EVALUATION OF PRE AND POST EMERGENCE HERBICIDES IN KHARIF MAIZE (Zea mays L.)

CHEEPURU RAMA RAO
B.Sc. (Ag.)

MASTER OF SCIENCE IN AGRICULTURE (AGRONOMY)

2015
ACKNOWLEDGEMENTS

Accomplishment of this thesis is the result of benevolence of Almighty, blessings of my teachers, love of my parents and motivation of my friends.

At the very outset, whole heartedly I wish to express my fidelity and deep sense of gratitude to the chairman of my advisory committee Dr. P.V.N. Prasad, Principal Scientist (Agronomy) and Head, Agricultural College Farm, Bapatla for his learned counsel, unstinted attention, arduous and meticulous guidance. I feel elated to express my heartfelt thanks for his immense interest, transcendent suggestions, affectionate encouragement and adroitness in handling the work in all its stages which provided me commendable encouragement and shaped my efforts into a successful research work.

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It gives me great pleasure to extend my sincere thanks to Dr. P.R.K. Prasad, Associate Dean, Agricultural College, Bapatla member of my advisory committee for his timely guidance and kind cooperation throughout my research work.

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I avail this opportunity with humbleness to sincerely thank Dr. Ch. Pulla Rao, Professor and Head of the Department of Agronomy, Agricultural College, Bapatla for the kind cooperation and guidance throughout my post graduation programme.

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I place my sincere thanks to my friends Ashok, Pradeep, Anil, Ramesh Babu and Prabhakar always being there beside me in difficult times during my course of study and giving constant motivation.

I shall be failing in my duty, if I don't express my thanks to ANGRAU for providing me the financial help in the form of stipend and also encouragement to complete the study successfully.

While travelling on this part of education, many hands pushed me forth, learned hearts put me on the right track. I ever rest THANKS to all of them.

Any omission in this brief acknowledgement doesn't mean lack of gratitude.

Place : Bapatla

Date : (Ch. Rama Rao)
DECLARATION

I, CH. RAMA RAO, hereby declare that the thesis entitled “EVALUATION OF PRE AND POST EMERGENCE HERBICIDES IN KHARIF MAIZE (Zea mays L.)” submitted to the Acharya N.G. Ranga Agricultural University for the degree of Master of Science in Agriculture is the result of original research work done by me. I also declare that no material contained in the thesis has been published earlier in any manner.

Place : (CH. RAMA RAO)

Date : I. D. No. BAM-13-05
EVALUATION OF PRE AND POST EMERGENCE HERBICIDES IN KHARIF MAIZE (Zea mays L.)

BY
CHEEPURU RAMA RAO
B.Sc. (Ag.)

THESIS SUBMITTED TO THE
ACHARYA N.G. RANGA AGRICULTURAL UNIVERSITY
IN PARTIAL FULFILMENT OF THE REQUIREMENTS
FOR THE AWARD OF THE DEGREE OF

MASTER OF SCIENCE IN AGRICULTURE
(AGRONOMY)

CHAIRPERSON: Dr. P.V.N. PRASAD

DEPARTMENT OF AGRONOMY
AGRICULTURAL COLLEGE, BAPATLA - 522 101
ACHARYA N.G. RANGA AGRICULTURAL UNIVERSITY
2015
CERTIFICATE

Mr. CH. RAMA RAO has satisfactorily prosecuted the course of research and that thesis entitled “EVALUATION OF PRE AND POST EMERGENCE HERBICIDES IN KHARIF MAIZE (Zea mays L.)” submitted is the result of original research work and is of sufficiently high standard to warrant its presentation to the examination. I also certify that neither the thesis nor its part thereof has been previously submitted by him for a degree of any University.

Date: (P.V.N. PRASAD)
Chairperson of the Advisory Committee
Principal Scientist (Agronomy) & Head
Agricultural College Farm, Bapatla
CERTIFICATE

This is to certify that the thesis entitled “EVALUATION OF PRE AND POST EMERGENCE HERBICIDES IN KHARIF MAIZE (Zea mays L.)” submitted in partial fulfilment of the requirements for the degree of ‘Master of Science in Agriculture’ of the Acharya N.G. Ranga Agricultural University, Hyderabad is a record of the bonafide original research work carried out by Mr. CH. RAMA RAO under my guidance and supervision.

