10 (3.12)	22 (3.99)	17 (4.22)	15 (3.89)
T₆	45 (6.76)	5 (2.41)	7 (2.74)	19 (3.55)	10 (3.23)	10 (3.15)
T₇	43 (6.58)	4 (2.00)	8 (2.93)	11 (3.34)	8 (2.91)	7 (2.65)
T₈	12 (3.48)	3 (1.90)	2 (1.62)	6 (2.45)	14 (3.76)	5 (2.41)
T₉	17 (4.41)	4 (2.08)	4 (2.11)	8 (2.48)	12 (3.53)	6 (2.41)
SEm±	0.13	0.12	0.16	0.14	0.12	0.13
C.d. 5%	0.39	0.34	0.47	0.42	0.36	0.40



4.2.3 Effect of second spray of herbicide on density of weeds in treatments (m²)

Weed density of *Ageratum houstonianum* was affected significantly with spray of weedicides (Table 4.7). The minimum weed density of *Ageratum houstonianum* (0) was noted with T₂ significantly followed by T₈ (1.39 m⁻²), T₉ (1.98 m⁻²), T₇ (5.12 m⁻²), T₆ (5.540 m⁻²), T₃ (5.71 m⁻²), T₅ (5.83 m⁻²) and T₄ (6.11 m⁻²). The maximum weed density (6.83 m⁻²) was recorded with control T₁.

Weed density of *Cynodon dactylon* was affected significantly with spray of weedicides (Table 4.7). The lowest weed density of *Cynodon dactylon* (0) was recorded with T₂ significantly followed by T₈ (0.40 m⁻²), T₇ (0.44 m⁻²), T₉ (0.48 m⁻²), T₆ (0.63 m⁻²), T₃ (0.99 m⁻²), T₄ (1.03 m⁻²) and T₅ (1.15 m⁻²). Whereas T₈, T₇ and T₉ were at par each other. The highest weed density (5.64 m⁻²) was recorded with T₁.

Weed density of *Parthenium hysterophorus* was affected significantly with spray of weedicides (Table 4.7). The lowest weed density of *Parthenium hysterophorus* (0) was recorded with T₂ significantly followed by T₈ (0.26 m⁻²), T₉ (0.48 m⁻²), T₆ (0.83 m⁻²), T₇ (0.99 m⁻²), T₄ (0.99 m⁻²), T₅ (1.15 m⁻²) and T₃ (1.43 m⁻²). However

T₈, T₉, T₇ and T₆ were at par each other. The maximum weed density (1.55 m⁻²) was recorded with control.

The lowest weed density (Table 4.7) of *Alternanthera sessilis* (0) was recorded with T₂ significantly followed by T₈(0.67 m⁻²), T₉(0.67 m⁻²), T₇(1.27m⁻²), T₄(1.43 m⁻²) T₆(1.47 m⁻²), T₅(1.59 m⁻²) and T₃(1.75 m⁻²). However T₈ and T₉ were at par each other. The maximum weed density was recorded with control T₁ (3.33 m⁻²).

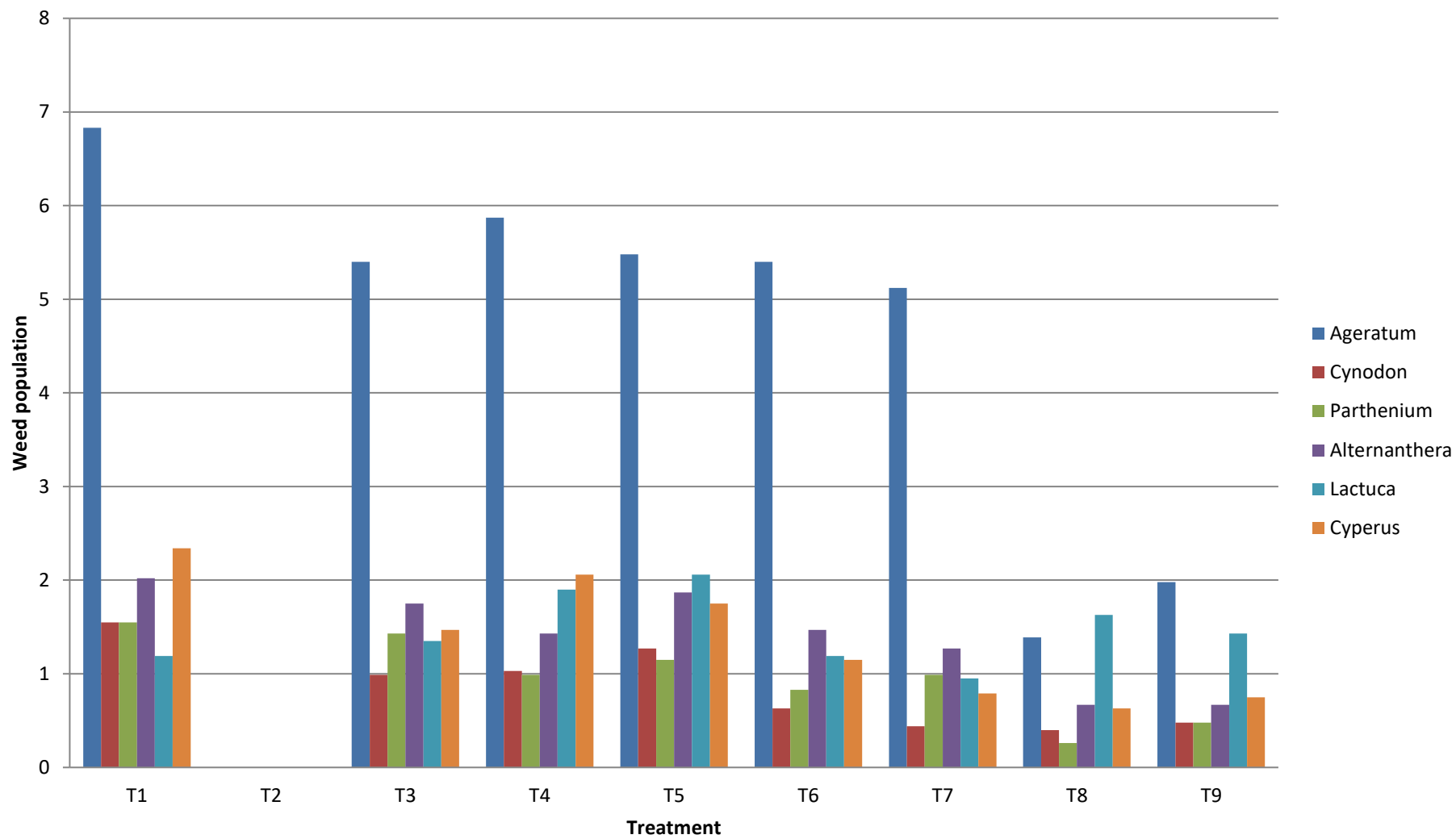
Weed density of *Cyperus rotundus* was affected significantly with spray of weedicides (Table 4.7). The minimum weed density of *Cyperus rotundus* (0) was noted with T₂ significantly followed by T₈(0.63 m⁻²), T₉ (0.75 m⁻²), T₇(0.79 m⁻²), T₆ (1.15 m⁻²), T₃(1.47 m⁻²), T₅(1.75 m⁻²), and T₄(2.06 m⁻²). However T₈, T₉ and T₇ were at par each other. The maximum weed density was recorded with control T₁ (2.34).

Weed density of *Lactuca Seriola* was affected significantly with spray of weedicides (Table 4.7). The minimum weed density of *Lactuca serriola* (0) was noted with T₂ significantly followed by T₇(0.95 m⁻²), T₆(1.19m⁻²), T₁(1.19 m⁻²), T₉(1.43 m⁻²), T₈(1.63 m⁻²) and T₄(1.90 m⁻²). However T₇ and T₆ were at par each other. The maximum weed density(2.06 m⁻²) was recorded T₅.

Table 4.7 Effect of second spray of herbicide on weed density at 90 DAS

Density of weed species						
Treatment	<i>Ageratum</i>	<i>Cynodon</i>	<i>Parthenium</i>	<i>Alternanthera</i>	<i>Lactuca</i>	<i>Cyperus</i>
T₁	6.83 (2.70)	1.55 (1.43)	1.55 (1.43)	2.02 (1.59)	1.19 (1.29)	2.34 (1.68)
T₂	0.00 (0.71)	0.00 (0.71)	0.00 (0.71)	0.00 (0.71)	0.00 (0.71)	0.00 (0.71)
T₃	5.40 (2.42)	0.99 (1.22)	1.43 (1.38)	1.75 (1.50)	1.35 (1.36)	1.47 (1.40)
T₄	5.87 (2.52)	1.03 (1.24)	0.99 (1.21)	1.43 (1.39)	1.90 (1.54)	2.06 (1.59)
T₅	5.48 (2.44)	1.27 (1.33)	1.15 (1.27)	1.87 (1.53)	2.06 (1.60)	1.75 (1.50)
T₆	5.40 (2.42)	0.63 (1.07)	0.83 (1.15)	1.47 (1.40)	1.19 (1.30)	1.15 (1.28)
T₇	5.12 (2.37)	0.44 (0.96)	0.99 (1.21)	1.27 (1.33)	0.95 (1.20)	0.79 (1.13)
T₈	1.39 (1.37)	0.40 (0.94)	0.26 (0.87)	0.67 (1.08)	1.63 (1.46)	0.63 (1.07)
T₉	1.98 (1.58)	0.48 (0.98)	0.48 (0.99)	0.67 (1.08)	1.43 (1.39)	0.75 (1.12)
SEm±	0.04	0.03	0.05	0.04	0.04	0.04
C.D. 5%	0.13	0.09	0.14	0.12	0.11	0.12

Fig. 4.5 Effect of second spray of herbicide on weed density



4.2.4 Effect of second spray of herbicide on drymatter production of weeds in *withania somnifera* per treatment

Weed biomass of *Ageratum houstonianum* was significantly affected with spray of weedicides (Table 4.8). The minimum weed drymatter of *Ageratum houstonianum* (84 g plot⁻¹) was recorded with T₈ which was significantly followed by T₉ (119 g plot⁻¹), T₇(291), T₂(396 plot⁻¹), T₅(461 plot⁻¹), T₃(428 plot⁻¹) and T₆(443 plot⁻¹). The maximum weed biomass(504 plot⁻¹) was recorded with T₆.

Weed biomass of *Cynodon dactylon* was affected significantly with spray of weedicides (Table 4.8). The minimum weed drymatter of *Cynodon dactylon* (22 g plot⁻¹) was recorded with T₈ which was significantly followed by T₉ (28 g plot⁻¹), T₇(32 g plot⁻¹), T₆(48 g plot⁻¹), T₂(56 g plot⁻¹), T₅(62 g plot⁻¹) and T₃(70 g plot⁻¹). The maximum weed matter (97 g plot⁻¹) was recorded with T₄.

Weed biomass of *Cyperus rotundus* was affected significantly with spray of weedicides (Table 4.8). The minimum weed drymatter of *Cyperus rotundus* (4 g plot⁻¹) was noted with T₈ which was significantly followed by T₇ (10 g plot⁻¹), T₉(11 g plot⁻¹), T₆ (15 g plot⁻¹), T₃(16 g plot⁻¹), T₅(16 g plot⁻¹) and T₄(19 g plot⁻¹). The maximum Weed biomass was recorded with T₂ (20 g plot⁻¹).

Weed biomass *Parthenium hysterophorus* was affected significantly with spray of weedicides (Table 4.8). The minimum weed drymatter of (30 g plot⁻¹) was recorded with T₈ which was significantly followed by T₉ (52 g plot⁻¹), T₇(72 g plot⁻¹), T₈(82 g plot⁻¹), T₂(86 g plot⁻¹), T₅ (102 g plot⁻¹) and T₃(117 g plot⁻¹). The maximum Weed biomass (163 g plot⁻¹) was recorded with T₄.

Spray of Weedicides T₈ was recorded of minimum Weed biomass *Alternanthera sessilis* (71 g plot⁻¹) which was significantly followed by T₉ (130 g plot⁻¹), T₇(167 g plot⁻¹), T₆(190 g plot⁻¹) T₅(218), T₃(223 g plot⁻¹) and T₂(233 g plot⁻¹). The maximum Weed biomass was recorded with T₅(298 g plot⁻¹).

Spray of Weedicides (Table 4.8) T₄ was recorded minimum Weed biomass of

Lactuca serriola (144 g plot⁻¹) which was at par with T₅(146 g plot⁻¹), T₂(149 g plot⁻¹), T₇(153 g plot⁻¹), T₈(159 g plot⁻¹) and T₃(167 g plot⁻¹). The maximum Weed biomass was recorded and T₉(172 g plot⁻¹).

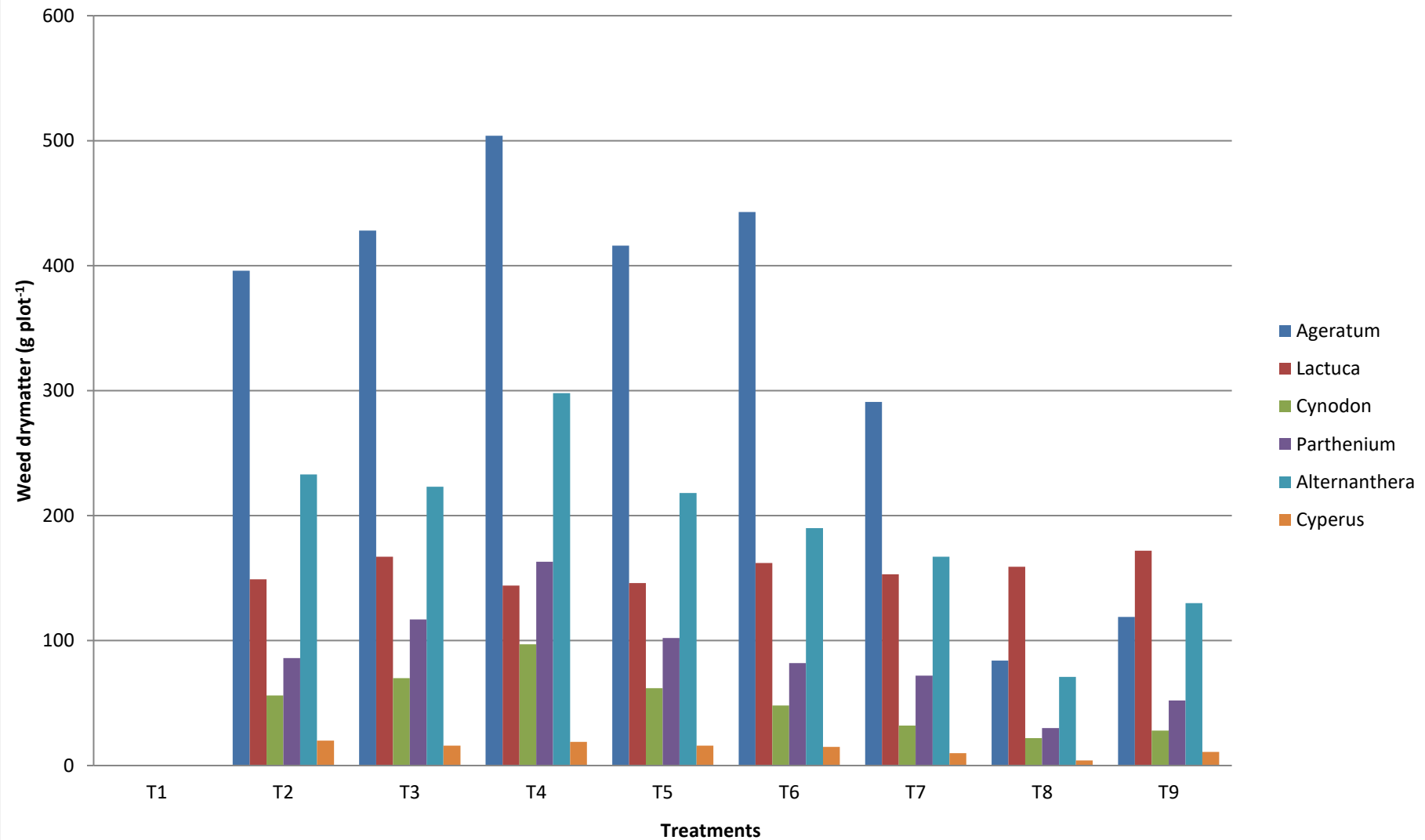
Total weed biomass (g plot⁻¹)

Spray of Weedicides (Table 4.8) T₈ was recorded minimum biomass of weed (370 g plot⁻¹) which was followed by T₉(511 g plot⁻¹), T₇(725 g plot⁻¹), T₄(939 g plot⁻¹), T₂(940 g plot⁻¹), T₅(960 g plot⁻¹) and T₃(1021 g plot⁻¹). The maximum Weed biomass was recorded T₄(1226 g plot⁻¹).

Table 4.8 Effect of second spray of herbicide on weed biomass at 90 DAS

Weed biomass per Treatment								
Treatm ent	<i>Ageratum</i>	<i>Lactuca</i>	<i>Cynodo n</i>	<i>Partheni um</i>	<i>Alternan thera</i>	<i>Cyperus</i>	Total weed biomass	Survival % of ashwag andha
T ₁	0 (0.71)	0 (0.71)	0 (0.71)	0 (0.71)	0 (0.71)	0 (0.71)	0	100
T ₂	396 (19.81)	149 (12.20)	56 (7.54)	86 (9.06)	233 (15.15)	20 (4.44)	940	100
T ₃	428 (20.68)	167 (12.94)	70 (8.32)	117 (10.80)	223 (14.75)	16 (3.97)	1021	100
T ₄	504 (22.46)	144 (12.02)	97 (9.86)	163 (12.58)	298 (17.25)	19 (4.43)	1226	100
T ₅	416 (20.40)	146 (12.08)	62 (7.87)	102 (10.10)	218 (14.77)	16 (4.10)	960	100
T ₆	443 (21.05)	162 (12.71)	48 (6.87)	82 (9.09)	190 (13.79)	15 (3.77)	939	100
T ₇	291 (16.71)	153 (12.33)	32 (5.64)	72 (8.51)	167 (12.93)	10 (3.23)	725	100
T ₈	84 (9.19)	159 (12.63)	22 (4.75)	30 (5.49)	71 (8.42)	4 (2.01)	370	16
T ₉	119 (10.92)	172 (13.12)	28 (5.28)	52 (7.22)	130 (11.35)	11 (3.35)	511	34
SEm ±	0.60	0.27	0.29	0.49	0.53	0.21	104	3
CD @ 5%	1.78	0.80	0.85	1.44	1.57	0.61	311	8

FIG 4.6 Effect of second spray of herbicide on weed biomass



4.3 Survival percentage of ashwagandha

Spray of Weedicides T₈(16) and T₉ (34) (Table No. 4.8) recorded minimum survival % of ashwagandha crop. The maximum survival % of ashwagandha *i.e.* T₇(100), T₄(100), T₂(100), T₅(100), T₆(100) and T₃(100) and T₁(100).

4.3 Phenological observation

4.3.1 Primary branches initiation

The results showed a non significant differences among the treatments. The result revealed that (Table No. 4.9) T₈(39.31) required the maximum days to primary branches initiation which was significantly followed by T₁(38.31), T₉ (38.86), T₄ (38.00), T₃(37.90), T₆(37.35), T₅(37.27) and T₇(36.76). The lowest time was require for primary branches initiation was recorded (36.52) with T₂.

