Performance of Pre-emergence Herbicides and Manual Weed Control in Maize (*Zea mays* L.) under Temperate Conditions

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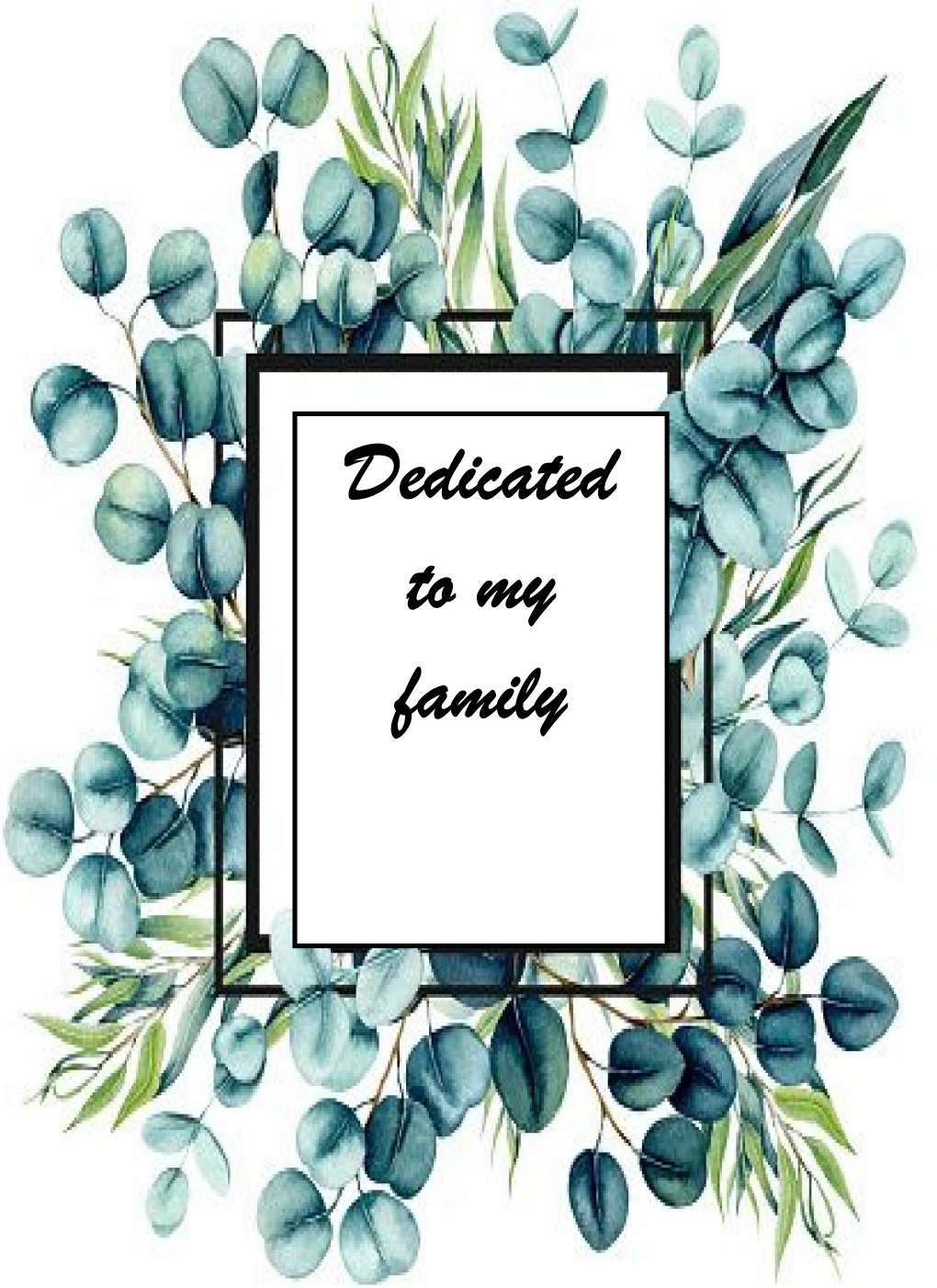
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Faculty of Agriculture, Division of Agronomy, Wadura

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It is further certified that information received during the course of investigation has duly been acknowledged.

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ABSTRACT

A field experiment entitled **"Performance of Pre-emergence Herbicides and Manual Weed Control in Maize (*Zea mays* L.) under Temperate Conditions"** was conducted at the crop research farm (CRF) of Division of Agronomy, Faculty of Agriculture, Sher-e- Kashmir University of Agricultural Sciences and Technology of Kashmir during *Kharif*, 2021 with the objective to study the effect of pre-emergence herbicides and manual weeding on growth and yield of maize. The weed dynamics and performance of different weed control measures was also studied. The soil of the experimental field was clay loam with neutral pH, medium in available nitrogen (335.67 kg ha^{-1}), phosphorous (21.23 kg ha^{-1}), potassium (197.13 kg ha^{-1}) and organic carbon (0.73 %). The investigation consisted of thirteen treatments viz. T_1 (Atrazine @ 1.5 kg ha^{-1} (pre-emergence) followed by hand weeding 3 weeks after sowing), T_2 (Atrazine @ 1.5 kg ha^{-1} (pre-emergence) followed by hand weeding 4 weeks after sowing), T_3 (Atrazine @ 1.5 kg ha^{-1} (pre-emergence) followed by hand weeding 5 weeks after sowing), T_4 (Atrazine @ 1.5 kg ha^{-1} (pre-emergence) followed by hand weeding 6 weeks after sowing), T_5 (Atrazine @ 1.5 kg ha^{-1} (pre-emergence) followed by hand weeding 7 weeks after sowing), T_6 (Pendimethalin @ 1.5 kg ha^{-1} (pre-emergence) followed by hand weeding 3 weeks after sowing), T_7 (Pendimethalin @ 1.5 kg ha^{-1} (pre-emergence) followed by hand weeding 4 weeks after sowing), T_8 (Pendimethalin @ 1.5 kg ha^{-1} (pre-emergence) followed by hand weeding 5 weeks after sowing), T_9 (Pendimethalin @ 1.5 kg ha^{-1} (pre-emergence) followed by hand weeding 6

weeks after sowing), T_{10} (Pendimethalin @ 1.5 kg ha^{-1} (pre-emergence) followed by hand weeding 7 weeks after sowing, T_{11} (Hand weeding after 3, 5 and 7 weeks after sowing), T_{12} (Weedy check), T_{13} (Weed free), laid out in randomized complete block design with 3 replications. Significant variations in growth, yield and economics were recorded among various treatments under investigation. Highest plant growth parameters, yield attributes and yield was recorded in T_{13} (Weed free) followed by T_{11} (Hand weeding after 3, 5 and 7 weeks after sowing). Lowest plant growth parameters, yield attributes and yield was recorded in T_{12} (Weedy check). In case of economic suitability, T_2 (Atrazine @ 1.5 kg ha^{-1} (pre-emergence) followed by hand weeding 4 weeks after sowing) revealed highest benefit cost ratio (2.17) and lowest benefit cost ratio (0.858) was recorded in T_{12} (Weedy check).

Major weeds reported in field were *Cynodon dactylon, Sorghum halepense, Digitaria sanguinalis* among grasses, *Chenopodium album*, *Amaranthus viridis, Rumex crispus* among broad leaved weeds and *Cyperus rotundus* among sedges. At 15 days after sowing highest weed control efficiency was recorded in T_2 (Atrazine @ 1.5 kg ha^{-1} (pre-emergence) followed by hand weeding 4 weeks after sowing), at 45 days after sowing highest weed control efficiency was observed in T_4 (Atrazine @ 1.5 kg ha^{-1} (pre-emergence) followed by hand weeding 6 weeks after sowing) and at 75 days after sowing highest weed control efficiency was obtained in T_{11} (Hand weeding after 3, 5 and 7 weeks after sowing). Lowest weed control efficiency was reported in T_{12} (weedy check) throughout the period of crop growth. Weed index was observed lowest in T_{11} (Hand weeding after 3, 5 and 7 weeks after sowing) and highest in T_{12} (Weedy check). In case of herbicide efficiency index no statistical difference was found between different treatments containing herbicides at 15 days after sowing. At 45 days after sowing T_4 (Atrazine @ 1.5 kg ha^{-1} (pre-emergence) followed by hand weeding 6 weeks after sowing) showed highest herbicide efficiency index and at 75 days after sowing highest herbicide efficiency index was reported in T_5 (Atrazine @ 1.5 kg ha^{-1} (pre-emergence) followed by hand weeding 7 weeks after sowing).

Keywords: Growth, Manual weeding, Pre-emergence herbicides, Weed dynamics, Yield, *Zea mays* L.

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Place:

Dated:

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Chapter-1

INTRODUCTION

Maize (*Zea mays* L.) is the most versatile crop among cereals in accordance with its adaptability, types and uses. It thrives well in tropical, subtropical and temperate climatic conditions due to its diverse genetic variability. It can be grown in different agro-ecological conditions and multiple growing seasons (Barla *et al*., 2016). Maize (*Zea mays* L.) belongs to family Poaceae (Gramineae) of grasses. It is monoecious, which makes it distinctive among cereal crops. The lateral branches (ears) bore grains and the main stem ends in a tassel. The genus Zea includes 4 species; the most economically important being *Zea mays* L. Maize is an important crop for billions of people as food, feed and raw material for industries. It is a good source of nutrition as well as phytochemical compounds such as carotenoids, phytosterols and phenolic compounds which play an important role in the prevention of different serious diseases (Shah *et al*., 2016). Maize is grown both for fodder as well as grain purpose. According to kernel type maize is classified as Dent corn, Flint corn, Flour corn, Sweet corn, Pop corn, Pod corn.

Globally, about 1147.7 million metric tonnes of maize are being produced from an area of 193.7 million ha with an average productivity of 5.75 t ha^{-1} (FAOSTAT, 2020). Maize (*Zea mays* L.) is third most important cereal in India after rice and wheat. The area under maize in India is 9.7 million ha and production 30.2 million metric tonnes (USDA, 2020). In India, the major maize growing states are Uttar Pradesh, Bihar, Rajasthan, Madhya Pradesh, Punjab, Haryana, Maharashtra, Andhra Pradesh, Himachal Pradesh, West Bengal, Karnataka, and Jammu and Kashmir, together accounting for over 95 % of the national maize production (Milind and Isha, 2013). Area under maize in Jammu and Kashmir is 0.31 million ha with a production of 0.51 million tonnes and productivity of 1.65 tonnes ha^{-1} (DES, 2020).

Maize production is affected by different biotic and abiotic factors. Among biotic factors, weeds are the main bottlenecks in crop production. Weeds cause a loss of 33%, diseases 20%, insects 26% and others 21% (Directorate of Weed Research, Jabalpur, 2017).

Maize, usually being a rainy season and widely spaced crop, is infested by different kinds of weeds due to which it is subjected to heavy weed competition, resulting in huge losses ranging from 28 - 100 % (Patel *et al.,* 2006). The yield of maize is dependent on various factors and among them weed is one of the most important yield limiting factor. Maize is usually grown in monoculture due to which it is subjected to heavy weed infestation resulting in severe yield reduction and losses upto 40-60 % (Rasool and Khan, 2016). There can be many effects of weeds on maize plant however competition over scarce resources is most prevalent leading to huge decrease in yield. Uncontrolled weed infestation in maize can result in 89 % yield loss (Imoloame and Omolalye, 2016). Weeds compete for nutrients, moisture, light, space, harbour different pests and diseases, ultimately affecting the growth, yield and quality of the crop. Weeds decrease the efficiency of fertilizer utilization by plants because a good portion of fertilizer added is taken up by weeds. Weeds not only affect the maize crop directly, but indirectly as well by showing different allelopathic effects. Weeds decrease soil fertility and soil moisture and also pose a possible threat to the succeeding crop (Khan *et al*., 2003).

Managing weeds on the basis of critical period for weed control (CPWC) is the most effective technique to improve methods of weed control and make them more efficient. With the help of CPWC, we can go for timely, need based and efficient weed control (Knezevic *et al.,* 2002). If weeds are not controlled in maize during the period of critical crop-weed competition, then grain losses occur between 28-100 % (Kumar *et al*., 2017). Thus, it is vital that maize should be kept weed-free during the period of critical crop -weed competition for better growth and higher yields.

Weed intensity and type of flora infesting the maize crop are functions of different factors such as climatic conditions, soil characteristics and management practices. These all factors vary from region to region and influence the type and intensity of weed species having economic importance in maize. In order to understand critical crop-weed competition and acquire the maximum yield potential of maize, weed management becomes crucial.

Chemical weed control plays an important and irreplaceable role in weed management of maize. Herbicides not only help in controlling of weeds timely but also provide a good opportunity for reducing the cost of manual weed control. Chemical weed management in maize by pre-emergence herbicides assists for efficient control of weeds in maize during period of critical crop-weed competition (Triveni *et al*., 2017). Different herbicides are available for weed control in maize including atrazine, simazine, pendimethalin, alachlor as pre emergence herbicides and 2,4-D as post emergence herbicide (Anonymous, 1994). Atrazine and pendimethalin are efficient pre-emergent herbicides to be used in maize (Rani *et al*., 2020). These herbicides when supplemented with hoeing operation form an ideal means for weed control in maize for both annual and perennial weeds (Chikoye *et al*., 2005).

Keeping the above mentioned aspects into consideration, the following investigation entitled **"Performance of Pre-emergence Herbicides and Manual Weed Control in Maize (*Zea mays* L.) under Temperate Conditions"** was conducted with the following objectives:

1. To study growth and yield of maize as influenced by pre-emergence herbicide application at varying intervals of manual weeding.
2. To study weed dynamics and performance of weed control measures.
3. To work out the relative economics.

Chapter-2

REVIEW OF LITERATURE

The brief resume of research work conducted in India and abroad on different aspects of current investigation entitled **"Performance of Pre-emergence Herbicides and Manual Weed Control in Maize (*Zea mays* L.) under Temperate Conditions"** has been summarized and put forward under following headings.

2.1 Weed population dynamics associated with maize

2.2 Crop-weed competition in maize

2.3 Yield reduction in maize due to weeds

2.4 Effect of weed management practices on nutrient content and uptake of maize

2.5 Effect of weed management practices on growth and yield of maize

2.6 Relative economics

2.1 Weed population dynamics associated with maize

Ishrat *et al*. (2012) observed that the weeds associated with maize crop were *Dinebra retroflexa, Cynodon dactylon, Cyperus rotundus, Eleusine indica, Parthenium hysterophorus, Phyllantus niruri, Amaranthus viridis, Echinochloa colonum.*

Dominant weed flora observed in maize fields on clay loam soils were *Echinochloa crusgalli, Cynodon dactylon, Commelina benghalensis, Cyperus rotundus, Phyllanthus niruri, Trianthema portulacastrum, Digera arvensis, Physalis minima, Meremia everta, Euphorbia hirta, Aristolochia bracteata* and *Cleome viscosa* (Praveena, 2013).

The dominant weed flora associated with maize crop include *Cynodon dactylon* among grasses, *Cyperus rotundus* among sedges and *Euphorbia hirta,*

Trianthema portulacastrum, Phyllanthus niruri, Cleome viscosa, and *Digera arvensis* among the dicots (Rama Devi, 2013).

The major weeds associated with maize among broad leaved weeds are *Melilotus alba, Tridax procumbens, Parthenium hysterophorus, Euphorbia geniculate, Amaranthus viridis, Trianthema portulacastrum, among grasses are Dinebra arabica, Eleusine indica, Cynodon dactylon*, *Digitaria spp* and among sedges is *Cyperus rotundus* (Madhavi *et al*., 2014).

Weed species associated with the maize crop include *Ageratum conyzoides, Stellaria media, Oldenlandia diffusa, Oldenlandia aquatic, Cynodon dactylon, Polygonum persicaria, Polygonum pensylvanicum, Polygonum orientale, Solanum nigrum, Digitaria ciliaris, Oxalis corniculata, Physalis minima, Cyperus rotundus, Setaria glauca, Echinochloa sp.* However, dominant weed species were *Cynodon dactylon, Polygonum sp., Digitaria ciliaris* (Mukherjee and Rai, 2015).

Abdullahi *et al*. (2016) observed the major species of weeds that were associated with maize crop were *Sorghum halepense, Cynodon dactylon, Parthenium hysterophorus L., Cyperus rotundus, Sperguala arvensis, Echinochloa colona*.

Ravi *et al*. (2017) observed that dominant weed species observed in maize field were *Cyperus rotundus*, *Cynodon dactylon, Digera arvensis*, *Dactyloctenium aegyptium*.

Kandasamy (2018) founded that the maize crop consists of following weeds: *Cleome viscosa, Echinochloa crusgalli, Cynodon dactylon Trianthema portulacastrum, Cyperus rotundus, Phyllanthus niruri.* However, *Echinochloa crusgalli*, *Cynodon dactylon, Trianthema portulacastrum, Cyperus rotundus,* are the predominant weeds.

The weed flora associated with maize consists of *Alternanthera philoxeroides, Digiteria sanguinalis, Amaranthus viridis, Echinochloa colona,*

Brachiaria mutica, Elusine indica, Cyperus rotundus, Phyllanthus niruri, Digera arvensis (Moinuddin *et al*., 2018).

The predominant weed species observed in the maize filed were *Echinochloa colona, Polygonum spp, Amaranthus viridis, Portulaca oleraceaes, Chenopodium album, Cynodon dactylon, Digitaria sanguinalis, Eleusine indica, Xanthium strumarium, Cyperus spp., Sorghum halepense* (Rasool *et al*., 2020).

2.2 Crop-weed competition in maize

To achieve higher yields in maize, crop-weed competition should be very less during the early stages of crop growth (Gopinath and Kundu, 2008).

Ghanizadeh *et al*. (2009) observed that the critical period for crop weed competition in maize was from 5 to 9 leaf stage.

Emergence, density and competitiveness of weed population are important parameters that determine the phase most critical for competition (Bystro *et al*., 2012).

Dass *et al*. (2012) reported that first 6 weeks in maize crop are most critical for crop-weed competition and if proper weed management practices are not followed during this period, it may decrease the yield by 28-100%.

Gantoli *et al.* (2013) noticed that in maize the period of critical crop weed competition begins from 6^{th} leaf stage and continues upto 10^{th} leaf stage or flowering stage.

In maize critical period for weed control ranged between 21 to 29 days after planting to avoid yield losses (Amare *et al*., 2014).

Farhad *et al*. (2014) recorded that at every stage of maize there is significant loss in yield due to infestation of weeds.

In maize, three-eight weeks after planting are most critical for weed emergence (Takim *et al*., 2014).

In maize, the most critical period of crop weed competition in is 20-60 days after sowing (Kumar *et al.*, 2015).

Ehsas *et al*. (2016) noticed that weed control practices after the period of critical crop weed competition resulted in grain yield loss upto 83%.

Kiranjit *et al.* (2016) reported that the period of critical crop weed competition in spring maize ranged between 30 to 60 days after sowing in sandy loams of PAU, Ludhiana.

Different experiments conducted at different locations specified that in maize crop 3 to 6 weeks after sowing are most critical for crop weed competition (Barad *et al*., 2016).

The period of critical crop weed competition in maize lied between 3-6 weeks after sowing which appreciably affected growth parameters and decreased yield of maize crop (Imoloame and Omolalye, 2017).

2.3 Yield reduction in maize due to weeds

Sen *et al*. (2000) observed that 15 -75 % yield loss occured in maize due to unchecked crop-weed competition.

In an experiment conducted by Pandey *et al*. (2002) grassy weed species put forward highest competition to maize crop decreasing grain yield by 77.4 % followed by broad leaved weed species of about 44.2 % and sedges 38.4 %.

Patel *et al.* (2006) noticed that maize being a widely spaced and rainy season crop is subjected to heavy weed competitions and if proper weed management practices are not followed, can result in yield losses from 28 – 100%.

In maize crop leaf area index was reduced by 44 % when compared with weed free during the full season crop weed competition (Maqbool *et al*., 2006).

In maize unchecked growth of weeds results in reduction of grain yield by 62.25 per cent (Paramjeet *et al*.,2014).

Maize is grown at wider spacing and during first 3-4 weeks its initial growth is very slow providing good opportunity for weeds to grow leading to severe competition and yield losses of about 30-93% (Yakadri *et al*., 2015).

In India, the yield of maize crop is reduced by 27-60 % due to crop-weed competition and the per centage of reduction depends on the weed persistence and growth pattern (Kumar *et al*., 2015).

Jagadish and Prashant (2016) reported in maize that yield loss of 18 to 85 per cent is caused due to various categories of weeds.

Crop- weed competition in maize results in yield loss of 33% to total failure depending on the intensity of competition (Kakade *et al*., 2016).

Das *et al*. (2016) observed that 28-100% yield losses may occur in maize and the quantity of yield loss depends upon the weed density and infestation pattern of weeds.

In maize 89 per cent yield reduction occurs because of unchecked infestation of weeds (Imoloame and Omolalye, 2016).

Uncontrolled weed management during the critical period of crop-weed competition may cause yield losses between 28-100% (Kumar *et al*., 2017).

Kandasamy (2018) observed shorter maize plants in unweeded control conditions because of more competition between crop and weeds resulting in reduced availability of inputs to maize plants.

Following proper methods for weed management in maize lead to increased grain yield of treated plots by 77 to 97 per cent than the weedy check plot (Dharam *et al.,* 2018).

2.4 Effect of weed management practices on nutrient content and uptake in maize

Significant differences in regard to nitrogen uptake by grain and stover in maize were reported with different treatments of weed management. The highest

nitrogen uptake was noticed in weed free treatment as compared to others (Jat and Gaur, 2000).

In maize the highest uptake by grain and stover was observed in the weed free conditions as compared to weedy check (Malviya and Singh, 2007).

Pervaiz *et al*. (2009) noted that weed management methods have a significant role in enhancing nitrogen and phosphorous concentration in maize shoots and their effect on potassium concentration was also appreciable.

Kour *et al*. (2014) observed that in weedy check plot there was maximum removal of nitrogen, phosphorous and potassium by weeds because of more dry matter accumulation of weeds.

Lowest dry matter of weeds was obtained in treatments atrazine (PE) @ 1 kg ha^{-1} followed by hand weeding at 30 days after sowing and pendimethalin (PE) @ 1 kg ha^{-1} followed by hand weeding at 30 days after sowing. It was attributed to less nutrient uptake by weeds resulting in effectual weed control (Gaurav *et al*. 2018).

Every weed management treatment appreciably increased nitrogen and phosphorous uptake both by grain and stover in maize crop as compared to weedy check. Also total uptake of these nutrients was noticed to be higher in all weed management treatments over weedy check (Deewan *et al.* 2018).

Jaybhaye *et al*. (2020) observed maximum total NPK uptake of 268.22, 39.76 and 148.69 kg ha^{-1} respectively in weed free treatment followed by atrazine @ 0.5 kg ha^{-1} *fb* tembotrione @ 0.120 kg ha^{-1} (264.40, 39.14 and 146.17 NPK kg ha^{-1}).

2.5 Effect of weed management practices on growth and yield of maize

Patel *et al*. (2000) reported that highest stover yield, grain yield, net returns and BC ratio were found with atrazine @ 1.0 kg *a.i*. ha^{-1} followed by hand weeding at 45 days after sowing.

Kolage *et al*. (2004) noted highest returns and BCR for treatment application of atrazine (PE) @ 1.0 kg ha^{-1} as compared to other herbicides.

Atrazine @ 1.0 kg *a.i*. ha^{-1} followed by hand weeding at 30 days after sowing was reported to be superior from all other treatments with highest gross returns, net returns and BCR (Mandal *et al*., 2004).

Highest gross returns were recorded in weed free treatment followed by 2 hand weedings at 20 and 40 days after sowing (Malviya and Singh, 2007).

Lowest weed density and weed dry weight was obtained with atrazine application @ 1.25 kg ha^{-1} or pendimethalin application @ 1.5 kg ha^{-1} together with spray of paraquat @ 0.6 kg ha^{-1} as directed spray in between rows at 3 weeks after sowing (Srividya *et al*., 2011).

Sanodiya *et al*. (2013) recorded highest benefit cost ratio in the tank mixed application of alachlor @ 2.25 kg ha^{-1} + atrazine @ 0.75 kg ha^{-1}.

Rani and Sagar (2013) while working on maize on sandy loam soils in Tirupati observed that lowest weed dry weight and density with 2 hand weedings at 20 and 40 days after sowing.

Kumari *et al*. (2014) while working on maize at crop research centre, RAU (Pusa), noticed that least density and dry matter accumulation of weeds was associated with application of atrazine (PE) @ 1.0 kg ha^{-1} followed by working with power weeder at 45 days after sowing.

Weed dry matter was found appreciably low with application of atrazine (PE) @ 0.75 kg ha^{-1} combined with application of pendimethalin @ 0.75 kg ha^{-1} (Amandeep *et al*., 2014).

Weed density and weed dry matter controlling capacity was found superior in atrazine @ 1.0 kg ha^{-1} followed by hand weeding at 30 days after sowing at Punjabrao Deshmukh Krishi Vidyapeeth, Akola (Deshmukh *et al*., 2014).

Application of atrazine @ 0.75 kg ha^{-1} succeeded by application of 2, 4-D @ 0.5 kg ha^{-1} as pre emergence recorded lowest density of weeds and it was found to be at par with two hand weedings at 20 and 40 days after sowing in maize crop (Sonawane *et al*., 2014).