No part of the thesis has been submitted by the student for any other degree or diploma. The published part and all the assistance received during the course of the investigations have been duly acknowledged by the author of the thesis.

Thesis approved by the Student’s Advisory Committee

Chairperson  Dr. P.V.N. PRASAD  
Principal Scientist (Agronomy) & Head 
Agricultural College Farm 
Bapatla

Member  Dr. B. VENKATESWARLU  
Principal Scientist (Agronomy) & Head 
Agricultural Research Station 
Garikapadu

Member  Dr. P.R.K. PRASAD  
Associate Dean 
Agricultural College, Bapatla

Date of final viva-voce:
ABSTRACT

Author: CH. RAMA RAO

Title of the thesis: EVALUATION OF PRE AND POST EMERGENCE HERBICIDES IN KHARIF MAIZE (Zea mays L.)

Degree to which it is submitted: MASTER OF SCIENCE IN AGRICULTURE

Faculty: AGRICULTURE

Department: AGRONOMY

Major Advisor: Dr. P.V.N. PRASAD

University: ACHARYA N. G. RANGA AGRICULTURAL UNIVERSITY

Year of Submission: 2015

A field experiment entitled “Evaluation of pre and post emergence herbicides in kharif maize” was conducted on sandy clay loam soil at Agricultural College Farm, Bapatla during kharif 2014 by adopting Randomized Block Design with nine treatments replicated thrice.

The treatments consisted of T₁-Weedy check; T₂-Hand weeding at 20 and 40 DAS; T₃-Pendimethalin @ 1.0 kg a.i ha⁻¹ (PE); T₄-Atrazine @ 1.0 kg a.i ha⁻¹ (PE); T₅-Topramezone @ 25 g a.i ha⁻¹ at 20 DAS (POE); T₆-Topramezone @ 25 g a.i ha⁻¹ at 40 DAS (POE); T₇-Topramezone @ 25 g a.i ha⁻¹ at 20 and 40 DAS (POE); T₈-Pendimethalin @ 1.0 kg a.i ha⁻¹ (PE) fb topramezone @ 25 g a.i ha⁻¹ at 20 DAS (POE); T₉-Atrazine @ 1.0 kg a.i ha⁻¹ fb (PE) topramezone @ 25 g a.i ha⁻¹ at 20 DAS (POE).

The predominant weed species observed in the experimental field were Cyperus rotundus among sedges, Trianthema portulacastrum, Cleome viscosa, Euphorbia hirta and Phyllanthus niruri among broad leaved weeds and Cynodon dactylon, Panicum repens and Dactyloctenium aegyptium among grasses.
The lowest density and dry weight of weeds and the highest weed control efficiency were recorded with hand weeding at 20 and 40 DAS (T2). Among herbicidal treatments, pre-emergence application of atrazine @ 1.0 kg a.i ha\(^{-1}\) fb topramezone spray @ 25 g a.i ha\(^{-1}\) at 20 DAS (T9) and pre-emergence application of pendimethalin @ 1.0 kg a.i ha\(^{-1}\) fb topramezone spray @ 25 g a.i ha\(^{-1}\) at 20 DAS (T8) recorded lower values for weed density, drymatter and higher weed control efficiency and were on a par with hand weeding at 20 and 40 DAS (T2). The highest density and drymatter of weeds was recorded in weedy check (T1).