4.3.2 Secondary branches initiation

The results showed a significant difference among the treatments. The result revealed that (Table No.4.9) T₈(50.46) was the maximum days required for secondary branches initiation which was at par with T₉(50.14) and T₁ (50.08) and significantly followed by T₄ (49.41), T₃(49.31), T₅(48.96), T₇(48.47) and T₆(48.37). The Minimum days required for secondary branches initiation was recorded (48.05) with T₂.

4.3.3 Flower initiation

The results showed a significant difference among the treatments. The result showed that (Table No.4.9) T₈(69.65) was the maximum days required for flower initiation which was at par with T₉(69.41), T₁(69.36) and T₃ (68.68) and significantly followed by T₄(68.55), T₅(68.35), T₆(68.31) and T₇(68.13). The lesser period required for flower initiation was recorded (67.21) with T₂.

4.3.4 Flower 50% initiation

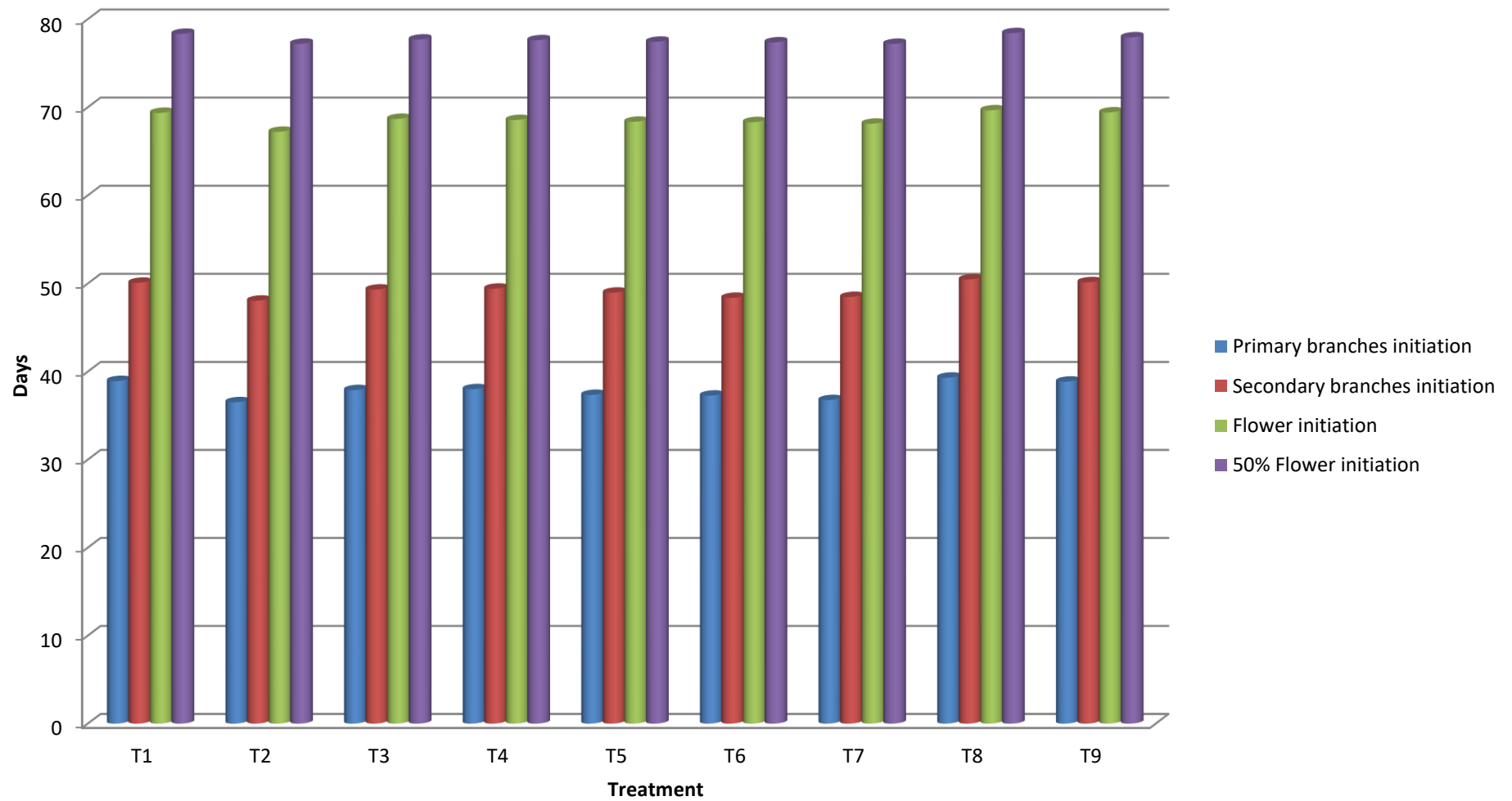
The results showed a significant difference among the treatments. The result

showed that (Table No. 4.9) T₈ (78.41) was the maximum days required for 50% flower initiation which was at par with T₁ (78.33) and T₉ (77.93) and significantly followed by T₃ (77.68), T₄ (77.60), T₅ (77.43), T₆ (77.36) and T₂ (77.20). The Minimum days required for flower 50% initiation was recorded (77.19) with T₇.

Table 4.9 Effect of herbicide on phenological observation of *Withania somnifera*

Treatment	Primary branches initiation	Secondary branches initiation	Flower initiation	50% Flower initiation
T₁	38.93	50.08	69.36	78.33
T₂	36.52	48.05	67.21	77.20
T₃	37.90	49.31	68.68	77.68
T₄	38.00	49.41	68.55	77.60
T₅	37.35	48.96	68.35	77.43
T₆	37.27	48.37	68.31	77.36
T₇	36.76	48.47	68.13	77.19
T₈	39.31	50.46	69.65	78.41
T₉	38.86	50.14	69.41	77.93
S.Em. $\pm$	0.94	0.31	0.35	0.16
C.D. (at 5%)	2.84	0.92	1.04	0.48

Fig 4.7 Effect of herbicide on phenological observation



4.3.5 Fruit initiation

The results showed a significant difference among the treatments. The result revealed that (Table No.4.10) T₈(85.84) the maximum days required for fruit initiation which was at par with T₁(85.8) and T₈(85.51) and significantly followed by T₃(84.76), T₄(84.73), T₅(84.34), T₆(83.90), T₆(83.83). The minimum days required for fruit initiation was (83.58) was noted with T₇.

4.3.6 Seed formation

The results showed a significant difference among the treatments. The result revealed (Table No.4.10) T₈(92.87) the maximum days required for Seed formation which was at par with T₁(92.80) and T₃(92.69) and T₉(92.65) and followed by T₄(92.40), T₅(92.14), T₆(91.82), T₂(91.17). The minimum days required for seed formation was (91.06) noted with T₇.

4.3.7 Physiological maturity

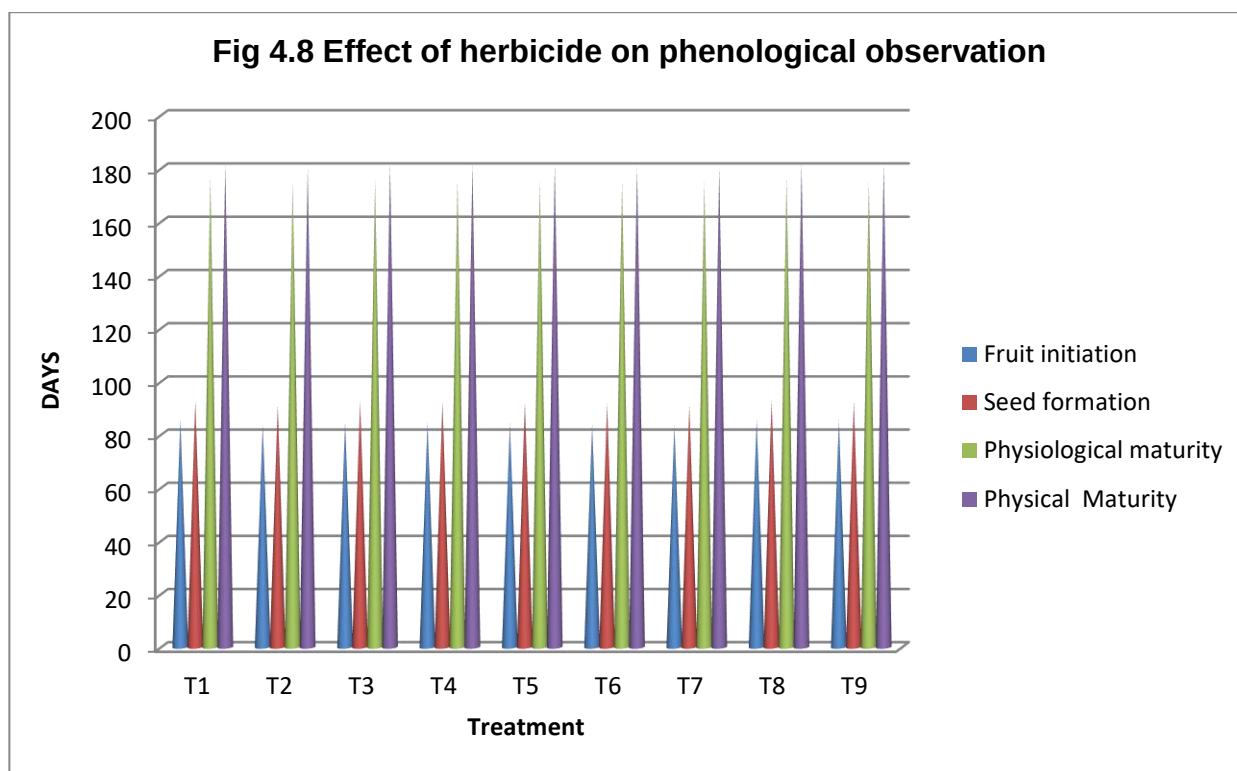
The results showed a significant difference among the treatments. The result revealed that (Table No.4.10) T₈(176.96) the maximum days required for physiological maturity which was at par with T₁ (176.83) and followed by T₃(175.68), T₄(175.57), T₅(175.42), T₆(175.18), T₉(175.01), T₇(174.86). The Minimum days required for physiological maturity was (174.65) was noted with T₂.

4.3.8 Physical maturity

The results showed a significant difference among the treatments. The result revealed that (Table No.4.10) T₈(181.97) the maximum days required for physical maturity which was at par with T₁(181.73) and T₃(181.72) and followed by T₉(181.70), T₄(181.50), T₅(181.21), T₆(180.59), T₇(180.22). The Minimum days required for physical maturity was (180.12) was noted with T₂.

Table 4.10 Effect of herbicide on phenological observation of *Withania somnifera*

Treatment	Fruit initiation	Seed formation	Physiological maturity	Physical Maturity
T₁	85.8	92.8	176.83	181.73
T₂	83.83	91.17	174.65	180.12
T₃	84.76	92.69	175.68	181.72
T₄	84.73	92.4	175.57	181.5
T₅	84.34	92.14	175.42	181.21
T₆	83.9	91.82	175.18	180.59
T₇	83.58	91.06	174.86	180.22
T₈	85.84	92.87	176.96	181.97
T₉	85.51	92.65	175.01	181.7
S.Em $\pm$	0.12	0.044	0.306	0.08
C D (at 5%)	0.36	0.13	0.91	0.26



4.4 Growth analytical parameters and biophysical traits

4.4.1 Leaf area index (LAI)

At 60 DAS

The results showed a significant difference among the treatments. The result revealed that (Table No 4.11) At 60 DAS the highest Leaf area index noted with T₆ (0.86) which was at par with T₃(0.86) T₂(0.78) and T₇(0.77) and significantly followed by T₅(0.65), T₄(0.59), T₁(0.57), T₉(0.44). The lesser Leaf area index was (0.40) noted with T₈.

At 90 DAS

The results showed a significant difference among the treatments. The result revealed that (Table No 4.11) At 90 DAS the highest Leaf area index recorded with T₇ (1.38) which was at par with T₂(1.28) and significantly followed by T₆(1.20), T₅(1.15), T₄(1.05), T₃(1.01), T₁(0.96), T₉(0.89). The lesser Leaf area index was (0.88) noted with T₈.

At 120 DAS

The results showed a significant difference among the treatments. The result revealed that (Table No 4.11) At 120 DAS the highest Leaf area index recorded with T₂ (1.82) which was at par with T₇(1.74) and significantly followed by T₆(1.53) T₅(1.38), T₄(1.22), T₃(1.15), T₉(1.07), T₁(1.06). The lesser Leaf area index was (1.03) noted with T₈.

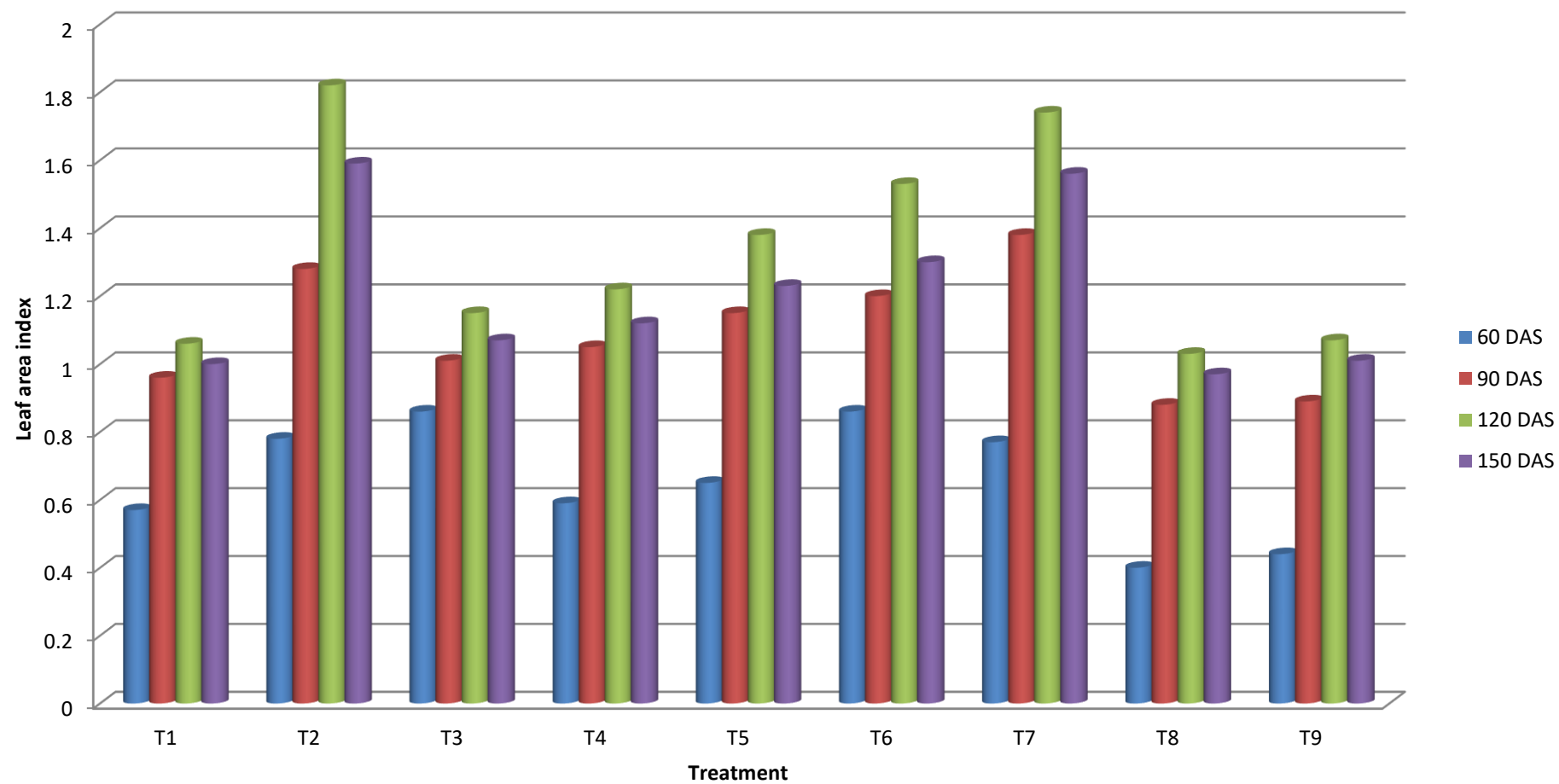
At 150 DAS

The results showed a significant differences among the treatments. The result revealed that (Table No 4.11) At 150 DAS the highest Leaf area index noted with T₂ (1.59) which was at par with T₇(1.56) and significantly followed by and T₆(1.30), T₅(1.23), T₄(1.12), T₃(1.07), T₉(1.01), T₁(1.00). The lesser Leaf area index was (0.97) noted with T₈.

Table 4.11 Effect of herbicide on Leaf area index of *Withania somnifera* crop

Treatment	LAI			
	60 DAS	90 DAS	120 DAS	150 DAS
T ₁	0.57	0.96	1.06	1.00
T ₂	0.78	1.28	1.82	1.59
T ₃	0.86	1.01	1.15	1.07
T ₄	0.59	1.05	1.22	1.12
T ₅	0.65	1.15	1.38	1.23
T ₆	0.86	1.20	1.53	1.30
T ₇	0.77	1.38	1.74	1.56
T ₈	0.40	0.88	1.03	0.97
T ₉	0.44	0.89	1.07	1.01
S.Em ±	0.06	0.05	0.08	0.04
CD (at5%)	0.17	0.15	0.24	0.12

Fig 4.9 Effect of herbicide on Leaf area index of *Withania somnifera*



4.4.2 LAD (Leaf Area Duration) (cm² days)

At 60-90 DAS

The results showed a significant differences among the treatments. The result revealed that leaf area duration of ashwagandha (Table No. 4.12) At 60-90 DAS the maximum leaf area duration recorded with T₂ (6440) which was at par with T₇(6199) and T₆(6168) and significantly followed by T₃(5632), T₅(5380), T₄(4905), T₁(4605), T₉(3986). The Minimum leaf area duration was (3923) was noted with T₈.

At 90-120 DAS

The results showed a significant differences among the treatments. The result revealed that (Table No. 4.12) At 90-120 DAS the maximum leaf area duration noted with T₂ (9354) which was at par with T₇(9324) and significantly followed by T₆(8175) T₅(7589), T₄(6811), T₃(6490), T₁(6079), T₉(5895). The Minimum leaf area duration (5805) was noted with T₈.