Shankar *et al*. (2015) concluded that pre-emergent application of atrazine @ 1.0 kg ha^{-1} recorded higher grain yield (7.079 t ha^{-1}) as compared to other weed control treatments.

Atrazine @ 0.75 kg ha^{-1} in comination with glyphosate @ 2.5 ml $litre^{-1}$ and atrazine @ 1.5 kg ha^{-1} as pre-emergence combined with 1 hand weeding at 40 days after sowing were found successful in decreasing yield loss and improving the yield attributes (Nidhi *et al*., 2015).

The most effective and economical weed management practice in maize consists of atrazine application @ 1.0 kg ha^{-1} as pre emergence followed by hand weeding at 30 days after sowing which resulted in higher grain yield and better nutrient uptake (Samant *et al*., 2015).

Higher growth and yield of maize was obtained by the application of atrazine @ 1.0 kg ha^{-1} as pre-emergence followed by hand weeding at 20 DAS (Rasool and Khan, 2016).

Dutta *et al*. (2016) observed that application of atrazine (PE) @ 2.0 kg ha^{-1} and atrazine (PE) @ 1.0 kg ha^{-1} followed by 1 hand weeding at 30 days after sowing revealed their excellence over other herbicides by decreasing weed density and weed dry weight at all stages of maize.

Application of atrazine (PE) @ 1.0 kg ha^{-1} followed by 1 hand weeding at 45 days after sowing resulted remarkably higher plant height, cob girth and length, no. of cobs $plant^{-1}$, grain yield and harvest index, lowest weed density and weed dry weight as compared with other doses of atrazine accompanying hand weeding (Abdullahi *et al*., 2016).

Sahoo *et al*. (2017) observed that with the pre-emergence application of atrazine @ 1.0 kg ha^{-1}, highest grain yield was obtained in maize.

Shambulinga and Guggari (2017) recorded that the pre-emergence application of atrazine @ 1.0 kg ha^{-1} followed by 1 hand weeding with intercultivation at 45 days after sowing resulted in higher weed control efficiency, lowest total weed density, weed dry matter, higher cob girth, cob length, grain weight cob^{-1}, grain and stover yield of maize.

Atrazine application @ 1.0 kg ha^{-1} as pre emergence succeeced by 2, 4-D @ 0.75 kg ha^{-1} as post emergence on 21 days after sowing is an efficient weed management practice for controlling weeds in maize (Kandasamy, 2018).

Application of atrazine @ 2.5 l ha^{-1} as pre-emergence + 1 hand weeding at 6 or 9 weeks after planting resulted in appreciably higher plant height, number of leaves $plant^{-1}$, leaf area index and ear length at 10 WAP in maize (Gbaraneh and Briggs, 2018).

The application of atrazine (PE) @ 1.0 kg ha^{-1} followed by HW at 30 days after sowing resulted in highest WCE (weed control efficiency) with least density and dry matter accumulation of weeds (Rai *et al*., 2018).

Highest yield was obtained with the atrazine application as pre emergence @ 1.5 kg ha^{-1} succeeded by application of tembotrione as post emergence @ 120 g ha^{-1} (Fayaz *et al*., 2019).

Magrey *et al*. (2019) observed highest dry matter accumulation and leaf area index in the treatment of earthing up and weeding at 30 and 45 days after sowing and weedy check had the lowest dry matter accumulation and LAI than all other treatments.

The application of atrazine and pendimethalin as pre emergence herbicides followed by one hand weeding at 30 DAS is a good method of weed management in maize (Rani *et al*., 2020).

Iqbal *et al.* (2020) recorded that atrazine @ 1.2 kg ha^{-1} and pendimethalin @ 1.0 kg ha^{-1} are a good option for managing weeds in maize because they are associated with higher weed control efficiency, low density of weeds and less dry matter accumulation of weeds.

Rasool *et al.* (2020) reported that atrazine 50% WP @ 1.0 kg ha^{-1} recorded higher grain as well as stover yield as compared to that of Paraquat dichloride 24 % SL @ 0.5 kg ha^{-1} and 2, 4-D sodium salt 58% WSC @ 1.0 kg ha^{-1}.

2.6 Relative economics

Kamble *et al.* (2015) studied different weed management practices in maize while working at Agricultural Research Station, Hagari, UAS, Raichur recorded that efficient method of weed control in maize with highest BCR (4.53) was atrazine @ 1.25 kg or lit ha^{-1} + Pendimethalin @ 2.5 lit ha^{-1}.

Application of atrazine @ 0.5 kg ha^{-1} as pre-emergence + hand weeding and inter cultivation at 30 days after sowing in maize was recorded with higher net returns and BCR among different pre-emergence herbicides applied in combination with hand weeding and inter cultivation (Dobariya *et al*., 2015).

Rao *et al*. (2016) reported that highest net returns were obtained with pre-emergence application of atrazine @ 1.0 kg ha^{-1} followed by topramezone spray @ 25 g ha^{-1} at 20 days after sowing and this treatment was followed by pendimethalin application (PE) @ 1.0 kg ha^{-1} followed by topramezone spray @ 25 g ha^{-1} at 20 days after sowing.

Pre-emergence application of atrazine @ 0.5 kg ha^{-1} followed by hand weeding and inter-cultivation at 30 days after sowing showed higher net returns and benefit: cost ratio in comparison with all other treatments applied (Barad *et al.*, 2016).

Swapna *et al.* (2017) recorded that atrazine (PE) @ 1.0 kg ha^{-1} followed by topramezone @ 25.2 g ha^{-1} at 25 days after sowing resulted in highest benefit:

cost ratio and it was followed by pre-emergence application of atrazine @ 1.0 kg ha^{-1} *fb* tembotrione @ 105 g ha^{-1} at 25 days after sowing.

Aruna *et al*. (2018) reported that in maize application of topramezone @ 12.5 g ha^{-1} in combination with atrazine @ 625 g ha^{-1} as post emergence via tank mix revealed greater returns.

Higher net returns and benefit: cost ratio was found with post-emergence application of topramezone @ 12.5 g ha^{-1} plus atrazine @ 625 g ha^{-1} (Bahirgul and Ramesh, 2019).

Fayaz *et al.* (2019) recorded that the atrazine application (PE) @ 1.5 kg ha^{-1} followed by tembotrione (PoE) @ 120 g ha^{-1} at 30 days after sowing resulted higher net returns and B:C ratio of 7.97.

Chapter-3

MATERIALS AND METHODS

A field experiment entitled **"Performance of Pre-Emergence Herbicides and Manual Weed Control in Maize (*Zea mays* L.) under Temperate Conditions"** was conducted during *Kharif season* 2021. The information pertaining to the materials and methods used during the experimentation are described in this chapter.

3.1 Experimental site

The experiment was outlaid in the research farm of Division of Agronomy at Faculty of Agriculture, SKUAST-K, Wadura, Sopore, and J&K during the *Kharif* season of 2021. The experimental site is situated between a latitude of 34^{o} 21' N, a longitude of 74^{o} 23' E with 1590 m above MSL. The site had uniform topography and was well-drained.

3.2 Climate and weather

The experimental site is located in the temperate zone of north-western Himalaya. The mean meteorological data gathered by the Meteorological Observatory at Wadura for the experimentation period during the *Kharif* season of year 2021 is displayed in Fig. 1. It was summarized from data that the maximum temperature ranged from 23.6 to 32.6 □C and minimum temperature ranged from 6.0 to 19.4 □C. The maximum relative humidity ranged from 74.9 to 90.7 % and minimum relative humidity ranged from 41.6 to 64.1 %. The annual rainfall was 821 mm and total rainfall during cropping season was 227 mm.

3.3 Physico-chemical properties of soil

Before the commencement of the experiment, soil samples were taken at random from the experimental field. Composite samples were obtained after thoroughly mixing the individual soil samples collected at 0-15 cm depth and were used to determine the physico-chemical properties of soil. The results of soil analysis declared that the soil of experimental field was neutral in reaction with

medium soil organic carbon content and sufficient in available N, P and K (Table 3).

3.4 Cropping history of the experimental site

The details concerning the cropping history of the experimental site for previous three years have been summed up in Table 1.

Table 1: Cropping history of the experimental site

Year	Crop	
	Kharif	***Rabi***
2018-2019	Maize	Fallow
2019-2020	Maize	Pea
2020-2021	Fallow	Fallow
2021	Present experimentation	-

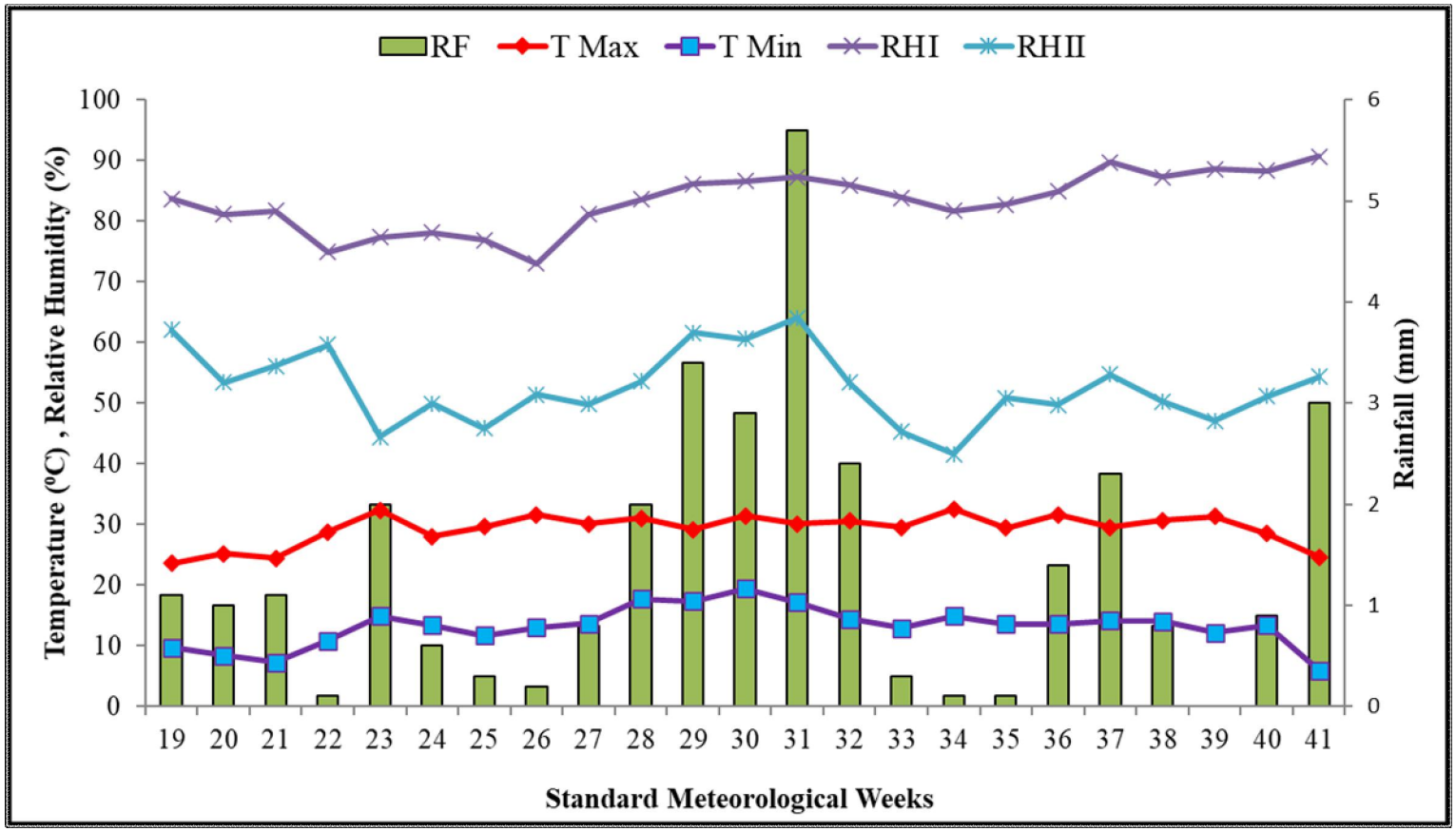

Fig. 1: Weather conditions during the *Kharif* season 2021

3.5 Experimental details

The experiment comprised of thirteen treatment combinations (Table 2) laid out in RCBD with three replications according to plan as detailed in Fig. 2.

Table 2: Treatment combinations

Symbol	Treatment details
T_1	Atrazine @ 1.5 kg ha^{-1} (pre-emergence) followed by HW 3 WAS.
T_2	Atrazine @ 1.5 kg ha^{-1}(pre-emergence) followed by HW 4 WAS
T_3	Atrazine @ 1.5 kg ha^{-1}(pre-emergence) followed by HW 5 WAS
T_4	Atrazine @ 1.5 kg ha^{-1}(pre-emergence) followed by HW 6 WAS
T_5	Atrazine @ 1.5 kg ha^{-1}(pre-emergence) followed by HW 7 WAS
T_6	Pendimethalin @ 1.5 kg ha^{-1}(pre-emergence) followed by HW 3 WAS
T_7	Pendimethalin @ 1.5 kg ha^{-1}(pre-emergence) followed by HW 4 WAS
T_8	Pendimethalin @ 1.5 kg ha^{-1}(pre-emergence) followed by HW 5 WAS
T_9	Pendimethalin @ 1.5 kg ha^{-1}(pre-emergence) followed by HW 6 WAS
T_{10}	Pendimethalin @ 1.5 kg ha^{-1}(pre-emergence) followed by HW 7 WAS
T_{11}	Hand weeding after 3, 5 and 7 WAS
T_{12}	Weedy check
T_{13}	Weed free

Where, WAS = Weeks after sowing, HW = Hand weeding

3.5.1 Other experimental details

Design of experiment	RCBD
Year of start	2021
Season	*Kharif*

Crop	Maize (*Zea mays* L.)
Variety	Shalimar Maize Composite-4
Treatments	13
Replications	3
Total no. of experimental plots	39
Spacing	60 cm x 20 cm
Net plot size	6 m x 3 m
Fertilizer recommendations	75:40:20:10 $N:P_2O_5:K_2O:ZnSO_4$ kg ha^{-1}

3.5.2 Description of Shalimar Maize Composite-4

It is dual-purpose composite maize, productive in nature, grows to an average height, and is resistant to common rust, turcicum leaf blight, aphids, stem borer, as well as lodging. It has a yield potential of 60-80 q ha^{-1} and a crude protein content of 10.66 %.

Table 3: Initial physico-chemical properties of soil of the experimental field

S.No.	Parameter	Value	Method of estimation	Remark
01.	pH	6.61	1:2.5 soil water suspension using pH meter (Jackson, 1973)	Neutral
02.	Electrical conductivity	0.32 dSm^{-1}	Conductivity meter (Jackson, 1973)	Normal
03.	Organic carbon	0.73 %	Walkley and Black wet oxidation method (Walkley and Black, 1934)	Medium
04.	Available nitrogen	335.67 kg ha^{-1}	Alkaline potassium permanganate method (Subbiah and Asija, 1956)	Medium
05.	Available phosphorus	21.23 kg ha^{-1}	Extraction with 0.5 M $NaHCO_3$ (Olsen, 1954)	Medium
06.	Available potassium	197.13 kg ha^{-1}	Flame photometer method (Jackson, 1974)	Medium

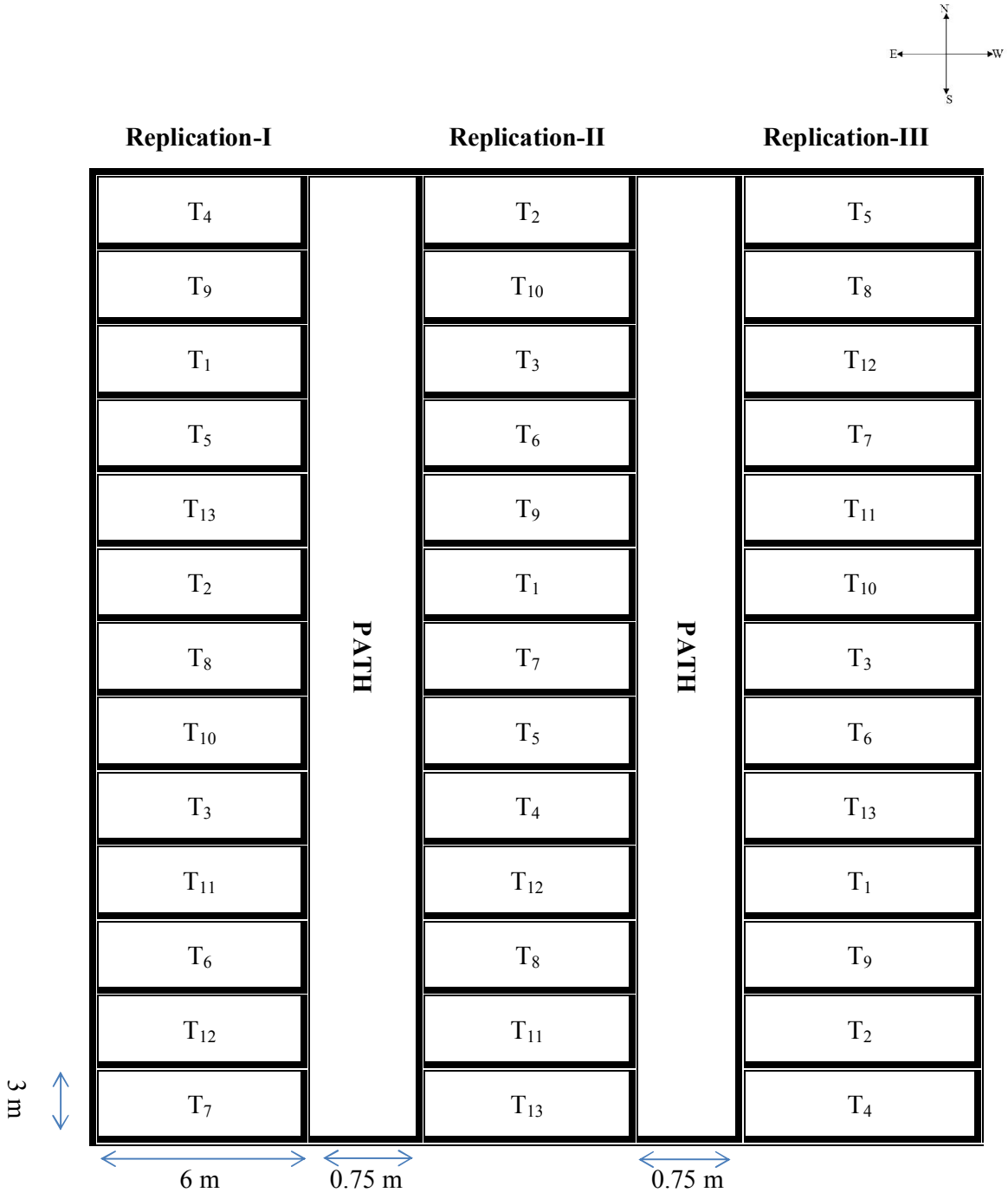

Fig. 2: Layout plan of the experimental field

3.6 Details of field operations

The details of field operations followed during the field trial are summarized in Table 4. Although, quick description of the field operations carried out are given below.

3.6.1 Preparation of land

A tractor-drawn cultivator was used to cross-cultivate the experimental field, which was then levelled with planking to ensure proper drainage. The site was cleaned by collecting and eliminating all the stubbles and debris. The experimental plots were laid out according to the plan manually.

3.6.2 Manures and fertilizer application

Before sowing, well decomposed farm yard manure @ 15 t ha^{-1} was applied to whole field and thoroughly mixed with soil. In case of inorganics, recommended dose of nitrogen, phosphorous, potassium, and zinc were applied through Urea, Diammonium phosphate (DAP), Muriate of potash (MOP) and Zinc sulphate respectively. 50 per cent of nitrogen plus full dose of phosphorous, potassium and zinc was applied as basal where as the remaining half dose of nitrogen was divided in two and supplied at two stages i.e., knee high and tasseling stage.

3.6.3 Sowing

Prior to sowing, it was ascertained that there was enough moisture content in the soil necessary for seed germination. Pre-treated seeds were sown in the manually opened furrows at a distance of 60 cm x 20 cm at the rate of 20 kg ha^{-1}. After sowing of seeds, furrows were closed and lightly compacted to ensure sufficient seed to soil contact for good germination.

3.6.4 Thinning

In order to maintain the desired population stand, thinning was done 20 days after sowing of the crop.

Table: 4: Details of the field operations done during experimentation

S. No.	Field operation	Date	Remarks
01	Primary tillage	17/5	The field was ploughed, stubbles were removed manually and well decomposed FYM @ 15 t ha^{-1} was applied evenly in the field
02	Secondary tillage	21/5	The field was ploughed again to attain a desirable soil tilth
03	Layout	22/5	Layout was done as per the experimental requirements
04	Application of basal dose of fertilizers	24/5	Half dose of nitrogen was applied through urea and full dose of phosphorous and potassium through DAP and MOP respectively
05	Application of carbofuran	24/5	Carbofuran 3% @ 20 kg ha^{-1} was applied to whole experimental site
06	Sowing of seed	24/5	Seeds were treated with α-methrin @ 3 ml kg^{-1} and were sown manually in lines at 5-6 cm deep with seed rate of 20 kg ha^{-1}
07	Application of atrazine	25/5	Atrazine @ 1.5 kg ha^{-1} was applied as pre-emergence as per treatment
08	Application of pendimethalin	25/5	Pendimethalin @ 1.5 kg ha^{-1} was applied as pre-emergence as per treatment
09	Irrigation	30/5	Irrigation was applied to aid the seeds in germination
10	First hand weeding	14/6	First hand weeding was done in plots as per treatment
11	Second hand weeding	21/6	2^{nd} hand weeding was done in plots as per treatment

12	Third hand weeding	28/6	3rd hand weeding was done in plots as per treatment
13	First top dose of nitrogen	05/7	First top dose of nitrogen was applied through urea at knee high stage
14	Fourth hand weeding	05/7	4th hand weeding was done in plots as per treatment
15	Irrigation	06/7	Irrigation was given to the crop at knee high stage
16	Fifth hand weeding	12/7	5th hand weeding was done in plots as per treatment
17	Second top dose of nitrogen	02/8	Second top dose of nitrogen was applied through urea at tasselling initiation stage
18	Harvesting	28/9	After completion of picking the cobs, maize plants were cut with the help of sickles
19	Shelling	14/10	Grains were removed from the cobs manually using a grain sheller

3.6.5 Plant protection measures

Due to absence of disease/insects and pest problems, no plant protection measures were adopted. But, Carbofuran 3% at the rate of 20 kg ha^{-1} was applied in the soil prior to sowing to combat cutworm, which is widespread in the valley.

3.7 Herbicides used

3.7.1 Atrazine

Atrazine, 2-chloro-4-ethylamino-6-isopropylamino-s-triazine (Fig. 3) has been a major herbicide to manage grasses and broad leaved weeds in field crops, used either alone or in mix with several other herbicides (Zhao *et al*., 2017). It was first produced and sold approximately 50 years earlier and is currently the

second most used pesticide globally (Cheng *et al*., 2016). The pesticide atrazine belongs to triazine family and is built around a heterocyclic ring with three nitrogen atoms at 1st, 3rd and 5th site. The molecule has chlorine attached to the 2nd carbon of the triazine ring and side chains of isopropyl amine and ethylamine are attached to carbons at sites 6th and 4th respectively. It is sold under a series of trade names such as Candex, Atrataf, Weedex, Aatrex, Solaro, etc. By influencing the generation of nicotinamide adenine dinucleotide phosphate (NADPH) and adenosine triphosphate (ATP), it disrupts the photosystem II activity, consequently decreasing the efficiency of carbon dioxide fixation reaction (Qian *et al*., 2014). By restricting the electron transport mechanism in chloroplasts and injuring the membrane, atrazine is also accounted for quick accumulation of reactive oxygen species (ROS) (Wang *et al*., 2015). Atrazine's low adsorption, long half-life and moderate aqueous solubility represent that it is highly persistent in soil and can be found there even 22 years after application (Jablonowski *et al*., 2009).