Though, plant height and drymatter accumulation in maize at 30, 60, 90 DAS and at maturity were highest in hand weeding at 20 and 40 DAS (T2), pre-emergence application of atrazine @ 1.0 kg a.i ha\(^{-1}\) fb topramezone spray @ 25 g a.i ha\(^{-1}\) at 20 DAS (T9) and pre-emergence application of pendimethalin @ 1.0 kg a.i ha\(^{-1}\) fb topramezone spray @ 25 g a.i ha\(^{-1}\) at 20 DAS (T8) were on a par with T2 treatment. Uptake of nutrients by maize was the highest in hand weeding at 20 and 40 DAS (T2). Pre-emergence application of atrazine @ 1.0 kg a.i ha\(^{-1}\) fb topramezone spray @ 25 g a.i ha\(^{-1}\) at 20 DAS (T9) and pre-emergence application of pendimethalin @ 1.0 kg a.i ha\(^{-1}\) fb topramezone spray @ 25 g a.i ha\(^{-1}\) at 20 DAS (T8) recorded a comparable nutrient uptake by maize with hand weeding treatment (T2). Significant increase in N, P and K uptake by weeds was associated in weedy check (T1) over all the remaining weed control treatments.

Among various treatments tested, sequential application of atrazine @ 1.0 kg a.i ha\(^{-1}\) (PE) fb topramezone spray @ 25 g a.i ha\(^{-1}\) at 20 DAS (T9) and pre-emergence application of pendimethalin @ 1.0 kg a.i ha\(^{-1}\) fb topramezone spray @ 25 g a.i ha\(^{-1}\) at 20 DAS (T8) recorded a kernel yield of 5627 kg ha\(^{-1}\) and 5282 kg ha\(^{-1}\), respectively and these treatments were statistically on a par with hand weeding at 20 and 40 DAS, which recorded the highest kernel yield (5974 kg ha\(^{-1}\)). Similar trend was observed in stover yield as well under different weed control treatments.

Even though hand weeding at 20 and 40 DAS recorded the highest gross returns (Rs. 81581 ha\(^{-1}\)), sequential application of atrazine @ 1.0 kg a.i ha\(^{-1}\) (PE) fb topramezone spray @ 25 g a.i ha\(^{-1}\) at 20 DAS (T9) and pre-emergence application of pendimethalin @ 1.0 kg a.i ha\(^{-1}\) fb topramezone spray @ 25 g a.i ha\(^{-1}\) at 20 DAS (T8) recorded a net profit of Rs. 51340 ha\(^{-1}\) and Rs. 45790 ha\(^{-1}\) with a returns per rupee investment of 2.00 and 1.73, respectively and were found to be superior to even hand weeding at 20 and 40 DAS which recorded a net return of Rs. 47744 ha\(^{-1}\) with a returns per rupee investment of 1.41, due to lower cost of herbicides that reduced the cost of cultivation.
## Appendix - I