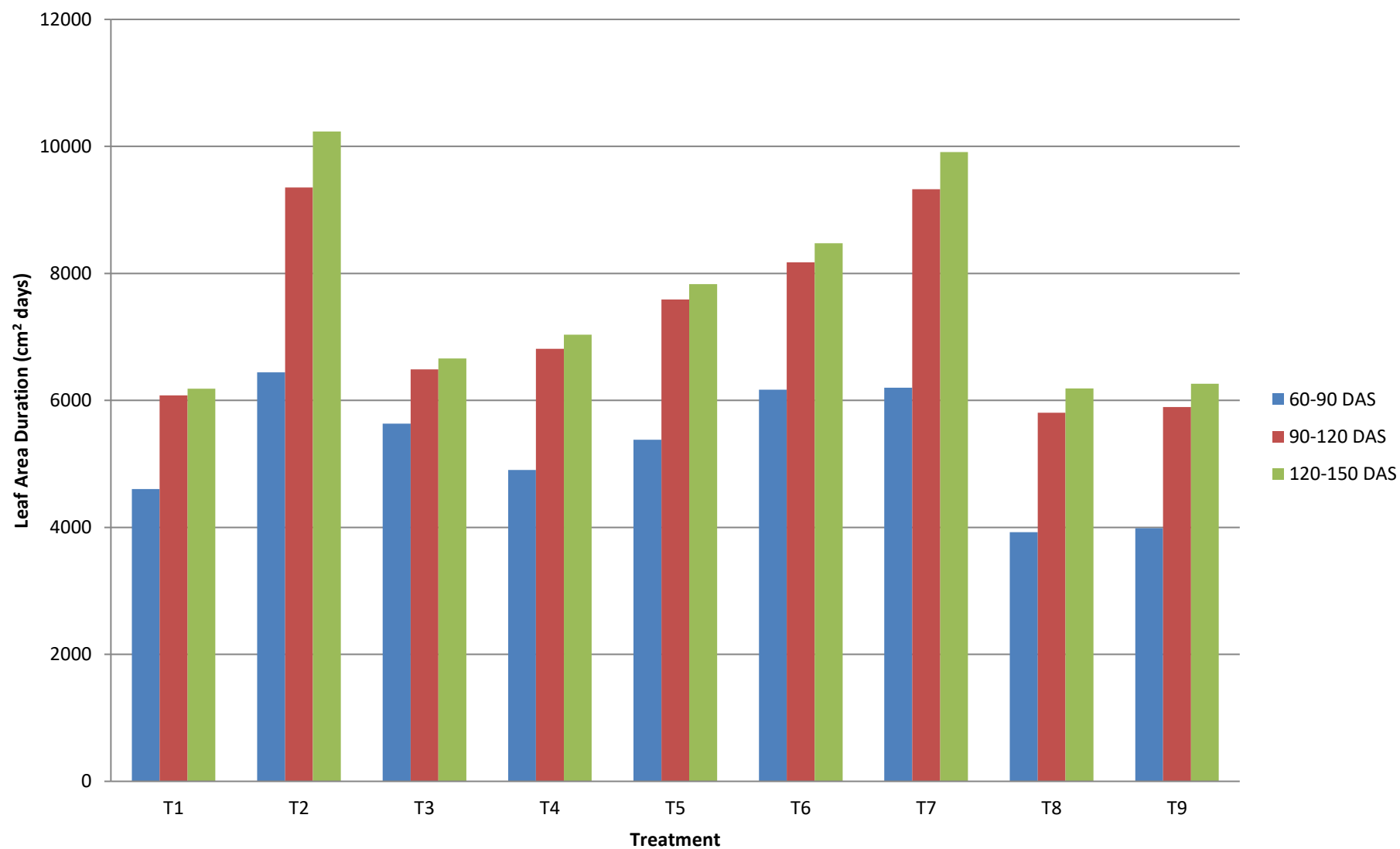
At 120-150 DAS

The results showed a significant differences among the treatments. The result revealed that (Table No. 4.12). At 120-150 DAS the maximum leaf area duration recorded with T₂ (10233) which was at par with T₇(9909.8) and significantly followed by T₆(8476.8) T₅(7831.2), T₄(7036.8), T₃(6662.7), T₁(6184.1), T₉(6264.3). The Minimum days required for leaf area duration was (6189) noted with T₈.

Table 4.12 Effect of herbicide on Leaf Area Duration (cm² days) of *Withania somnifera*

Treatment	LAD		
	60-90 DAS	90-120 DAS	120-150 DAS
T₁	4605	6079	6184
T₂	6440	9354	10233
T₃	5632	6490	6662
T₄	4905	6811	7036
T₅	5380	7589	7831
T₆	6168	8175	8476
T₇	6199	9324	9909
T₈	3923	5805	6189
T₉	3986	5895	6264
S.Em ±	259	217	247
CD (at 5%)	777	650	739

Fig 4.10 Effect of herbicide on Leaf Area Duration of *Withania somnifera*



4.4.3 Crop Growth Rate (CGR) ($\text{g cm}^{-2} \text{ day}^{-1}$)

At 60-90 DAS

The results showed a significant differences among the treatments. The result revealed that (Table No. 4.13) At 60-90 DAS T_3 the maximum crop growth rate noted with T_3 (0.000428) which was at par with T_5 (0.000412) and T_2 (0.000398) T_6 (0.000369), T_7 (0.000360), T_4 (0.000348), T_1 (0.000307) and significantly followed by T_9 (0.000210). The Minimum days required for crop growth rate was (0.000123) noted with T_8 .

At 90-120 DAS

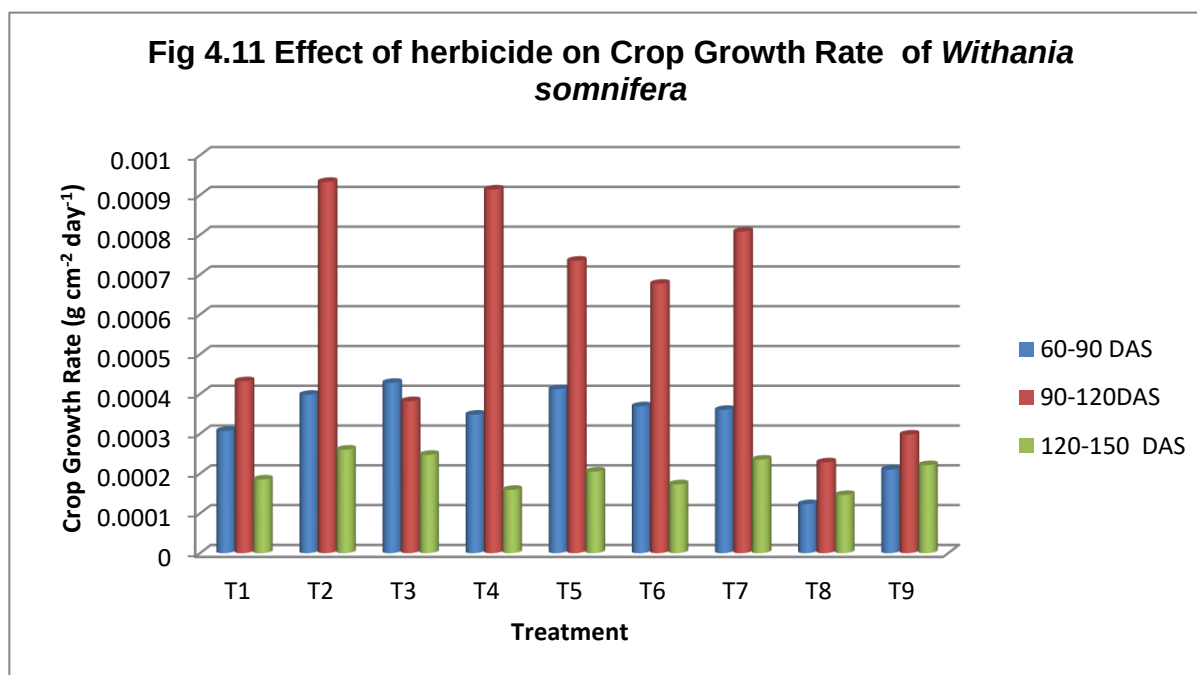
The results showed a significant differences among the treatments. The result revealed that (Table No. 4.13) At 90-120 DAS the maximum crop growth rate recorded with T_2 (0.000933) which was at par with T_4 (0.000914) and T_7 (0.000808) and significantly followed by T_5 (0.000735), T_6 (0.000677), T_1 (0.000432), T_3 (0.000382), T_9 (0.000298). The Minimum days required for crop growth rate was (0.000228) noted with T_8 .

At 120-150 DAS

The results didn't showed any significant differences among the treatments. The result revealed that (Table No. 4.13) At 120-150 DAS the maximum crop growth rate noted with T_2 (0.000260) which was at par with T_3 (0.000247), T_7 (0.000235), T_9 (0.000221), T_5 (0.000205), T_1 (0.000185), T_6 (0.000173), T_4 (0.000159). The Minimum days required for crop growth rate was (0.000146) noted with T_8 .

Table 4.13 Effect of herbicide on Crop Growth Rate ($\text{g cm}^{-2} \text{ day}^{-1}$) of *Withania somnifera*

Treatment	CGR 60-90 DAS	CGR 90-120DAS	CGR 120-150 DAS
T ₁	0.000307	0.000432	0.000185
T ₂	0.000398	0.000933	0.000260
T ₃	0.000428	0.000382	0.000247
T ₄	0.000348	0.000914	0.000159
T ₅	0.000412	0.000735	0.000205
T ₆	0.000369	0.000677	0.000173
T ₇	0.000360	0.000808	0.000235
T ₈	0.000123	0.000228	0.000146
T ₉	0.000210	0.000298	0.000221
S.Em $\pm$	0.000048	0.000057	0.0000307
CD (at5%)	0.000143	0.000167	0.000111



4.4.4 Relative growth rate RGR ($\text{g g}^{-1}\text{days}^{-1}$)

At 60-90 DAS

The results didn't showed any significant differences among the treatments. The result revealed that relative growth rate of (Table No. 4.14) At 60-90 DAS the highest relative growth rate noted T_2 (0.0286) which was at par with T_5 (0.0260), T_1 (0.0255) T_4 (0.0211), T_7 (0.0209), T_6 (0.000199), T_3 (0.000194), and significantly followed by T_8 (0.000174). The lesser relative growth rate was (0.000164) noted with T_9 .

At 90-120 DAS

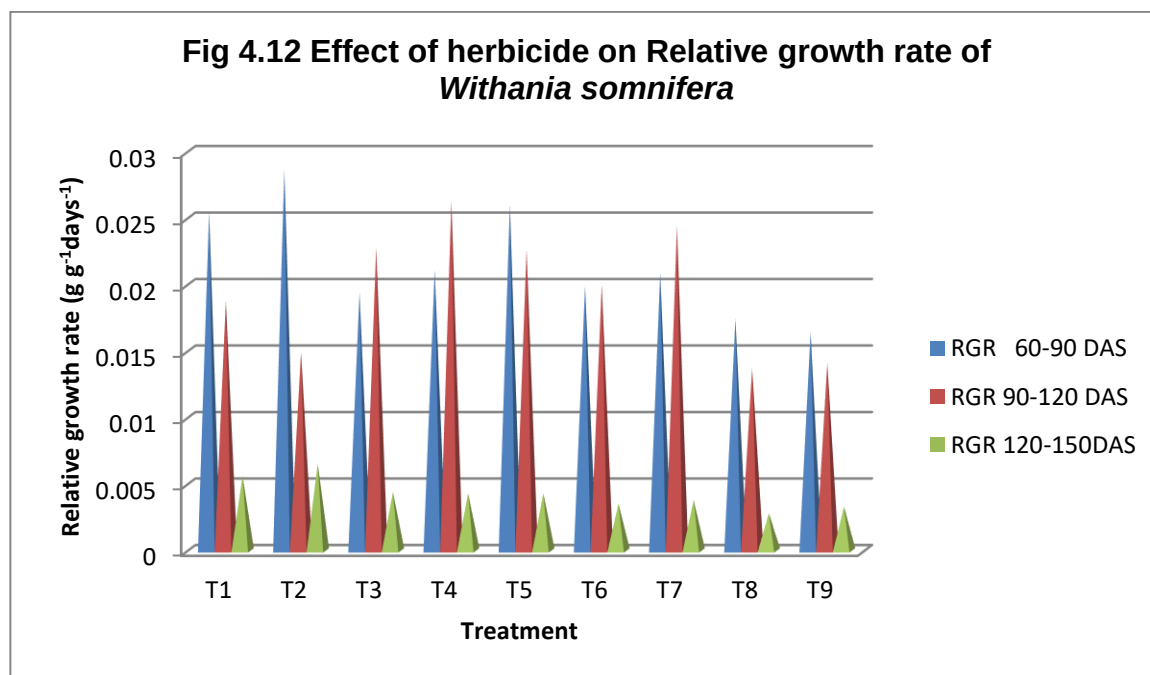
The results showed a significant differences among the treatments. The result revealed that (Table No. 4.14) At 90-120 DAS the highest relative growth rate noted T_4 (0.0263) which was at par with T_7 (0.0244) , T_3 (0.0228) and T_5 (0.0226) and significantly followed by T_6 (0.0200), T_1 (0.0188), T_2 (0.0149), T_9 (0.0141). The lesser relative growth rate was (0.0138) noted with T_8 .

At 120-150 DAS

The results didn't showed any significant differences among the treatments. The result revealed that (Table No. 4.14) At 120-150 DAS the highest relative growth rate noted T_2 (0.0065) which was at par with T_3 (0.0044) , T_4 (0.0043) , T_5 (0.0043) and T_7 (0.00385) and significantly followed by T_6 (0.0035) and T_9 (0.0033). The lesser relative growth rate was (0.0287) noted with T_8 .

Table 4.14 Effect of herbicide on Relative growth rate ($\text{g g}^{-1}\text{days}^{-1}$) of *Withania somnifera*

Treatment	RGR 60-90 DAS	RGR 90-120 DAS	RGR 120-150DAS
T₁	0.0255	0.0188	0.0056
T₂	0.0286	0.0149	0.0065
T₃	0.0194	0.0228	0.0044
T₄	0.0211	0.0263	0.0043
T₅	0.0260	0.0226	0.0043
T₆	0.0199	0.0200	0.0035
T₇	0.0209	0.0244	0.0038
T₈	0.0174	0.0137	0.0028
T₉	0.0164	0.0141	0.0033
S.Em $\pm$	0.0032	0.0019	0.0009
CD (at5%)	0.0095	0.0058	0.0029



4.4.5 Net assimilation ratio (NAR) ($\text{g cm}^{-2} \text{ days}^{-1}$)

At 60-90 DAS

The results didn't showed any significant differences among the treatments. The result revealed that (Table No. 4.15) At 60-90 DAS the highest net assimilation ratio noted T_5 (0.00028) which was at par with T_7 (0.00027), T_2 (0.00026) T_1 (0.00024), T_6 (0.00023), T_3 (0.00021), T_4 (0.00021), T_9 (0.00019). The lesser net assimilation ratio (0.000151) was noted with T_8 .

At 90-120 DAS

The results showed a significant differences among the treatments. The result revealed that (Table No. 4.15) At 90-120 DAS the highest net assimilation ratio noted T_2 (0.00048) which was at par with T_6 (0.00041) and T_5 (0.00035) and significantly followed by T_3 (0.00031), T_4 (0.00026), T_1 (0.00025), T_7 (0.000213), T_9 (0.000183). The lesser net assimilation ratio was (0.000172) noted with T_8 .

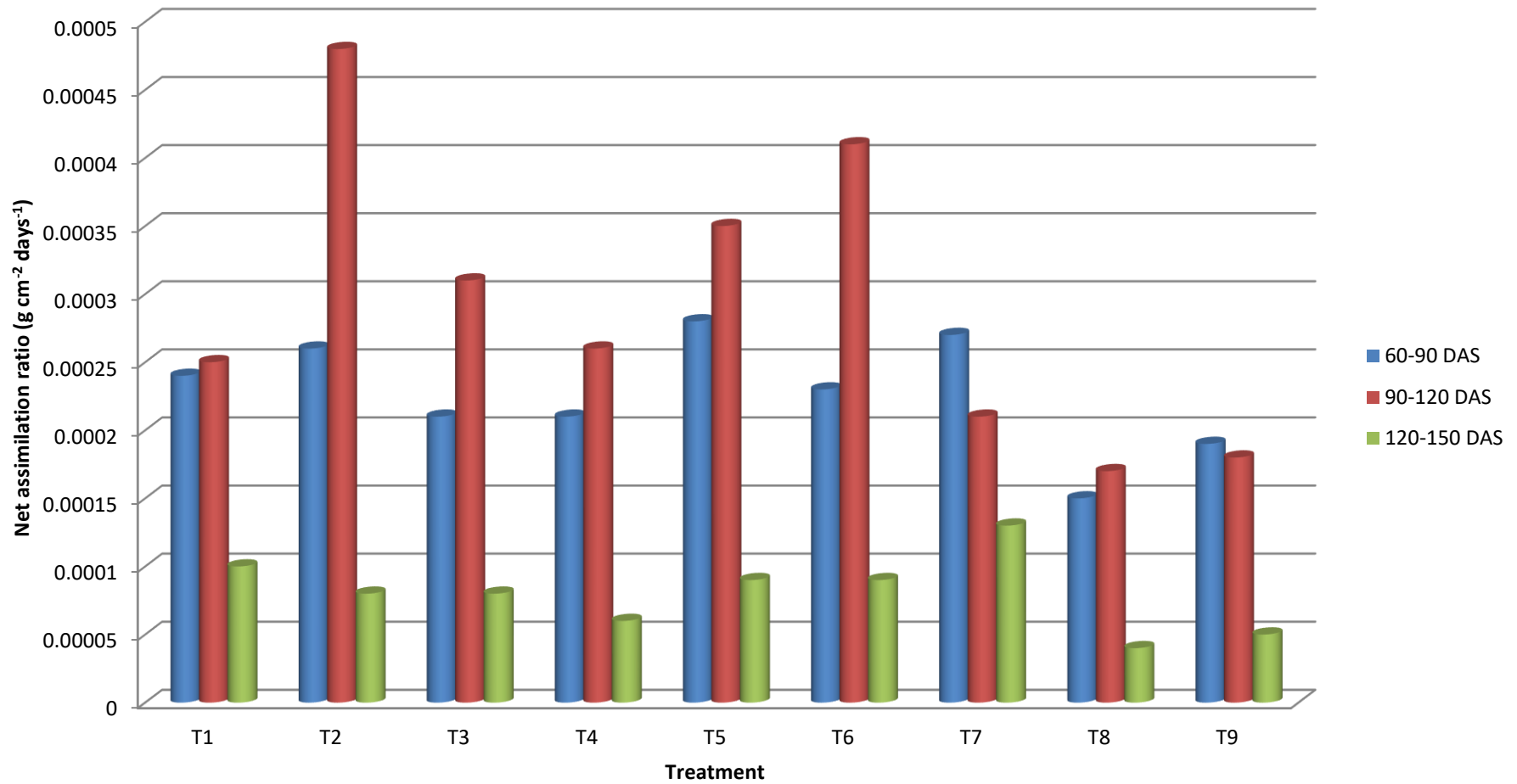
At 120-150 DAS

The results showed a significant differences among the treatments. The result revealed that (Table No. 4.15) At 120-150 DAS the highest net assimilation ratio noted T_2 (0.000134) which was at par with T_6 (0.000094) and T_5 (0.000094), T_3 (0.000082), T_2 (0.000082), T_1 (0.000077), T_4 (0.000062) and significantly followed by T_9 (0.000053). The lesser net assimilation ratio was (0.000047) was noted with T_8 .

Table 4.15 Effect of herbicide on Net assimilation ratio (g cm⁻² days⁻¹) of *Withania somnifera*

Treatment	NAR		
	60-90 DAS	90-120 DAS	120-150 DAS
T₁	0.00024	0.00025	0.00008
T₂	0.00026	0.00048	0.00013
T₃	0.00021	0.00031	0.00008
T₄	0.00021	0.00026	0.00006
T₅	0.00028	0.00035	0.00009
T₆	0.00023	0.00041	0.00009
T₇	0.00027	0.00021	0.00013
T₈	0.00015	0.00017	0.00004
T₉	0.00019	0.00018	0.00005
S.Em ±	0.00003	0.00002	0.00001
CD (at5%)	0.00011	0.00008	0.00004

Fig. 4.13 Effect of herbicide on Net assimilation ratio of *Withania somnifera*



4.4.6 Biomass duration (BMD) (g days)

At 60-90 DAS

The results showed a significant differences among the treatments. The result revealed that (Table No. 4.16) At 60-90 DAS the highest biomass duration noted T₂ (68.97) which was at par with T₇ (66.82), T₆ (66.76), T₄(61.44) and T₅ (57.62) and significantly followed by T₃(54.25) ,T₉(45.40), T₁(43.11). The lesser biomass duration was (41.25) noted with T₈.