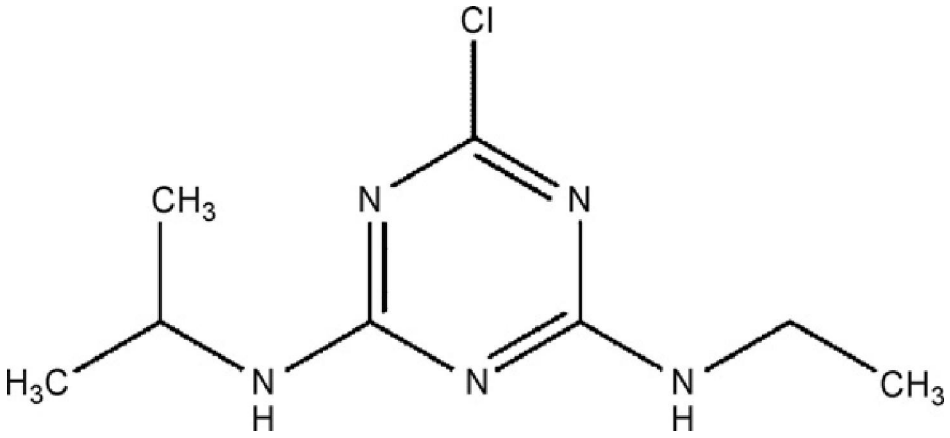

Fig. 3: The structure of atrazine

(2-chloro-4-ethylamino-6-isopropylamino-s-triazine)

3.7.2 Pendimethalin

Pendimethalin, 3, 4-Dimethyl-2, 6-dinitro-N-pentan-3-yl-aniline (Fig. 4), is a dinitroaniline compound, used in pre-emergence and post-emergence applications to control grasses and some broad leaved weeds. It is sold under different trade names such as prowl, pentagon, stomp, pendilin, etc. According to the classification of Herbicide Resistance Action Committee (HRAC), pendimethalin belongs to K1-group of herbicides. Pendimethalin suppresses weed growth via prevention of microtubule generation in cells, leading to interruption of cell division and cell elongation in shoot and root meristems of vulnerable plants. Following absorption through the shoot area and hypocotyls, the growth is immediately inhibited, soon after emerging from soil, the plants perish (Farm Chemicals International, 2015).

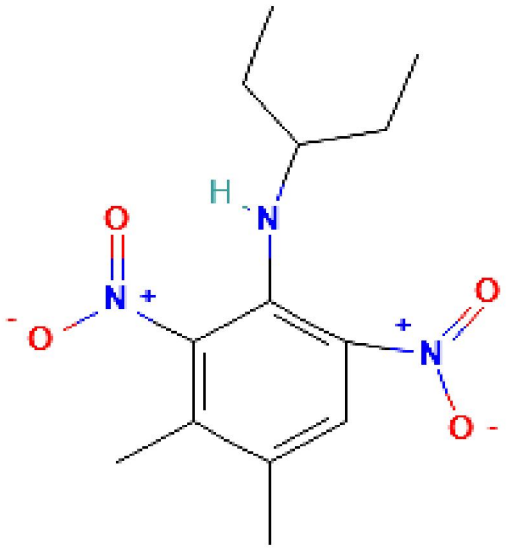

Fig. 4: The structure of pendimethalin

(3, 4-Dimethyl-2, 6-dinitro-N-pentan-3-yl-aniline)

3.8 Details of observations recorded

Five plants were randomly chosen from each plot of the three replications for observational purposes, eliminating the boundary rows, and the chosen plants were tagged. Then observations were periodically collected from the same plants. The following observations were recorded throughout the experimentation process.

3.8.1 Growth parameters

The growth parameters which comprised of plant height, number of functional leaves per plant, leaf area index, crop growth rate, relative growth rate, net assimilation rate and dry matter accumulation were computed at 30 days interval i.e., 30 DAS, 60 DAS, 90 DAS and at the time of harvesting. Five tagged plants were used to collect the observations for each treatment of each replication. The data was then averaged in order to get the mean values for each treatment.

3.8.1.1 Plant height (cm)

The height of five randomly tagged plants was measured from the base of the plant to the tip of the flag leaf from each plot at 30 days interval. Plant height was recorded as the average of these five tagged plants and expressed in centimetres.

3.8.1.2 Number of functional leaves plant^{-1}

From the five randomly tagged plants, all the green leaves deemed to be functional leaves were counted at 30 days interval and the average result was noted as number of functional leaves per plant.

3.8.1.3 Leaf area index

The same selected and marked plants were used to calculate the leaf area index, which was done at 30 days interval using the formula below:

$$Leaf\ area\ index\ (LAI) = \frac{Leaf\ area\ per\ plant(m^2)}{Ground\ area\ per\ plant(m^2)}$$

3.8.1.4 Crop growth rate (g m^{-2} day)

The increase in plant biomass per unit area per unit time was used to calculate crop growth rate, given in g m^{-2} day^{-1}. It was computed at the intervals between 0-30 DAS, 30-60 DAS, 60-90 DAS and 90 days – harvest. Redford's formula was used to calculate it (1967):

$$CGR\ (g\ m^{-2}\ day^{-1}) = \frac{W2\text{-}W1}{T_2\text{-}T_1} \times \frac{1}{A}$$

Where,

A is the area

W_1 and W_2 are dry matter production at time T_1 and T_2 respectively.

3.8.1.5 Relative growth rate (g g^{-1} day^{-1})

Relative growth rate indicates the increase in dry weight per unit time in comparison to its initial dry weight. It was calculated using Blackman's formula (1919) given below at intervals between 0-30 DAS, 30-60 DAS, 60-90 DAS, 90 days – harvest.

$$RGR\ (g\ g^{-1}\ day^{-1}) = \frac{In\ W2 - In\ W1}{T_2\text{-}T_1}$$

Where,

W_1 = dry weight at time T_1

W_2 = dry weight at time T_2.

3.8.1.6 Net assimilation rate (g m^{-2} day^{-1})

Net assimilation rate represents the rate of increase in dry weight per unit leaf area. It was also calculated at the intervals between 0-30 DAS, 30-60 DAS,

60-90 DAS and 90 days – harvesting using Gregory's formula (1926) as mentioned below:

$$NAR\ (g\ m^{-2}\ day^{-1}) = \frac{W2 - W1}{T_2 - T_1} \times \frac{In\ L2 - In\ L1}{L2 - L1}$$

Where,

W_1 = dry weight at time T_1

W_2 = dry weight at time T_2

L_1 and L_2 are total leaf area at time T_1 and T_2, respectively.

3.8.1.7 Dry matter accumulation (q ha^{-1})

At 30 days interval, five plants were cut from the base from each plot and sun-dried for a period of 2-3 days and then oven dried at 60-65 □C temperature till constant weight was obtained. After that they were weighed on weighing balance and the average was recorded as g plant^{-1} wich was then converted into q ha^{-1}.

3.8.2 Yield attributing characters

All the observations pertaining to yield attributing characters were recorded at post-harvest. The methodology for each of them is mentioned below:

3.8.2.1 Number of cobs plant^{-1}

The number of cobs per plant of selected and tagged plants was counted and average was represented as number of cobs plant^{-1}.

3.8.2.2 Number of grain rows cob^{-1}

From the five selected and tagged plants, number of grain rows per cob was counted and average was recorded as number of grains cob^{-1}.

3.8.2.3 Number of grains cob^{-1}

To find out the number of grains per cob, the total number of grains per cob of tagged plants was calculated manually and average was reported as number of grains cob^{-1}.

3.8.2.4 Seed index (g)

100 seeds were counted randomly for each plot, weighed by electric weighing machine and recorded as seed index in g.

3.8.3 Crop yield

3.8.3.1 Grain yield (q ha^{-1})

Cobs of de-husked plants from net plot area were properly sun dried and shelled with the help of cob-sheller. The produce was cleaned, weighed and recorded in kg ha^{-1} and then converted into q ha^{-1}.

3.8.3.2 Stover yield (q ha^{-1})

The fodder from net area of each plot was cut from ground level with the help of sickles, tied in the form of bundles, weighed in kg plot^{-1}, and then converted into q ha^{-1}. Husk obtained from de-husking of cobs was also included in stover yield.

3.8.3.3 Biological yield (q ha^{-1})

The produce from net area of each plot was weighed separately for grain and stover yield. Eventually biological yield was calculated by adding the grain and stover yield and recorded in q ha^{-1}.

3.8.3.4 Harvest index

It is the ratio of economic yield (i.e., grain yield) to biological yield (i.e., grain yield + stover yield) and is calculated by formula:

$$Harvest\ index = \frac{Grain\ yield}{Biological\ yield} \times 100$$

3.8.4 Plant analysis

Plant samples were collected before harvesting from each plot, shade dried for 24-48 hours and then oven dried at 60-65 □C for about 48 hours till constant weight. These samples were ground and stored in paper bags for further analysis. The different methods utilized during chemical analysis are mentioned below:

3.8.4.1 Plant nutrients

3.8.4.1.1 Nitrogen content and uptake

Nitrogen content of ground plant samples of maize was estimated using Modified Kjeldahl's Method (Jackson, 1973). The estimated nitrogen content of grain and stover was used to calculate the nitrogen uptake of grain and stover respectively, at harvest using formula given below:

$$\textit{Nitrogen uptake (kg ha}^{-1}\textit{)} = \frac{\textit{N content (\%)} \times \textit{Weight of dry matter}}{100}$$

3.8.4.1.2 Phosphorous content and uptake

The phosphorous content of grain and stover was estimated by Vanado-molybdate phosphoric acid yellow colour method **(**Jackson 1974). The phosphorous uptake of grain and stover was calculated by using estimated phosphorous content in grain and stover, respectively using formula:

$$\textit{Phosphorous uptake (kg ha}^{-1}\textit{)} = \frac{\textit{P content (\%)} \times \textit{Weight of dry matter}}{100}$$

3.8.4.1.3 Potassium content and uptake

The ground samples of grain and stover were digested separately with a di-acid mixture of nitric acid and perchloric acid and potassium content was determined by using Flame photometer after appropriate dilution process

(Jackson, 1974). The potassium uptake of grain and stover was estimated using potassium content of grain and stover, respectively using formula:

$$\textit{Potassium uptake (kg ha}^{-1}\textit{)} = \frac{\textit{K content (\%)} \times \textit{Weight of dry matter}}{100}$$

8.5 Soil analysis

Soil samples were collected before and after harvesting of crop from 0-15 cm soil profile. The samples were oven-dried for about 48 hours, processed and stored in paper bags for further analysis. The available N was estimated using alkaline $KMnO_4$ method (Subbiah and Asija, 1956) and recorded in kg ha^{-1}. The available phosphorous was estimated by Olsen's method (Olsen et al., 1954) and expressed as kg ha^{-1}. The available potassium was determined by neutral 1 N ammonium acetate extraction method (Jackson, 1973) and also expressed as kg ha^{-1}. The organic carbon was estimated by Walkley and Black wet oxidation method (Walkley and Black, 1934) and expressed as %.

3.8.6 Weed parameters

3.8.6.1 Weed identification

The major weeds associated with the maize crop were identified during the crop growth.

3.8.6.2 Weed density (No. m^{-2})

Weed density was calculated at periodic intervals, first reading was taken at 15 DAS then at 30 days interval i.e., 45 DAS, 75 DAS, and 105 DAS. A quadrant of 1 m^2 was thrown randomly in each plot at specific intervals; weeds inside it were cautiously cut near ground level and counted as total number of weeds per meter square. Further, the total weed number was classified as grasses, broad leaf weeds and sedges.

3.8.6.3 Weed dry matter accumulation (g m^{-2})

Weed dry matter accumulation was also calculated at periodic intervals i.e., 15 DAS, 45 DAS, 75 DAS, and 115 DAS. Weed samples inside 1 m^2 quadrant were counted species wise, oven dried at 60-65 □C temperature till constant weight was obtained and recorded in g m^{-2}.

3.8.6.4 Weed control efficiency (%)

The weed control efficiency (WCE) was calculated using formula given by Patel *et al*., 2006:

$$WCE\ (\%) = \frac{(DWC\text{-}DWT)}{DWC} \times 100$$

Where,

WCE = Weed Control Efficiency

DWC = Weed dry matter accumulation from control plot

DWT = Weed dry matter accumulation from treated plot

3.8.6.5 Weed index (%)

At harvest, weed index was calculated for different treatments using the following formula (Gill and Kumar, 1969):

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

Where,

WI = Weed Index

X = Yield from weed free plot

Y = Yield from treated plot

3.8.6.6 Herbicide efficiency index (%)

Herbicide efficiency index (HEI) was calculated using below mentioned formula (Krishnamurthy *et al*., 1975):

$$HEI\ (\%) = \frac{\frac{(Y_T - Y_C)}{Y_T} \times 100}{\frac{WDM_T}{WDM_C} \times 100}$$

Where,

Y_T = Yield from treated plot

Y_C = Yield from control plot

WDM_T = Weed dry matter accumulation from treated plot

WDM_C = Weed dry matter accumulation from control plot

3.8.7 Relative economics

3.8.7.1 Cost of cultivation (₹ ha^{-1})

This was worked out on the basis of cost of cultivation i.e., cost of fertilizers, herbicides, insecticides, seed, labour, FYM, tractorization and other miscellaneous costs involved and then expressed in ₹ ha^{-1}.

3.8.7.2 Gross returns (₹ ha^{-1})

Gross returns were calculated from cost of the produce i.e., grain and stover present in the market after harvest of crop and was recorded in ₹ ha^{-1}.

3.8.7.3 Net returns (₹ ha^{-1})

Net returns were calculated by subtracting gross returns from cost of cultivation and represented in ₹ ha^{-1}.

3.8.7.4 Benefit : cost ratio

Benefit: cost ratio (BCR) was calculated by dividing net returns with cost of cultivation and expressed as benefit per rupee invested in the crop.

3.9 Statistical analysis

The standard method of analysis of variance with RCBD was used to statistically analyse the experimental data. The significance of treatments was evaluated using F-test at the 0.05 level of probability. The software package used for data analysis was "OPSTAT". In case of treatments that were statistically significant at ($p<0.05$) critical difference was calculated to compare the effects of different treatments and pair-wise comparisons were done in R- software.

Pre-sowing field operation

Sowing of seeds

Calculation of weed density

Measuring plant height of maize

Sample collection for analysis

Counting number of functional leaves

Plate 1: An overview of field activities

Phosphorous estimation in soil

Nitrogen estimation in soil

Digestion in block digester

pH determination in soil

Readings from spectrophotometer

Phosphorous estimation in plants

Plate 2: An overview of lab activities

Chapter – 4

EXPERIMENTAL FINDINGS

This chapter summarizes the observations recorded and findings obtained during the course of investigation. After carrying out the proper statistical analysis the data has been represented in the form of tables and demonstrated in the form of graphs wherever deemed to be mandatory.

4.1 Growth parameters

4.1.1 Plant height (cm)

The data pertaining to plant height of maize for different treatments, recorded at 30 days interval is presented in Table 5 and Fig. 5. Plant height being an important growth parameter was found to vary significantly among different weed management practices. It was observed that the plant height of maize crop increased from sowing to harvest, however, the magnitude of increment was more than double during the interval of 30–60 days after sowing.

At all the intervals, highest plant height was recorded in T_{13} (weed free treatment) and lowest plant height was recorded in T_{12} (weedy check). At 30 days after sowing (DAS), T_{13} (weed free treatment) was followed by T_{11} (hand weeding after 3, 5 and 7 WAS), however, it was at par with T_2 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 4 WAS), T_1 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 3 WAS), T_7 (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 4 WAS), T_6 (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 3 WAS) T_3 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 5 WAS) and T_8 (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 5 WAS) respectively. From 60 DAS to harvest, highest plant height was recorded in T_{13} (weed free treatment) followed by T_{11} (hand weeding at 3, 5 and 7 WAS) and T_2 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 4 WAS) respectively. However, T_2 was at par with T_1 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 3 WAS), T_7 (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 4 WAS), T_6 (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand

weeding at 3 WAS), T_3 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 5 WAS) and T_8 (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 5 WAS). The other treatments followed the trend: T_4 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 6 WAS) > T_9 (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 6 WAS) > T_5 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 7 WAS) > T_{10} (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 7 WAS) (Plate 3).

4.1.2 Number of functional leaves plant^{-1}

The data pertaining to number of functional leaves per plant taken at 30 days interval is shown in Table 6 and Fig. 6. It was observed that there was increase in number of functional leaves per plant upto 60 days after sowing, afterwards it decreased upto harvest and same trend was recorded in other treatments.

Highest number of functional leaves per plant was recorded in T_{13} (weed free treatment) and lowest number of functional leaves per plant was recorded in T_{12} (weedy check) throughout the crop growth period. At 30 DAS, T_{13} (weed free treatment) was followed by T_{11} (hand weeding after 3, 5 and 7 WAS) though, it was at par with T_2 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 4 WAS), T_1 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 3 WAS), T_7 (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 4 WAS), T_6 (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 3 WAS), T_3 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 5 WAS) and T_8 (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 5 WAS) respectively. At 60 days after sowing upto harvest T_{13} (weed free treatment) was followed by T_{11} (hand weeding at 3, 5 and 7 WAS) and T_2 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 4 WAS). However, T_2 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 4 WAS) was statistically at par with T_1 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 3 WAS), T_7 (Pendimethalin @

Table 5: Effect of weed management practices on plant height (cm) of maize at periodic intervals

Treatments	30 DAS	60 DAS	90 DAS	At harvest
T_1 Atrazine @ 1.5 kg ha^{-1} (PE) *fb* HW 3 WAS	50.93	153.96	192.17	199.58
T_2 Atrazine @ 1.5 kg ha^{-1} (PE) *fb* HW 4 WAS	51.58	154.45	193.30	200.38
T_3 Atrazine @ 1.5 kg ha^{-1} (PE) *fb* HW 5 WAS	49.96	150.67	189.63	198.55
T_4 Atrazine @ 1.5 kg ha^{-1} (PE) *fb* HW 6 WAS	46.56	137.54	175.59	183.55
T_5 Atrazine @ 1.5 kg ha^{-1} (PE) *fb* HW 7 WAS	45.41	135.14	170.13	179.08
T_6 Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* HW 3 WAS	50.12	151.95	191.16	199.08
T_7 Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* HW 4 WAS	50.67	152.52	191.23	199.25
T_8 Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* HW 5 WAS	49.78	149.61	189.52	197.10
T_9 Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* HW 6 WAS	46.17	137.47	175.36	183.16
T_{10} Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* HW 7 WAS	45.02	134.29	170.03	179.05
T_{11} Hand weeding after 3, 5 and 7 WAS	52.49	166.56	206.80	213.85
T_{12} Weedy check	32.10	104.48	127.19	135.02
T_{13} Weed free	56.57	178.31	219.43	227.38
SE (m) ±	0.99	3.54	4.62	4.68
CD ($p \leq 0.05$)	**2.91**	**11.33**	**13.17**	**13.42**

Where, HW = hand weeding, DAS = days after sowing, WAS = weeks after sowing

Table 6: Effect of weed management practices on number of functional leaves plant^{-1} of maize at periodic intervals

Treatments	30 DAS	60 DAS	90 DAS	At harvest
T_1 Atrazine @ 1.5 kg ha^{-1} (PE) *fb* HW 3 WAS	8.03	12.45	10.13	6.37
T_2 Atrazine @ 1.5 kg ha^{-1} (PE) *fb* HW 4 WAS	8.04	12.46	10.14	6.42
T_3 Atrazine @ 1.5 kg ha^{-1} (PE) *fb* HW 5 WAS	7.95	12.34	10.02	6.28
T_4 Atrazine @ 1.5 kg ha^{-1} (PE) *fb* HW 6 WAS	7.02	10.68	8.64	5.18
T_5 Atrazine @ 1.5 kg ha^{-1} (PE) *fb* HW 7 WAS	6.92	10.34	8.42	5.11
T_6 Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* HW 3 WAS	7.97	12.38	10.05	6.32
T_7 Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* HW 4 WAS	7.98	12.39	10.07	6.35
T_8 Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* HW 5 WAS	7.92	12.31	10.00	6.26
T_9 Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* HW 6 WAS	6.98	10.67	8.63	5.16
T_{10} Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* HW 7 WAS	6.90	10.31	8.36	5.09
T_{11} Hand weeding after 3, 5 and 7 WAS	8.08	14.07	11.34	7.43
T_{12} Weedy check	5.98	8.27	7.01	4.03
T_{13} Weed free	8.99	15.54	12.54	8.55
SE (m) ±	0.30	0.41	0.34	0.30
CD ($p \leq 0.05$)	**0.87**	**1.15**	**1.06**	**0.87**

Where, HW = hand weeding, DAS = days after sowing, WAS = weeks after sowing

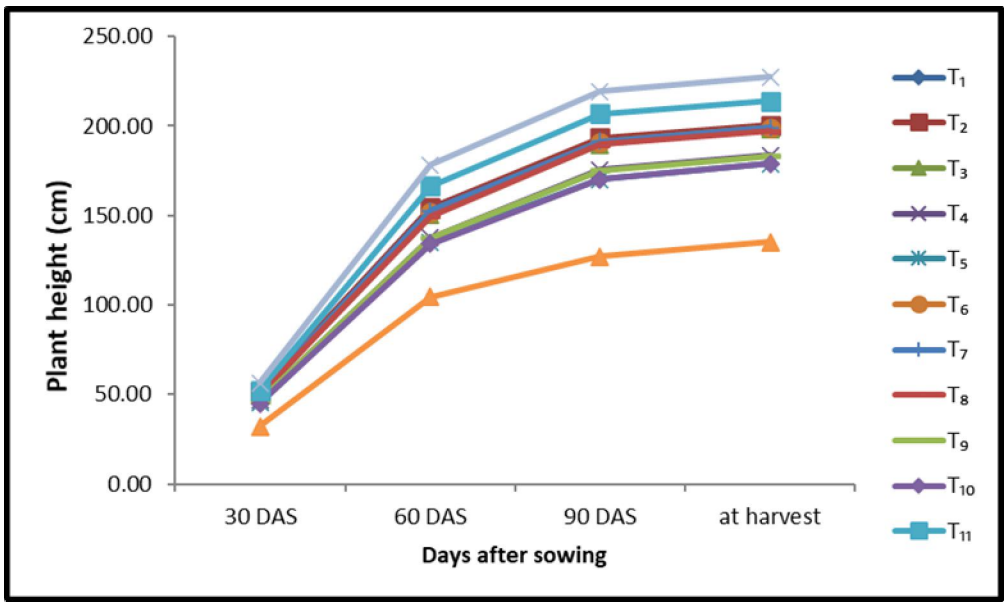

Fig. 5: Effect of weed management practices on plant height (cm) of maize at periodic intervals

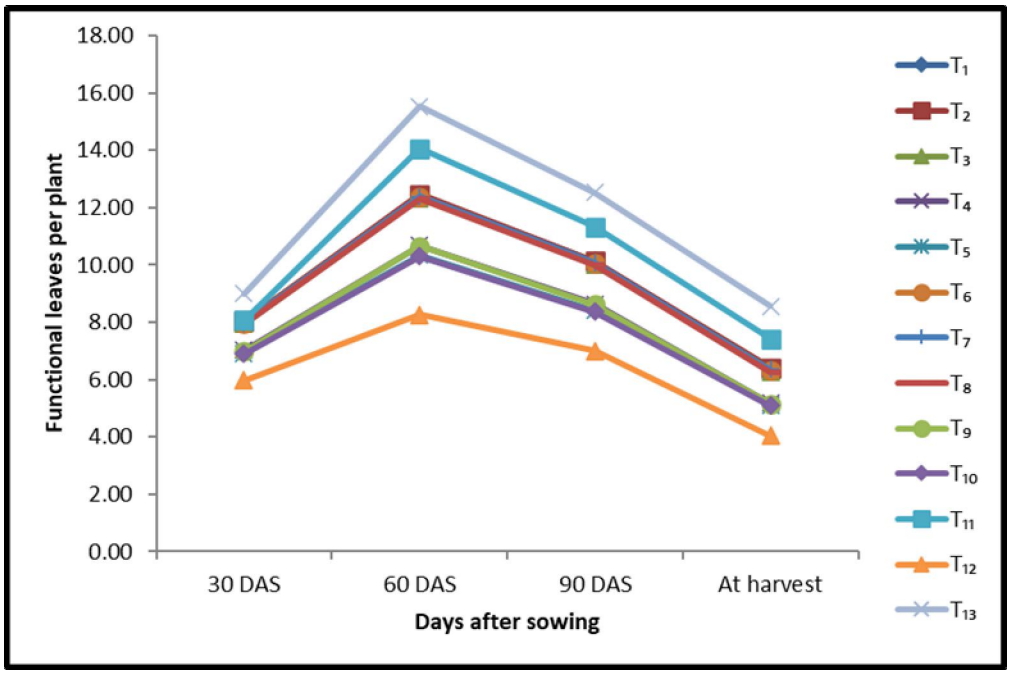

Fig. 6: Effect of weed management practices on number of functional leaves plant^{-1} of maize at periodic intervals T_{12} (Weedy check)

T_{12} (Weedy check)

T_2 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 4 WAS)

Plate 3: Comparison between T_{12} and T_2

1.5 kg ha^{-1} (PE) *fb* hand weeding at 4 WAS), T_6 (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at WAS), T_3 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 5 WAS) and T_8 (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 5 WAS). The remaining treatments showed the trend: T_4 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 6 WAS) >T_9 (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 6 WAS) >T_5 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 7 WAS) >T_{10} (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 7 WAS).

4.1.3 Dry matter accumulation (q ha^{-1})

The effect of different weed management practices on dry matter accumulation at 30 days interval i.e., 30, 60, 90 DAS and harvest is recorded in Table 7 and graphically indicated in Fig. 7. Perusal of the data revealed that dry matter accumulation was increasing with the development of the crop and there was manifold increase during the interval of 30-60 days after sowing.