### CALENDAR OF OPERATIONS

<table>
<thead>
<tr>
<th>S.No.</th>
<th>Particulars of the field operations performed</th>
<th>Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Ploughing with tractor drawn cultivator</td>
<td>30-7-14</td>
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<tr>
<td>2.</td>
<td>Harrowing with rotavator</td>
<td>31-7-14</td>
</tr>
<tr>
<td>3.</td>
<td>Removal of stubbles and layout of the field</td>
<td>01-8-14</td>
</tr>
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<td>4.</td>
<td>Basal application of N, P, K fertilizers and sowing</td>
<td>02-8-14</td>
</tr>
<tr>
<td>5.</td>
<td>Pre-emergence herbicide spraying</td>
<td>03-8-14</td>
</tr>
<tr>
<td>6.</td>
<td>Gap filling and thinning</td>
<td>10-8-14</td>
</tr>
<tr>
<td>7.</td>
<td>Chlorpyriphos spray</td>
<td>14-8-14</td>
</tr>
<tr>
<td>8.</td>
<td>1&lt;sup&gt;st&lt;/sup&gt; irrigation</td>
<td>20-8-14</td>
</tr>
<tr>
<td>9.</td>
<td>Hand weeding and post-emergence herbicide spraying</td>
<td>21-8-14</td>
</tr>
<tr>
<td>10.</td>
<td>Carbofuran granules application for stem borer</td>
<td>22-8-14</td>
</tr>
<tr>
<td>11.</td>
<td>2&lt;sup&gt;nd&lt;/sup&gt; irrigation</td>
<td>02-9-14</td>
</tr>
<tr>
<td>12.</td>
<td>1&lt;sup&gt;st&lt;/sup&gt; topdressing of N fertilizer</td>
<td>03-9-14</td>
</tr>
<tr>
<td>13.</td>
<td>Hand weeding and post-emergence herbicide spraying</td>
<td>11-9-14</td>
</tr>
<tr>
<td>14.</td>
<td>3&lt;sup&gt;rd&lt;/sup&gt; irrigation</td>
<td>10-9-14</td>
</tr>
<tr>
<td>15.</td>
<td>2&lt;sup&gt;nd&lt;/sup&gt; top dressing of N fertilizer</td>
<td>16-9-14</td>
</tr>
<tr>
<td>16.</td>
<td>4&lt;sup&gt;th&lt;/sup&gt; irrigation</td>
<td>20-10-14</td>
</tr>
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<td>17.</td>
<td>Harvesting of cobs</td>
<td>17-11-14 to 18-11-14</td>
</tr>
<tr>
<td>18.</td>
<td>Sundrying of cobs</td>
<td>19-11-14 to 03-12-14</td>
</tr>
<tr>
<td>19.</td>
<td>Shelling of cobs</td>
<td>04-12-14 to 08-12-14</td>
</tr>
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</table>
Fig. 3.1. Weekly mean maximum and minimum temperatures (°C) recorded during the crop growth period
Fig. 3.2. Weekly rainfall (mm) and mean relative humidity (%) recorded during the crop growth period
Table 3.3. Details of herbicides used in the experiment

<table>
<thead>
<tr>
<th>Particulars</th>
<th>Atrazine</th>
<th>Pendimethalin</th>
<th>Topramezone</th>
</tr>
</thead>
<tbody>
<tr>
<td>Common name</td>
<td>Atrazine</td>
<td>Pendimethalin</td>
<td>Topramezone</td>
</tr>
<tr>
<td>Trade name</td>
<td>Solaro</td>
<td>Stomp</td>
<td>-</td>
</tr>
<tr>
<td>Active ingredient</td>
<td>50%</td>
<td>30%</td>
<td>33.6%</td>
</tr>
<tr>
<td>Formulation</td>
<td>Wettable Powder</td>
<td>Emulsifiable Concentrate</td>
<td>Suspension Concentrate</td>
</tr>
<tr>
<td>Time of application</td>
<td>Pre-emergence</td>
<td>Pre-emergence</td>
<td>Post-emergence</td>
</tr>
<tr>
<td>Chemical name</td>
<td>6-Chloro-N-ethyl-N(1-methylethyl)-1,3,5-triazine-2,4-diamine</td>
<td>N-(1-ethyl propyl)-3,4-dimethyl-2,6-dinitro benzenamine</td>
<td>[3-(4,5-dihydro-isoxazol-3-yl)-4-methylsulfonyl-2-methylphenyl][5-hydroxy-1-methyl-1H-pyrazol-4-y1]methanone</td>
</tr>
<tr>
<td>Chemical family</td>
<td>Triazines</td>
<td>Dinitroanilines</td>
<td>Pyrazolone</td>
</tr>
<tr>
<td>Mode of action</td>
<td>Inhibition of photosystem-II</td>
<td>Inhibition of microtubule assembly</td>
<td>Inhibition of 4-hydroxyphenylpyruvate dioxygenase enzyme (HPPD)</td>
</tr>
<tr>
<td>Molecular structure</td>
<td><img src="image1" alt="Molecular structure Atrazine" /></td>
<td><img src="image2" alt="Molecular structure Pendimethalin" /></td>
<td><img src="image3" alt="Molecular structure Topramezone" /></td>
</tr>
</tbody>
</table>
Fig. 3.3. Layout plan of the experiment