At 90-120 DAS

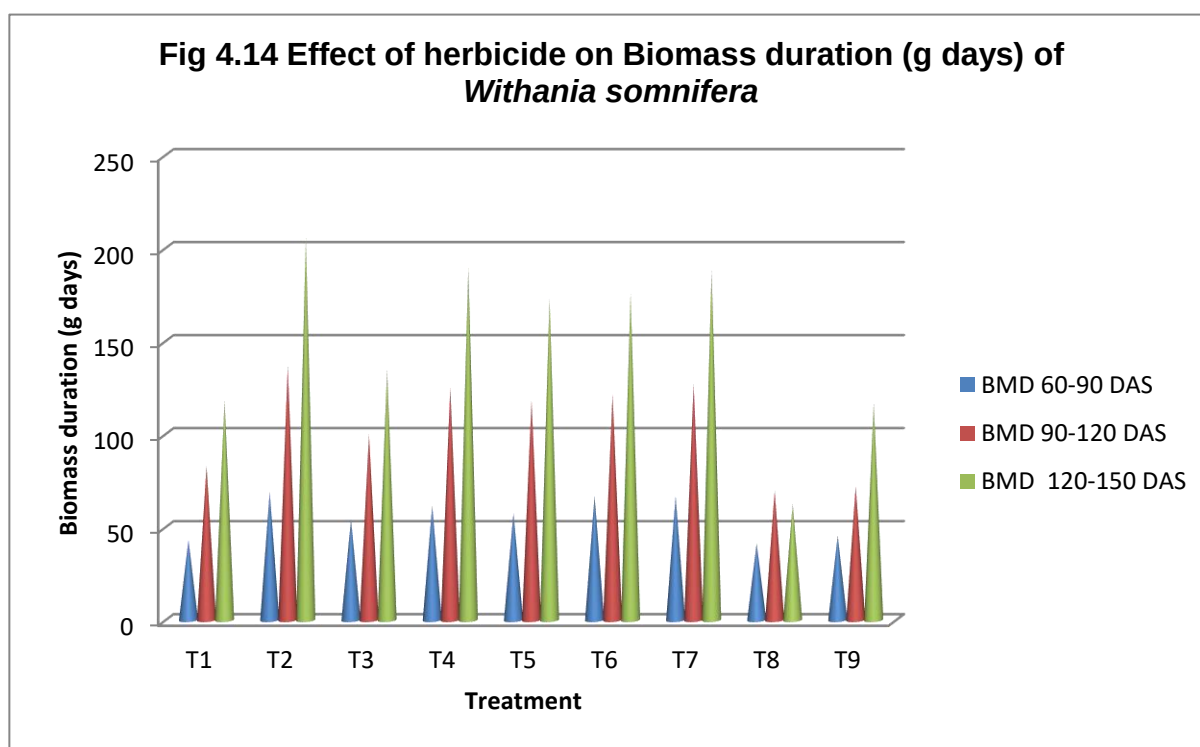
The results showed a significant differences among the treatments. The result revealed that (Table No. 4.16). At 90-120 DAS the highest biomass duration noted T₂ (136.96) which was at par with T₇ (126.79) and T₄ (125.06) and significantly followed by T₆ (121.48), T₅ (118.11), T₃ (99.92) T₁(82.92) and T₉(72.03). The lesser biomass duration was (69.53) was noted with T₈.

At 120-150 DAS

The results showed a significant differences among the treatments. The result revealed that (Table No. 4.16). At 120-120 DAS the highest biomass duration noted T₂ (205.18) which was at par with T₄ (189.49) and T₇ (187.75) and significantly followed by T₆ (175.67), T₅ (173.15), T₃ (134.84), T₁(118.17), T₉(116.62). The lesser biomass duration was (62.45) noted with T₈.

Table 4.16 Effect of herbicide on Biomass duration (g days) of *Withania somnifera*

Treatment	BMD 60-90 DAS	BMD 90-120 DAS	BMD 120-150 DAS
T₁	43.11	82.97	118.17
T₂	68.97	136.96	205.18
T₃	54.25	99.92	134.84
T₄	61.44	125.06	189.49
T₅	57.62	118.11	173.15
T₆	66.76	121.48	175.67
T₇	66.82	126.79	187.75
T₈	41.25	69.53	62.45
T₉	45.40	72.03	116.62
S.Em ±	3.82	4.03	7.05
CD (at5%)	11.44	12.08	21.14



4.4.7 Specific leaf area (cm²g⁻¹)

At 60 DAS

The results showed a significant differences among the treatments. The result revealed that (Table No. 4.17) At 60 DAS the maximum specific leaf area reported with T₂ (433.69) which was at par with T₇(430.30) and T₆(416.43) and significantly followed by T₃(410.13), T₄(405.46), and T₁(383.62) and significantly followed by T₉(362.94), T₅(360.40). The Minimum days required for specific leaf area was (349.15) noted with T₈.

At 90 DAS

The results showed a significant differences among the treatments. The result revealed that (Table No. 4.17) At 90 DAS the maximum specific leaf area reported T₂(484.09) which was at par with T₇ (474.43) and significantly followed by T₆(437.87), T₄(425.45), T₃(402.12), T₅(367.54), T₉(358.27), T₁(352.27). The Minimum days required for specific leaf area (340.18) was noted with T₈.

At 120 DAS

The results showed a significant differences among the treatments. The result revealed that (Table No. 4.17) At 120 DAS maximum specific leaf area reported T₂ (322.62) which was at par with T₇ (317.32) and T₄(309.95) and significantly followed by T₆(275.66), T₁(262.55), T₅(261.92), T₉(260.11), T₃(260.00). The Minimum days required for specific leaf area was (213.55) noted with T₈.

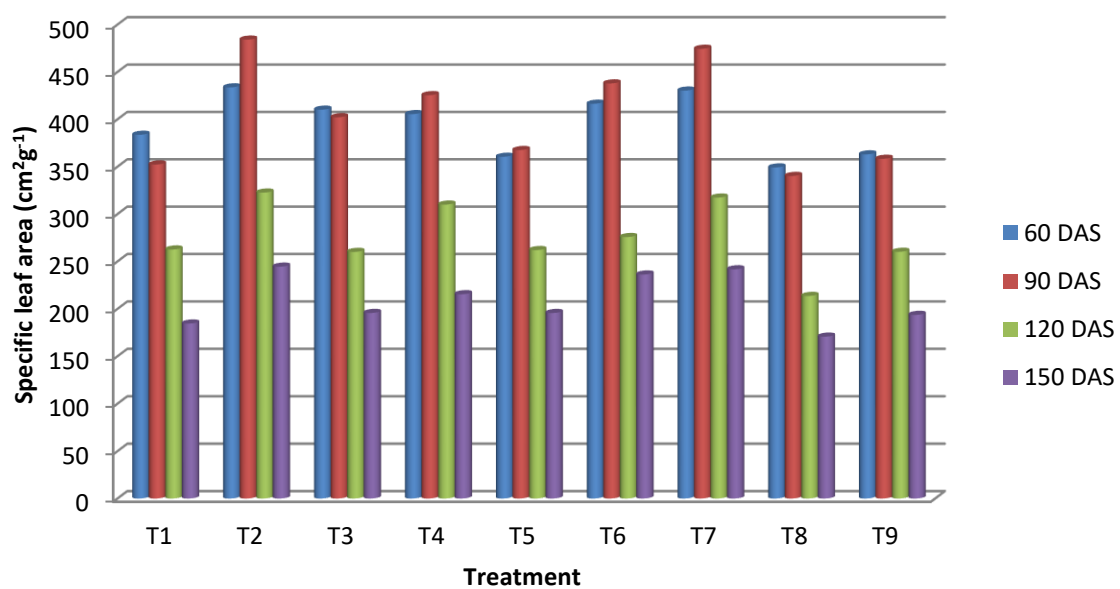
At 150 DAS

The results showed a significant differences among the treatments. The result revealed that (Table No. 4.17). At 120 DAS T₂ the maximum days required for specific leaf area (244.44) which was at par with T₇(241.63) and T₆(236.15) and significantly followed by T₄(215.36), T₃(195.61), T₅(195.58), T₉(193.59), T₁(184.45). The Minimum days required for specific leaf area was (170.62) noted with T₈.

Table 4.17 Effect of herbicide on Specific leaf area (cm²g⁻¹) of *Withania somnifera*

Treatment	SLA			
	60 DAS	90 DAS	120 DAS	150 DAS
T₁	383.62	352.27	262.55	184.45
T₂	433.69	484.09	322.62	244.44
T₃	410.13	402.12	260.00	195.61
T₄	405.46	425.45	309.95	215.36
T₅	360.40	367.54	261.92	195.58
T₆	416.43	437.87	275.66	236.15
T₇	430.30	474.43	317.32	241.63
T₈	349.15	340.18	213.55	170.62
T₉	362.94	358.27	260.11	193.59
S.Em ±	22.59	12.72	16.69	7.50
CD (at5%)	67.74	38.12	50.02	22.48

Fig 4.15 Effect of herbicide on Specific Leaf Area of *Withania somnifera* crop



4.4.8 Specific leaf weight (SLW) (g m⁻²)

At 60 DAS

The results showed a significant differences among the treatments. The result revealed that specific leaf weight (SLW) of (Table No. 4.18). At 60 DAS, T₈ recorded the maximum specific leaf weight (SLW) (0.002868) which was at par with T₅ (0.00279) and T₉(0.00276) and significantly followed by T₁(0.00260) T₃ (0.00248), T₄(0.00246), T₆(0.00244), T₇(0.00232). The minimum SLW recorded (0.00196) with T₂.

At 90 DAS

The results showed a significant differences among the treatments. The result revealed that (Table No. 4.18) At 90 DAS, T₈ recorded the maximum specific leaf weight (SLW) (0.00294) which was at par with T₁(0.00285), T₉ (0.00279) T₅ (0.00272) and T₃ (0.00249) and significantly followed by T₄(0.00236), T₆(0.00228), T₆(0.00228) and T₇(0.00211). The minimum SLW was (0.00206) noted with T₂.

At 120 DAS

The results showed a significant differences among the treatments. The result revealed that (Table No. 4.18) At 120 DAS, T₈ recorded the maximum specific leaf weight (SLW) (0.00402) which was at par with T₃(0.00393) and T₉ (0.00386), T₅ (0.00386), T₁ (0.00385), T₆(0.00363) and significantly followed by T₄(0.00323) and T₂(0.00318). The Minimum SLW was (0.00315) was noted with T₇.

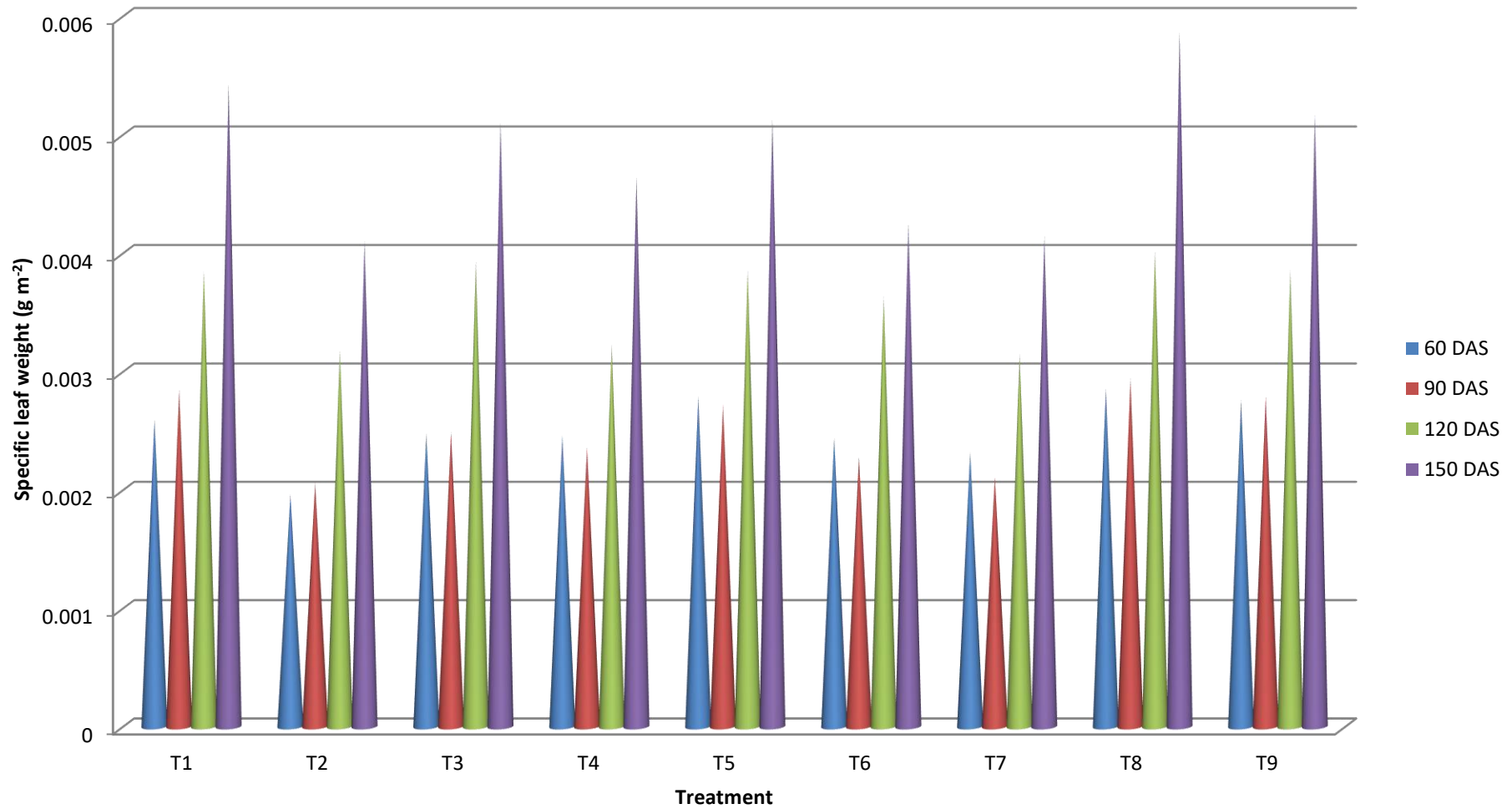
At 150 DAS

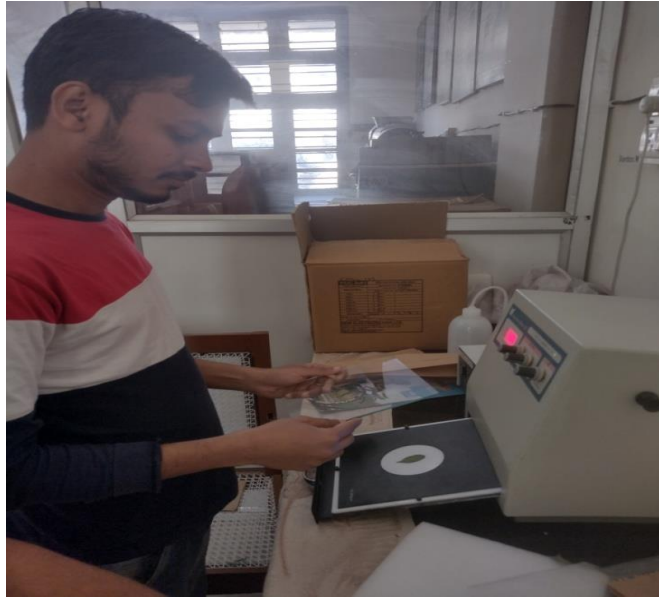
The results showed a significant differences among the treatments. The result revealed that (Table No. 4.18). At 150 DAS, T₈ recorded the maximum specific leaf weight (SLW)(0.005170) which was at par with T₁(0.005433) and significantly followed by T₉ (0.005170), T₅(0.005139), T₃ (0.005118), T₇(0.004149), T₆(0.004254), T₇(0.004149). The Minimum SLW was (0.004101) noted with T₂.

Table 4.18 Effect of herbicide on Specific leaf weight (g m⁻²) of *Withania somnifera*

Treatment	SLW			
	60 DAS	90 DAS	120 DAS	150 DAS
T₁	0.00260	0.00285	0.00385	0.00543
T₂	0.00196	0.00206	0.00318	0.00410
T₃	0.00248	0.00249	0.00393	0.00511
T₄	0.00246	0.00236	0.00323	0.00464
T₅	0.00279	0.00272	0.00386	0.00513
T₆	0.00244	0.00228	0.00363	0.00425
T₇	0.00232	0.00211	0.00315	0.00414
T₈	0.00286	0.00294	0.00402	0.00587
T₉	0.00276	0.00279	0.00386	0.00517
S.Em ±	0.00012	0.00008	0.00020	0.00017
CD (at5%)	0.00037	0.00024	0.00059	0.00051

Fig 4.16 Effect of herbicide on Specific leaf weight of *Withania somnifera*





Measurement of leaf area by leaf area metre



Recording of Chlorophyll Content Index by SPAD-502 meter

4.4.9 Chlorophyll content index (SPAD 502)

At 60 DAS

The results showed a significant differences among the treatments. The result revealed that (Table No. 4.19) At 60 DAS T₆ recorded the maximum chlorophyll content index (CCI)(37.61) which was at par with T₄(36.31) ,T₇ (35.79) and T₃(35.61) and significantly followed by T₅(35.15), T₂(34.70), T₈(33.17) and T₉(32.63). The Minimum CCI was (31.54) noted with T₁.

At 90 DAS

The results showed a significant differences among the treatments. The result revealed that (Table No. 4.19). At 90 DAS, T₄ recorded the maximum chlorophyll content index (CCI)(37.28) which was at par with T₅(36.51) and T₁ (36.15) ,T₇ (35.30), T₃ (35.23), T₂(34.74), T₆(34.12), T₈(33.98). The Minimum CCI was (33.72) noted with T₉.

At 120 DAS

The results showed a significant differences among the treatments. The result revealed that (Table No. 4.19) At 120 DAS, T₇ recorded the maximum chlorophyll content index (CCI)(41.13) which was at par with T₅(39.35) and T₆ (39.34) and significantly followed by T₃ (36.73), T₁ (36.64), T₄(36.51), T₂(34.24), T₈(34.10). The Minimum CCI (33.26) was noted with T₉.