Highest dry matter accumulation was recorded in T_{13} (Weed free treatment) at all periodic intervals. At 30 days after sowing, T_{13} (weed free treatment) was followed by T_{11} (hand weeding at 3, 5 and 7 WAS). Although T_{11} was at par with T_2 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 4 WAS), T_1 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 3 WAS), T_7 (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 4 WAS), T_6 (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 3 WAS), T_3 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 5 WAS) and T_8 (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 5 WAS) respectively. At subsequent periodic interval upto harvest, after T_{13} (weed free treatment) highest dry matter accumulation was recorded in T_{11} (hand weeding after 3, 5 and 7 WAS) followed by T_2 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 4 WAS) but T_2 was at par with T_1 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 3 WAS), T_7 (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 4 WAS), T_6 (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 3 WAS), T_3 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 5 WAS) and T_8 (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 5 WAS) respectively. Rest weed management practices revealed the trend: T_4 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb*

hand weeding at 6 WAS) >T_9 (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 6 WAS) >T_5 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 7 WAS) > T_{10} (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 7 WAS). Least dry matter accumulation was reported in weedy check plots (T_{12}) throughout the crop growth (Plate 4).

4.1.4 Leaf area index

The data on leaf area index of maize crop at 30 days interval during experimentation is presented in Table 8. The pattern of increment in leaf area index is graphically depicted in Fig. 8. The data indicated that leaf area index increased consistently upto 60 days after sowing and decreased thereafter irrespective of treatments.

The results revealed that highest leaf area index was recorded in T_{13} (weed free) and lowest leaf area was observed in T_{12} (weedy check). Among other treatments under study T_{13} (weed free) was followed by T_{11} (hand weeding after 3, 5 and 7 WAS) however, T_{11} was at par with T_2 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 4 WAS), T_1 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 3 WAS), T_7 (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 4 WAS), T_6 (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 3 WAS), T_3 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 5 WAS) and T_8 (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 5 WAS) at 30 DAS. At remaining intervals after 30 DAS, T_{13} (weed free) was followed by T_{11} (hand weeding after 3, 5 and 7 WAS) and T_2 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 4 WAS) but T_2 was at par with T_1 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 3 WAS), T_7 (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 4 WAS), T_6 (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 3 WAS), T_3 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 5 WAS) and T_8 (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 5 WAS) respectively. The other treatments followed the trend: T_4 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 6 WAS) > T_9 (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 6 WAS) > T_5 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 7 WAS) > T_{10} (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 7 WAS) .

Table 7: Effect of weed management practices on dry matter accumulation (q ha^{-1}) of maize at periodic intervals

Treatments	30 DAS	60 DAS	90 DAS	Harvest
T_1 Atrazine @ 1.5 kg ha^{-1} (PE) *fb* HW 3 WAS	9.34	50.43	98.24	107.12
T_2 Atrazine @ 1.5 kg ha^{-1} (PE) *fb* HW 4 WAS	9.49	50.70	99.11	108.16
T_3 Atrazine @ 1.5 kg ha^{-1} (PE) *fb* HW 5 WAS	9.18	48.27	91.36	100.21
T_4 Atrazine @ 1.5 kg ha^{-1} (PE) *fb* HW 6 WAS	8.16	40.63	76.29	85.25
T_5 Atrazine @ 1.5 kg ha^{-1} (PE) *fb* HW 7 WAS	8.05	38.27	73.86	82.79
T_6 Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* HW 3 WAS	9.23	49.24	96.84	105.91
T_7 Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* HW 4 WAS	9.27	49.46	97.09	106.11
T_8 Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* HW 5 WAS	9.15	47.53	91.28	100.14
T_9 Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* HW 6 WAS	8.15	40.45	76.16	85.20
T_{10} Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* HW 7 WAS	8.00	38.19	73.76	82.68
T_{11} Hand weeding after 3, 5 and 7 WAS	9.61	57.49	112.10	122.07
T_{12} Weedy check	6.93	18.83	47.03	56.02
T_{13} Weed free	10.82	64.18	125.45	134.64
SE (m) ±	0.29	2.20	3.79	4.01
CD ($p \leq 0.05$)	**0.86**	**6.45**	**11.12**	**11.77**

Where, HW = hand weeding, DAS = days after sowing, WAS = weeks after sowing

Table 8: Effect of weed management practices on LAI of maize at periodic intervals

Treatments	30 DAS	60 DAS	90 DAS	Harvest
T_1 Atrazine @ 1.5 kg ha^{-1} (PE) *fb* HW 3 WAS	2.25	5.42	4.24	1.60
T_2 Atrazine @ 1.5 kg ha^{-1} (PE) *fb* HW 4 WAS	2.26	5.43	4.26	1.61
T_3 Atrazine @ 1.5 kg ha^{-1} (PE) *fb* HW 5 WAS	2.06	5.36	4.19	1.54
T_4 Atrazine @ 1.5 kg ha^{-1} (PE) *fb* HW 6 WAS	1.75	4.41	3.21	1.13
T_5 Atrazine @ 1.5 kg ha^{-1} (PE) *fb* HW 7 WAS	1.62	4.36	3.18	1.06
T_6 Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* HW 3 WAS	2.15	5.38	4.22	1.56
T_7 Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* HW 4 WAS	2.18	5.40	4.23	1.58
T_8 Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* HW 5 WAS	2.06	5.35	4.17	1.54
T_9 Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* HW 6 WAS	1.73	4.40	3.20	1.13
T_{10} Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* HW 7 WAS	1.61	4.34	3.17	1.05
T_{11} Hand weeding after 3, 5 and 7 WAS	2.28	6.37	5.21	2.03
T_{12} Weedy check	1.20	3.43	2.25	0.62
T_{13} Weed free	2.67	7.32	6.15	2.45
SE (m) ±	0.08	0.25	0.28	0.12
CD ($p \leq 0.05$)	**0.23**	**0.74**	**0.83**	**0.34**

Where, HW = hand weeding, DAS = days after sowing, WAS = weeks after sowing

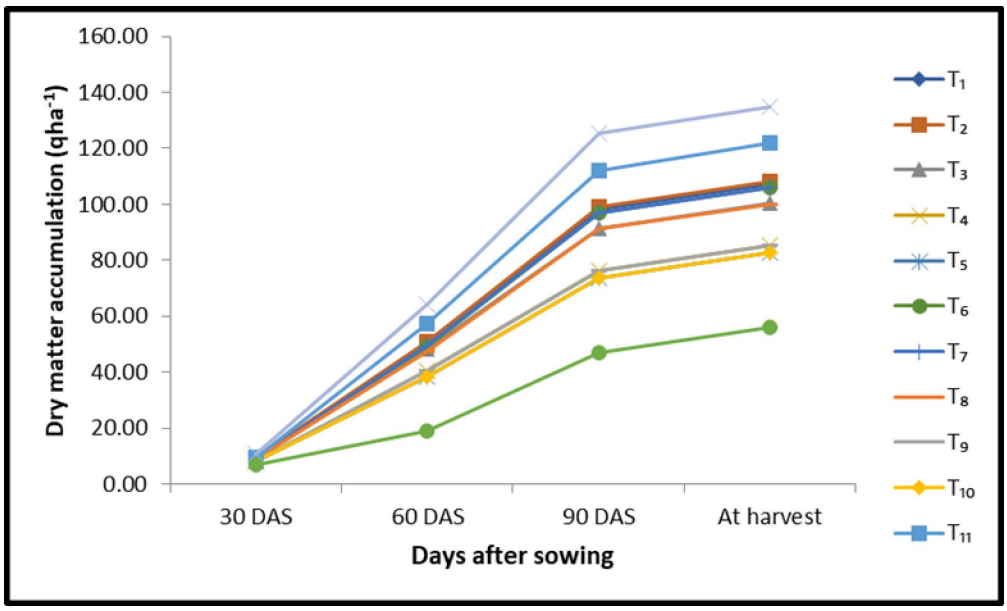

Fig. 7: Effect of weed management practices on dry matter accumulation (q ha^{-1}) of maize at periodic intervals

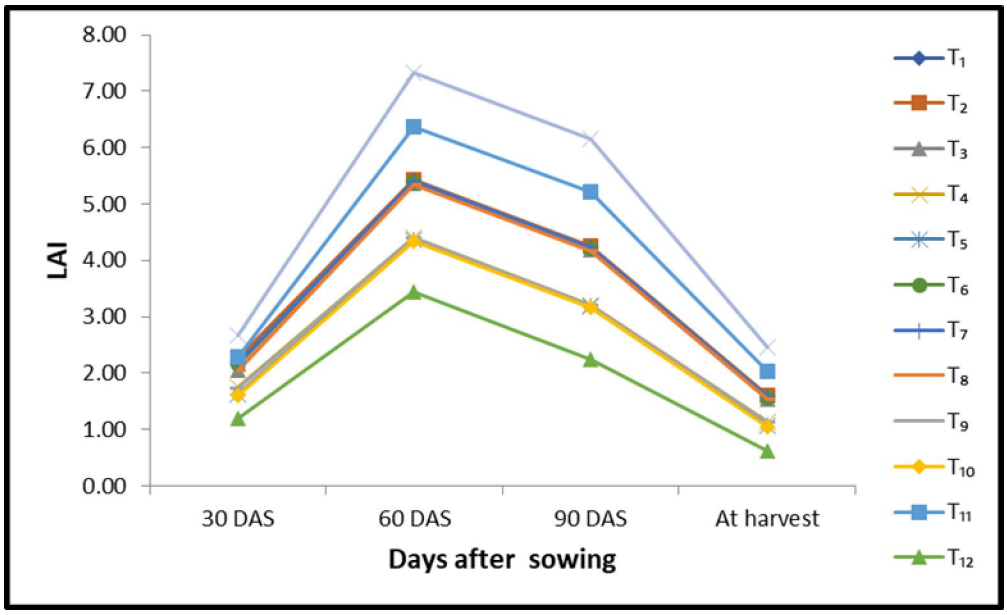

Fig. 8: Effect of weed management practices on LAI of maize at periodic intervals

T_{11} (Hand weeding at 3, 5 and 7 weeks after sowing)

T_{10} (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 7 WAS)

Plate 4: Comparison between T_{11} and T_{10}

4.1.5 Growth analysis

The data petaining to crop growth rate (CGR) in maize crop recorded at 30 days interval i.e., 0-30 DAS, 30-60 DAS, 60-90 DAS and 90-Harvest is presented in Table 9 and Fig. 9. The results indicated that CGR increased upto 90 days after sowing and decreased thereafter irrespective of the treatments. Highest crop growth rate for all treatments was obtained during 60-90 days after sowing. During second interval i.e., from 30-60 DAS, T_{13} (weed free) excelled all other treatments and recorded highest crop growth rate, it was followed by T_{11} (hand weeding after 3, 5 and 7 WAS) and T_2 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 4 WAS). However, T_2 was at par with T_1 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 3 WAS), T_7 (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 4 WAS), T_6 (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 3 WAS), T_3 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 5 WAS) and T_8 (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 5 WAS) respectively. During all other intervals higher crop growth rate was obtained for T_{13} (weed free) followed by T_{11} (hand weeding after 3, 5 and 7 weeks after sowing). Though, T_{11} was statistically at par with T_2 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 4 WAS), T_1 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 3 WAS), T_7 (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 4 WAS), T_6 (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 3 WAS), T_3 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 5 WAS) and T_8 (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 5 WAS). The other treatments revealed the trend: T_4 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 6 WAS) > T_9 (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 6 WAS) > T_5 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 7 WAS) > T_{10} (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 7 WAS). Least crop growth rate was obtained in T_{12} (weedy check) among all the treatments.

The data pertaining to relative growth rate was calculated by using the prescribed formula at 30 days interval and is shown in the Table 10 and

graphically outlined in Fig. 10. Evaluating the data revealed that relative growth rate decreased from first interval upto harvest in all treatments. At all intervals highest relative growth rate was observed in T_{13} (weed free) followed by plots treated with T_{11} (hand weeding after 3, 5 and 7 weeks after sowing). Although, T_{11} was found to be statistically at par with T_2 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 4 WAS), T_1 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 3 WAS), T_7 (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 4 WAS), T_6 (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 3 WAS), T_3 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 5 WAS) and T_8 (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 5 WAS). Throughout the growth period lowest relative growth rate was observed in T_{12} (weedy check).

The data representing net assimilation rate is recorded in Table 11 and outlined graphically in Fig. 11. Assessing the data showed that net assimilation rate increased from 30 - 90 days after sowing and declined after that upto harvest. Lowest net assimilation rate was shown by plants in T_{12} (weedy check) and highest rate of net assimilation was observed by T_{13} (weed free) which was at par with T_{11} (hand weeding after 3, 5 and 7 WAS), T_2 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 4 WAS), T_1 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 3 WAS), T_7 (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 4 WAS), T_6 (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 3 WAS). The remaining treatments were observed as: T_3 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 5 WAS) > T_8 (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 5 WAS) > T_4 Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 6 WAS) >T_9 (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 6 WAS) > T_5 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 7 WAS) >T_{10} (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 7 WAS).

Table 9: Effect of weed management practices on crop growth rate (g m^{-2} day^{-1}) of maize at periodic intervals

Treatments	0-30 DAS	30-60 DAS	60-90 DAS	90-Harvest
T_1 Atrazine @ 1.5 kg ha^{-1} (PE) *fb* HW 3 WAS	2.59	11.41	13.81	3.24
T_2 Atrazine @ 1.5 kg ha^{-1} (PE) *fb* HW 4 WAS	2.64	11.45	13.91	3.25
T_3 Atrazine @ 1.5 kg ha^{-1} (PE) *fb* HW 5 WAS	2.55	10.86	13.72	3.15
T_4 Atrazine @ 1.5 kg ha^{-1} (PE) *fb* HW 6 WAS	2.27	9.02	12.67	2.56
T_5 Atrazine @ 1.5 kg ha^{-1} (PE) *fb* HW 7 WAS	2.24	8.39	12.33	2.50
T_6 Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* HW 3 WAS	2.56	11.11	13.77	3.18
T_7 Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* HW 4 WAS	2.57	11.16	13.80	3.20
T_8 Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* HW 5 WAS	2.54	10.66	13.66	3.14
T_9 Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* HW 6 WAS	2.26	8.97	12.36	2.54
T_{10} Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* HW 7 WAS	2.22	8.39	12.31	2.48
T_{11} Hand weeding after 3, 5 and 7 WAS	2.67	13.30	15.17	3.40
T_{12} Weedy check	1.93	6.19	8.64	1.43
T_{13} Weed free	3.01	15.21	17.49	4.30
SE (m) ±	**0.08**	**0.62**	**0.76**	**0.27**
CD ($p \leq 0.05$)	**0.25**	**1.82**	**2.23**	**0.79**

Where, HW = hand weeding, DAS = days after sowing, WAS = weeks after sowing

Table 10: Effect of weed management practices on relative growth rate (mg g^{-1} day^{-1}) of maize at periodic intervals

Treatments	0-30 DAS	30-60 DAS	60-90 DAS	90-Harvest
T_1 Atrazine @ 1.5 kg ha^{-1} (PE) *fb* HW 3 WAS	74.47	55.75	25.00	3.38
T_2 Atrazine @ 1.5 kg ha^{-1} (PE) *fb* HW 4 WAS	74.98	55.96	25.91	3.77
T_3 Atrazine @ 1.5 kg ha^{-1} (PE) *fb* HW 5 WAS	73.90	55.27	23.81	2.94
T_4 Atrazine @ 1.5 kg ha^{-1} (PE) *fb* HW 6 WAS	69.99	53.07	23.39	2.90
T_5 Atrazine @ 1.5 kg ha^{-1} (PE) *fb* HW 7 WAS	69.52	51.84	22.85	2.86
T_6 Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* HW 3 WAS	73.95	55.36	23.96	2.96
T_7 Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* HW 4 WAS	74.01	55.61	24.93	3.19
T_8 Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* HW 5 WAS	73.79	54.78	23.65	2.91
T_9 Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* HW 6 WAS	69.93	53.07	22.88	2.89
T_{10} Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* HW 7 WAS	69.31	51.92	22.63	2.79
T_{11} Hand weeding after 3, 5 and 7 WAS	75.42	56.50	26.32	3.81
T_{12} Weedy check	64.52	24.84	18.12	2.30
T_{13} Weed free	79.29	61.21	30.26	5.73
SE (m) ±	1.01	1.44	1.15	0.25
CD ($p \leq 0.05$)	**2.98**	**4.21**	**3.39**	**0.74**

Where, HW = hand weeding, DAS = days after sowing, WAS = weeks after sowing

Table 11: Effect of weed management practices on net assimilation rate (g m^{-2} day^{-1}) of maize at periodic intervals

Treatments	0-30 DAS	30-60 DAS	60-90 DAS	90-Harvest
T_1 Atrazine @ 1.5 kg ha^{-1} (PE) *fb* HW 3 WAS	1.326	1.760	2.875	2.462
T_2 Atrazine @ 1.5 kg ha^{-1} (PE) *fb* HW 4 WAS	1.329	1.766	2.878	2.476
T_3 Atrazine @ 1.5 kg ha^{-1} (PE) *fb* HW 5 WAS	1.220	1.515	2.601	1.885
T_4 Atrazine @ 1.5 kg ha^{-1} (PE) *fb* HW 6 WAS	1.218	1.319	2.489	1.865
T_5 Atrazine @ 1.5 kg ha^{-1} (PE) *fb* HW 7 WAS	1.211	1.257	2.471	1.821
T_6 Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* HW 3 WAS	1.321	1.749	2.797	2.440
T_7 Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* HW 4 WAS	1.324	1.754	2.838	2.445
T_8 Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* HW 5 WAS	1.220	1.474	2.570	1.882
T_9 Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* HW 6 WAS	1.215	1.314	2.485	1.852
T_{10} Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* HW 7 WAS	1.210	1.231	2.468	1.816
T_{11} Hand weeding after 3, 5 and 7 WAS	1.333	1.860	2.906	2.512
T_{12} Weedy check	1.120	1.095	2.156	1.171
T_{13} Weed free	1.340	1.898	2.945	2.542
SE (m) ±	0.036	0.064	0.103	0.213
CD ($p \leq 0.05$)	**0.075**	**0.133**	**0.302**	**0.627**

Where, HW = hand weeding, DAS = days after sowing, WAS = weeks after sowing

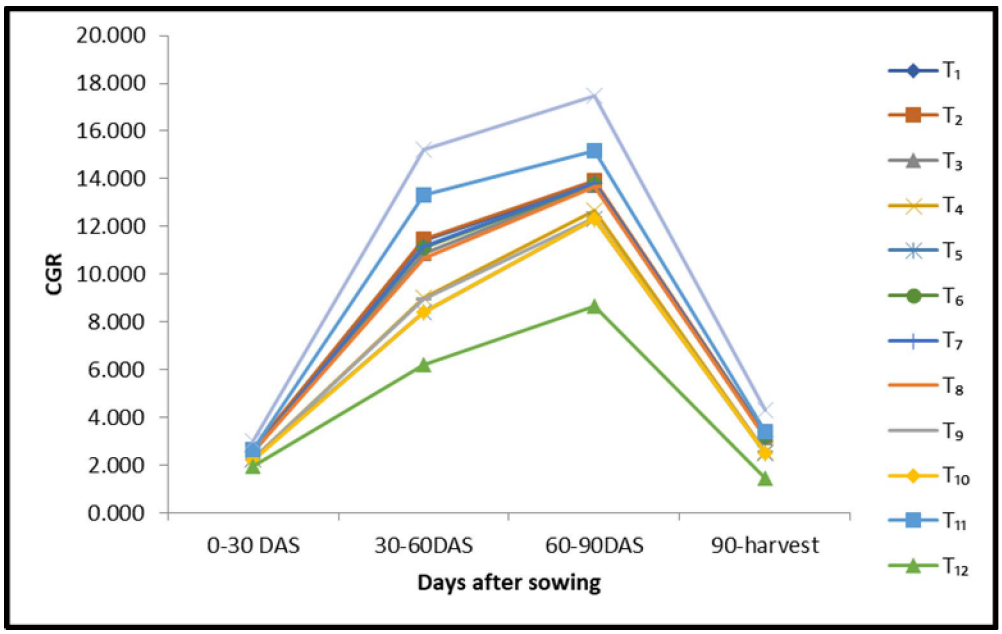

Fig. 9: Effect of weed management practices on crop growth rate (g m^{-2} day^{-1}) of maize at periodic intervals

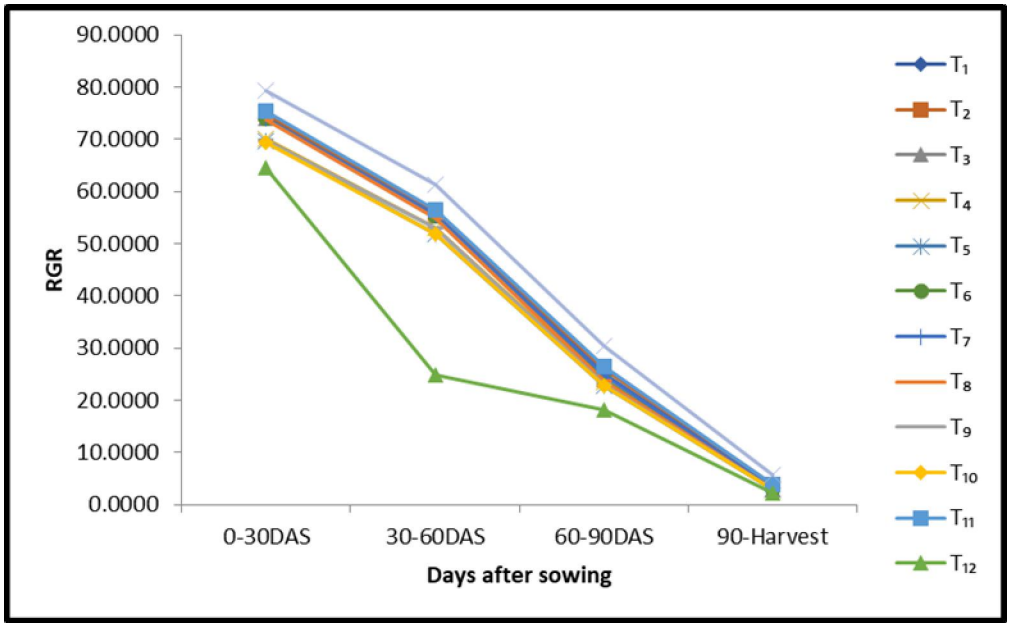

Fig. 10: Effect of weed management practices on net assimilation rate (g m^{-2} day^{-1}) of maize at periodic intervals

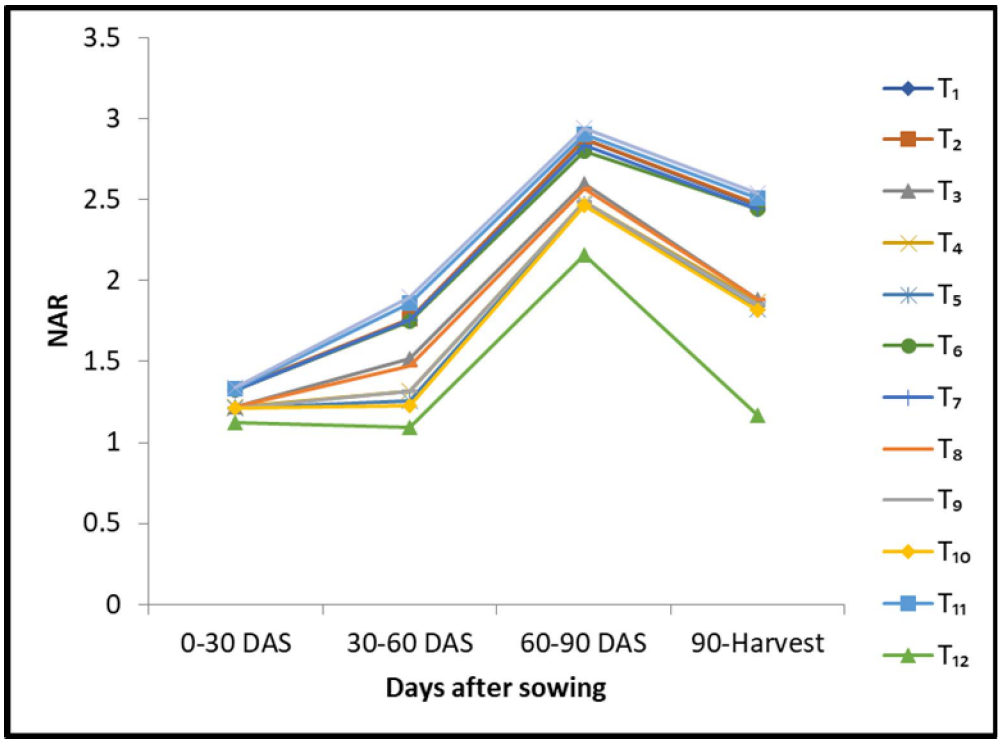

Fig. 11: Effect of weed management practices on net assimilation rate (g m^{-2} day^{-1}) of maize at periodic intervals

4.2 Yield attributing characters

4.2.1 Number of cobs plant^{-1}

The data pertaining to number of cobs per plant is represented in Table 12. Analysis of the data revealed that some weed management practices were found significant with respect to number of cobs per plant. Highest number of cobs per plant were found in T_{13} (weed free) which was statistically at par with all other treatments except T_{12} (weedy check). Lowest number of cobs per plant were found in T_{12} (weedy check).