Design: Randomized Block Design
Replications: Three
Treatments: Nine
Gross plot size: 6.0 m × 4.0 m (24.00 m²)
Net plot size: 4.8 m × 3.2 m (15.36 m²)
Season: *kharif*, 2014
Spacing: 60 cm × 20 cm
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<td>Weed drymatter production (g m(^{-2})) as influenced by different weed control treatments in maize</td>
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<td>Weed control efficiency (%) as influenced by different weed control treatments in maize</td>
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<td>Drymatter production (kg ha(^{-1})) of maize as influenced by different weed control treatments</td>
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<td>4.6</td>
<td>Weed index (%) as influenced by different weed control treatments in maize</td>
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<td>Symbol</td>
<td>Definition</td>
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<td>@</td>
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<td>a.i.</td>
<td>Active ingredient</td>
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<td>$^0\text{C}$</td>
<td>Degree Celsius</td>
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<td>BCR</td>
<td>Benefit Cost Ratio</td>
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<td>Cob$^{-1}$</td>
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<td>CD (p=0.05)</td>
<td>Critical Difference at 5 per cent probability level</td>
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<td>DAS*</td>
<td>Days after spraying</td>
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<tr>
<td>WAS</td>
<td>Weeks after sowing</td>
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<td>dS m$^{-1}$</td>
<td>Deci Siemens per metre</td>
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<td>EC</td>
<td>Electrical conductivity</td>
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<td>for example, for instance</td>
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<td>et al.</td>
<td>And others</td>
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<td>etc.</td>
<td>And so on; and other people/things</td>
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<td>fb</td>
<td>Followed by</td>
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<td>Fig.</td>
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<tr>
<td>g</td>
<td>Gram (s)</td>
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<tr>
<td>g m$^{-2}$</td>
<td>Grams per square metre</td>
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<tr>
<td>ha$^{-1}$</td>
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<td>HI</td>
<td>Harvest Index</td>
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<td>IARI</td>
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<td>TNAU</td>
<td>Tamil Nadu Agricultural University</td>
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</tr>
<tr>
<td>i.e.</td>
<td>That is</td>
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</tr>
<tr>
<td>IC</td>
<td>Intercultivation</td>
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</tr>
<tr>
<td>K</td>
<td>Potassium</td>
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</tr>
<tr>
<td>kg</td>
<td>Kilogram (s)</td>
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</tr>
<tr>
<td>kg$^{-1}$</td>
<td>Per kilogram</td>
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<tr>
<td>kg ha$^{-1}$</td>
<td>Kilogram per hectare</td>
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<tr>
<td>3.4</td>
<td>Qualitative description of treatment effects on crop in the visual scoring scale of 0-10 (equal to 0 to 100%)</td>
<td></td>
</tr>
<tr>
<td>4.1</td>
<td>Weed density (No. m⁻²) as influenced by different weed control treatments in maize</td>
<td></td>
</tr>
<tr>
<td>4.2</td>
<td>Weed drymatter production (g m⁻²) as influenced by different weed control treatments in maize</td>
<td></td>
</tr>
<tr>
<td>4.3</td>
<td>Weed control efficiency (%) as influenced by different weed control treatments in maize</td>
<td></td>
</tr>
<tr>
<td>4.4</td>
<td>Plant height (cm) of maize as influenced by different weed control treatments</td>
<td></td>
</tr>
<tr>
<td>4.5</td>
<td>Drymatter production (kg ha⁻¹) of maize as influenced by different weed control treatments</td>
<td></td>
</tr>
<tr>
<td>4.6</td>
<td>Days to 50% tasseling and 50% silking as influenced by different weed control treatments in maize</td>
<td></td>
</tr>
<tr>
<td>4.7</td>
<td>Phytotoxic effect of different herbicidal treatments on maize</td>
<td></td>
</tr>
<tr>
<td>4.8</td>
<td>Yield attributing characters of maize as influenced by different weed control treatments</td>
<td></td>
</tr>
<tr>
<td>4.9</td>
<td>Kernel yield (kg ha⁻¹), stover yield (kg ha⁻¹), harvest index (%) and weed index (%) as influenced by different weed control treatments in maize</td>
<td></td>
</tr>
<tr>
<td>4.10</td>
<td>Nitrogen uptake (kg ha⁻¹) by maize as influenced by different weed control treatments</td>
<td></td>
</tr>
<tr>
<td>4.11</td>
<td>Phosphorus uptake (kg ha⁻¹) by maize as influenced by different weed control treatments</td>
<td></td>
</tr>
<tr>
<td>4.12</td>
<td>Potassium uptake (kg ha⁻¹) by maize as influenced by different weed control treatments</td>
<td></td>
</tr>
<tr>
<td>4.13</td>
<td>Nutrient uptake (kg ha⁻¹) by weeds as influenced by different weed control treatments in maize</td>
<td></td>
</tr>
<tr>
<td>4.14</td>
<td>Economics of maize as influenced by different weed control treatments.</td>
<td></td>
</tr>
</tbody>
</table>
Plate 1. General view of the experimental plot
INTRODUCTION