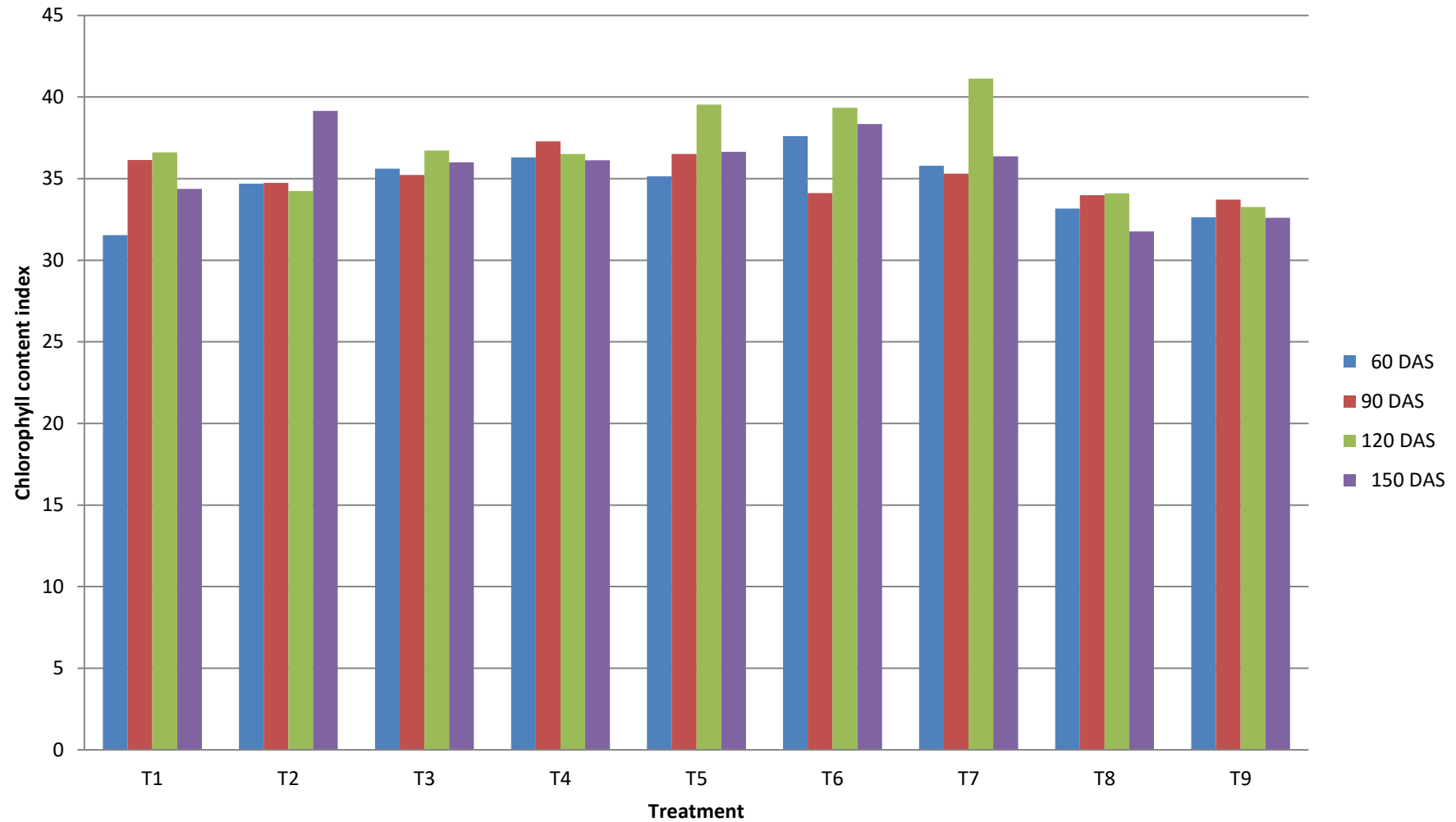
At 150 DAS

The results showed a significant differences among the treatments. The result revealed that chlorophyll content index (CCI) of ashwagandha (Table No. 4.19). At 150 DAS T₂ recorded the maximum chlorophyll content index (CCI) (39.15) which was at par with T₆(38.34), T₅ (36.64), T₇ (36.37), T₄ (36.13), T₃(35.99) and significantly followed T₁(34.38), T₉(32.60). The Minimum CCI was (31.77) was noted with T₉.

Table 4.19 Effect of herbicide on Chlorophyll content index (CCI) of *Withania somnifera*

Treatment	60 DAS	90 DAS	120 DAS	150 DAS
T₁	31.54	36.15	36.61	34.38
T₂	34.70	34.74	34.24	39.15
T₃	35.61	35.23	36.73	35.99
T₄	36.31	37.29	36.51	36.13
T₅	35.15	36.51	39.54	36.64
T₆	37.61	34.12	39.34	38.34
T₇	35.79	35.3	41.13	36.37
T₈	33.17	33.98	34.10	31.77
T₉	32.63	33.72	33.26	32.6
S.Em ±	0.81	1.17	1.75	1.16
CD (at5%)	2.44	3.52	5.72	3.47

Fig 4.17 Effect of herbicide on Chlorophyll content index (CCI) of *Withania somnifera*



4.5 Yield and yield attributes yield

Plant height (cm)

The results showed a significant differences among the treatments. The result revealed that plant height of ashwagandha showed an increasing pattern with the advancement of age (Table No. 4.20). T₇ recorded the maximum plant height (33.7) which was at par with T₆ (33.0) and significantly followed by T₇ (31.5), T₅ (30.8), T₄ (30.6), T₃ (29.5), T₁ (27.2) and T₉ (24.8). The Minimum plant height was (23.2) noted with T₈.

Number of leaves

The results showed a significant differences among the treatments. The result revealed that (Table No. 4.20) T₂ reported the maximum number of leaves plant⁻¹ (28.4) which was at par with T₆ (28.3), T₇ (26.8) and T₅ (26.2) and significantly followed by T₃ (23.0), T₄ (22.6), T₁ (22.3) and T₉ (19.7). The Minimum number of leaves plant⁻¹ was (18.5) noted with T₈.

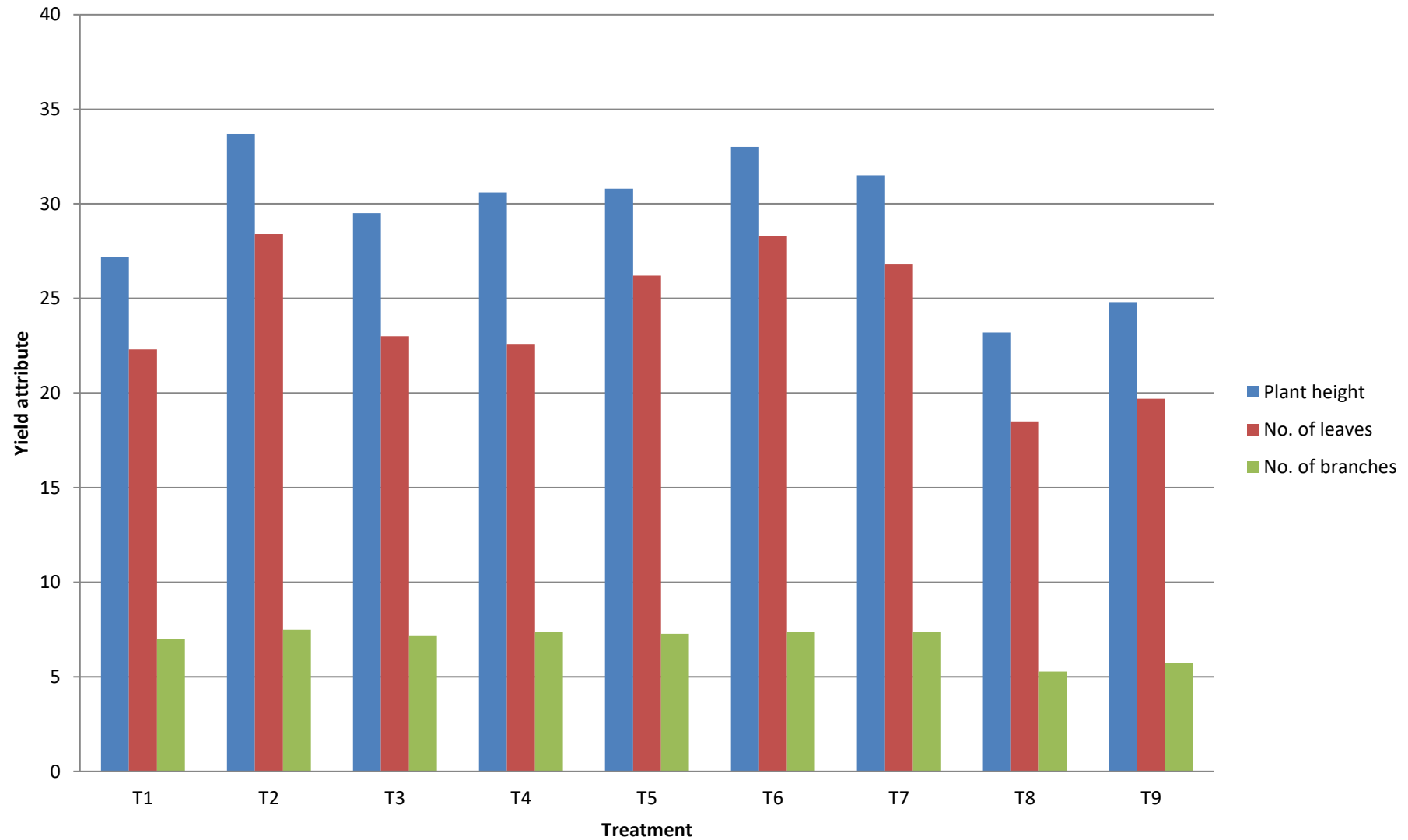
Number of branches plant⁻¹

The results showed a significant differences among the treatments. The result revealed that (Table No. 4.20) the maximum number of branches plant⁻¹ noted with T₂ (7.49) which was at par with T₆ (7.38), T₄ (7.38), T₇ (7.37), T₅ (7.28), T₃ (7.15) and T₁ (7.01) significantly followed by T₉ (5.71). The Minimum number of branches plant⁻¹ was (5.28) was noted with T₈.

Table 4.20 Effect of herbicide on morphological yield attribute of *Withania somnifera* crop at maturity

Treatment	Plant height	No. of leaves	No. of branches
T₁	27.2	22.3	7.01
T₂	33.7	28.4	7.49
T₃	29.5	23.0	7.15
T₄	30.6	22.6	7.38
T₅	30.8	26.2	7.28
T₆	33.0	28.3	7.38
T₇	31.5	26.8	7.37
T₈	23.2	18.5	5.28
T₉	24.8	19.7	5.71
S.Em ±	0.6	1.3	0.2.8
CD (at5%)	1.9	3.8	0.85

Fig 4.18 Effect of herbicide on morphological yield attribute of *Withania somnifera*



Seed yield plant⁻¹

The results showed a significant differences among the treatments. The result revealed that (Table No. 21) T₂ reported the maximum Seed yield plant⁻¹ (1.23) which was at par with T₆ (1.17) and significantly followed by T₅ (1.08) T₇ (1.07), T₄ (1.06), T₃ (0.99), T₁ (0.98) and T₉ (0.74). The minimum Seed yield plant⁻¹ was (0.45) noted with T₈.

Root yield plant⁻¹

The results showed a significant differences among the treatments. The result revealed that (Table No. 21) T₂ reported the maximum root yield plant⁻¹ (1.30) which was at par with T₇ (1.24) and T₆ (1.18) and significantly followed by T₇ (1.24), T₅ (1.05) T₃ (0.99), T₄ (0.95), T₉ (0.76) and T₁ (0.76). The Minimum root yield plant⁻¹ was (0.71) noted with T₈.

Number of capsule plant⁻¹

The results showed a significant differences among the treatments. The result revealed that (Table No. 21) the maximum number of capsule plant⁻¹ noted with T₇ (43.50) which was at par with T₄ (41.30) T₆ (38.98), T₄ (38.56) and T₃ (37.32) and followed by T₅ (36.42), T₁ (29.90), T₉ (24.63). The Minimum number of capsule plant⁻¹ was (14.34) noted with T₈.

Leaf biomass (g plant⁻¹)

The results showed a significant differences among the treatments. The result revealed that (Table No. 4.21) T₂ the maximum number of leaf biomass plant⁻¹ noted (1.28) which was at par with T₇ (1.27) and T₆ (1.02) and followed by T₅ (0.88), T₃ (0.86), T₄ (0.86), T₁ (0.67) and T₄ (0.86). The minimum number of leaf biomass plant⁻¹ was (0.35) noted with T₈.

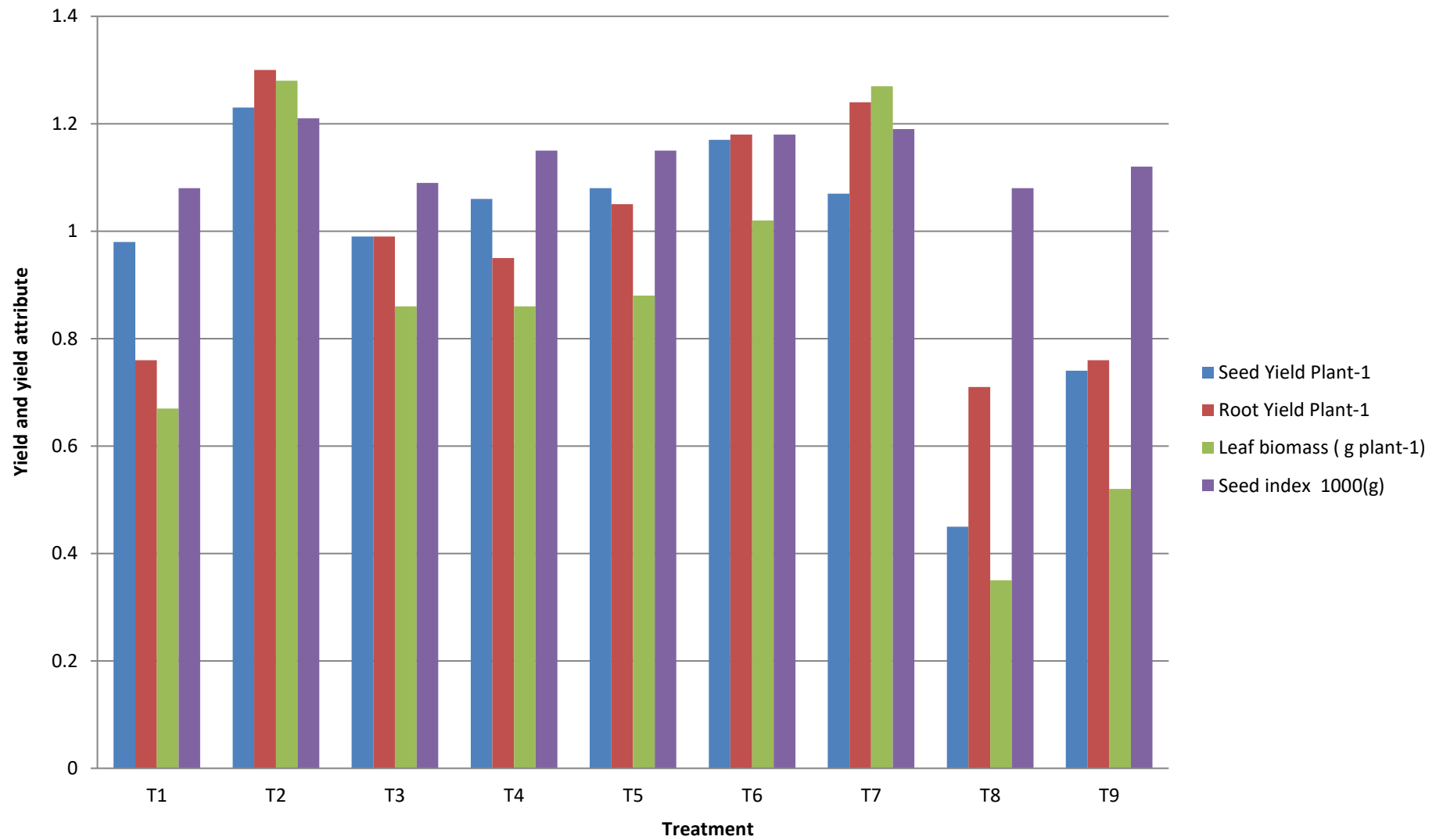
Seed index 1000(g)

The results showed a significant differences among the treatments. The result revealed that (Table No. 4.21) the maximum number of seed index noted T₂ (1.21) which was at par with T₇(1.19), T₆ (1.18), T₄ (1.15) and T₅ (1.15) followed by T₉ (1.12) and T₃ (1.09). The Minimum number of seed index was (1.08) was noted with T₁ and T₈

Table 4.21 Effect of herbicide on per plant yield and seed index 1000(g) of *Withania somnifera* at maturity

Treatment	Seed Yield Plant ⁻¹	Root Yield Plant ⁻¹	Number of Capsule Plant ⁻¹	Leaf biomass (g plant ⁻¹)	Seed index 1000(g)
T ₁	0.98	0.76	29.90	0.67	1.08
T ₂	1.23	1.30	41.30	1.28	1.21
T ₃	0.99	0.99	37.32	0.86	1.09
T ₄	1.06	0.95	38.56	0.86	1.15
T ₅	1.08	1.05	36.42	0.88	1.15
T ₆	1.17	1.18	38.98	1.02	1.18
T ₇	1.07	1.24	43.50	1.27	1.19
T ₈	0.45	0.71	14.34	0.35	1.08
T ₉	0.74	0.76	24.63	0.52	1.12
S.Em ±	0.03	0.07	2.15	0.12	0.03
CD (at5%)	0.09	0.21	6.46	0.35	0.08

Fig 4.19 Effect of herbicide on per plant yield and seed index



Leaf yield (kg ha⁻¹)

The results showed a significant differences among the treatments. The result revealed that (Table No. 4.22) the maximum leaf yield kg ha⁻¹ was recorded with T₂ (537) which was at par with T₇ (532) and T₆ (426) and significantly followed by T₅ (371), T₃ (361.55) and T₄ (359), T₁ (280) and T₉(219). The minimum number was leaf yield kg ha⁻¹ (147.00) was noted with T₈.

Root yield (kg ha⁻¹)

The results showed a significant differences among the treatments. The result revealed that (Table No. 4.22) the maximum root yield kg ha⁻¹ noted with T₂ (546) which was at par with T₇ (518) and T₆ (495) and significantly followed by T₅ (441), T₃ (417), T₄ (400) , T₉ (320) and T₁ (319). The minimum root yield kg ha⁻¹ (299) was noted with T₈.

Seed yield (kg ha⁻¹)

The results showed a significant differences among the treatments. The result revealed that (Table No. 4.22) the maximum seed yield kg ha⁻¹ noted with T₂ (518) which was at par with T₆ (492) and T₇ (448) and significantly followed by T₅ (452), T₄ (445) and T₃ (414) T₁ (412) and T₉ (311). The minimum seed yield kg ha⁻¹ (187) was noted with T₈.