4.2.2 Number of grain rows cob^{-1}

Data related to number of grains rows per cob is shown in Table 12. The data indicated that weed management practices were significant in relation with number of grain rows per cob. Highest number of grain rows per cob were observed in T_{13} (weed free), however, it was at par with T_{11}, T_2 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 4 WAS), T_1 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 3 WAS), T_7 (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 4 WAS), T_6 (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 3 WAS), T_3 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 5 WAS), T_8 (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 5 WAS). The rest of the treatments revealed the pattern: T_4 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 6 WAS) >T_9 (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 6 WAS) > T_5 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 7 WAS) >T_{10} (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 7 WAS). Lowest number of grain rows per cob were found in T_{12} (weedy check).

4.2.3 Number of grains cob^{-1}

Number of grains per cob were found significant concerning different weed management practices and data pertaining to it is presented in Table 12. Examining the data revealed that T_{13} (weed free) outperformed all other treatments and recorded highest number of grains per cob but it was at par with

T_{11} (hand weeding after 3, 5 and 7 WAS). T_{11} was followed by T_2 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 4 WAS) which was at par with T_1 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 3 WAS), T_7 (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 4 WAS), T_6 (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 3 WAS), T_3 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 5 WAS), T_8 (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 5 WAS). Least number of grains per cob were reported in T_{12} (weedy check). Other weed management practices showed the trend as: T_4 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 6 WAS) > T_9 (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 6 WAS) > T_5 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 7 WAS) >T_{10} (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 7 WAS).

4.2.4 Seed index

The data related to seed index is shown in Table 12, it represented that weed management practices were found significant in relation to seed index. Highest seed index was found in T_{13} (weed free) being at par with T_{11} (hand weeding after 3, 5 and 7 WAS) and lowest seed index was recorded in T_{12} (weedy check). T_{11} was followed by T_2 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 4 WAS). But, T_2 was statistically at par with T_1 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 3 WAS), T_7 (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 4 WAS), T_6 (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 3 WAS), T_3 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 5 WAS), T_8 (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 5 WAS). Rest treatments followed trend: T_4 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 6 WAS) > T_9 (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 6 WAS) > T_5 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 7 WAS) > T_{10} (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 7 WAS).

Table 12: Effect of weed management practices on yield attributes of maize

Treatments	No. of cobs plant^{-1}	No. of grain rows cob^{-1}	No. of grains cob^{-1}	Seed index (g)
T_1 Atrazine @ 1.5 kg ha^{-1} (PE) *fb* HW 3 WAS	1.20	14.27	355.58	20.10
T_2 Atrazine @ 1.5 kg ha^{-1} (PE) *fb* HW 4 WAS	1.21	14.39	357.66	20.12
T_3 Atrazine @ 1.5 kg ha^{-1} (PE) *fb* HW 5 WAS	1.19	13.95	346.44	19.94
T_4 Atrazine @ 1.5 kg ha^{-1} (PE) *fb* HW 6 WAS	1.17	13.18	330.82	18.15
T_5 Atrazine @ 1.5 kg ha^{-1} (PE) *fb* HW 7 WAS	1.17	12.87	313.02	17.92
T_6 Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* HW 3 WAS	1.20	14.02	348.60	20.05
T_7 Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* HW 4 WAS	1.20	14.04	349.70	20.07
T_8 Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* HW 5 WAS	1.18	13.91	345.98	19.91
T_9 Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* HW 6 WAS	1.17	13.15	320.47	18.13
T_{10} Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* HW 7 WAS	1.16	12.82	310.15	17.89
T_{11} Hand weeding after 3, 5 and 7 WAS	1.21	16.36	372.68	21.86
T_{12} Weedy check	1.07	9.25	242.75	12.73
T_{13} Weed free	1.21	16.56	374.23	21.91
SE (m) ±	0.03	0.86	3.98	0.88
CD ($p \leq 0.05$)	**0.05**	**2.53**	**11.71**	**2.58**

Where, HW = hand weeding, WAS = weeks after sowing

4.3 Crop yield

4.3.1 Grain yield

The effect of different weed management practices on grain yield is represented in Table 13 and Fig. 12. Different weed management practices varied significantly in relation to grain yield. T_{13} treatment (Weed free) excelled all treatments under investigation and recorded highest grain yield. T_{13} was followed by T_{11} (hand weeding after 3, 5 & 7 WAS) and T_2 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 4 WAS). However, T_2 was at par with T_1 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 3 WAS), T_7 (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 4 WAS), T_6 (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 3 WAS), T_3 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 5 WAS), T_8 (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 5 WAS). Moreover, the other treatments revealed the trend as: T_4 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 6 WAS) > T_9 (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 6 WAS) > T_5 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 7 WAS) > T_{10} (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 7 WAS). The lowest grain yield was found in T_{12} (weedy check).

4.3.2 Stover yield

The data related to stover yield of maize is represented in Table 13 and depicted in Fig. 12. The weed management practices differed significantly with respect to stover yield. T_{13} (Weed free) outperformed all other weed management practices for stover yield and least stover yield was witnessed in T_{12} (weedy check). Among other treatments under study T_{13} was followed by T_{11} (hand weeding after 3, 5 and 7 WAS) and T_2 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 4 WAS). Although, T_2 was at par with T_1 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 3 WAS), T_7 (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 4 WAS), T_6 (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 3 WAS), T_3 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 5 WAS), T_8

(Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 5 WAS). Rest of the treatments showed the trend as follows; T_4 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 6 WAS) > T_9 (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 6 WAS) > T_5 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 7 WAS) > T_{10} (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 7 WAS).

4.3.3 Biological yield

All the weed management practices differed significantly in relation to biological yield and the data related to it is shown in Table 13 and portrayed in Fig. 12. T_{13} (weed free) was found superior in comparison to all other treatments under study, recorded highest biological yield and lowest biological yield was reported in T_{12} (weedy check). T_{13} was succeeded by T_{11} (hand weeding after 3, 5 and 7 WAS) and T_2 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 4 WAS) but T_2 was statistically at par with T_1 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 3 WAS), T_7 (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 4 WAS), T_6 (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 3 WAS), T_3 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 5 WAS), T_8 (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 5 WAS). Remaining weed management practices showed the pattern: T_4 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 6 WAS) > T_9 (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 6 WAS) > T_5 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 7 WAS) > T_{10} (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 7 WAS).

Table 13: Effect of weed management practices on grain yield, stover yield, biological yield and harvest index of maize

Treatments	Grain yield (q ha^{-1})	Stover yield (q ha^{-1})	Biological yield (q ha^{-1})	Harvest index (%)
T_1 Atrazine @ 1.5 kg ha^{-1} (PE) *fb* HW 3 WAS	52.09	68.85	120.93	43.05
T_2 Atrazine @ 1.5 kg ha^{-1} (PE) *fb* HW 4 WAS	52.15	68.91	121.06	43.11
T_3 Atrazine @ 1.5 kg ha^{-1} (PE) *fb* HW 5 WAS	50.73	67.25	117.97	42.92
T_4 Atrazine @ 1.5 kg ha^{-1} (PE) *fb* HW 6 WAS	41.14	55.68	96.82	42.24
T_5 Atrazine @ 1.5 kg ha^{-1} (PE) *fb* HW 7 WAS	39.52	54.57	94.09	41.74
T_6 Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* HW 3 WAS	51.42	68.41	119.83	43.02
T_7 Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* HW 4 WAS	51.65	68.42	120.07	43.04
T_8 Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* HW 5 WAS	50.69	67.12	117.81	42.33
T_9 Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* HW 6 WAS	41.07	55.63	96.69	41.98
T_{10} Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* HW 7 WAS	39.02	54.43	93.45	40.55
T_{11} Hand weeding after 3, 5 and 7 WAS	60.96	80.30	141.26	43.14
T_{12} Weedy check	21.37	45.60	66.96	31.84
T_{13} Weed free	69.85	91.66	161.51	43.27
SE (m) ±	2.99	3.87	5.25	1.85
CD ($p \leq 0.05$)	**8.77**	**11.36**	**15.40**	**5.42**

Where, HW = hand weeding, WAS = weeks after sowing

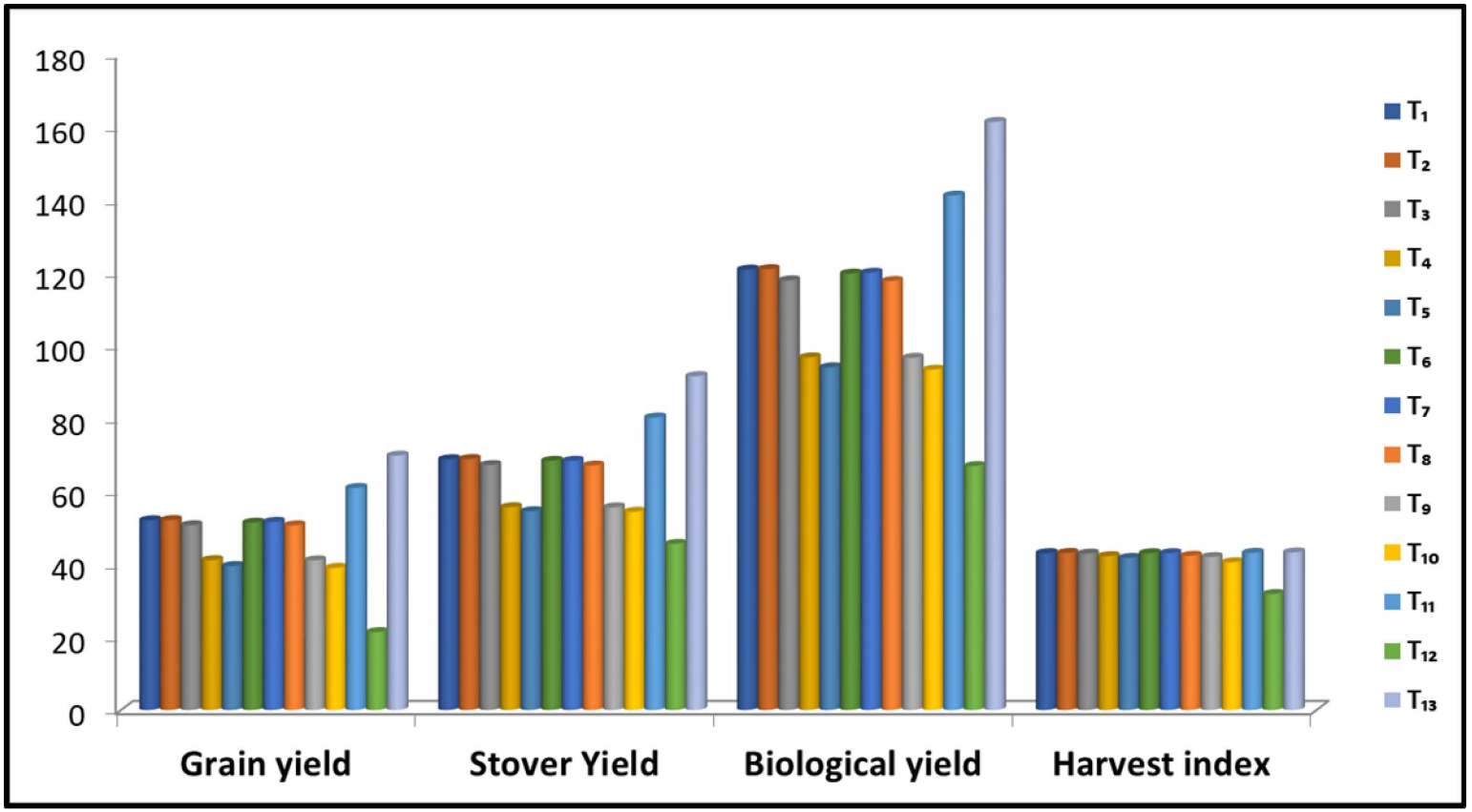

Fig. 12: Effect of weed management practices on yield and harvest index of maize

4.3.4 Harvest index

The data pertaining to harvest index is indicated in Table 13. Analysis of the data revealed that all the weed management practices varied in relation to harvest index. Highest harvest index was recorded in T_{13} (Weed free), however, it was at par with rest of the treatments except T_{12} (weedy check) and T_{10} (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 7 WAS). Among all the treatments least harvest index was reported in T_{12} (weedy check).

4.4 Nutrient studies of maize

4.4.1 NPK content in grain and stover

The recorded data pertaining to nitrogen, phosphorous and potassium content of maize is illustrated in Table 14. Different treatments differed in respect with NPK content in grain and stover.

Among different weed management practices higher NPK content in grain and stover was displayed by plants of T_{13} treatment (weed free) though it was at par with every other treatment except T_{12} (weedy check). Among all the treatments lowest NPK content in both grain and stover was reported in T_{12}.

4.4.2 NPK uptake in plants

The data regarding nitrogen, phosphorous and potassium uptake of maize is depicted in Table 15. Examining the data, it was explored that different treatments varied significantly concerning the NPK uptake in maize.

Highest uptake of nitrogen, phosphorous and potassium was witnessed in maize plants of T_{13} treatment (weed free) and least uptake was shown by maize plants in T_{12} (weedy check). Out of rest treatments under consideration, T_{13} was followed by T_{11} (hand weeding after 3, 5 and 7 WAS) and T_2 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 4 WAS). Even though, T_2 was statistically at par with T_1 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 3 WAS), T_7 (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 4 WAS), T_6 (Pendimethalin

@ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 3 WAS), T_3 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 5 WAS), T_8 (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 5 WAS). Considering the left treatments they were in decreasing order as: T_4 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 6 WAS) > T_9 (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 6 WAS) > T_5 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 7 WAS) > T_{10} (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 7 WAS).

4.5 Soil analysis

Data pertaining to chemical properties of soil after crop harvest viz. pH, EC, organic carbon, available N, P and K is indicated in Table 16.

Perusal of data indicated that all weed management practices under contemplation did not influence significantly the chemical properties of soil after crop harvest. However, numerically higher available N, P and K was found in soils of T_{13} (weed free) and least available N, P and K was found in soils of T_{12} (weedy check).

4.6 Weed indices

4.6.1 Weeds identified

The crop under investigation was infested with several kinds of weeds including grasses, broad leaf weeds and sedges. The list indicating the predominant weed species during the crop growth period of maize are summarized in Table 17 (Plate 5).

4.6.2 Total weed density

Data presented in Table 18 indicated that total weed density in maize differed significantly concerning different weed management practices under consideration. At 15 DAS, highest total weed density was observed in T_{12} (weedy check) followed by T_{11} (hand weeding after 3, 5 and 7 WAS). The trend followed in other tretments with respect to total weed density in the decreasing order as:

Table 14: Effect of weed management practices on nitrogen, phosphorous and potassium content (%) of maize

Treatments	Nitrogen content (%)		Phosphorous content (%)		Potassium content (%)	
	Grain	Stover	Grain	Stover	Grain	Stover
T_1 Atrazine @ 1.5 kg ha^{-1} (PE) *fb* HW 3 WAS	1.338	0.651	0.508	0.414	0.737	1.601
T_2 Atrazine @ 1.5 kg ha^{-1} (PE) *fb* HW 4 WAS	1.342	0.662	0.515	0.418	0.742	1.606
T_3 Atrazine @ 1.5 kg ha^{-1} (PE) *fb* HW 5 WAS	1.324	0.636	0.476	0.396	0.734	1.561
T_4 Atrazine @ 1.5 kg ha^{-1} (PE) *fb* HW 6 WAS	1.295	0.607	0.471	0.392	0.727	1.557
T_5 Atrazine @ 1.5 kg ha^{-1} (PE) *fb* HW 7 WAS	1.210	0.596	0.420	0.375	0.718	1.482
T_6 Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* HW 3 WAS	1.333	0.638	0.481	0.401	0.733	1.584
T_7 Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* HW 4 WAS	1.335	0.640	0.490	0.404	0.739	1.592
T_8 Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* HW 5 WAS	1.312	0.632	0.466	0.383	0.726	1.517
T_9 Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* HW 6 WAS	1.291	0.604	0.461	0.377	0.721	1.505
T_{10} Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* HW 7 WAS	1.205	0.586	0.422	0.369	0.707	1.465
T_{11} Hand weeding after 3, 5 and 7 WAS	1.345	0.674	0.521	0.421	0.755	1.617
T_{12} Weedy check	1.037	0.431	0.284	0.250	0.595	0.987
T_{13} Weed free	1.348	0.687	0.530	0.427	0.761	1.621
SE (m) ±	0.057	0.048	0.045	0.033	0.037	0.116
CD ($p \leq 0.05$)	**0.161**	**0.154**	**0.134**	**0.113**	**0.108**	**0.329**

Where, HW = hand weeding, WAS = weeks after sowing

Table 15: Effect of weed management practices on nitrogen, phosphorous and potassium uptake (kg ha^{-1}) of maize

Treatments	Nitrogen uptake (kg ha^{-1})		Phosphorous uptake (kg ha^{-1})	Potassium uptake (kg ha^{-1})		
	Grain	Stover	Grain	Grain	Stover	Grain
T_1 Atrazine @ 1.5 kg ha^{-1} (PE) *fb* HW 3 WAS	69.94	45.20	26.65	69.94	45.20	26.65
T_2 Atrazine @ 1.5 kg ha^{-1} (PE) *fb* HW 4 WAS	69.78	45.76	27.01	69.78	45.76	27.01
T_3 Atrazine @ 1.5 kg ha^{-1} (PE) *fb* HW 5 WAS	67.08	42.50	23.86	67.08	42.50	23.86
T_4 Atrazine @ 1.5 kg ha^{-1} (PE) *fb* HW 6 WAS	52.71	33.96	19.22	52.71	33.96	19.22
T_5 Atrazine @ 1.5 kg ha^{-1} (PE) *fb* HW 7 WAS	47.70	32.28	16.57	47.70	32.28	16.57
T_6 Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* HW 3 WAS	68.51	43.81	24.54	68.51	43.81	24.54
T_7 Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* HW 4 WAS	69.20	44.21	25.15	69.20	44.21	25.15
T_8 Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* HW 5 WAS	66.12	42.60	23.72	66.12	42.60	23.72
T_9 Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* HW 6 WAS	52.63	33.52	18.63	52.63	33.52	18.63
T_{10} Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* HW 7 WAS	46.76	31.96	16.67	46.76	31.96	16.67
T_{11} Hand weeding after 3, 5 and 7 WAS	81.62	54.35	31.61	81.62	54.35	31.61
T_{12} Weedy check	22.14	19.78	6.15	22.14	19.78	6.15
T_{13} Weed free	94.23	63.22	36.90	94.23	63.22	36.90
SE (m) ±	3.24	2.26	1.38	3.24	2.26	1.38
CD ($p \leq 0.05$)	**9.74**	**6.78**	**4.12**	**9.74**	**6.78**	**4.12**

Where, HW = hand weeding, WAS = weeks after sowing

Table 16: Effect of weed management practices on chemical properties of soil after harvesting of maize

Treatments	Ph	EC (dSm^{-1})	OC (%)	Available N ($kg\ ha^{-1}$)	Available P ($kg\ ha^{-1}$)	Available K ($kg\ ha^{-1}$)
T_1 Atrazine @ 1.5 kg ha^{-1} (PE) *fb* HW 3 WAS	6.65	0.33	0.72	330.06	19.57	182.91
T_2 Atrazine @ 1.5 kg ha^{-1} (PE) *fb* HW 4 WAS	6.65	0.32	0.71	331.53	19.60	184.30
T_3 Atrazine @ 1.5 kg ha^{-1} (PE) *fb* HW 5 WAS	6.64	0.32	0.71	329.72	19.56	181.59
T_4 Atrazine @ 1.5 kg ha^{-1} (PE) *fb* HW 6 WAS	6.64	0.34	0.70	330.32	19.47	180.91
T_5 Atrazine @ 1.5 kg ha^{-1} (PE) *fb* HW 7 WAS	6.67	0.33	0.72	330.51	19.39	179.30
T_6 Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* HW 3 WAS	6.67	0.34	0.71	330.27	19.67	183.14
T_7 Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* HW 4 WAS	6.59	0.32	0.70	330.85	19.51	182.49
T_8 Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* HW 5 WAS	6.62	0.33	0.72	328.15	19.63	180.34
T_9 Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* HW 6 WAS	6.61	0.34	0.70	330.55	19.43	180.22
T_{10} Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* HW 7 WAS	6.66	0.33	0.71	329.58	19.67	179.49
T_{11} Hand weeding after 3, 5 and 7 WAS	6.61	0.32	0.71	331.89	19.77	185.81
T_{12} Weedy check	6.63	0.34	0.70	319.08	18.79	178.22
T_{13} Weed free	6.68	0.33	0.72	332.31	19.99	190.07
SE (m) ±	0.06	0.01	0.03	2.84	0.41	2.71
CD ($p \leq 0.05$)	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**

Where, HW = hand weeding, WAS = weeks after sowing

T_{10} (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 7 WAS) > T_8 (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 5 WAS) > T_9 (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 6 WAS) T_6 (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 3 WAS) > T_7 (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 4 WAS) > T_4 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 6 WAS) > T_5 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 7 WAS) > T_3 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 5 WAS) > T_1 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 3 WAS) > T_2 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 4 WAS). Lowest total weed density was observed in T_2 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 4 WAS) and no weeds were allowed to grow in weed free plot.

At 45 DAS, highest total weed density was obtained in T_{12} (weedy check) followed by T_{10} (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 7 WAS) and T_5 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 7 WAS). Rest of the treatments followed the trend: T_6 (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 3 WAS) > T_7 (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 4 WAS) > T_1 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 3 WAS) > T_2 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 4 WAS) > T_8 (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 5 WAS) > T_3 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 5 WAS) > T_{11} (hand weeding after 3, 5 and 7 WAS). Lowest total weed density was obtained in T_4 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 6 WAS) which was at par with T_9 (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 6 WAS).

At 75 DAS, highest total weed density was found in T_{12} (weedy check) and lowest in T_{11} (hand weeding after 3, 5 and 7 WAS). The remaining treatments were present in decreasing manner as: T_6 (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 3 WAS) > T_7 (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 4 WAS) > T_1 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 3 WAS > T_2 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 4 WAS) > T_8

(Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 5 WAS) > T_3 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 5 WAS) > T_9 (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 6 WAS) > T_4 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 6 WAS) > T_{10} (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 7 WAS) > T_5 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 7 WAS).

4.6.2.1 Density of grassy weeds

The density of grassy weeds in maize crop is summarized in Table 19. Analysing the data showed that different weed management practices differed with respect to density of grassy weeds.

At 15 DAS, highest density of grassy weeds was observed in T_{12} (weedy check) followed by T_{11} (hand weeding after 3, 5 and 7 WAS). There was no statistical difference between other treatments and were in the order as follows: T_{10} (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 7 WAS) > T_8 (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 5 WAS) > T_9 (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 6 WAS) T_6 (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 3 WAS) > T_7 (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 4 WAS) > T_4 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 6 WAS) > T_5 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 7 WAS) > T_3 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 5 WAS) > T_1 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 3 WAS) > T_2 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 4 WAS). Lowest density of grassy weeds was observed in T_2 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 4 WAS).

At 45 DAS, highest density of grassy weeds was obtained in T_{12} (weedy check) followed by T_{10} (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 7 WAS) and T_5 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 7 WAS). Rest of the treatments followed the trend: T_6 (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 3 WAS) > T_7 (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 4 WAS) > T_1 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 3 WAS) > T_2

(Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 4 WAS) > T_8 (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 5 WAS) > T_3 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 5 WAS) > T_{11} (hand weeding after 3, 5 and 7 WAS). Lowest density of grassy weeds was obtained in T_4 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 6 WAS) which was at par with T_9 (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 6 WAS).

At 75 DAS, highest density of grassy weeds was found in T_{12} (weedy check) and lowest in T_{11} (hand weeding after 3, 5 and 7 WAS). The remaining treatments were present in decreasing manner as: T_6 (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 3 WAS) > T_7 (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 4 WAS > T_1 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 3 WAS) > T_2 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 4 WAS) > T_8 (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 5 WAS) > T_3 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 5 WAS) > T_9 (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 6 WAS) > T_4 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 6 WAS) > T_{10} (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 7 WAS) > T_5 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 7 WAS).

4.6.2.2 Density of broad leaved weeds

Data represented in Table 20 indicated that density of broad leaved weeds in maize differed concerning different weed management practices under investigation.

At 15 DAS, highest density of broad leaved weeds was observed in T_{12} (weedy check) followed by T_{11} (hand weeding after 3, 5 and 7 WAS). The trend followed in other tretments with respect to density of broad leaved weeds was in the order as follows: T_{10} (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 7 WAS) > T_8 (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 5 WAS) > T_9 (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 6 WAS) > T_6 (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 3 WAS) > T_7

(Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 4 WAS) > T_4 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 6 WAS) > T_5 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 7 WAS) > T_3 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 5 WAS) > T_1 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 3 WAS) > T_2 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 4 WAS). Lowest density of broad leaved weeds was observed in T_2 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 4 WAS).

At 45 DAS, highest density of broad leaved weeds was obtained in T_{12} (weedy check) followed by T_{10} (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 7 WAS) and T_5 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 7 WAS). Rest of the treatments followed the trend: T_6 (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 3 WAS) > T_7 (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 4 WAS) > T_1 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 3 WAS) > T_2 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 4 WAS) > T_8 (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 5 WAS) > T_3 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 5 WAS) > T_{11} (hand weeding after 3, 5 and 7 WAS). Lowest density of broad leaved weeds was obtained in T_4 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 6 WAS) which was at par with T_9 (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 6 WAS).