Maize, a cereal grain produced worldwide, assumes importance to subsistence farmers and commercial farmers while occupying a prominent position in global agriculture. In India, it is grown in an area of 9.43 million hectares with an annual production of 24.35 million tonnes. (Ministry of Agriculture, Government of India, 2013-14) and ranks third after rice and wheat in terms of production besides contributing nearly 9% to the national food basket. Its grain is mainly used as raw material for formulating livestock feed, besides extracting ethanol and also for human consumption.

Although maize varieties and hybrids with high grain yield potential are available, the average grain yield on farmers’ fields is still very low in India. Some of the factors responsible for low yield of maize include insect pests, diseases, low soil fertility and weed infestation. Among various maize yield limiting factors, serious infestation of weeds is of immense importance. Weeds inflict enormous loss in maize production than insect pests and diseases thus hindering its productivity.

Maize, which is mostly grown as rainfed crop during kharif faces a formidable weed problem, compete severely for growth resources. The yield loss owing to weeds may extend from 33 to 50 Per cent (Sharma et al., 2000). Rainy season corresponds to heavy and continuous rains besides scarcity of labour, renders difficult to control the weeds by conventional, cultural and mechanical methods. Thus, chemical weed control assumes significance in the cultivation of maize. Maximum yield loss of maize due to weed competition is estimated to occur during the first 3-6 weeks, i.e., before the canopy has developed thick enough to smother the weeds (Shad et al., 1993).

Wider row spacing and slow crop growth during the initial 3-4 weeks (Nagalakshmi et al., 2006) makes maize highly sensitive to weed competition upto 6 weeks growth period. Weeds can establish and grow rapidly during
this period and can cause immense loss to crop growth and yield. Hence, to realize optimum yields in maize thorough weed management is a must during the initial 6 weeks of crop growth which is to be considered critical for crop weed competition.

The yield losses reported in maize due to uncontrolled weed growth ranged from 30 to 100% (Singh et al., 1996 and Rout and Satpathy, 1996). Oerke (2005) reported that weeds reduce crop yield by competing for light and carbon dioxide, interfere with harvesting and increase the cost involved in crop production. Dalley et al. (2006) reported that season long weed competition caused considerable yield losses in maize.

Manual weeding though very effective in controlling weeds, very often is cumbersome, labour intensive, expensive and time consuming. Of late due to shift in traditional agricultural labours to non agricultural sectors, the availability of labour in required number for manual weeding is becoming difficult year by year. Hence, there is a need to look for alternative methods of weed control to manual weeding. Use of herbicides for weed control can be an alternative strategy as they can control the weeds timely, effectively and also at lower cost. Even though herbicides are effective considering the severity of the weed problem, the weed free window with a single pre-emergence or post-emergence application of herbicide may not always be sufficient for satisfactory crop growth and yield in maize.