Table 4.22 Effect of herbicide on yield (kg ha⁻¹) and harvest index of *Withania somnifera* crop at maturity

Treatment	Seed Yield	Leaf yield	Root Yield	Harvest Index (HI%)	Harvest Index (HI%)
	(kg ha ⁻¹)	(kg ha ⁻¹)	(kg ha ⁻¹)	(seed as Economic yield)	(root as Economic yield)
T₁	412	280	319	22.19	20.18
T₂	518	537	546	26.01	26.17
T₃	414	361	417	24.03	24.1
T₄	445	359	400	25.76	23.16
T₅	452	371	441	25.47	24.29
T₆	492	426	495	26.15	24.97
T₇	448	532	518	24.82	24.95
T₈	187	147	299	17.09	21.04
T₉	311	219	320	21.95	22.9
S.Em	12.3	48.9	29.7	1.25	1.28
CD(0.05)	37	146.7	89	3.76	3.85

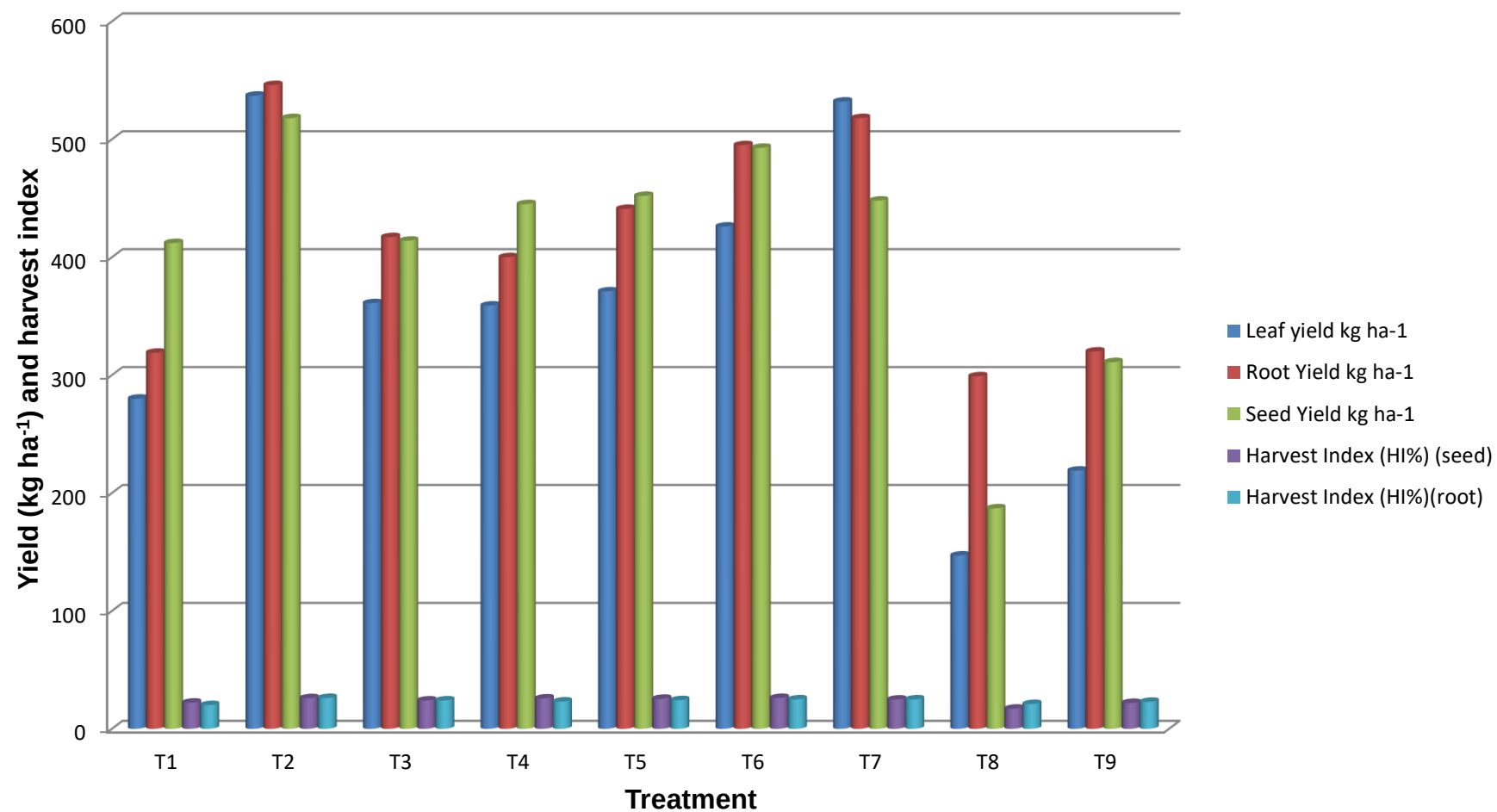
Harvest index (%) for seed

The results showed a significant differences among the treatments. The result revealed that (Table No. 4.23) the maximum harvest index (%) percentage noted with T₆(26.15) which was at par with T₂(26.01), T₄(25.76), T₅(25.47), T₇(24.82) and T₃(24.03) and significantly followed by T₁(22.19) and T₉(21.95). The minimum harvest index (%) was (17.10) noted with T₈.

Harvest index (%) for root

The results showed a significant difference among the treatments. The result revealed that (Table No. 4.23) the maximum harvest index (%) percentage noted with T₂ (26.17) which was at par with T₇(24.95), T₆(24.95), T₅(24.29), T₃(24.10) and T₄ (23.16) and significantly followed by T₉(22.9) and T₈(21.04). The minimum harvest index (%) was (20.18) was noted with T₈.

Fig 4.20 Effect of herbicide on yield (kg ha⁻¹) and harvest index





Estimation of ASH content by Muffle Furnace



Estimation of Protein analysis

4.7 Proximate analysis

Moisture (%)

The results showed a significant differences among the treatments. The result revealed that (Table No. 4.24) T₂ recorded the maximum moisture (%) percentage (2.63) which was at par with T₆ (2.36) and significantly followed by T₇(2.21), T₄ (2.16), T₁(2.15), T₃(2.05), T₅(1.99) and T₉(1.93). The Minimum moisture (%) percentage was (1.91) noted with T₈.

Fat (%)

The results showed a significant differences among the treatments. The result revealed that (Table No. 4.24) the maximum fat (%) percentage noted with T₂(0.56) which was at par with T₇(0.50) and T₆(0.48) and significantly followed by T₅(0.47), T₄ (0.42), T₁(0.41), T₃(0.39), T₈(0.33). The Minimum fat % was (0.32) noted with T₉.

Crude fiber (%)

The results showed a significant differences among the treatments. The result revealed that (Table No. 4.24) the maximum Crude fiber (%) percentage noted with T₂(32.58) which was at par with T₇(31.92), T₄(31.75), T₁(31.53), T₆(31.39), T₅(30.92), T₃(30.32) and significantly followed by T₈(29.92). The minimum Crude fiber (%) was (29.80) was noted with T₉.

Protein (%)

The results showed a significant differences among the treatments. The result revealed that (Table No. 4.24) the maximum protein (%) percentage noted T₂(8.50) which was at par with T₇(8.13) and T₅(7.93) and significantly followed by T₆(7.63) T₈(7.33), T₉(7.33), T₁ (7.13) and T₃(7.03). The minimum protein (%) was (6.96) noted with T₄.

Ash (%)

The results showed a significant differences among the treatments. The result revealed that (Table No. 4.24) the maximum ash (%) percentage noted T₉(5.31) which was at par with T₂(5.20), T₇(5.16), T₈(5.16) and T₁(5.05) and significantly followed by T₆(4.98), T₅(4.84), T₄(4.64). The minimum ash content (4.63) was noted with T₃.

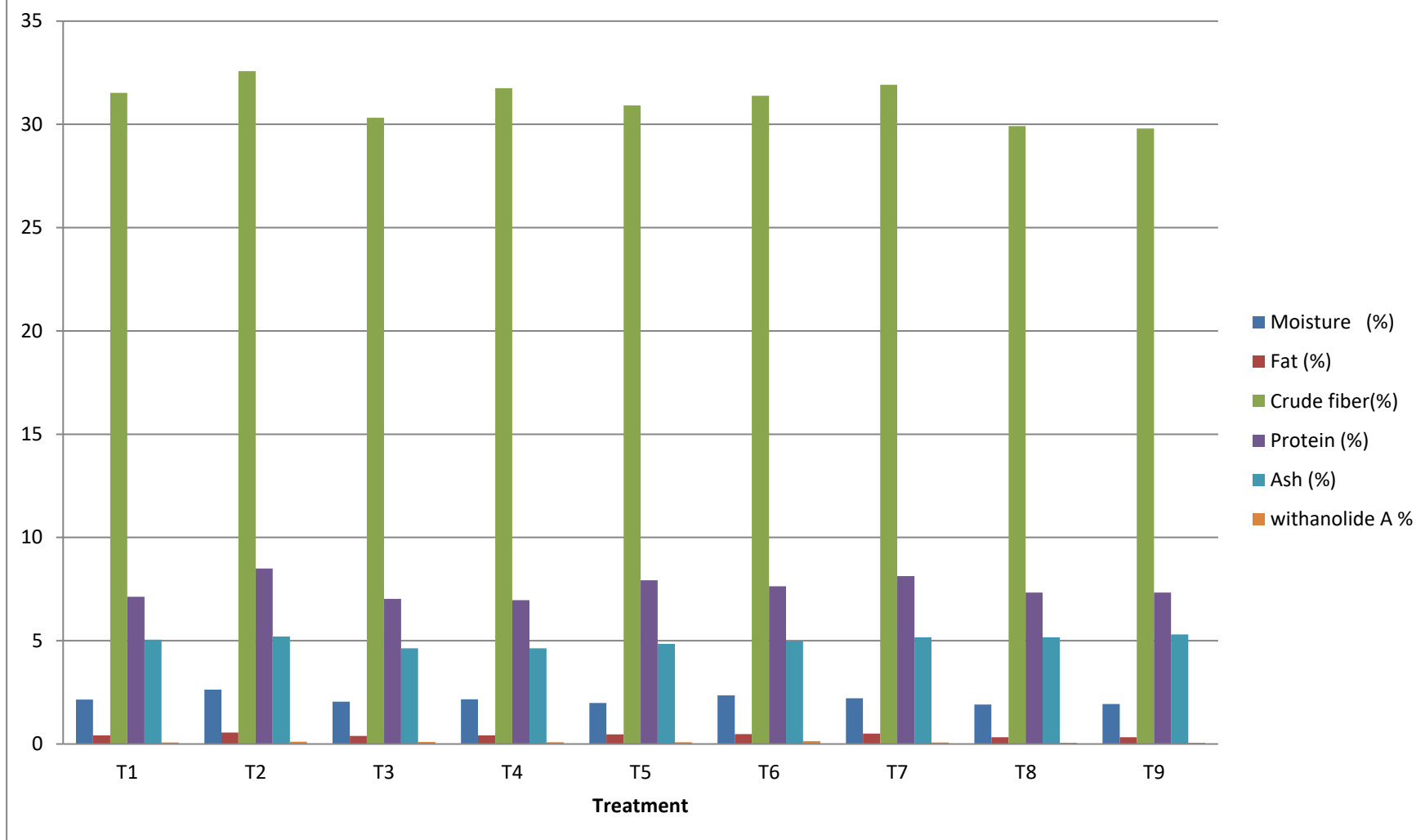
Withanolide A (%)

The results showed a significant differences among the treatments. The result revealed that (Table No. 4.24) the maximum Withanolide (%) percentage noted T₆ (0.133) which was at par with T₂(0.115) and T₃(0.104) significantly followed by T₄ (0.091), T₅ (0.081), T₁ (0.075), T₇ (0.072) and T₈ (0.066). The minimum Withanolide content (0.057) was noted with T₉.

Table 4.23 Effect of herbicide on proximate analysis of *Withania somnifera* root powder

Treatment	Moisture (%)	Fat (%)	Crude fiber(%)	Protein (%)	Ash (%)	withanolide A %
T₁	2.15	0.41	31.53	7.13	5.05	0.075
T₂	2.63	0.56	32.58	8.5	5.2	0.115
T₃	2.05	0.39	30.32	7.03	4.63	0.104
T₄	2.16	0.42	31.75	6.97	4.64	0.091
T₅	1.99	0.47	30.92	7.93	4.85	0.081
T₆	2.36	0.48	31.39	7.63	4.98	0.133
T₇	2.21	0.5	31.92	8.13	5.16	0.072
T₈	1.91	0.33	29.92	7.33	5.16	0.066
T₉	1.93	0.33	29.8	7.33	5.31	0.057
S.Em ±	0.09	0.02	0.48	0.23	0.08	0.012
CD (at 5%)	0.28	0.07	1.44	0.69	0.25	0.035

Fig 4.21 Effect of herbicide on proximate analysis of *Withania somnifera* root powder



Chapter- V

DISCUSSION

Discussion

In the production of the ashwagandha crop (*Withania somnifera* (L.) Dunal.), weed management is an important and expensive practice. Weeds and ashwagandha have similar growth and development demands for carbon dioxide and nitrogen from the atmosphere, water and minerals from the soil, and light from the sun. The growth of ashwagandha plants is inhibited and yield is lowered when weeds use these components. ashwagandha are a poor weed competitor and grow slowly at first.

The ashwagandha crop is generally cultivated as the late *kharif* and *rabi* seasons crop in India especially in Madhya Pradesh. Weed invasion is more likely in this crop since it grows slowly in the early stages. It is possible that if effective weed management strategies are not used, the crop fails completely. Hand weeding is expensive than chemical weed management. Hence present experiment was conducted find suitable weedicides or combination of weedicides for weed management in ashwagandha crop under winter sown condition.

Results obtained under the experiment are discussed with suitable justification under the following subheads.

5.1 Weed population and its management

Winter sown ashwagandha crop have severe infestation of variety of weeds. There were 9 and 6 species of weeds were found in crop before first and second spray of herbicide at 40 DAS interval two-time spray of herbicide.

5.1.1 Diversity and number of weed before the first application of weedicide (40 DAS)

Variety of weed were found with varying population in ashwagandha crop. They were *Ageratum houstonianum*, *Euphorbia hirta*, *Cynodon dactylon*, *Tridax procumbens*, *Parthenium hysterophorus*, *Alternanthera sessilis*, *Cloris barbata*, *Commelina benghalensis* and *Cyperus rotundus*. They were found in crop before first application weedicides. Out of these weeds *Ageratum houstonianum* and *Alternanthera sessilis* the dominant weeds in the experimental field. *Euphorbia hirta* had least infestation in the crop.

5.1.2 Diversity and number of weed after the first application of weedicides (50 DAS)

Nine treatments of weeds management strategy were applied in field. Spray of the single and combination of herbicide *i.e.* Seven herbicides spray like Quizalofop-p-ethyl, Haloxyfop r-methyl, Clodinofof-propargyl, Quizalofop-p-ethyl+Haloxyfop-r-methyl, Quizalofop-p-ethyl+Haloxyfop-r-methyl+Clodinofofpropargyl, Oxyflourfen, Metribuzin along with one hand weeding (control) and one control (untreated) were tested in *Withania somnifera* (L.) Dunal crop for weed management, growth, physiology and productivity of crop.

Oxyflourfen @ 100 g ha⁻¹ was found highly effective in managing ageratum population in withania crop as compared to all other weedicides and untreated control. However, hand weeding (control) was effective in fully managing weed population. The highest dominance of this weed in the field was found when no application herbicide or hand weeding at 40 DAS. Oxyflourfen is very effective in controlling broad leaved weeds and narrow leaf weeds of many crops.

Population of *Euphorbia hirta* was also effectively controlled by applying oxyflourfen @ 100 g ha⁻¹. These results were due to killing of broad-leaved weeds by this herbicide which is supported by various scientist in another crop. (Ziemniaka and ochrony, 1990)

Cynodondactylon (a grassy weed) was effectively managed by using Oxyflourfen @ 100 g ha⁻¹. The similar result was found with Metribuzin @ 525 g ha⁻¹.

Metribuzin @ 100 g ha⁻¹ and oxyflourfen @ 525 g ha⁻¹ were quite suitable in controlling *Tridax procumbens* (broad leaved) which is broad leaved species. These two herbicides have specific for this weed. Quizalofop-p-ethyl @ 50 g ha⁻¹+Haloxyfop-r-methyl @ 750 g ha⁻¹+Clodinofofpropargyl @ 60 g ha⁻¹, were also found effective but did not kill the weed completely rather than decreasing population to some extent Clodinofof-p-propargyl was not found effective against *Tridax procumbens*. our result is similar with Ziemniaka and Ochrony (1990) who reported that metribuzin controlled

both grasses and broadleaved weeds.

Parthenium hysterophorus (broad leaved) and *Alternanthera sessilis* was effectively controlled by Oxyflourfen @ 100 g ha⁻¹. The similar result found with Metribuzin @ 525 g ha⁻¹, the extent of less population. All these are very effective in controlling both broad leaved weeds and narrow leaved one. Our result is similar with Singh *et al.* (1995) who found that oxyfluorfen @ 0.3 kg ha⁻¹ was found the most effective against all the weeds (95.2%).

Cyperus rotundus, *cloris barbata*, and *Commelina benghalensis* (narrow leaved weeds) found in Withania crop was controlled effectively by almost of the herbicides and the effectively controlling of weed by oxyfluorfen @ 100 g ha⁻¹. Spray of combination of herbicide these weeds again effectively controlled by Quizalofop-p-ethyl @ 50 g ha⁻¹+Haloxypop-r-methyl @ 750 g ha⁻¹+Clodinofofpropargyl @ 60 g ha⁻¹ was found. The highest dominance of this weed in the field was found when no application herbicide control. Our result is similar with Leela (1993) who reported that application of oxyfluorfen controlled the dominant *monocotyledonous weeds* such as *Cyperus rotundus*, *C. iris* and *Cynodon dactylon* for 60 days in tomato.

5.1.3 Effect of first spray of herbicide on weed density in ashwagandha crop

Ageratum houstonianum, *Parthenium hysterophorus* (broad leaved) which was minimum weed density found when application of Oxyflourfen @ 100 g ha⁻¹. Our result was similar with Reddy CN (2000) who found that application of oxyflourfen minimum weed density as compared to control.

Euphorbia hirta, *Tridax procumbens* and *Alternanthera sessilis* (broad leaved), a potent broad-leaved weed of Late *kharif* season crop which was minimum weed density found when application of Oxyflourfen @ 100 g ha⁻¹ and the similar result found with spray of herbicide (Metribuzin @ 525 g ha⁻¹) as compared to no weeding / other weedicide application.

Cyperus rotundus, *Cynodon dactylon* and *Cloris barbata* was weed density effectively controlled by application of oxyflourfen @ 100 g ha⁻¹ which effective for broad leaf and narrow leaf weeds.

Commelina benghalensis (narrow leaved weeds) was weed density effectively managed by application of oxyflourfen @ 100 g ha⁻¹. The minimum weed density was again found with spraying of combination of weedicides (Quizalofop-p-ethyl @ 50 g ha⁻¹+Haloxypop-r-methyl @ 750 g ha⁻¹+Clodinofofpropargyl @ 60 g ha⁻¹) as compared to no weeding / other weedicide application. All these herbicides effective for narrow leaf weed without harming ashwagandha crop. Our result similar with Dixit *et al* (2012) who found that application of Quizalofop-p-ethyl @ 50 g ha⁻¹ is effective controlled narrow leaved weeds.

5.1.4 Effect of first spray of herbicide on Dry matter production of weed

In present study 50 DAS to spray of weedicide *Ageratum houstonianum* weed biomass was effectively managed to using Oxyflourfen @ 100 g ha⁻¹. The similar result was found with spray of Metribuzin @ 525 g ha⁻¹. Our result was similar with Singh *et al.* (1985) who stated that application Oxyflourfen @ 0.30 kg ha Significantly lower density and dry matter of weeds were recorded with weed free.

Euphorbia hirta, *Alternanthera sessilis*, *Tridax procumbens* and *Parthenium hysterophorus* (broad leaved) was weed biomass effectively controlled by application of Oxyflourfen @ 100 g ha⁻¹. These herbicides cause necrosis of leaves and stems of broad and narrow leaf weeds. Our result was similar with Reddy CN *et al* (2000) who observed that application oxyfluorfen @ 0.10 kg ha⁻¹ fb HW at 40 DAP was effective for weed control in brinjal.

Cyprus rotundus, *Cloris barbata*, *Commelina benghalensis* and *Cynodon dactylon* (narrow leaved weeds) was weed biomass effectively controll by Oxyflourfen @ 100 g ha⁻¹. The similar result was found with combined spray of weedicides (Metribuzin @ 525 g ha⁻¹) and (Quizalofop-p-ethyl @ 50 g ha⁻¹+Haloxypop-r-methyl @ 750 g ha⁻¹+Clodinofofpropargyl @ 60 g ha⁻¹). These result was similar with Semidey *et al.* (1990) who reported that application of Quizalofop-p-ethyl at 0.28 - 0.56 kg ha⁻¹ controll 90 % of grasses and Ziemniaka and Ochrony (1990) also was revealed that 250-375 g/ha haloxypop-ethoxyethyl gave excellent control of grasses.