At 75 DAS, highest density of broad leaved weeds was found in T_{12} (weedy check) and lowest in T_{11} (hand weeding after 3, 5 and 7 WAS). The remaining treatments were present in decreasing manner as: T_6 (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 3 WAS) > T_7 (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 4 WAS) > T_1 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 3 WAS > T_2 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 4 WAS) > T_8 (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 5 WAS) > T_3 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 5 WAS) > T_9 (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 6 WAS) > T_4 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 6 WAS) > T_{10} (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand

weeding at 7 WAS) > T_5 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 7 WAS).

4.6.2.3 Density of sedges

The data regarding density of sedges is indicated in Table 21. The different treatments differed in relation to density of sedges in maize crop.

At 15 DAS, highest density of sedges was observed in T_{12} (weedy check) followed by T_{11} (hand weeding after 3, 5 and 7 WAS). There was no statistical difference between other treatments and were in the order as follows: T_{10} (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 7 WAS) > T_8 (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 5 WAS) > T_9 (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 6 WAS) T_6 (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 3 WAS) > T_7 (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 4 WAS) > T_4 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 6 WAS) > T_5 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 7 WAS) > T_3 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 5 WAS) > T_1 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 3 WAS) > T_2 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 4 WAS). Lowest density of sedges was observed in T_2 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 4 WAS).

At 45 DAS, highest density of sedges was obtained in T_{12} (weedy check) followed by T_{10} (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 7 WAS) and T_5 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 7 WAS). Rest of the treatments followed the trend: T_6 (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 3 WAS) > T_7 (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 4 WAS) > T_1 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 3 WAS) > T_2 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 4 WAS) > T_8 (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 5 WAS) > T_3 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 5 WAS) > T_{11} (hand weeding after 3, 5 and 7 WAS). Lowest density of sedges was obtained in T_4 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand

weeding at 6 WAS) which was at par with T_9 (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 6 WAS).

At 75 DAS, highest density of sedges was found in T_{12} (weedy check) and lowest in T_{11} (hand weeding after 3, 5 and 7 WAS). The remaining treatments were present in decreasing manner as: T_6 (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 3 WAS) > T_7 (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 4 WAS > T_1 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 3 WAS) > T_2 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 4 WAS) > T_8 (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 5 WAS) > T_3 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 5 WAS) > T_9 (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 6 WAS) > T_4 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 6 WAS) > T_{10} (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 7 WAS) > T_5 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 7 WAS).

4.6.3 Total dry matter accumulation of weeds

Different treatments varied with respect to total dry matter accumulation of weeds and the data pertaining to total dry matter accumulation of weeds is summarized in Table 22.

At 15 DAS, highest total dry matter accumulation of weeds was observed in T_{12} (weedy check) followed by T_{11} (hand weeding after 3, 5 and 7 WAS). Non significant difference was obtained among other treatments and were in the order as follows: T_{10} (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 7 WAS) > T_8 (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 5 WAS) > T_9 (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 6 WAS) T_6 (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 3 WAS) > T_7 (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 4 WAS) > T_4 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 6 WAS) > T_5 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 7 WAS) > T_3 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 5 WAS) > T_1(Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 3 WAS) > T_2 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 4 WAS). Lowest total dry matter accumulation of weeds was observed in T_2 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 4 WAS).

Table 17: Major weed flora identified during the crop growth of maize (*Zea mays* L.)

	Common name	Scientific name	Local name	Family
Grassy weeds	Johnson's grass	*Sorghum helepense*	*Durham*	Poaceae
	Bermuda grass	*Cynodon dactylon*	*Dramun*	Poaceae
	Crab grass	*Digitaria sanguinalis*		Poaceae
Broad leaved weeds	Field bind weed	*Convolvulus arvensis*	*Thrir*	Convolvulacae
	Common lambsquarters	*Chenopodium album*	*Koni*	Chenopodiacae
	Thorn apple	*Datura stramonium*	*Datur*	Solanaceae
	Common purslane	*Portulaca oleracea*	*Nunner*	Portulacaceae
	White clover	*Trifolium repens*	*Tre pater*	Fabaceae
	Red clover	*Trifolium pratense*	*Tre pater*	Fabaceae
	Curly dock	*Rumex crispus*	*Abij*	Polygonaceae
	Pig weed	*Amaranthus viridis*	*Lissi*	Amaranthaceae
	Chamomile	*Matricaria chamomilla*	*Phoke ghass*	Asteraceae
	Canada thistle	*Cirsium arvense*	*Kaend kul*	Asteraceae
	Spotted lady's thumb	*Persicaria maculosa*	*Marchangan ghass*	Polygonaceae
Sedges	Nut sedge	*Cyperus rotundus*	*Zab*	Cyperacae

Table 18: Total weed density (No. m^{-2}) in maize as influenced by different weed management practices

Treatments	15 DAS	45 DAS	75 DAS
T_1 Atrazine @ 1.5 kg ha^{-1} (PE) *fb* HW 3 WAS	3.207 (9.57)	2.649 (6.23)	4.277 (17.37)
T_2 Atrazine @ 1.5 kg ha^{-1} (PE) *fb* HW 4 WAS	3.152 (9.50)	2.510 (5.25)	4.261 (17.32)
T_3 Atrazine @ 1.5 kg ha^{-1} (PE) *fb* HW 5 WAS	3.228 (9.63)	2.368 (4.63)	4.173 (16.44)
T_4 Atrazine @ 1.5 kg ha^{-1} (PE) *fb* HW 6 WAS	3.265 (9.70)	0.481 (0.23)	3.652 (13.32)
T_5 Atrazine @ 1.5 kg ha^{-1} (PE) *fb* HW 7 WAS	3.270 (9.73)	7.745 (61.4)	3.313 (9.65)
T_6 Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* HW 3 WAS	3.350 (10.62)	2.890 (7.38)	4.382 (18.21)
T_7 Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* HW 4 WAS	3.279 (10.61)	2.765 (6.79)	4.361 (18.03)
T_8 Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* HW 5 WAS	3.406 (10.64)	2.498 (5.27)	4.244 (17.04)
T_9 Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* HW 6 WAS	3.409 (10.66)	0.861 (0.74)	3.781 (14.29)
T_{10} Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* HW 7 WAS	3.449 (10.96)	8.044 (64.7)	3.324 (10.70)
T_{11} Hand weeding after 3, 5 and 7 WAS	4.424 (19.30)	1.561 (1.44)	2.937 (7.66)
T_{12} Weedy check	4.973 (24.33)	9.953 (98.3)	12.16 (147.7)
T_{13} Weed free	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)
SE (m) ±	0.400	0.328	0.291
CD ($p \leq 0.05$)	**1.175**	**0.962**	**0.854**

Where, HW = hand weeding, WAS = weeks after sowing, DAS = days after sowing

Note: Data has been subjected to square root transformation $(\sqrt{x+1})$ and original values are presented in parenthesis

Table 19: Density (No. m^{-2}) of grassy weeds in maize as influenced by different weed management practices

Treatments	15 DAS	45 DAS	75 DAS
T_1 Atrazine @ 1.5 kg ha^{-1} (PE) *fb* HW 3 WAS	1.990 (3.03)	1.709 (1.97)	2.548 (5.50)
T_2 Atrazine @ 1.5 kg ha^{-1} (PE) *fb* HW 4 WAS	1.966 (3.01)	1.632 (1.67)	2.544 (5.48)
T_3 Atrazine @ 1.5 kg ha^{-1} (PE) *fb* HW 5 WAS	1.997 (3.05)	1.568 (1.46)	2.489 (5.20)
T_4 Atrazine @ 1.5 kg ha^{-1} (PE) *fb* HW 6 WAS	2.015 (3.07)	0.265 (0.07)	2.127 (4.52)
T_5 Atrazine @ 1.5 kg ha^{-1} (PE) *fb* HW 7 WAS	2.017 (3.08)	4.438 (19.4)	1.990 (3.05)
T_6 Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* HW 3 WAS	2.064 (3.35)	1.824 (2.33)	2.599 (5.76)
T_7 Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* HW 4 WAS	2.035 (3.34)	1.764 (2.15)	2.589 (5.71)
T_8 Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* HW 5 WAS	2.089 (3.37)	1.629 (1.66)	2.527 (5.39)
T_9 Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* HW 6 WAS	2.089 (3.36)	0.480 (0.23)	2.207 (4.87)
T_{10} Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* HW 7 WAS	2.109 (3.47)	4.601 (20.5)	2.035 (3.37)
T_{11} Hand weeding after 3, 5 and 7 WAS	2.627 (6.11)	1.205 (0.46)	1.848 (2.42)
T_{12} Weedy check	2.920 (7.70)	5.660 (31.1)	6.893 (46.8)
T_{13} Weed free	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)
SE (m) ±	0.207	0.182	0.153
CD ($p \leq 0.05$)	**0.608**	**0.535**	**0.499**

Where, HW = hand weeding, WAS = weeks after sowing, DAS = days after sowing

Note: Data has been subjected to square root transformation $(\sqrt{x+1})$ and original values are presented in parenthesis

Table 20: Density (No. m^{-2}) of broad leaved weeds in maize as influenced by different weed management practices

Treatments	15 DAS	45 DAS	75 DAS
T_1 Atrazine @ 1.5 kg ha^{-1} (PE) *fb* HW 3 WAS	2.249 (4.16)	1.906 (2.71)	2.923 (7.55)
T_2 Atrazine @ 1.5 kg ha^{-1} (PE) *fb* HW 4 WAS	2.218 (4.13)	1.811 (2.29)	2.919 (7.53)
T_3 Atrazine @ 1.5 kg ha^{-1} (PE) *fb* HW 5 WAS	2.258 (4.19)	1.734 (2.01)	2.852 (7.15)
T_4 Atrazine @ 1.5 kg ha^{-1} (PE) *fb* HW 6 WAS	2.281 (4.22)	0.332 (0.11)	2.566 (6.58)
T_5 Atrazine @ 1.5 kg ha^{-1} (PE) *fb* HW 7 WAS	2.284 (4.23)	5.164 (26.7)	2.249 (4.19)
T_6 Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* HW 3 WAS	2.338 (4.61)	2.049 (3.21)	2.986 (7.92)
T_7 Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* HW 4 WAS	2.299 (4.60)	1.975 (2.95)	2.973 (7.84)
T_8 Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* HW 5 WAS	2.368 (4.62)	1.810 (2.28)	2.898 (7.41)
T_9 Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* HW 6 WAS	2.370 (4.63)	0.591 (0.35)	2.674 (7.15)
T_{10} Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* HW 7 WAS	2.396 (4.77)	5.358 (28.1)	2.299 (4.62)
T_{11} Hand weeding after 3, 5 and 7 WAS	3.016 (8.39)	1.274 (0.63)	2.078 (3.33)
T_{12} Weedy check	3.366 (10.6)	6.606 (42.8)	8.056 (64.3)
T_{13} Weed free	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)
SE (m) ±	0.250	0.215	0.184
CD ($p \leq 0.05$)	**0.735**	**0.631**	**0.540**

Where, HW = hand weeding, WAS = weeks after sowing, DAS = days after sowing

Note: Data has been subjected to square root transformation $(\sqrt{x + 1})$ and original values are presented in parenthesis

Table 21: Density (No. m^{-2}) of sedges in maize as influenced by different weed management practices

Treatments	15 DAS	45 DAS	75 DAS
T_1 Atrazine @ 1.5 kg ha^{-1} (PE) *fb* HW 3 WAS	1.825 (2.38)	1.585 (1.55)	2.306 (4.32)
T_2 Atrazine @ 1.5 kg ha^{-1} (PE) *fb* HW 4 WAS	1.805 (2.36)	1.518 (1.31)	2.303 (4.31)
T_3 Atrazine @ 1.5 kg ha^{-1} (PE) *fb* HW 5 WAS	1.830 (2.40)	1.466 (1.15)	2.254 (4.09)
T_4 Atrazine @ 1.5 kg ha^{-1} (PE) *fb* HW 6 WAS	1.846 (2.41)	0.224 (0.05)	1.984 (3.94)
T_5 Atrazine @ 1.5 kg ha^{-1} (PE) *fb* HW 7 WAS	1.847 (2.42)	3.963 (15.3)	1.825 (2.40)
T_6 Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* HW 3 WAS	1.888 (2.62)	1.682 (1.83)	2.351 (4.53)
T_7 Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* HW 4 WAS	1.866 (2.60)	1.632 (1.69)	2.341 (4.49)
T_8 Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* HW 5 WAS	1.908 (2.63)	1.516 (1.31)	2.288 (4.24)
T_9 Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* HW 6 WAS	1.909 (2.64)	0.401 (0.16)	2.012 (4.05)
T_{10} Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* HW 7 WAS	1.927 (2.73)	4.106 (16.1)	1.866 (2.65)
T_{11} Hand weeding after 3, 5 and 7 WAS	2.377 (4.80)	1.166 (0.36)	1.702 (1.91)
T_{12} Weedy check	2.630 (6.05)	5.039 (24.5)	6.129 (36.8)
T_{13} Weed free	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)
SE (m) ±	0.180	0.161	0.133
CD ($p \leq 0.05$)	**0.520**	**0.472**	**0.390**

Where, HW = hand weeding, WAS = weeks after sowing, DAS = days after sowing

Note: Data has been subjected to square root transformation $(\sqrt{x+1})$ and original values are presented in parenthesis

Cynodon dactylon

Digitaria sanguinalis

Sorghum halepense

Persicaria maculosa

Portulaca oleracea

Plate 5 Contd…

Convolvulus arvensis

Datura stramonium

Trifolium repens *Cyperus rotundus*

Plate 5: Major weed flora associated with maize (*Zea mays* L.)

Rumex spp.

Amaranthus viridis

Convolvulus arvensis

Sorghum halepense

Datura stramonium

Chenopodium album

Plate 6: Weed seeds and propagules collected during experimentation

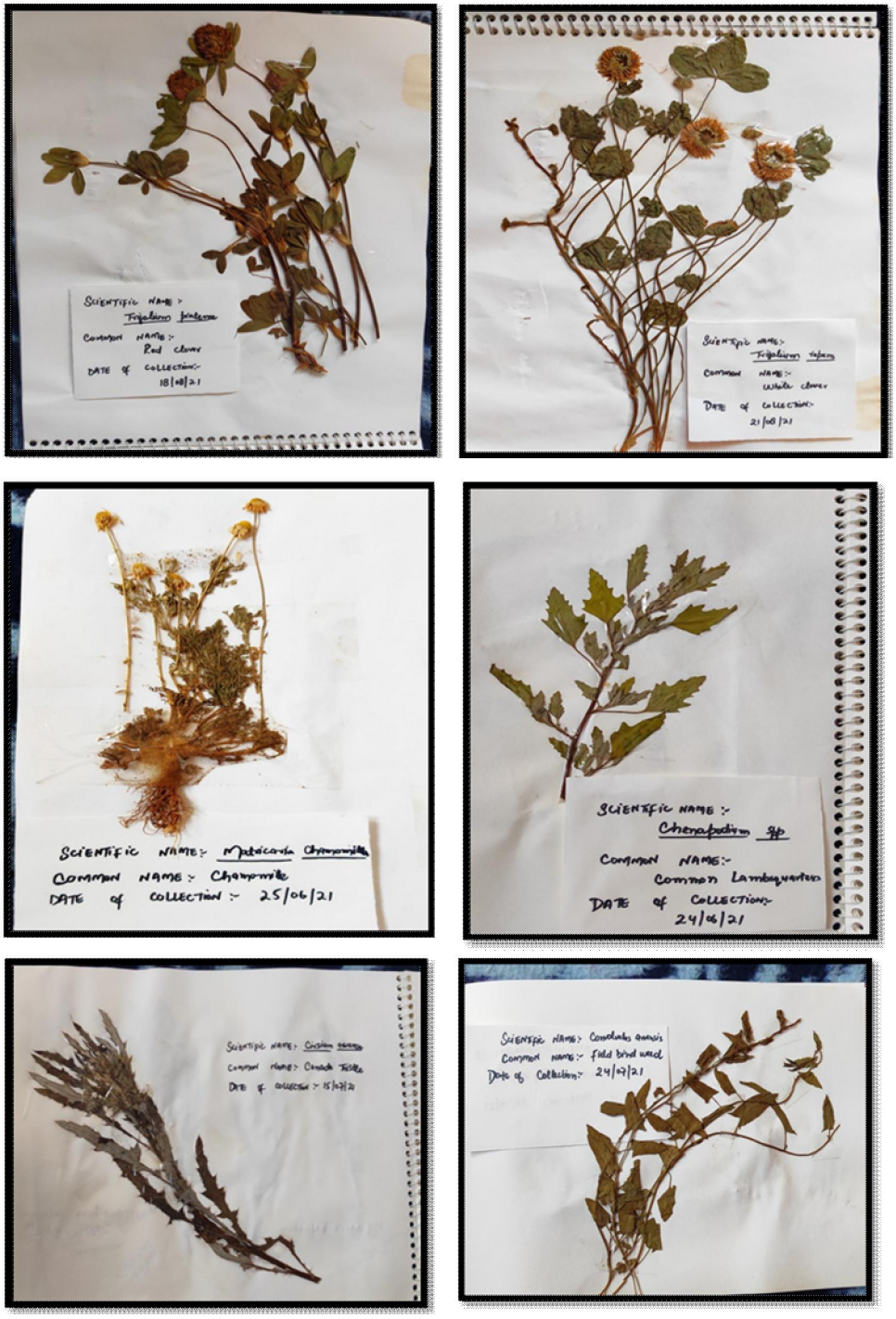

Plate 7: Herbarium preparation of weeds during experimentation

At 45 days after sowing, highest total dry matter accumulation of weeds was observed in T_{12} (weedy check) followed by T_{10} (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 7 WAS) and T_5 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 7 WAS). Rest of the treatments followed the trend: T_6 (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 3 WAS) > T_7 (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 4 WAS) > T_1 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 3 WAS) > T_2 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 4 WAS) > T_8 (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 5 WAS) > T_3 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 5 WAS) > T_{11} (hand weeding after 3, 5 and 7 WAS). Lowest total dry matter accumulation of weeds was obtained in T_4 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 6 WAS) which was at par with T_9 (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 6 WAS).

At 75 days after sowing, highest total dry matter accumulation of weeds was recorded in T_{12} (weedy check) and lowest in T_{11} (hand weeding after 3, 5 and 7 WAS). The remaining treatments were present in decreasing manner as: T_6 (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 3 WAS) > T_7 (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 4 WAS) > T_1 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 3 WAS > T_2 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 4 WAS) > T_8 (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 5 WAS) > T_3 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 5 WAS) > T_9 (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 6 WAS) > T_4 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 6 WAS) > T_{10} (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 7 WAS) > T_5 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 7 WAS).

4.6.3.1 Dry matter accumulation of grassy weeds

The data pertaining to dry matter accumulation of grassy weeds is shown in Table 23.

At 15 DAS, highest dry matter accumulation of grassy weeds was observed in T_{12} (weedy check) followed by T_{11} (hand weeding after 3, 5 and 7 WAS). There was no statistical difference between other treatments and were in the order as follows: T_{10} (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 7 WAS) > T_8 (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 5 WAS) > T_9 (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 6 WAS) T_6 (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 3 WAS) > T_7 (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 4 WAS) > T_4 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 6 WAS) > T_5 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 7 WAS) > T_3 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 5 WAS) > T_1 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 3 WAS) > T_2 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 4 WAS). Lowest dry matter accumulation of grassy weeds was observed in T_2 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 4 WAS).

At 45 days after sowing, highest dry matter accumulation of grassy weeds was observed in T_{12} (weedy check) followed by T_{10} (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 7 WAS) and T_5 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 7 WAS). Rest of the treatments followed the trend: T_6 (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 3 WAS) > T_7 (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 4 WAS) > T_1 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 3 WAS) > T_2 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 4 WAS) > T_8 (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 5 WAS) > T_3 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 5 WAS) > T_{11} (hand weeding after 3, 5 and 7 WAS). Lowest dry matter accumulation of grassy weeds was obtained in T_4 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 6 WAS) which was at par with T_9 (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 6 WAS).

At 75 days after sowing, highest dry matter accumulation of grassy weeds was recorded in T_{12} (weedy check) and lowest in T_{11} (hand weeding after 3, 5 and 7 WAS). The remaining treatments were present in decreasing manner as: T_6

(Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 3 WAS) > T_7 (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 4 WAS) > T_1 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 3 WAS > T_2 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 4 WAS) > T_8 (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 5 WAS) > T_3 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 5 WAS) > T_9 (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 6 WAS) > T_4 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 6 WAS) > T_{10} (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 7 WAS) > T_5 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 7 WAS).

4.6.3.2 Dry matter accumulation of broad leaved weeds

Different treatments varied concerning the dry matter accumulation of broad leaved weeds and the data pertaining to it is depicted in Table 24.

At 15 DAS, highest dry matter accumulation of broad leaved weeds was observed in T_{12} (weedy check) followed by T_{11} (hand weeding after 3, 5 and 7 WAS). Non significant difference was obtained among other treatments and were in the order as follows: T_{10} (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 7 WAS) > T_8 (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 5 WAS) > T_9 (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 6 WAS) T_6 (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 3 WAS) > T_7 (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 4 WAS) > T_4 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 6 WAS) > T_5 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 7 WAS) > T_3 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 5 WAS) > T_1 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 3 WAS) > T_2 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 4 WAS). Lowest dry matter accumulation of broad leaved weeds was observed in T_2 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 4 WAS).

At 45 days after sowing, highest dry matter accumulation of broad leaved weeds was observed in T_{12} (weedy check) followed by T_{10} (Pendimethalin @ 1.5

kg ha^{-1} (PE) *fb* hand weeding at 7 WAS) and T_5 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 7 WAS). Rest of the treatments followed the trend: T_6 (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 3 WAS) > T_7 (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 4 WAS) > T_1 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 3 WAS) > T_2 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 4 WAS) > T_8 (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 5 WAS) > T_3 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 5 WAS) > T_{11} (hand weeding after 3, 5 and 7 WAS). Lowest dry matter accumulation of broad leaved weeds was obtained in T_4 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 6 WAS) which was at par with T_9 (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 6 WAS).

At 75 days after sowing, highest dry matter accumulation of broad leaved weeds was recorded in T_{12} (weedy check) and lowest in T_{11} (hand weeding after 3, 5 and 7 WAS). The remaining treatments were present in decreasing manner as: T_6 (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 3 WAS) > T_7 (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 4 WAS) > T_1 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 3 WAS > T_2 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 4 WAS) > T_8 (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 5 WAS) > T_3 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 5 WAS) > T_9 (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 6 WAS) > T_4 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 6 WAS) > T_{10} (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 7 WAS) > T_5 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 7 WAS).

4.6.3.3 Dry matter accumulation of sedges

The data related to dry matter accumulation of sedges is summarized in Table 25.

At 15 DAS, highest dry matter accumulation of sedges was observed in T_{12} (weedy check) followed by T_{11} (hand weeding after 3, 5 and 7 WAS). There

was no statistical difference between other treatments and were in the order as follows: T_{10} (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 7 WAS) > T_8 (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 5 WAS) > T_9 (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 6 WAS) T_6 (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 3 WAS) > T_7 (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 4 WAS) > T_4 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 6 WAS) > T_5 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 7 WAS) > T_3 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 5 WAS) > T_1 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 3 WAS) > T_2 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 4 WAS). Lowest dry matter accumulation of sedges was observed in T_2 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 4 WAS).

At 45 days after sowing, highest dry matter accumulation of sedges was observed in T_{12} (weedy check) followed by T_{10} (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 7 WAS) and T_5 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 7 WAS). Rest of the treatments followed the trend: T_6 (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 3 WAS) > T_7 (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 4 WAS) > T_1 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 3 WAS) > T_2 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 4 WAS) > T_8 (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 5 WAS) > T_3 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 5 WAS) > T_{11} (hand weeding after 3, 5 and 7 WAS). Lowest dry matter accumulation of sedges was obtained in T_4 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 6 WAS) which was at par with T_9 (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 6 WAS).

At 75 days after sowing, highest dry matter accumulation of sedges was recorded in T_{12} (weedy check) and lowest in T_{11} (hand weeding after 3, 5 and 7 WAS). The remaining treatments were present in decreasing manner as: T_6 (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 3 WAS) > T_7 (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 4 WAS) > T_1 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 3 WAS > T_2 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb*

hand weeding at 4 WAS) > T_8 (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 5 WAS) > T_3 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 5 WAS) > T_9 (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 6 WAS) > T_4 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 6 WAS) > T_{10} (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 7 WAS) > T_5 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 7 WAS).

4.6.4 Weed control efficiency

Data indicating weed control efficiency of different weed management practices in maize crop is shown in Table 26. Scrutinizing the data revealed that different treatments varied significantly in regard to weed control efficiency.

At 15 DAS lowest weed control efficiency was found in T_{11} (hand weeding after 3, 5 and 7 WAS). The weed control efficiency of remaining treatments containing atrazine and pendimethalin varied but there was no statistical difference and followed the trend as: T_2 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 4 WAS) > T_1 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 3 WAS) > T_3 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 5 WAS) > T_4 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 6 WAS) > T_5 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 7 WAS) > T_7 (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 4 WAS) > T_6 (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 3 WAS) > T_8 (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 5 WAS) > T_9 (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 6 WAS) > T_{10} (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 7 WAS).