The choice of weed control strategies, therefore, depends largely on effectiveness and economics. With decreased labour force and increased cost in manual weeding, herbicides not only curb the weeds timely and effectively but also offer greater scope for minimizing the cost of weed control irrespective of the situation. Though several workers have earlier studied integrated approach on weed management in kharif maize, an effective evaluation in weed management is still to be re-investigated.
Thus looking into the difficulties of other agronomic practices, suitable study on weed control strategies in maize with sequential use of pre-emergence and post-emergence herbicides has been a long felt need. Keeping this in view, a field trial was carried out on “Evaluation of pre and post emergence herbicides in kharif maize” at Agricultural College Farm, Bapatla during kharif 2014 with the following objectives.

1. To study the effect of pre-emergence and post-emergence herbicides on growth and yield of maize.

2. To study the weed dynamics as affected by pre-emergence and post-emergence application of herbicides in maize.

3. To work out the economics of application of pre-emergence and post-emergence herbicides in maize.
LITERATURE CITED

*AICRPWC, ICAR. 1988. Third annual report of All India Co ordinate Research Project on Weed control. Sriniketan Center, Viswa Bharati, Sriniketan. 185-190.


Ramadevi, B. 2013. Performance of baby corn as influenced by nitrogen levels and weed control practices. *M.Sc (Ag) Thesis* submitted to Acharya N.G. Ranga Agricultural University, Rajendranagar, Hyderabad.


*Original not seen*

**Note:** The pattern of Literature Cited presented above is in accordance with the guidelines for thesis presentation, Acharya N.G. Ranga Agricultural University, Hyderabad.
Chapter - III

MATERIAL AND METHODS

The material used and methods followed during the experimentation are presented in this chapter.

3.1 EXPERIMENTAL SITE

A field experiment entitled “Evaluation of pre and post emergence herbicides in kharif maize” was laid out in field No. 26 A, of the Southern Block of the Agricultural College Farm, Bapatla of Acharya N.G. Ranga Agricultural University during kharif 2014. The experimental site is situated at 80° 25'E longitude, 15° 54'N latitude and at an altitude of 5.49 m and 7 km away from Bay of Bengal. It is located in upland coastal area of the Krishna Agro Climatic Zone of Andhra Pradesh.

3.2 WEATHER DURING THE CROP GROWING PERIOD

Weather data recorded at Agricultural College Farm, Bapatla during the crop period (30.07.2014 to 18.11.2014) are presented in Table 3.1 and depicted in Figures 3.1 and 3.2.

The weekly mean maximum and minimum temperatures during the crop period ranged from 30.3 °C to 37.4 °C and 20.3 °C to 26.6 °C, respectively while the average maximum and minimum temperatures during the crop growth period were 33.4 °C and 24.2 °C, respectively. The weekly mean relative humidity ranged between 56.5 to 85.7 per cent with an average of 74.7 per cent. A total of 464.7 mm rainfall was received in 20 rainy days during the crop period.

3.3 EXPERIMENTAL SOIL

Composite soil samples from the experimental field were collected from 0 to 30 cm depth at random one week prior to starting of field preparation and a representative soil sample of about one kilogram was drawn by quartering method. The samples were analysed for physical and physico-chemical properties (Table 3.2).
Table 3.2. Physical and physico-chemical properties of the experimental soil

<table>
<thead>
<tr>
<th>S.No</th>
<th>Particulars</th>
<th>Value</th>
<th>Method of Analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Mechanical analysis</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Sand (%)</td>
<td>49</td>
<td>Bouyoucos hydrometer method (Piper, 1966)</td>
</tr>
<tr>
<td></td>
<td>Silt (%)</td>
<td>20</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Clay (%)</td>
<td>31</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Textural class</td>
<td></td>
<td>Sandy clay loam</td>
</tr>
<tr>
<td>3</td>
<td>Chemical properties</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>pH (1:2.5 soil water suspension)</td>
<td>7.4</td>
<td>Glass electrode method (Jackson, 1973)</td>
</tr>
<tr>
<td></td>
<td>EC (dS m(^{-1}) at 25°C)</td>
<td>0.21</td>
<td>Digital electrical conductivity meter (Jackson, 1973)</td>
</tr>
<tr>
<td></td>
<td>Organic carbon (%)</td>
<td>0.52</td>
<td>Walkley and Black’s modified method (Walkley and Black, 1934)</td>
</tr>
<tr>
<td></td>
<td>Available nitrogen (kg ha(^{-1}))</td>
<td>258</td>
<td>Alkaline permanganate method (Subbiah and Asija, 1956)</td>
</tr>
<tr>
<td></td>
<td>Available P(_2)O(_5) (kg ha(^{-1}))</td>
<td>53.9</td>
<td>Olsen’s method (Olsen et al., 1954)</td>
</tr>
<tr>
<td></td>
<td>Available K(_2)O (kg ha(^{-1}))</td>
<td>539.8</td>
<td>Neutral normal ammonium acetate method (Jackson, 1973)</td>
</tr>
</tbody>
</table>