Total dry matter production of weeds was effectively controlled by Oxyflourfen @ 100 g ha⁻¹. The minimum dry matter of weed again found with spray (Metribuzin @ 525 g ha⁻¹) and (Quizalofop-p-ethyl @ 50 g ha⁻¹+Haloxypop-r-methyl @ 750 g ha⁻¹+Clodinofofpropargyl @ 60 g ha⁻¹). Our result is similar with Kundu *et al* (2009) who

was found that application of quizalofop-p-ethyl 50 g a.i. maximum reduction of weed population, weed dry weight and the highest weed control efficiency vis-a-vis crop yield, and maximum benefit: cost ratio was obtained.

5.2 Weed flora before the second application of weedicide in ashwagandha crop

They were *Ageratum houstonianum*, *Cynodon dactylon*, *Parthenium hysterophorus*, *Alternanthera sessilis*, *Lactuca serriola* and *Cyperus rotundus*. They were found in crop before second spray of weedicides. Out of these weeds *Ageratum houstonianum* and *Alternanthera sessilis* the dominant weeds in the experimental field. *Lactuca serriola* least infestation in the crop.

Ageratum houstonianum *Alternanthera sessilis* and *lactuca serriola* very effectively managed using Oxyflourfen @ 100 g ha⁻¹ as compared to other herbicides and weed management strategy. All these herbicides selectively kill the broad-leaved weeds.

Oxyflourfen @ 100 g ha⁻¹ and Metribuzin @ 525 g ha⁻¹ was equally effective for of killing *Parthenium hysterophorus* with Withania crop as compared to no weeding/ other weedicide application. Our result is similar Pandey and Padhiar (1998) who evaluated that application of metribuzin the control of cyprus rotandus.

Cyprus rotundus, and *Cynodon dactylon* (narrow leaved weeds) found in Withania crop was effectively controlling by spray of Oxyflourfen @ 100 g ha⁻¹.

Cynodon dactylon found in Withania crop was effectively controlled by application of combination of herbicides (Quizalofop-p-ethyl+Haloxypop-r-methyl+Clodinofofpropargyl). Our result was similar with Singh *et al.* who reported that spray of Quizalofop-p-ethyl found lower weed index.

5.2.1 Effect of second spray of herbicide on weed density in ashwagandha crop

Ageratum Houstonian, *Alternanthera sessilis* and *Parthenium hysterophorus*(broad leaved) , a potent broad-leaved weed of *rabi* season crop which was minimum weed density found when application of Oxyflourfen @ 100 g ha⁻¹, and Metribuzin. Oxyflourfen cause membrane disruption through lipid peroxidation. These herbicide cause necrosis of leaf and stem.

Cyprus rotandus and *Cynodon dactylon* (narrow leaved weeds) was weed density effectively managed by application of Quizalofop-p-ethyl+Haloxypop-r-methyl+Clodinofofpropargyl. All these herbicides selectively kill the narrow-leaved weeds. Growth of newly developing leaves was suppressed within 48 hr after the herbicide was applied to the leaf surface, being followed by appearances of yellowing and then necrotic symptoms 6 days after application.

Lactuca serriola weed density effectively managed by application of Quizalofop-p-ethyl+Haloxypop-r-methyl+Clodinofofpropargyl.

5.2.2 Effect of second spray of herbicide on Dry matter production of weed per treatment

80 DAS to spray of weedicide *Ageratum houstonianum* weed biomass was effectively managed to using Oxyflourfen @ 100 g ha⁻¹ and Metribuzin equally effective for lower weed biomass. Our result was similar with Fortino and Splittstoesser (2017) who reported Metribuzin more effective in controlling broadleaf weeds.

Alternanthera sessilis and *Parthenium hysterophorus* (broad leaved) was weed biomass effectively controlled by application of Oxyflourfen @ 100 g ha⁻¹. These herbicides cause necrosis of leaves and stems of broad and narrow leaf weeds. Our result was similar with Shaikh (2005) who reported the minimum weed control efficiency was found when application of oxyfluorfen at 0.10 kg ha⁻¹ in chill field.

Cyprus rotundus, and *Cynodon dactylon* (narrow leaved weeds) was weed biomass effectively controlled by Quizalofop-p-ethyl+Haloxypop-r-methyl+Clodinofofpropargyl was found. This result was similar with R.S. Singh *et al.* (2017) who reported by the treatment combination of quizalofop-p-ethyl (T7) and it was equally good with hand weeding twice (T10) with respect to tuber yield.

Application of herbicides no significant effect on weed biomass was found in *Lactuca serriol* minimum weed biomass found application of Haloxypop-r-methyl

Total dry matter production of weeds was effectively controlled by Quizalofop-p-ethyl+Haloxypop-r-methyl+Clodinofofpropargyl was found without the toxic effect of the crop because these weedicide impact on narrow leaf weeds. Our result is similar with Kundu *et al* (2009) who was found that the maximum reduction of weed population, weed dry weight and the highest weed control efficiency vis-a-vis crop

yield, and maximum benefit: cost ratio were obtained.

5.3 Survival of Ashwagandha crop

Out of all herbicide single and combination of weedicide Quizalofop-p-ethyl+Haloxypfop-r-methyl+Clodinofofpropargyl was effective weed control without any serious effect on *Withania* crop. The similar result was found with another herbicide except oxyflourfen and metribuzin. These results were also did not kill *Withania* crop. They kill only monocots weeds in the field of ashwagandha. After these two weedicides, hand weeding of *Withania somnifera* (L.) Dunal is most effective for growth, development and productivity of ashwagandha. On the other hand, application of, Oxyflourfen and metribuzin maximum no of mortility of *Withania* was found along with broad leaved weeds and narrow leaved weeds in the crop field.

5.4 Effect of herbicide on phenology of ashwagandha crop

Withania phenology, or the number of days required to complete the development stages of crop during its life cycle, was influenced differently by different weed management practises. Chemical weedicide, no weed management approaches and hand weeding have different effects on crop vegetative phenophases. Primary branch showed no significant difference it might be because there is no application of treatment at that time. During vegetative phases, hand weeding and combined spray of weedicides (Quizalofop-p-ethyl+Haloxypfop-r-methyl+Clodinofofpropargyl) rapidity the occurrence of secondary branches over the application of oxyflourfen and metribuzin. Late branching in oxyflorfen and mertribuzin because the herbicidal impact on plant.

Flower initiation and 50% flowering was delayed to its maximum due to oxyflorfen and mertribuzin spray. These herbicide impact on plant phenology and Maximum no of mortility was ashwagandha. The Minimum time for completion of these stage in hand weeding and (Quizalofop-p-ethyl+Haloxypfop-r-methyl+Clodinofofpropargy) was found in ashwagandha.

On the other hand, fruit initiation, seed formation, physiological and physical maturity was minimum time for completion of these stage in spraying of combination of herbicide (Quizalofop-p-ethyl+Haloxypfop-r-methyl+Clodinofofpropargyl). Quizalofop-p-ethyl+Haloxypfop-r methyl+Clodinofofpropargy is selective, systemic

herbicide completely kill narrow leaved weed by inhibiting accase enzyme which is tern affect membrane synthesis and fatty acid synthesis. These herbicides no significant impact on crop. Compare with other treatments like oxyflorfen and metribuzin delayed the phenophase of ashwagandha maximum mortility of ashwagandha was reported. Some plant which was survive they regain their growth after weedicide application so that late of this may be reason behind the delayed occurrence of phenophases of Withania crop under the experimental field.

5.5 Effect of herbicide on growth analytical parameter and biophysical traits in withania somnifera

Leaf area index was increasing from 60 DAS, 90 DAS and 120 DAS and but decreased after to 120 DAS to 150 DAS because the photo assimilates produce by leaves and fruit wall is translocated towards the developing sink. Combination of herbicides (Quizalofop-p-ethyl+Haloxifop-r-methyl+Clodinofofpropargyl) was found best treatment in increasing LAI of *Withania Somnifera* crop during all stages of growth after herbicide spray at 40 and 80 DAS. As this treatment effective as handweeding (untreated control) in maximum leaf area index hence this was more prominent for weed management as hand weeding is very expensive economically. The mean maximum LAI was noted of this treatment (1.363) because of its least toxic effect on Withania. Our result is contrash with Kubsad *et al* (2009) who found that application fertilizer 24 kg N and 48 kg P ha⁻¹ increased the leaf area index (3.918) in ashwagandha crop.

Leaf area duration measurement of the persistence of photosynthetic leaves responsible for increased biomass production and yield. Combined spray of weedicides (Quizalofop-p-ethyl+Haloxifop-r-methyl+Clodinofofpropargyl) (9909.8 cm².days) recorded the maximum LAD at 150 DAS. The minimum LAD at 150 DAS was found with the spray of oxyflourfen (6041.2 cm².days). Welbank *et al* (1988) reported that the ratio of grain yield to LAD increased with increase in daily radiation during grain filling.

The present study showed that the CGR was found to be enhanced with progressive increase in life span of the crop till 90-120 DAS, thereafter it showed reduction during subsequent growth phase. The maximum CGR recorded with spray of herbicide (Haloxifop-r-methyl) (0.000914 g cm⁻²day⁻¹) and combination of spray

weedicides (Quizalofop-p-ethyl+Haloxypop-r-methyl+Clodinofofpropargyl) again found best in maximum CGR ($0.000808 \text{ g cm}^{-2}\text{day}^{-1}$) in ashwagandha. There was no difference of herbicide spray on CGR during 120-150 DAS. CGR at 90-120 DAS was maximum and decreasing there after due to fall of leaves after start of fruit maturing. Our result is similar with Shekhar (1974) who found that CGR reached a maximum level on 82nd day after transplanting onion.

During early stages of growth, RGR increase with increased light intensity. Asana (1968). In present result indicate that there were no differences of herbicides spray on RGR at 60-90 DAS and 120-150 DAS. The combined spray of weedicides (Quizalofop-p-ethyl+Haloxypop-r-methyl+Clodinofofpropargyl) possessed a higher RGR ($0.024 \text{ gg}^{-1}\text{day}^{-1}$) at 90-120DAS indicating the efficiency of this treatment in enhancing increment in plant biomass per unit of biomass present. The highest relative growth rate (RGR) during 90-120 DAS and decreased during 120-150 DAS. The higher photosynthetic leaves responsible for increasing in biomass production and yield. Our result is similar with Karimi *et al.* (1991) who reported that the modern wheat cultivars were higher RGR during the vegetative phase.

The increase of NAR in the life span of crop and decrease in later growth phases was attributed to enhancement of LAI and LAD in early growth phase and decline in later growth period of the crop. There was no differences of herbicide spray on NAR at 60-90 DAS. The combined spray of herbicide (Quizalofop-p-ethyl+Haloxypop-r-methyl) recorded higher magnitudes for NAR ($0.00027 \text{ g cm}^{-2}\text{day}^{-1}$) at 60-90 DAS. The minimum NAR recorded with oxyflourfen.

The combined spray of weedicides (Quizalofop-p-ethyl+Haloxypop-r-methyl+Clodinofofpropargyl) possessed an average higher BMD (127.12 g days) indicating the efficiency of these treatments in enhancing increment in plant biomass. The maximum BMD recorded during 120-150 DAS over the 60-90 DAS .The photosynthetic leaves responsible for increasing in biomass production and yield. As this treatment equally effective as hand weeding (untreated control) in maximum BMD this was most prominent for weed management as hand weeding is very expensive economically.

According to the current study SLA had a higher magnitude during the early life span of the crop, followed by a subsequent drop in the remaining growth period, with the lowest at 150 DAS. The combined spray of weedicides (Quizalofop-p-ethyl+Haloxypop-r-methyl+Clodinofofpropargyl) was recorded maximum average SLA($365.9 \text{ cm}^2\text{g}^{-1}$) during all successive stage of growth. The higher magnitudes of SLA during the early growth stage show that as crop life duration increased, the relative proportion of leaf area to leaf dry weight declined. our result similar with Sahoo and Guru (1998) who observed the positive association of SLA with grain yield.

The SLW represents leaf thickness and gives an estimative of the proportion between the assimilatory surface and the veins that sustain those leaf tissues (Evans, 1972 and Cruz *et al.*, 2004). The spray of herbicide (oxyflourfen) recorded an average maximum SLW all the stages of growth.

Bonner (1952) observed that the chloroplast accounts for 25% of total dry matter production and 40% of the total nitrogen of leaves. The chlorophyll content index estimated by the chlorophyll meter gives an indirect measure of chlorophyll content (34.10) in the plant which was found to be maximum with combined spray of (Quizalofop-p-ethyl+Haloxypop-r-methyl+Clodinofofpropargyl) at 120 DAS progressive growth period. Our result is similar with Choudhary *et al* (1994) who reported that the grain development was accompanied by decreases in chlorophyll contents of the leaf as a result of ageing.

5.6 Effect of herbicide on Yield and yield contributing attributes in ashwagandha

5.6.1 Plant height (cm)

All the treatments significantly influenced by herbicidal treatments. The earlier plant height was altered due to application of herbicides oxyflourfen and metribuzin. The higher plant height (23.2 cm) was recorded. Our result contrast with Goel *et al.* (2011) who demonstrated that significantly taller plants (47.7 cm) was found in comparison to other treatments over control (31.7 cm) of ashwagandha. The present study indicated that the treatments hand weeding taller plant (33 cm) because free

space for the proper growth and development of plant was found. Our result contrast with Kumar *et al.* (2013) who reported that the highest plant height (49.9 cm) was found in ashwagandha when application of 100% recommended dose of NPK (RDF) at 40:60:20 kg, 50% RDF at 20:30:10 kg, vermicompost @ 2, 4, 6 t, Jatropa cake @ 1, 2 and 3 t ha⁻¹, respectively along with PSB @ 2 kg+Azospirillum @ 2 kg ha⁻¹.

5.6.2 No. of branches plant⁻¹

The present study indicated that all the treatments significantly influenced no. of branches plant⁻¹ minimum no of branches recorded with spray of weedicides (oxyflourfen) and (metribuzin).

The maximum no of branches (7.38) spray of combination of herbicides (Quizalofop-p-ethyl+Haloxypop-r-methyl) was recorded. The similar result was found with spray of combination of weedicides (Quizalofop-p-ethyl+Haloxypop-r-methyl+Clodinofofpropargyl). The results were in contrash with Goel *et al.* (2011) Application of FYM @ 12.5 and 25 t/ha average number of primary branches significantly from 2.0 to 2.3 and 2.6 over control was reported. The maximum no of branches recorded at the time interval between 120-150 DAS found in treatment t2 and t7 because of low crop weed competition for growth and development. Our result with similar with Karad *et al.* (2003) The wider spacing of 30×30 cm recorded higher number of branches in ashwagandha was recorded.

5.6.3 No. of leaves plant⁻¹

The present study indicated that all the treatments significantly influenced no. of leaves plant⁻¹ except oxyflourfen and metribuzin lesser no of leaves was found due to application of herbicide maximum no of leaf fall out . The higher no of leaves (26.8) was recorded with combined spray of weedicide (Quizalofop-p-ethyl+Haloxypop-r-methyl+Clodinofofpropargyl) at 150 DAS. The similar result (28.3) was found the spray of (Quizalofop-p-ethyl+Haloxypop-r-methyl).

5.6.4 No. of capsule plant⁻¹

The present investigations showed that application of combined weedicides (Quizalofop-p-ethyl+Haloxypop-r-methyl+Clodinofofpropargyl) attained the maximum number of pods per plant (43.50). On the other hand, spray of oxyflourfen recorded the minimum (14.34) at the maturity stage. This result was correlated with Chhokar and Balyan, (1999) reported that the weed free up to 45 DAS resulted in a

74% increase in number of pods per plant and grain yield of soybean than the weedy check.

5.6.5 Seed index (1000 g)

The present study showed that spray of combined weedicides (Quizalofop-p-ethyl+Haloxypop-r-methyl+Clodinofofpropargyl) were found to be associated with the highest magnitudes for this yield component. The lowest seed index (1.08g) was found with spray of oxyflourfen.

5.6.6 Seed yield (g plant⁻¹ and kg ha⁻¹)

The results indicated that all the treatments significantly increased seed yield in ashwagandha except Oxyflourfen @ 100 g ha⁻¹ (0.45 g plant⁻¹) and Metribuzin @ 525 g ha⁻¹ (0.74 g plant⁻¹). The maximum seed yield was recorded with Combined spray of herbicide (Quizalofop-p-ethyl @ 50 g ha⁻¹+Haloxypop-r-methyl @ 750 g ha⁻¹) was found best in maximum seed yield (1.17 g plant⁻¹) as compared to other treatment because this combination was least lethal to ashwagandha crop. Hence inspite of less per plant seed yield. The similar result was found with handweeding and spray of combination of weedicides (Quizalofop-p-ethyl+Haloxypop-r-methyl+Clodinofofpropargyl). Our result was similar with Ali *et al* (2011) maximum yield of greengram was found when application of herbicide Quizalofop-p-ethyl 100 g ha⁻¹ applied at 15–20 DAS.

The results indicated that all the treatments significantly increased seed yield in ashwagandha except Oxyflourfen @ 100 g ha⁻¹ (187.6 kg ha⁻¹) and Metribuzin @ 525 g ha⁻¹ (311.5 kg ha⁻¹). Our result similar with Sajjapongse *et al* (1983) who reported degree of severity increased with higher application rates, significantly reducing tomato yields phytotoxicity was severe with oxyfluorfen. The maximum seed yield was recorded spray of weedicides (Quizalofop-p-ethyl @ 50 g ha⁻¹+Haloxypop-r-methyl @ 750 g ha⁻¹ (492.8 kg ha⁻¹) at the maturity of crop. our result was similar with Pratap *et al* (2014) Result revealed that that application of quizalofop-ethyl 5% EC (SS) at 50 g ha⁻¹ resulted in significantly higher kernel yield (0.98 t ha⁻¹) of groundnut.

5.6.7 Root yield (g plant⁻¹ and kg ha⁻¹)

The results indicated that all the treatments significantly increased root yield in ashwagandha except Oxyflourfen @ 100 g ha⁻¹ (0.71 g plant⁻¹) and Metribuzin @

525 g ha⁻¹ (0.76 g plant⁻¹). our result is similar with Onofriet al. (1995) reported that application of >100 g metribuzin caused significant phytotoxicity when applied alone or in combination in Tomatoes.

The maximum root yield (1.24 g plant⁻¹) was recorded with combination (Quizalofop-p-ethyl @ 50 g ha⁻¹+ Haloxyfop-r-methyl @ 750 g ha⁻¹ + Clodinofof-propargyl @ 60 g ha⁻¹) which was similar with hand weeding and combined spray of weedicide Quizalofop-p-ethyl @ 50 g ha⁻¹+Haloxfop-r-methyl @ 750 g ha⁻¹ at the maturity of crop. The maximum root yield (518 kg ha⁻¹) was recorded spray of combination of herbicide Quizalofop-p-ethyl @ 50 g ha⁻¹+Haloxfop-r-methyl @ 750 g ha⁻¹ + Clodinofof-propargyl @ 60 g ha⁻¹. Combination (Quizalofop-p-ethyl @ 50 g ha⁻¹+ Haloxfop-r-methyl @ 750 g ha⁻¹ + Clodinofof-propargyl @ 60 g ha⁻¹) was superior because handweeding increases labour cost and time consuming process.

5.6.8 leaf yield (g plant⁻¹ and kg ha⁻¹)

The results indicated that all the treatments significantly increased leaf yield in ashwagandha except Oxyflourfen @ 100 g ha⁻¹ (0.35 g plant⁻¹) and Metribuzin @ 525 g ha⁻¹ (0.52 g plant⁻¹). our result is similar with Wax *et al* (1976) stated that Metribuzin controls several species of troublesome annual broadleaf weeds in soybeans but it sometimes causes excessive crop injury when application in higher rate.