Table 22: Total weed dry matter accumulation (g m^{-2}) in maize as influenced by different weed management practices

Treatments	15 DAS	45 DAS	75 DAS
T_1 Atrazine @ 1.5 kg ha^{-1} (PE) *fb* HW 3 WAS	1.544 (1.400)	1.891 (2.73)	2.810 (6.92)
T_2 Atrazine @ 1.5 kg ha^{-1} (PE) *fb* HW 4 WAS	1.541 (1.389)	1.839 (2.39)	2.751 (6.64)
T_3 Atrazine @ 1.5 kg ha^{-1} (PE) *fb* HW 5 WAS	1.547 (1.408)	1.682 (1.83)	2.652 (6.20)
T_4 Atrazine @ 1.5 kg ha^{-1} (PE) *fb* HW 6 WAS	1.553 (1.418)	0.481 (0.73)	2.453 (5.48)
T_5 Atrazine @ 1.5 kg ha^{-1} (PE) *fb* HW 7 WAS	1.556 (1.423)	3.212 (9.73)	2.371 (4.76)
T_6 Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* HW 3 WAS	1.587 (1.553)	2.397 (5.00)	2.871 (7.26)
T_7 Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* HW 4 WAS	1.574 (1.551)	2.100 (3.49)	2.842 (7.10)
T_8 Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* HW 5 WAS	1.597 (1.555)	1.713 (1.89)	2.671 (6.37)
T_9 Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* HW 6 WAS	1.598 (1.558)	0.501 (0.84)	2.613 (6.27)
T_{10} Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* HW 7 WAS	1.613 (1.608)	3.293 (10.26)	2.480 (5.16)
T_{11} Hand weeding after 3, 5 and 7 WAS	3.104 (8.673)	1.012 (1.14)	2.291 (4.33)
T_{12} Weedy check	3.179 (9.120)	6.96 (35.6)	12.27 (127.2)
T_{13} Weed free	1.00 (0.00)	1.00 (0.00)	1.0 (0.00)
SE (m) ±	0.094	0.245	0.334
CD ($p \leq 0.05$)	**0.276**	**0.742**	**0.991**

Where, HW = hand weeding, WAS = weeks after sowing, DAS = days after sowing

Note: Data has been subjected to square root transformation $(\sqrt{x+1})$ and original values are presented in parenthesis

Table 23: Dry matter accumulation (g m^{-2}) of grassy weeds in maize as influenced by different weed management practices

Treatments	15 DAS	45 DAS	75 DAS
T_1 Atrazine @ 1.5 kg ha^{-1} (PE) *fb* HW 3 WAS	1.200 (0.44)	1.354 (0.86)	1.784 (2.19)
T_2 Atrazine @ 1.5 kg ha^{-1} (PE) *fb* HW 4 WAS	1.196 (0.43)	1.325 (0.76)	1.756 (2.10)
T_3 Atrazine @ 1.5 kg ha^{-1} (PE) *fb* HW 5 WAS	1.201 (0.44)	1.258 (0.58)	1.714 (1.96)
T_4 Atrazine @ 1.5 kg ha^{-1} (PE) *fb* HW 6 WAS	1.203 (0.45)	0.501 (0.25)	1.657 (1.77)
T_5 Atrazine @ 1.5 kg ha^{-1} (PE) *fb* HW 7 WAS	1.204 (0.45)	1.991 (3.08)	1.575 (1.51)
T_6 Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* HW 3 WAS	1.219 (0.48)	1.588 (1.58)	1.813 (2.30)
T_7 Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* HW 4 WAS	1.217 (0.48)	1.444 (1.10)	1.799 (2.25)
T_8 Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* HW 5 WAS	1.221 (0.49)	1.259 (0.60)	1.732 (2.02)
T_9 Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* HW 6 WAS	1.222 (0.49)	0.519 (0.27)	1.735 (2.02)
T_{10} Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* HW 7 WAS	1.227 (0.51)	2.034 (3.25)	1.621 (1.63)
T_{11} Hand weeding after 3, 5 and 7 WAS	2.161 (2.75)	1.123 (0.38)	1.532 (1.37)
T_{12} Weedy check	2.198 (2.89)	4.356 (11.26)	7.344(40.25)
T_{13} Weed free	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)
SE (m) ±	0.050	0.120	0.061
CD ($p \leq 0.05$)	**0.160**	**0.370**	**0.179**

Where, HW = hand weeding, WAS = weeks after sowing, DAS = days after sowing

Note: Data has been subjected to square root transformation $(\sqrt{x+1})$ and original values are presented in parenthesis

Table 24: Dry matter accumulation (g m^{-2}) of broad leaved weeds in maize as influenced by different weed management practices

Treatments	15 DAS	45 DAS	75 DAS
T_1 Atrazine @ 1.5 kg ha^{-1} (PE) *fb* HW 3 WAS	1.265 (0.60)	1.461 (1.19)	2.001 (3.01)
T_2 Atrazine @ 1.5 kg ha^{-1} (PE) *fb* HW 4 WAS	1.263 (0.60)	1.427 (1.04)	1.965 (2.89)
T_3 Atrazine @ 1.5 kg ha^{-1} (PE) *fb* HW 5 WAS	1.266 (0.61)	1.340 (0.80)	1.914 (2.69)
T_4 Atrazine @ 1.5 kg ha^{-1} (PE) *fb* HW 6 WAS	1.268 (0.61)	0.557 (0.31)	1.843 (2.43)
T_5 Atrazine @ 1.5 kg ha^{-1} (PE) *fb* HW 7 WAS	1.270 (0.62)	2.285 (4.23)	1.740 (2.07)
T_6 Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* HW 3 WAS	1.287 (0.65)	1.756 (2.17)	2.035 (3.16)
T_7 Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* HW 4 WAS	1.271 (0.62)	1.579 (1.52)	2.018 (3.09)
T_8 Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* HW 5 WAS	1.294 (0.67)	1.340 (0.82)	1.935 (2.76)
T_9 Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* HW 6 WAS	1.295 (0.68)	0.616 (0.38)	1.940 (2.77)
T_{10} Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* HW 7 WAS	1.302 (0.70)	2.302 (4.46)	1.798 (2.24)
T_{11} Hand weeding after 3, 5 and 7 WAS	2.441 (3.77)	1.231 (0.52)	1.687 (1.88)
T_{12} Weedy check	2.485 (3.97)	4.918(15.35)	8.437 (55.3)
T_{13} Weed free	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)
SE (m) ±	0.054	0.125	0.075
CD ($p \leq 0.05$)	**0.158**	**0.367**	**0.220**

Where, HW = hand weeding, WAS = weeks after sowing, DAS = days after sowing

Note: Data has been subjected to square root transformation $(\sqrt{x+1})$ and original values are presented in parenthesis

Table 25: Dry matter accumulation (g m^{-2}) of sedges in maize as influenced by different weed management practices

Treatments	15 DAS	45 DAS	75 DAS
T_1 Atrazine @ 1.5 kg ha^{-1} (PE) *fb* HW 3 WAS	1.158 (0.33)	1.288 (0.68)	1.649 (1.72)
T_2 Atrazine @ 1.5 kg ha^{-1} (PE) *fb* HW 4 WAS	1.155 (0.32)	1.262 (0.59)	1.625 (1.65)
T_3 Atrazine @ 1.5 kg ha^{-1} (PE) *fb* HW 5 WAS	1.160 (0.34)	1.207 (0.46)	1.589 (1.54)
T_4 Atrazine @ 1.5 kg ha^{-1} (PE) *fb* HW 6 WAS	1.162 (0.35)	0.413 (0.17)	1.501 (1.36)
T_5 Atrazine @ 1.5 kg ha^{-1} (PE) *fb* HW 7 WAS	1.163 (0.35)	1.827 (2.42)	1.472 (1.19)
T_6 Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* HW 3 WAS	1.176 (0.38)	1.484 (1.24)	1.673 (1.81)
T_7 Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* HW 4 WAS	1.174 (0.37)	1.362 (0.87)	1.661 (1.77)
T_8 Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* HW 5 WAS	1.177 (0.38)	1.209 (0.47)	1.603 (1.59)
T_9 Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* HW 6 WAS	1.179 (0.39)	0.436 (0.19)	1.606 (1.59)
T_{10} Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* HW 7 WAS	1.183 (0.40)	1.863 (2.55)	1.509 (1.28)
T_{11} Hand weeding after 3, 5 and 7 WAS	1.971 (2.16)	1.139 (0.30)	1.435 (1.08)
T_{12} Weedy check	2.015 (2.27)	3.977 (8.86)	6.604(31.64)
T_{13} Weed free	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)
SE (m) ±	0.040	0.120	0.052
CD ($p \leq 0.05$)	**0.130**	**0.310**	**0.153**

Where, HW = hand weeding, WAS = weeks after sowing, DAS = days after sowing

Note: Data has been subjected to square root transformation $(\sqrt{x+1})$ and original values are presented in parenthesis

At 45 DAS highest weed control efficiency was reported in T_4 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 6 WAS). However, it was statistically at par with T_9 (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 6 WAS). Lowest weed control efficiency was found in T_{10} (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 7 WAS) and T_5 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 7 WAS). Remaining weed management practices followed the trend: T_{11} (hand weeding after 3, 5 and 7 WAS) > T_3 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 5 WAS) > T_8 (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 5 WAS) > T_2 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 4 WAS > T_1 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 3 WAS) > T_7 (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 4 WAS) > T_6 (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 3 WAS).

At 75 DAS highest weed control efficiency was found in T_{11} (hand weeding after 3, 5 and 7 WAS). Other tretaments followed the trend in decreasing order as: T_5 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 7 WAS) > T_{10} (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 7 WAS) > T_4 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 6 WAS) > T_9 (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 6 WAS) > T_3 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 5 WAS) > T_8 (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 5 WAS) > T_2 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 4 WAS) > T_1 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 3 WAS) > T_7 (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 4 WAS) > T_6 (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 3 WAS).

4.6.5 Weed index

The data representing weed index of different weed management practices in maize is depicted in Table 26.

Examining the data regarding weed index illustrated that highest weed index was recorded in T_{12} (weedy check) followed by T_{10} (Pendimethalin @ 1.5

kg ha^{-1} (PE) *fb* hand weeding at 7 WAS), however, T_{10} was at par with T_5 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 7 WAS), T_4 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 6 WAS) and T_9 (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 6 WAS). Lowest weed index was recorded in T_{11} (hand weeding after 3, 5 and 7 WAS) followed by T_2 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 4 WAS). Though, T_2 was at par with T_1 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 3 WAS), T_7 (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 4 WAS), T_6 (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 3 WAS), T_3 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 5 WAS) and T_8 (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 5 WAS).

4.6.6 Herbicide efficiency index

Different treatments differed with respect to herbicide efficiency index and the data regarding it is summarized in Table 27. Considering the herbicidal treatments at 15 DAS, highest herbicide efficiency index was recorded in treatment T_2 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 4 WAS). However, T_2 was statistically at par with T_1 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 3 WAS), T_3 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 5 WAS), T_4 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 6 WAS), T_5 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 7 WAS), T_7 (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 4 WAS), T_6 (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 3 WAS), T_8 (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 5 WAS), T_9 (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 6 WAS), T_{10} (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 7 WAS).

At 45 DAS highest herbicide efficiency index was reported in T_4 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 6 WAS) and lowest herbicide efficiency index was reported in T_{10} (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 7 WAS). The rest treatments in decreasing order of herbicide efficiency index were as: T_9 (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 6 WAS) > T_3 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 5 WAS) > T_8 (Pendimethalin @

1.5 kg ha^{-1} (PE) *fb* hand weeding at 5 WAS) > T_2 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 4 WAS > T_1 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 3 WAS) > T_7 (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 4 WAS) > T_6 (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 3 WAS) > T_5 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 7 WAS) > T_{10} (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 7 WAS) and).

At 75 DAS highest herbicide efficiency index was recorded in T_5 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 7 WAS) and lowest herbicide efficiency index was observed in T_6 (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 3 WAS). Other treatments followed the trend in decreasing order as: T_{10} (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 7 WAS) > T_4 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 6 WAS) > T_9 (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 6 WAS) > T_3 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 5 WAS) > T_8 (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 5 WAS) > T_2 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 4 WAS) > T_1 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 3 WAS) > T_7 (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 4 WAS).

4.7 Relative economics

The data pertaining to cost of cultivation, gross returns, net returns and benefit cost ratio as influenced by different weed management practices in maize is depicted in Table 28.Analysing the data revealed that highest net returns of (₹ 140154) were recorded in T_{13} (weed free), however, pertaining to its high cost of cultivation, its benefit cost ratio (1.789) lowered very much and among other treatments highest benefit cost ratio (2.170) was obtained for T_2 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 4 WAS) followed by T_1 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 3 WAS) (2.166). Least returns (₹ 32894) and benefit cost ratio (0.858) was recorded for T_{12} (weedy check).

Table 26: Weed Control Efficiency and Weed Index in maize as influenced by different weed management practices

Treatments	WCE at 15 DAS	WCE at 45 DAS	WCE at 75 DAS	Weed index (%)
T_1 Atrazine @ 1.5 kg ha^{-1} (PE) *fb* HW 3 WAS	84.42	82.61	75.18	24.85
T_2 Atrazine @ 1.5 kg ha^{-1} (PE) *fb* HW 4 WAS	84.84	83.91	76.48	24.60
T_3 Atrazine @ 1.5 kg ha^{-1} (PE) *fb* HW 5 WAS	84.32	87.73	77.15	26.43
T_4 Atrazine @ 1.5 kg ha^{-1} (PE) *fb* HW 6 WAS	84.16	94.80	80.38	39.97
T_5 Atrazine @ 1.5 kg ha^{-1} (PE) *fb* HW 7 WAS	83.92	34.48	83.46	41.74
T_6 Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* HW 3 WAS	82.91	79.36	74.02	25.65
T_7 Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* HW 4 WAS	83.10	80.48	74.65	25.38
T_8 Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* HW 5 WAS	82.83	87.51	76.63	26.92
T_9 Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* HW 6 WAS	82.46	94.47	77.46	39.58
T_{10} Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* HW 7 WAS	82.45	32.57	81.59	41.89
T_{11} Hand weeding after 3, 5 and 7 WAS	5.31	91.91	84.92	11.88
T_{12} Weedy check	-	-	-	58.68
T_{13} Weed free	-	-	-	-
SE (m) ±	3.29	2.35	1.01	2.12
CD ($p \leq 0.05$)	**9.78**	**7.27**	**2.94**	**5.40**

Where, HW = hand weeding, WAS = weeks after sowing, DAS = days after sowing

Table 27: Effect of different weed management practices on Herbicide Efficiency Index (%) in maize

Treatments	15 DAS	45 DAS	75 DAS
T_1 Atrazine @ 1.5 kg ha^{-1} (PE) *fb* HW 3 WAS	3.971	7.674	10.54
T_2 Atrazine @ 1.5 kg ha^{-1} (PE) *fb* HW 4 WAS	4.479	8.813	10.82
T_3 Atrazine @ 1.5 kg ha^{-1} (PE) *fb* HW 5 WAS	3.886	11.14	11.20
T_4 Atrazine @ 1.5 kg ha^{-1} (PE) *fb* HW 6 WAS	3.860	22.93	11.53
T_5 Atrazine @ 1.5 kg ha^{-1} (PE) *fb* HW 7 WAS	3.808	1.693	12.34
T_6 Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* HW 3 WAS	3.283	4.124	9.41
T_7 Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* HW 4 WAS	3.793	6.000	10.15
T_8 Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* HW 5 WAS	3.421	10.88	10.92
T_9 Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* HW 6 WAS	3.418	19.65	11.33
T_{10} Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* HW 7 WAS	2.769	1.579	11.75
T_{11} Hand weeding after 3, 5 and 7 WAS	-	-	-
T_{12} Weedy check	-	-	-
T_{13} Weed free	-	-	-
SE (m) ±	0.919	0.795	0.232
CD ($p \leq 0.05$)	**NS**	**2.380**	**0.694**

Where, HW = hand weeding, WAS = weeks after sowing, DAS = days after sowing

Table 28: Relative economics of maize as influenced by different weed management practices

Treatments	Cost of cultivation (₹ ha^{-1})	Gross returns (₹ ha^{-1})	Net returns (₹ ha^{-1})	Benefit :Cost ratio (₹ ha^{-1})
T_1 Atrazine @ 1.5 kg ha^{-1} (PE) *fb* HW 3 WAS	51507.22	163054	111547	2.166
T_2 Atrazine @ 1.5 kg ha^{-1} (PE) *fb* HW 4 WAS	51507.22	163257	111750	2.170
T_3 Atrazine @ 1.5 kg ha^{-1} (PE) *fb* HW 5 WAS	51507.22	158846	107339	2.084
T_4 Atrazine @ 1.5 kg ha^{-1} (PE) *fb* HW 6 WAS	51507.22	129111	77604	1.507
T_5 Atrazine @ 1.5 kg ha^{-1} (PE) *fb* HW 7 WAS	51507.22	124299	72791	1.413
T_6 Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* HW 3 WAS	51432.22	161087	109655	2.132
T_7 Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* HW 4 WAS	51432.22	161716	110283	2.144
T_8 Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* HW 5 WAS	51432.22	158712	107280	2.086
T_9 Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* HW 6 WAS	51432.22	128893	77461	1.506
T_{10} Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* HW 7 WAS	51432.22	122864	71431	1.389
T_{11} Hand weeding after 3, 5 and 7 WAS	68332.22	190754	122421	1.792
T_{12} Weedy check	38332.22	71226	32894	0.858
T_{13} Weed free	78332.22	218487	140154	1.789

Input cost (₹):
(₹)
Seed = 25 kg^{-1}, labour = 500 Mandays^{-1}
Atrazine = 450 kg^{-1}, Pendimethalin = 400 L^{-1}
Urea = 5.5 kg^{-1}, DAP = 33 kg^{-1}, MOP = 22.6 kg^{-1}

Output cost

Grain = 2800 q^{-1}
Stover = 250 q^{-1}

Chapter-5

DISCUSSION

The field experiment entitled **"Performance of Pre-emergence Herbicides and Manual Weed Control in Maize (*Zea mays* L.) under Temperate Conditions"** was conducted at research farm of Division of Agronomy, Faculty of Agriculture, Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir during *Kharif*, 2021. Description of different treatment effects on various characters studied has been put forth in previous chapter. This chapter is regarding the interpretation of possible reasons behind the results witnessed. This investigation has been corroborated by research findings of the prior researchers.

5.1 Effect of weed management practices on plant growth parameters

The plant height is a crucial growth parameter to have an idea about the pattern of dry matter accumulation by the plants and ultimately yield. Different weed management practices had a significant effect on plant height. Plants under T_{13} treatment (weed free) showed significantly higher plant height and were superior to rest of the treatments. At 30 DAS, T_{13} (weed free treatment) was followed by T_{11} (hand weeding after 3, 5 and 7 WAS), however, it was at par with T_2 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 4 WAS), T_1 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 3 WAS), T_7 (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 4 WAS), T_6 (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 3 WAS), T_3 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 5 WAS) and T_8 (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 5 WAS). From 60 DAS to harvest, tallest plants were recorded in T_{13} (weed free treatment) followed by T_{11} (hand weeding at 3, 5 and 7 WAS) and T_2 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 4 WAS), though, T_2 was at par with T_1 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 3 WAS), T_7 (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 4 WAS), T_6 (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 3 WAS), T_3

(Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 5 WAS) and T_8 (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 5 WAS). At all intervals the lowest plant height was shown by plants under T_{12} treatment (weedy check). The other weed management practices followed the trend: T_4 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 6 WAS) > T_9 (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 6 WAS) > T_5 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 7 WAS) > T_{10} (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 7 WAS). This may be ascribed to higher total density and dry matter accumulation of weeds under T_{12} treatment conditions that lead to increased crop-weed competition for different factors viz. soil moisture, sunlight, nutrients, space and carbon dioxide. These results were found in corroboration with reports of Naveed *et al.* (2008) and Malviya *et al*. (2012).

Number of functional leaves per plant at 30 days interval was significantly influenced by different weed management practices. Highest number of functional leaves per plant were witnessed in T_{13} (weed free) followed by T_{11} (hand weeding after 3, 5 and 7 WAS) and lowest number of functional leaves per plant were found in T_{12} (weedy check). At 30 DAS, T_{13} (weed free treatment) was followed by T_{11} (hand weeding at 3, 5 and 7 WAS) but, it was at par with T_2 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 4 WAS), T_1 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 3 WAS), T_7 (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 4 WAS), T_6 (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 3 WAS), T_3 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 5 WAS) and T_8. At 60 days after sowing upto harvest T_{13} (weed free treatment) was followed by T_{11} (hand weeding after 3, 5 and 7 WAS) and T_2 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 4 WAS). However, T_2 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 4 WAS) was statistically at par with T_1 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 3 WAS), T_7 (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 4 WAS), T_6 (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 3 WAS), T_3 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 5 WAS) and T_8 (Pendimethalin @ 1.5 kg ha^{-1}

(PE) *fb* hand weeding at 5 WAS). The remaining weed management practices revealed the trend: T_4 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 6 WAS) > T_9 (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 6 WAS) > T_5 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 7 WAS) > T_{10} (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 7 WAS). This may be attributed to the fact that plants under weedy check conditions faced more crop-weed competition for every factor due to higher weed population thus rendering maize plants weak to produce more number of functional leaves. Negligible crop-weed competition under weed free conditions allowed the plants to increase number of functional leaves per plant. Similar reports were witnessed by Abouzienz *et al*. (2008).

Dry matter accumulation is of paramount importance when we take into consideration the growth and efficiency of metabolic activities in a plant and finally the yield. Different weed management practices differed significantly with respect to dry matter accumulation. T_{13} (weed free) outperformed all other treatments under observation, revealed highest dry matter production at all intervals. At first periodic interval i.e., 30 days after sowing T_{13} (weed free treatment) was followed by T_{11} (hand weeding at 3, 5 and 7 WAS) though T_{11} was at par with T_2 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 4 WAS), T_1 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 3 WAS), T_7 (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 4 WAS), T_6 (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 3 WAS), T_3 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 5 WAS) and T_8 (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 5 WAS). At second periodic interval upto harvest, after T_{13} (weed free treatment) highest dry matter accumulation was recorded in T_{11} (hand weeding after 3, 5 and 7 WAS) followed by T_2 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 4 WAS) which was at par with T_1 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 3 WAS), T_7 (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 4 WAS), T_6 (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 3 WAS), T_3 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 5 WAS) and T_8 (Pendimethalin @ 1.5 kg ha^{-1}

(PE) *fb* hand weeding at 5 WAS) respectively. The rest weed management practices revealed the trend: T_4 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 6 WAS) > T_9 (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 6 WAS) > T_5 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 7 WAS) > T_{10} (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 7 WAS). Lowest dry matter production was observed in T_{12} (weedy check) throughout the crop growth period. This might be credited to higher weed density and weed dry matter accumulation in weedy check treatment leading to increased competition and depletion of important factors such as nutrients, soil moisture, sunlight, carbon dioxide, etc. by weeds reducing the total biomass production. The findings are in authorization with reports of Malviya and Singh (2007) and Rasool and Khan (2016).

Leaf area index is an important growth parameter in all crops because it governs the solar radiation interception which in turn controls the process of photosynthesis and total dry matter production. Optimum leaf area index is the key for maximum light interception and ultimately no partial shading and enhanced total biomass production. The highest leaf area was recorded at 60 DAS in plants under T_{13} (weed free) followed by T_{11} (hand weeding after 3, 5 and 7 WAS). Among other treatments under study T_{13} (weed free) was followed by T_{11} (hand weeding at 3, 5 and 7 WAS) and T_2 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 4 WAS) which inturn was at par with T_1 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 3 WAS), T_7 (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 4 WAS), T_6 (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 3 WAS), T_3 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 5 WAS) and T_8. The other treatments were in the following trend: T_4 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 6 WAS) > T_9 (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 6 WAS) > T_5 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 7 WAS) > T_{10} (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 7 WAS). Lowest leaf area index was reported in T_{12} (weedy check) at all periodic intervals. The decrease in leaf area index of plants under weedy check conditions may be

attributed to presence of higher weed flora and hence increased competition with weeds. The results are in close justification with the results of Mahmoodi and Rahman (2009).

Crop growth rate, relative growth rate and net assimilation rate are useful indicators for understanding the behaviour of growth in a crop. These varied significantly in consideration with various treatments under study. Plants under T_{13} (weed free) showed the highest crop growth rate, relative growth rate and net assimilation rate at all periodic intervals and least CGR, RGR and NAR was observed in plants under T_{12} (weedy check). Among other treatments T_{13} was followed by T_{11} (hand weeding after 3, 5 and 7 WAS). The higher rate of these indicators in T_{13} may be ascribed to least crop-weed competition faced by the plants, maintaining favourable conditions and allowing the plants to show maximum possible growth. Similar observations were drawn by Lindquist *et al*. (2005).

5.2 Effect of weed management practices on yield attributes

All the weed management practices influenced the yield attributing characters viz. number of cobs per plant, number of grain rows per cob, number of grains per cob and seed index. Examining the data, it was explored that highest yield attributing characters were recorded in T_{13} (weed free) followed by T_{11} (hand weeding after 3, 5 and 7 WAS). The lowest values were reported in T_{12} (weedy check). The increase in yield attributes may be attributed towards the better efficiency of controlling weeds and thereby reducing the intensity of crop-weed competition and allowing enhanced growth and development of maize plants. These results are in close coherence with conclusions made by Malviya and Singh (2007), Shantveerayya and Agasimani (2012), Nadiger *et al.* (2013) and Rasool and Khan (2016).

5.3 Effect of weed management practices on yield and harvest index

Grain yield, stover yield and biological yield varied significantly across various treatments under investigation. The variations caused in yield attributes due to different weed management practices directly impacted the grain yield of maize plants because grain yield is the cumulative response of these yield attributing characters. It was observed that highest grain, stover and biological yield was reported from T_{13} (weed free) treatment followed by T_{11} (hand weeding after 3, 5 and 7 WAS) and lowest yield was obtained from plants under T_{12} (weedy check). As for harvest index, highest harvest index was obtained in T_{13} (weed free) which was at par with all other treatments under study except T_{12} (weedy check) and lowest harvest index was obtained in T_{12} (weedy check) treatment. This may be assigned to the fact that higher density and dry weight of weeds under weedy check conditions increased the competition level between crop plants and weeds, badly impacting the growth and development of maize plants reducing the yield attributes which ultimately decreased the yield. Numerous researchers have also reported yield losses in maize due to unchecked crop-weed competition. 30-90 % yield loss was recorded by Yakadri *et al*. (2015). 28-100% yield loss was reported by Das *et al*. (2016) and Kumar *et al*. (2017). 77-97 % higher grain yield of maize was obtained in treated plots than weedy check plots by Dharam *et al*. (2018).

5.4 Effect of weed management practices on NPK content and uptake of maize plants

Different weed management practices varied in relation to the nitrogen, phosphorous and potassium content and uptake of maize plants. Considering the NPK content, highest content was witnessed in T_{13} (weed free) plants, however, it was at par with all other treatments except T_{12} (weedy check) and lowest nutrient content was recorded in plants under T_{12} (weedy check) treatment.

With respect to NPK uptake, highest uptake was recorded in plants under T_{13} (weed free) followed by T_{11} (hand weeding after 3, 5 and 7 WAS) and lowest uptake was reported from plants of T_{12} (weedy check). The increased nutrient content and uptake by maize plants in T_{13} and T_{11} might be credited to least depletion of nutrients by weeds in these plots. Under weedy check conditions, weeds depleted more nutrients due to their unchecked growth and more dry matter accumulation posing severe competition to maize plants and ultimately decreasing their nutrient content and uptake. These findings are in corroboration with results of Kour *et al*. (2014), Deewan *et al*. (2018) and Satheesh *et al.* (2018).

5.5 Effect of weed management practices on soil chemical properties

As for the chemical properties of soil viz. pH, EC, organic carbon, available N, P and K, different weed management practices under contemplation did not influence significantly the chemical properties of soil after crop harvest. The results are in contrast with the findings of Sidorov (1974), he declared that improved nutrient stock of soil following atrazine application might be credited to collaborative effect of decreased nutrient uptake by weeds and enhanced activities of microbes present in soil.

5.6 Effect of weed management practices on weed indices

Weeds identified: The major weed species associated with the crop were *Sorghum helepense, Digitaria sanguinalis, Convolvulus arvensis, Chenopodium album, Datura stramonium, Rumex crispus, Amaranthus viridis, Matricaria chamomilla, Persicaria maculosa, Cyperus rotundus.* These results are in close coherence with findings of Bahar *et al*. (2009).

Weed density and weed dry matter accumulation: It was found that various weed management practices decreased the weed density and dry matter accumulation as compared to that of weedy check.

At 15 DAS, highest weed density and weed dry matter accumulation was observed in T_{12} (weedy check) followed by T_{11} (hand weeding after 3, 5 & 7

WAS). Non significant difference was obtained among other treatments and were in the order as follows: T_{10} (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 7 WAS) > T_8 (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 5 WAS) > T_9 (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 6 WAS) T_6 (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 3 WAS) > T_7 (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 4 WAS) > T_4 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 6 WAS) > T_5 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 7 WAS) > T_3 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 5 WAS) > T_1 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 3 WAS) > T_2 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 4 WAS) respectively. Lowest weed density and weed dry matter accumulation of weeds was observed in T_2 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 4 WAS). The higher weed density and weed dry matter accumulation in T_{12} and T_{11} may be attributed to no removal of weeds in these plots, increasing the period of weed interference and hence weed dry weight. Lower weed density and weed dry matter accumulation in rest treatments may be assigned to control of weeds with pre-emergence application of atrazine and pendimethalin in respective treatments. Similar reports were recorded by Sharma *et al*. (2000) and Mukundam *et al*. (2011). At 45 DAS, highest weed density and weed dry matter accumulation was obtained in T_{12} (weedy check) followed by T_{10} (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 7 WAS) and T_5 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 7 WAS). Lowest weed density and weed dry matter accumulation was obtained in T_4 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 6 WAS) which was at par with T_9 (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 6 WAS). At 75 DAS, highest weed density and weed dry matter accumulation was found in T_{12} (weedy check) and lowest in T_{11} (hand weeding after 3, 5 and 7 WAS). The higher weed density and weed dry matter accumulation in weedy check at all intervals is due to uncontrolled conditions favouring enhanced growth of weeds and the lower weed density in other treatments at each interval may be assigned to the removal of weeds by hand weeding. These results are in close confirmation with conclusions of Riaz *et al*.

(2007) and Arvadiya *et al*. (2012). Reduction in weed density and weed dry weight in weed free and other herbicidal treatments in contrast to weedy check was also recorded by Shankar *et al*. (2015).

Weed control efficiency: At 15 DAS lowest weed control efficiency was found in T_{11} (hand weeding after 3, 5 and 7 WAS). Non significant difference in weed control efficiency was found in remaining treatments containing atrazine and pendimethalin. Numerically, the treatments containing atrazine showed higher weed control efficiency than treatments containing pendimethalin and were present in the trend as: T_2 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 4 WAS) > T_1 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 3 WAS) > T_3 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 5 WAS) > T_4 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 6 WAS) > T_5 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 7 WAS) > T_7 (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 4 WAS) > T_6 (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 3 WAS) > T_8 (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 5 WAS) > T_9 (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 6 WAS) > T_{10} (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 7 WAS). The higher weed control efficiency of treatments containing atrazine and pendimethalin might be credited to the aspect that there was less weed density and weed dry weight in these treatments corresponding to effectual herbicidal activity of atrazine and pendimethalin. T_{11} showed lowest weed control efficiency due to the fact that no hand weeding had been done in these plots upto 15 days after sowing allowing weeds to grow freely. The results are in close coherence with findings of Rani *et al*. (2020) and Rai *et al*. (2018). At 45 DAS highest weed control efficiency was reported in T_4 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 6 WAS). However, it was statistically at par with T_9 (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 6 WAS). Lowest weed control efficiency was found in T_{10} (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 7 WAS) and T_5 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 7 WAS). The higher weed control

efficiency in T_4 and T_5 may be attributed to the fact that in these plots one hand weeding was done at 42 days after sowing and the weed data was recorded at 45 days after sowing i.e., just 3 days after hand weeding allowing negligible growth of weeds during this time span. The results are in close coherence with conclusions made by Usman (2013). At 75 DAS highest weed control efficiency was found in T_{11} (hand weeding after 3, 5 and 7 WAS) and lowest in T_6 (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 3 WAS). The highest weed control efficiency in T_{11} may be ascribed to the aspect that in these plots 3 hand weedings were done during the critical period of crop-weed competition, encouraging crop growth and controlling weed growth to its maximum. The low efficiency of T_6 treatment as compared to others might be owing to the consideration that hand weeding was done at 21 days after sowing in these plots permitting some weed growth thereafter upto next weed data collection interval i.e., 75 days after sowing. The above findings are in near corroboration with the reports put forward by Tahir *et al*. (2009), Samant *et al*. (2015).

Weed index: Highest weed index was recorded in T_{12} (weedy check) followed by T_{10} (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 7 WAS), however, T_{10} was at par with T_5 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 7 WAS), T_4 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 6 WAS) and T_9 (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 6 WAS). Lowest weed index was recorded in T_{11} (hand weeding after 3, 5 and 7 WAS) followed by T_2 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 4 WAS). But, T_2 was at par with T_1 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 3 WAS), T_7 (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 4 WAS), T_6 (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 3 WAS), T_3 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 5 WAS) and T_8 (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 5 WAS). Higher weed index under weedy check conditions might be ascribed to increased crop-weed interference leading to more yield loss and lower weed index in respective mentioned treatments may be due to less crop-weed competition

favouring better crop growth and development leading to low yield losses. Similar conclusions were drawn by Sanodiya *et al*. (2013) and Samant *et al*. (2015).

Herbicide efficiency index: At 15 DAS no statistical difference was found between different treatments containing herbicides, but numerically highest herbicide efficiency index was found in treatment T_2 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 4 WAS). The remaining treatments followed the trend in decreasing order as: T_1 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 3 WAS), T_3 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 5 WAS), T_4 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 6 WAS), T_5 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 7 WAS), T_7 (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 4 WAS), T_6 (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 3 WAS), T_8 (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 5 WAS), T_9 (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 6 WAS), T_{10} (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 7 WAS).The herbicidal efficiency of treatments containing atrazine and pendimethalin varied numerically but there was no statistical difference found. It might be attributed to the fact that both atrazine and pendimethalin have efficient herbicidal activities. At 45 DAS highest herbicide efficiency index was reported in T_4 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 6 WAS) and lowest herbicide efficiency index was reported in T_{10} (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 7 WAS). The rest treatments in decreasing order of herbicide efficiency index were observed as: T_9 (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 6 WAS) > T_3 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 5 WAS) > T_8 (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 5 WAS) > T_2 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 4 WAS > T_1 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 3 WAS) > T_7 (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 4 WAS) > T_6 (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 3 WAS) > T_5 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 7 WAS) > T_{10} (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 7 WAS). The higher efficiency of T_4 might be attributed

to the aspect that one hand weeding was done in this plot at 42 days after sowing allowing negligible weed population to grow there. Lowest herbicide efficiency index of T_{10} could be accredited to the fact that no hand weeding had been done yet in this plot providing more scope for weeds to grow and increase in weight. At 75 DAS highest herbicide efficiency index was found in T_5 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 7 WAS) and lowest herbicide efficiency index was observed in T_6 (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 3 WAS). Other treatments followed the trend in decreasing order as: T_{10} (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 7 WAS) > T_4 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 6 WAS) > T_9 (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 6 WAS) > T_3 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 5 WAS) > T_8 (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 5 WAS) > T_2 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 4 WAS) > T_1 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 3 WAS) > T_7 (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 4 WAS). The higher efficiency of T_5 may be imputed to the fact that in this treatment after pre emergence application of atrazine one hand weeding was done at 49 DAS which supressed the weed growth thereafter, decreasing weed dry weight and increasing efficiency index. The low efficiency of T_6 might be because of the fact that in this treatment hand weeding was done at 21 DAS, permitting some weed growth thereafter, increasing weed dry weight and decreasing efficiency index. The results are in close conformity with findings of Triveni *et al*. (2017).

5.7 Effect of weed management practices on relative economics

Efficacy of any treatment is ultimately finalized by working out its economics (benefit: cost ratio) because it is crucial to justify the increase in economic yield with the cost of cultivation involved. This investigation revealed that highest net returns of (₹ 140154) were recorded in T_{13} (weed free), however, pertaining to its high cost of cultivation, its benefit cost ratio (1.789) lowered very much and same was the case with T_{11} (hand weeding after 3, 5 and 7 WAS)

treatment which revealed good returns but its benefit cost ratio was also reduced owing to high cost of cultivation. Among other treatments highest benefit cost ratio (2.170) was obtained for T_2 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 4 WAS) followed by T_1 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 3 WAS) (2.166). This might be assigned to the fact that lower cost was involved in treatments T_2 and T_1 due to low cost of herbicides and low labour requirement combined with high returns, permitted the higher benefit cost ratio. Least returns (32894) and benefit cost ratio (0.858) was recorded for T_{12} (weedy check). There was no control of weeds throughout the crop growth period in weedy check, resulting in poor crop growth associated with low yield, eventually lowest net returns and benefit cost ratio. These results are in close conformity with findings of Pandey *et al*. (2002), Dobariya *et al*. (2015) and Barad *et al*. (2016).

Chapter-6

SUMMARY AND CONCLUSION

The field experiment entitled "Performance of Pre-emergence Herbicides and Manual Weed Control in Maize (*Zea mays* L.) under Temperate Conditions" was conducted at research farm of Division of Agronomy, Faculty of Agriculture, Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir during *Kharif*, 2021 with following objectives:

1. To study growth and yield of maize as influenced by pre-emergence herbicide application at varying intervals of manual weeding.
2. To study weed dynamics and performance of weed control measures.
3. To work out the relative economics.

The experiment consisted of 13 treatments laid out in randomized complete block design with three replications: T_1: Atrazine @ 1.5 kg ha^{-1} (PE) followed by hand weeding 3 WAS, T_2: Atrazine @ 1.5 kg ha^{-1} (PE) followed by hand weeding 4 WAS, T_3 : Atrazine @ 1.5 kg ha^{-1} (PE) followed by hand weeding 5 WAS, T_4 : Atrazine @ 1.5 kg ha^{-1} (PE) followed by hand weeding 6 WAS, T_5 : Atrazine @ 1.5 kg ha^{-1} (PE) followed by hand weeding 7 WAS, T_6: Pendimethalin @1.5 kg ha^{-1} (PE) followed by hand weeding 3 WAS, T_7: Pendimethalin @1.5 kg ha^{-1} (PE followed by hand weeding 4 WAS, T_8: Pendimethalin @1.5 kg ha^{-1} (PE) followed by hand weeding 5 WAS, T_9 : Pendimethalin @1.5 kg ha^{-1} (PE) followed by hand weeding 6 WAS, T_{10}: Pendimethalin @1.5 kg ha^{-1} (PE) followed by hand weeding 7 WAS, T_{11}: Hand weeding after 3, 5 and 7 WAS, T_{12} : Weedy check, T_{13}: Weed free. The effect of different treatments under investigation on various characters have been discussed and explained in preceding chapter. The important findings of present investigation have been summarized in this chapter:

6.1 Growth parameters

- Different growth parameters viz. plant height, number of functional leaves per plant, dry matter accumulation, leaf area index, crop growth rate, relative growth rate and net assimilation rate differed significantly concerning all the weed management practices.
- Highest plant growth parameters were witnessed in T_{13} plots (weed free) which was followed by T_{11} (hand weeding after 3, 5 and 7 WAS) and T_2 (Atrazine @ 1.5 kg ha^{-1} (PE) followed by hand weeding 4 WAS). However, T_2 was at par with T_1 (Atrazine @ 1.5 kg ha^{-1} (PE) followed by hand weeding 3 WAS), T_7 (Pendimethalin @1.5 kg ha^{-1} (PE) followed by hand weeding 4 WAS), T_6 (Pendimethalin @1.5 kg ha^{-1} (PE) followed by hand weeding 3 WAS), T_3 (Atrazine @ 1.5 kg ha^{-1} (PE) followed by hand weeding 5 WAS) and T_8 (Pendimethalin @1.5 kg ha^{-1} (PE) followed by hand weeding 5 WAS).
- Lowest growth parameters were reported in T_{12} plots (weedy check).

6.2 Yield attributes and yield

- Yield attributing characters and yield varied significantly across several weed management practices.
- T_{13} treatment (weed free) outperformed all other treatments under investigation and reported highest yield attributes and yield. Amongst rest of the treatments, T_{13} (weed free) was followed by T_{11} (hand weeding after 3, 5 and 7 WAS) and T_2 (Atrazine @ 1.5 kg ha^{-1} (PE) followed by hand weeding 4 WAS). Although, T_2 was at par with T_1 (Atrazine @ 1.5 kg ha^{-1} (PE) followed by hand weeding 3 WAS), T_7 (Pendimethalin @1.5 kg ha^{-1} (PE) followed by hand weeding 4 WAS), T_6 (Pendimethalin @1.5 kg ha^{-1} (PE) followed by hand weeding 3 WAS), T_3 (Atrazine @ 1.5 kg ha^{-1} (PE) followed by hand weeding 5 WAS) and T_8 (Pendimethalin @1.5 kg ha^{-1} (PE) followed by hand weeding 5 WAS).
- Lowest yield attributes and yield were reported in T_{12} plots (weedy check).

6.3 Nutrient content and uptake

- Among different weed management practices higher nutrient content in grain and stover was displayed by plants of T_{13} treatment (weed free) yet it was at par with every other treatment except T_{12} (weedy check) and T_{12} reported lowest nutrient content in both grain and stover.
- Highest uptake of nitrogen, phosphorous and potassium was observed in maize plants of T_{13} treatment (weed free) and least uptake was shown by maize plants in T_{12} (weedy check). Out of rest treatments under consideration, T_{13} was followed by T_{11} (hand weeding after 3, 5 and 7 WAS) and T_2 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 4 WAS). Even though, T_2 was statistically at par with T_1 (Atrazine @ 1.5 kg ha^{-1} (PE) followed by hand weeding 3 WAS), T_7 (Pendimethalin @1.5 kg ha^{-1} (PE) followed by hand weeding 4 WAS), T_6 (Pendimethalin @1.5 kg ha^{-1} (PE) followed by hand weeding 3 WAS), T_3 (Atrazine @ 1.5 kg ha^{-1} (PE) followed by hand weeding 5 WAS), T_8 (Pendimethalin @1.5 kg ha^{-1} (PE) followed by hand weeding 5 WAS).

6.4 Weed indices

- The predominant weeds associated with the maize crop were: *Sorghum helepense, Digitaria sanguinalis, Convolvulus arvensis, Chenopodium album, Datura stramonium, Rumex crispus, Amaranthus viridis, Matricaria chamomilla, Persicaria maculosa, Cyperus rotundus.*
- The different weed indices viz. weed density, weed dry matter accumulation, weed control efficiency, weed index and herbicide efficiency index were found significant in regard to various weed management treatments under consideration. At 15 DAS, highest weed density and weed dry matter accumulation was observed in T_{12} (weedy check) followed by T_{11} (hand weeding after 3, 5 and 7 WAS). Lowest weed density and weed dry matter accumulation was observed in T_2 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 4 WAS). But, T_2 was at

par with other treatments of atrazine and pendimethalin. At 45 DAS, highest weed density and weed dry matter accumulation was obtained in T_{12} (weedy check) followed by T_{10} (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 7 WAS) and T_5 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 7 WAS). Lowest weed density and weed dry matter accumulation was obtained in T_4 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 6 WAS) which was at par with T_9 (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 6 WAS). At 75 DAS, highest weed density and weed dry matter accumulation was found in T_{12} (weedy check) and lowest in T_{11} (hand weeding after 3, 5 and 7 WAS).

- At 15 DAS highest weed control efficiency was found in T_2 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 4 WAS) and lowest weed control efficiency was found in T_{11} (hand weeding after 3, 5 and 7 WAS). However, T_2 was statistically at par with other treatments containing atrazine and pendimethalin. At 45 DAS highest weed control efficiency was reported in T_4 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 6 WAS). However, it was statistically at par with T_9 (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 6 WAS). Lowest weed control efficiency was found in T_{10} (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 7 WAS) and T_5 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 7 WAS). At 75 DAS highest weed control efficiency was found in T_{11} (hand weeding after 3, 5 and 7 WAS) and least in T_6 (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 3 WAS).
- Highest weed index was recorded in T_{12} (weedy check) followed by T_{10} (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 7 WAS). Lowest weed index was recorded in T_{11} (hand weeding after 3, 5 and 7 WAS) followed by T_2 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 4 WAS).
- At 15 DAS all the weed management practices featuring atrazine and pendimethalin herbicides differed numerically with respect to herbicide efficiency index, however, there was no statistical significance observed.

At 45 DAS highest herbicide efficiency index was found in T_4 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 6 WAS) and lowest herbicide efficiency index was found in T_{10} (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 7 WAS). At 75 DAS highest herbicide efficiency index was reported in T_5 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 7 WAS) and lowest in T_6 (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 3 WAS).

6.5 Relative economics

- This investigation revealed that highest benefit cost ratio (2.170) was obtained in T_2 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 4 WAS) followed by T_1 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 3 WAS) (2.166).
- Least benefit cost ratio (0.858) was recorded for T_{12} (weedy check).

CONCLUSION

On the basis of generalization of the results obtained from present investigation, it was concluded that:

- All the weed management practices were significantly superior in managing weeds, enhancing crop growth, development and yield attributes which in succession increased yield and recorded higher net returns and benefit cost ratio as compared to weedy check
- T_{11} (hand weeding after 3, 5 and 7 WAS) though being superior in managing weeds, recorded higher growth parameters and yield, but failed in cost-effectiveness due to high labour requirement
- Among other treatments T_2 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 4 WAS) was effective in managing weeds, decreased crop-weed competition and revealed highest benefit cost ratio. However, T_2 was statistically at par with T_1 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at

4 WAS), T_7 (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 4 WAS), T_6 (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 3 WAS), T_3 (Atrazine @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 4 WAS) and T_8 (Pendimethalin @ 1.5 kg ha^{-1} (PE) *fb* hand weeding at 5 WAS).

❖ Based on the study, it can be concluded that under existing circumstances Atrazine or Pendimethalin @ 1.5 kg ha^{-1} (PE) integrated with a hand weeding at 3 - 5 WAS can be used for efficient and cost-effective weed management in maize. Although, further research studies are necessary to be conducted at various locations of the Kashmir valley before final recommendations are made.

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APPENDIX-I

Meteorological data for cropping season 2021

Standard meteorological weeks	Temperature (□C)		Rainfall (mm)	Relative Humidity (%)	
	Max. T	Min. T		RH I	RH II
19	23.6	9.7	1.1	83.7	62.1
20	25.2	8.4	1.0	81.1	53.4
21	24.4	7.3	1.1	81.7	56.1
22	28.8	10.9	0.1	74.9	59.6
23	32.4	14.9	2.0	77.4	44.4
24	28.0	13.4	0.6	78.1	49.9
25	29.6	11.7	0.3	76.9	45.9
26	31.6	13.0	0.2	73.0	51.4
27	30.1	13.7	0.8	81.1	49.8
28	31.0	17.7	2.0	83.6	53.6
29	29.2	17.4	3.4	86.1	61.6
30	31.4	19.4	2.9	86.6	60.6
31	30.1	17.2	5.7	87.3	64.1
32	30.6	14.4	2.4	85.9	53.4
33	29.5	12.9	0.3	83.9	45.3
34	32.6	14.9	0.1	81.7	41.6
35	29.4	13.6	0.1	82.7	50.9
36	31.6	13.6	1.4	84.9	49.7
37	29.5	14.2	2.3	89.7	54.7
38	30.7	14.1	0.8	87.3	50.3
39	31.3	12.2	0.0	88.6	47.1
40	28.5	13.4	0.9	88.3	51.1
41	24.6	6	3.0	90.7	54.3

Appendix-II

COMMON COST OF CULTIVATION (₹ ha^{-1}) DURING *KHARIF* 2021

S. No.	Particulars		Quantity	RAte (₹)	Amount (₹)
01	Tractor charges		20 kanals	500 kanal^{-1}	10000
02	Field preparation charges		7 MD	500 MD^{-1}	3500
03	Seed cost		20 kg	25 kg^{-1}	500
04	Labour charges for sowing		5 MD	500 MD^{-1}	2500
05	Fertilizer cost	Urea	129.02 kg ha^{-1}	5.5 kg^{-1}	709
		DAP	86.95 kg ha^{-1}	33 kg^{-1}	2869
		MOP	33.3 kg ha^{-1}	22.6 kg^{-1}	753
06	Labour charges for fertilizer application		4 MD	500 MD^{-1}	2000
07	Cob picking and harvesting		20 MD	500 MD^{-1}	10000
08	Cob drying and shelling		8 MD	500 MD^{-1}	4000
09	Miscellaneous		3 MD	500 MD^{-1}	1500
Total cost A					**38332**

Where, MD = Mandays

Appendix-III

TREATMENT WISE COST DURING *KHARIF* 2021

Treatment	COST-A	Treatment charges	Total cost
T□	38332	13175	51507
T□	38332	13175	51507
T□	38332	13175	51507
T□	38332	13175	51507
T□	38332	13175	51507
T□	38332	13100	51432
T□	38332	13100	51432
T□	38332	13100	51432
T□	38332	13100	51432
T□□	38332	13100	51432
T□□	38332	30000	68332
T□□	38332	0	38332
T□□	38332	40000	78332

Appendix-IV

RATE OF GRAIN AND STOVER

S. No.	Particulars	Rate
01	Grain	2800 q^{-1}
02	Stover	250 q^{-1}

Sher-e-Kashmir
University of Agricultural Sciences & Technology of Kashmir,
Division of Agronomy, Faculty of Agriculture, Wadura – 193201

CERTIFICATE

Certified that the all the corrections/amendments as suggested by External Examiner **Dr. Brij Nandan,** Professor cum Chief Scientist (Agronomy), PRSS-SKUAST-Jammu during Viva-Voce examination held on **07-10-2022** have been incorporated in the manuscript entitled **"Performance of Pre-emergence herbicides and Manual Weed Control in Maize (*Zea mays* L.) under Temperate Conditions"** Submitted by **Ms. Ishrat Mumtaz (Regd. No. MSA-2020-1321).**

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Chairman
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