The maximum leaf yield (1.27 g plant⁻¹) was recorded with combined spray of weedicides (Quizalofop-p-ethyl @ 50 g ha⁻¹+Haloxfop-r-methyl @ 750 g ha⁻¹ + Clodinofof-propargyl @ 60 g ha⁻¹). The maximum leaf yield (1.02 g plant⁻¹) again was found with handweeding and (Quizalofop-p-ethyl @ 50 g ha⁻¹+Haloxfop-r-methyl @ 750 g ha⁻¹. The maximum leaf yield (532 kg ha⁻¹) was recorded spray of combination of herbicide (Quizalofop-p-ethyl @ 50 g ha⁻¹+Haloxfop-r-methyl @ 750 g ha⁻¹ + Clodinofof-propargyl @ 60 g ha⁻¹.

5.6.9.1 Harvest index (%) (when root taken as economic yield)

The harvest index (HI) measures the percentage of economic yield to biological yield, and greater HI has been related to higher crop plant economic productivity.

The present study indicated that spray of combination of herbicide (Quizalofop-p-ethyl +Haloxypop-r-methyl + Clodinofof-propargyl and Quizalofop-p-ethyl +Haloxypop-r-methyl) possessed the higher values (26.1%), whereas oxyflourfen (17.1%) recorded the minimum.

5.6.9.2 Harvest index (%) (when seed taken as economic yield)

The present study indicated that treatments handweeding (untreated control) (26.2%) possessed the higher values, whereas control (20.2 %) recorded the minimum value.

5.7 Proximate analysis in ashwagandha root powder

5.7.1 Ash (%)

The present study indicated that treatment metribuzin (5.1 %) recorded the highest value for this trait. The lowest ash content recorded with hand weeding (4.6%). Our result is similar with Sangita Kumari and Alka Gupta (2016) reported in ashwagandha root powder the crude fiber content was 4.41%.

4.7.2 Crude fiber (%)

The present study indicated that treatment handweeding (32.58 %) recorded the highest value for this traits and T₉ (29.8 %) lowest Crude fiber contents, respectively. Our result is similar with Sangita Kumari and Alka Gupta (2016) reported in ashwagandha root powder the crude fiber content was 32.3%.

4.7.3 Protein (%)

In the present investigations the Protein % was found to be in the range of 8.5 % in Handweeding (untreated control) and 6.9 % with spray of (Haloxypop-r-methyl), respectively. our result was contrast with Sangita Kumari and Alka Gupta (2016) reported in ashwagandha root powder Protein (%) the content was 3.9 %.

4.7.4 Fat (%)

The present study indicated that handweeding (0.56 %) recorded the highest and lowest Fat was recorded with metribuzin (0.327 %) lowest Fat contents our result was similar with Sangita Kumari and Alka Gupta (2016) reported in ashwagandha root powder the fat content was 0.3%.

4.7.5 Moisture (%)

The present investigations, the moisture (%) was found to be in the range of 2.6 % in handweeding and 1.9 % in oxyflourfen. our result was contrast with Sangita Kumari and Alka Gupta (2016) reported in ashwagandha root power the moisturecontent was 7.45 %.

5.1.5 Withanolide A (%)

The present investigations, the Withanolide A (%) was found to be in the range of (0.133) % in combined spray of (Quizalofop-p-ethyl +Haloxyfop-r-methyl) and (0.057) % in spray of metribuzin. Our result contrast with Kubsad *et al.* (2009) reported that the crop harvested at 180 DAS had significantly higher total withanolide content in roots of Ashwagandha (0.560%).

Chapter- VI

SUMMARY, CONCLUSIONS AND SUGGESTIONS FOR FURTHER WORK

SUMMARY, CONCLUSIONS AND SUGGESTIONS FOR FURTHER WORK

The present research experiment entitled “**Efficacy of various weedicides on weed management, growth, physiology and productivity of winter sown Ashwagandha [*Withania somnifera* (L.) Dunal.]**” was conducted at Herbal Garden, Department of plant physiology, J.N.K.V.V., Jabalpur (M.P.) during *Kharif* season of 2021-22. The research experiment was laid out in a Completely Randomized Block design with three replications. Treatments comprised of nine combinations as well as single and combination of two or more two herbicides T₁ Control(untreated), T₂ (Hand weeding @ 40 and 80 DAS), T₃ (Quizalofop p-ethyl @ 50 gm ha⁻¹), T₄ (Haloxypop R.methyl @ 750 gm ha⁻¹), T₅ (Clodinafop propagyl a.i 60 gm ha⁻¹), T₆ (Quizalofop p-ethyl @ 50 gm ha⁻¹+Haloxypop R.methyl @ 750 gm ha⁻¹), T₇ (Quizalofop p-ethyl @ 50 gm ha⁻¹+Haloxypop R.methyl @ 750 gm ha⁻¹+ Clodinafop propagyl a.i 60 gm ha⁻¹), T₈ (Oxyflourfen @ 100 gm ha⁻¹) and T₉ (Metribuzin a.i 525 gm ha⁻¹).

Two spray of weedicides was done at 40 and 80 days after sowing. There were 9 species of weeds found with *Withania somnifera* crop before spraying of weedicides and other weed management application. These species were *Ageratum houstonianum*, *Euphorbia hirta*, *Cynodon dactylon*, *Tridax procumbens*, *Parthenium hysterophorus*, *Alternanthera sessilis*, *Cloris barbata*, *Commelina benghalensis* and *Cyperus rotundus*. Out of these weeds *Ageratum houstonianum* was the dominant weed having maximum average population (66 plant⁻¹).

Out of 9 weed species only 6 were found with lesser population after first spray of weedicides. These species were *Ageratum houstonianum*, *Cynodon dactylon*, *Parthenium hysterophorus*, *Alternanthera sessilis*, *Lactuca serriola* and *Cyperus rotundus*.

For weed control in *Withania somnifera* crop first and second spray of Quizalofop-p-ethyl+Haloxypop-r-methyl+Clodinafopproparg was quite effective in controlling weeds population, weed density and weed biomass without any serious injury of ashwagandha crop. Oxyflourfen was effective of controlling broad leaf and narrow leaf weed but it was lethal to ashwagandha also.

Quizalofop-p-ethyl+Haloxypop-r-methyl+Clodinofofpropargyl prolonged vegetative phases and late reproductive phases (from 50% flowering to maturity). On the other hand, oxyflourfen delayed floral and fruit initiation. From the early development phase LAI in treatments showed a increasing trend up to 90 DAS there after declining at 120 DAS. The LAI was highest when spray combined of Quizalofop-p-ethyl+Haloxypop-r-methyl+Clodinofofpropargyl during all stages.

LAD was increasing with crop age. Spray of combination of weedicides (Quizalofop-p-ethyl+Haloxypop-r-methyl+Clodinofofpropargyl) recorded the maximum value of LAD. The LAD minimum was found with spray of oxyflourfen during all the stages.

There was an enhancement in CGR with the age advancement of crop till 90-120 DAS there after it declined. The treatments with the highest CGR were found with spray of combination of weedicides (Quizalofop-p-ethyl+ Haloxypop-r-methyl+Clodinofofpropargyl).

The RGR had inconsistent pattern with the highest RGR values were shared with spray of combination of weedicides (Quizalofop-p-ethyl+Haloxypop-r-methyl+Clodinofofpropargyl) and oxyflourfen at 120-150 DAS.

The NAR increased till 90-120 DAS during advancement of crop age but later at 120-150 DAS, it declined. Spray of Quizalofop-p-ethyl+ Haloxypop r-methyl recorded higher values at 90-120 DAS and 120-150 DAS.

Up to maturity, all treatments resulted in a consistent improvement in BMD. However, spray of combination of herbicide (Quizalofop-p-ethyl+Haloxypop-r-methyl+Clodinofofpropargyl) recorded the maximum BMD at 150 DAS. The minimum BMD recorded with application of oxyflourfen at till maturity.

Early life span of crop had seen a larger magnitude of SLA, which was then reduced in the remaining growth period, with the lowest magnitude reaching 150 DAS. The treatments with the highest SLA, however, were spray of weedicides (Quizalofop-p-ethyl+Haloxypop-r-methyl+Clodinofofpropargyl) Up to 60 DAS, SLW increased with longer crop growth periods The greatest value for this parameter was obtained for spray of oxyflourfen.

Chlorophyll content index (cci) was the maximum with spray of herbicide (Quizalofop-p-ethyl+ Haloxypop r-methyl) at 120 DAS after capsule formation decreases in chlorophyll content of the leaf as a result of ageing.

Yield attributes parameters such as plant height, number of branch plant⁻¹ and number of leaf plant⁻¹ were found maximum with the spray of Quizalofop-p-ethyl+Haloxypop r-methyl. The maximum number of capsule plant⁻¹ and seed index were recorded in Quizalofop-p-ethyl+Haloxypop-r-methyl+Clodinofofpropargyl.

Yield attributes are the parameters contributing in root yield, seed yield and leaf yield were maximum with the spray of combination of Quizalofop-p-ethyl+Haloxypop-r-methyl+Clodinofofpropargyl. Root is the main economic product of *Withania*. The maximum root yield (1.24 g plant⁻¹ and 518 kg ha⁻¹) and maximum leaf (1.27 g plant⁻¹ and 532 kg ha⁻¹) were recorded with combined spray of (Quizalofop-p-ethyl+Haloxypop-r-methyl+Clodinofofpropargyl). The maximum seed yield (1.17 g plant⁻¹ and 492.8 kg ha⁻¹) recorded with combined spray of herbicide (Quizalofop-p-ethyl+Haloxypop-r-methyl). Harvest index (%) was maximum in combined spray of herbicide (Quizalofop-p-ethyl +Haloxypop-r-methyl).

In proximate analysis of root powder of ashwagandha, the maximum fat (0.50 %), protein (8.13 %) and crude fiber (31.92 %) contents were registered in Quizalofop-p-ethyl +Haloxypop-r-methyl +Clodinofofpropargyl while Moisture (8.34 %) in Quizalofop-p-ethyl +Haloxypop-r-methyl. Significantly maximum ash content was registered in treatment metribuzin.

6.2 Conclusions

Out of nine weed management techniques, spraying of combination of Quizalofop-p-ethyl (50 g ha⁻¹) +Haloxypop-r-methyl (750 g ha⁻¹) +Clodinofofpropargyl (60 g ha⁻¹) at 40 and 80 days after sowing was highly successful in improving growth, physiology and productivity of *Withania somnifera* while also effective for suppressing weeds growth and least biomass production.

6.3 Suggestions for further work

- 2.1** It is also recommended to calculate the benefit-cost ratio while taking into consideration the treatments' economic output.
- 2.2** The investigations must be carried out in various agro-climatic regions of India for the purpose of authenticating the results.
- 2.3** For different herbicides, the genotypic variability may be examined.
- 2.4** Analysis of any residual herbicide present in final product will be done as future work.

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APPENDICES

APPENDICES

Mean sum of square of weed population after the first herbicide application

Source of variation	D.F	<i>Ageratum</i>	<i>Euphorbia</i>	<i>Cynodon</i>	<i>Tridax</i>	<i>Parthenium</i>	<i>Alternanthera</i>	<i>Cloris</i>	<i>Commelina</i>	<i>Cyperus</i>
Replication	8	0.01584	0.40725	0.42322	1.81106	0.01534	0.17607	0.01166	0.01557	0.33601
Treatment	2	18.8378	2.91737	11.8671	5.94848	3.59329	8.25988	2.59313	2.56137	10.9270
Error	16	0.08772	0.21536	0.37078	0.29661	0.06511	0.13814	0.08088	0.06018	0.09663

Mean sum of square of weed density after the first herbicide application

Source of variation	D. F	<i>Ageratum</i>	<i>Euphorbia</i>	<i>Cynodon</i>	<i>Tridax</i>	<i>Parthenium</i>	<i>Alternanthera</i>	<i>Cloris</i>	<i>Commelina</i>	<i>Cyperus</i>
Replication	8	0.002154	0.029219	0.038639	0.178949	0.00106	0.005921	0.0008	0.001221	0.031937
Treatment	2	1.699914	0.182237	0.993668	0.446523	0.238042	0.533101	0.161821	0.162757	0.936942
Error	16	0.009326	0.01769	0.037679	0.029119	0.005871	0.20161	0.006634	0.005114	0.009294

Mean sum of square of weed biomass after the first herbicide application

Source of variation	D.F	<i>Ageratum</i>	<i>Euphorbia</i>	<i>Cynodon</i>	<i>Parthenium</i>	<i>Tridax</i>	<i>Alternanthera</i>	<i>Commelina</i>	<i>Cloris</i>	<i>Cyperus</i>
Replication	2	2.04411	0.06012	5.40044	9.30523	0.86835	3.15390	0.48511	0.98817	0.24497
Treatment	8	210.727	2.58460	31.7081	36.2449	4.16321	93.5081	4.87369	7.62329	5.63211
Error	16	5.18920	0.18764	3.62390	3.97199	0.15958	6.80812	0.32022	0.47619	0.49565

Mean sum of square of weed population after the second herbicide application

Source of variation	D.F.	<i>Ageratum</i>	<i>Cynodon</i>	<i>Parthenium</i>	<i>Alternanthera</i>	<i>Lactuca</i>	<i>Cyperus</i>
Treatment	8	0.63385	0.253925	0.456882	0.08125	0.093582	0.53659
Replication	2	15.62027	2.449659	2.703106	3.582911	3.189938	3.954931
Error	16	0.136498	0.108871	0.202494	0.159067	0.11753	0.1453932

Mean sum of square of weed density after the second herbicide application

Source of variation	D.F.	<i>Ageratum</i>	<i>Cynodon</i>	<i>Parthenium</i>	<i>Alternanthera</i>	<i>Lactuca</i>	<i>Cyperus</i>
Treatment	8	0.071401	0.014644	0.042157	0.007644	0.008563	0.0481823
Replication	2	1.37384	0.152635	0.16931	0.239533	0.203918	0.2779011
Error	16	0.014775	0.007538	0.017045	0.014007	0.010611	0.0130947

Mean sum of square of weed biomass after the second herbicide application

Source of variation	D.F.	<i>Ageratum</i>	<i>Lactuca</i>	<i>Cynodon</i>	<i>Parthenium</i>	<i>Alternanthera</i>	<i>Cyperus</i>
Replication	2	3.688563	1.869595	0.024682	1.904142	1.473775	0.289933
Treatment	8	160.9501	46.82977	13.64241	35.84756	74.0318	4.596669
Error	16	2.906192	0.5935	0.444091	1.907946	2.259003	0.351831

Mean sum of square of various phenophases of ashwagandha

source of variation	D.F.	Days to primary branch initiation	Days to secondary branch initiation	Days to flower initiation	Days to 50 % flower initiation	Days fruit initiation	Days to seed formation	Days to physiological maturity	Days to harvesting
Replication	2	0.40626	1.117457	0.3851592	0.0109777	0.1201370	0.0001592	0.443426	0.012804
Treatment	8	2.95566	2.193336	1.7308703	0.630525	2.2164203	1.4261759	1.29757	1.483259
Error	16	0.12681	0.2801758	0.3634634	0.0774777	0.0432662	0.0058925	0.281676	0.02312

Mean sum of square of LAI

Source of variation	D.F.	60 DAS	90 DAS	120DAS	150 DAS
Replication	2	0.035019925	0.008376443	0.023292368	0.003577
Treatment	8	0.220161872	0.486153989	0.861875969	0.650281
Error	16	0.009578892	0.007570674	0.019104678	0.00459

Mean sum of square of LAD

Source of variation	D.F.	60-90 DAS	90 -120DAS	120 -150 DAS
Replication	2	454833.9805	90800.64231	100288.9028
Treatment	8	11736446.32	23562062.62	27036556.68
Error	16	206734.1844	137204.619	156923.1736

Mean sum of square of CGR

Source of variation	D.F.	60-90 DAS	90 -120DAS	120 -150 DAS
Replication	2	0.000000001	0.000000067	0.000000033
Treatment	8	0.000000055	0.000000299	0.000000063
Error	16	0.000000007	0.000000010	0.000000006

Mean sum of square of RGR

Source of variation	D.F.	60-90 DAS	90 -120DAS	120 -150 DAS
Replication	2	0.0000090	0.0000236	0.0000043
Treatment	8	0.0016645	0.0001914	0.0000102
Error	16	0.0004854	0.0000104	0.0000028

Mean sum of square of NAR

Source of variation	D.F.	60-90 DAS	90 -120DAS	120 -150 DAS
Replication	2	0.0000000077	0.0000000134	0.0000000026
Treatment	8	0.0000000227	0.0000000599	0.0000000222
Error	16	0.0000000017	0.0000000026	0.0000000039

Mean sum of square of BMD

Source of variation	D.F.	60-90 DAS	90 -120DAS	120 -150 DAS
Replication	2	5.107910887	214.5726016	16726.5182
Treatment	8	1378.809111	2894.902569	400441.6246
Error	16	37.14599509	59.6100138	5861.983917

Mean sum of square of CCI

Source of variation	D.F.	60 DAS	90 DAS	120DAS	150 DAS
Replication	2	2.739	2.205	2.647	2.297
Treatment	8	16.100	4.506	26.695	13.768
Error	16	1.822	4.156	1.086	4.023

Mean sum of square of SLA

Source of variation	D.F.	60 DAS	90 DAS	120DAS	150 DAS
Replication	2	8665.0478	760.4255192	6181.854405	177.88022
Treatment	8	2998.6684	8681.75015	3683.144214	2163.4207
Error	16	1531.5421	485.0362456	835.268752	168.65345

Mean sum of square of SLW

Source of variation	D.F.	60 DAS	90 DAS	120DAS	150 DAS
Replication	2	0.000000148	0.000000034	0.000000908	0.000000089
Treatment	8	0.000000232	0.000000322	0.000000374	0.000001161
Error	16	0.000000047	0.000000020	0.000000119	0.000000089

Mean sum of square of yield attribute and yield

Source of variation	D.F.	Plant Height	No. Of Leaves	No. Of Branches
Replication	2	4.111111	14.54503	0.104815
Treatment	8	73.47307	128.9361	2.591759
Error	16	2.029444	0.999625	0.228981

Source of Variation	D. F.	No. Of Capsule Plant ⁻¹	1000 Seed Weight	Leaf Biomass g plant ⁻¹	Leaf Yield kg ha ⁻¹	Seed Yield g plant ⁻¹	Seed Yield kg ha ⁻¹	Root Yield g plant ⁻¹	Root Yield kg Ha ⁻¹
Treatment	2	4.274444	0.028744	0.119643	21105.03	0.012904	2276.370	0.0259	4568.76
Replication	8	261.2871	0.007916	0.291406	51404.14	0.174744	30824.88	0.141398	24942.59
Error	16	9.308231	0.002340	0.040739	7186.369	0.002598	458.4087	0.015015	2648.573

Source of Variation	D.F.	Harvest index of root	Harvest index of seed
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Replication	2	4.496704	14.63761
Treatment	8	24.11316	11.68078
Error	16	4.71475	6.50929

Mean sum of square of proximate analysis

Source of variation	d.f.	ash (%)	protein (%)	fat (%)	moisture (%)	total fibre (%)	Withanolide A(%)
Replication	2	0.743033 3	0.21	0.00053781 5	0.17773455 7	0.6709925 9	0.000133806
Treatment	8	0.7141	0.85166666 7	0.01816614 8	0.15630569 9	2.7284009 2	0.000296353
Error	16	0.275820 8	0.15833333 3	0.00165864 8	0.02579932 8	0.6915925 9	0.000265614

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