The results of the soil analysis indicated that the experimental soil was classified as sandy clay loam in texture, slightly alkaline in reaction (pH 7.4), medium in organic carbon (0.52%), low in available nitrogen (258 kg ha\(^{-1}\)) and high in available phosphorus (53.9 kg ha\(^{-1}\)) and potassium (539.8 kg ha\(^{-1}\)).
3.4 CROPPING HISTORY OF THE EXPERIMENTAL FIELD

The cropping history of the experimental field for the three consecutive preceding years is given below.

<table>
<thead>
<tr>
<th>Year</th>
<th>Kharif</th>
<th>Rabi</th>
</tr>
</thead>
<tbody>
<tr>
<td>2011-12</td>
<td>Maize</td>
<td>Fallow</td>
</tr>
<tr>
<td>2012-13</td>
<td>Fallow</td>
<td>Sweet corn</td>
</tr>
<tr>
<td>2013-14</td>
<td>Fallow</td>
<td>Sweet corn</td>
</tr>
<tr>
<td>2014-15</td>
<td>Present experiment</td>
<td></td>
</tr>
</tbody>
</table>

3.5 EXPERIMENTAL DETAILS

The experiment was laid out in Randomized Block Design (RBD) with nine weed control treatments replicated thrice. The layout plan besides other necessary details is depicted in Fig. 3.3

3.5.1 Details of Treatments

T₁ - Weedy check
T₂ - Hand weeding at 20 & 40 days after sowing (DAS)
T₃ - Pendimethalin @ 1.0 kg a.i ha⁻¹ as pre-emergence application
T₄ - Atrazine @ 1.0 kg a.i ha⁻¹ as pre-emergence application
T₅ - Topramezone @ 25 g a.i ha⁻¹ as post-emergence application at 20 DAS
T₆ - Topramezone @ 25 g a.i ha⁻¹ as post-emergence application at 40 DAS
T₇ - Topramezone @ 25 g a.i ha⁻¹ as post-emergence application at 20 and 40 DAS
T₈ - Pendimethalin @ 1.0 kg a.i ha⁻¹ as pre-emergence application fb
topramezone @ 25 g a.i ha⁻¹ as post-emergence application at 20 DAS
T₉ - Atrazine @ 1.0 kg a.i ha⁻¹ as pre-emergence application fb
topramezone @ 25 g a.i ha⁻¹ as post-emergence application at 20 DAS
3.5.2 Plot Size

- Gross : 6.0 m X 4.0 m (24.00 m²)
- Net : 4.8 m X 3.2 m (15.36 m²)

3.5.3 Plant Spacing

- Inter row : 60 cm
- Intra row : 20 cm

3.5.4 Varietal Description

A popular maize hybrid LAXMI 2277 released by M/s Yaaganti Seeds Private Limited, Hyderabad was used for the study. It is a high yielding single cross hybrid, yellow - orange, semi - flint and medium bold kernel with a yield potential of 10-12 t ha⁻¹ and tolerant to lodging.

3.6 CULTIVATION DETAILS

The particulars of cultivation practices are presented here under and the calendar of operations are furnished in Appendix-I

3.6.1 Field Preparation

The experimental field was ploughed with a tractor drawn cultivator and later harrowed with a rotavator in order to get a fine tilth. The area was cleared off weeds, trash and then divided into required number of plots as shown in the layout plan (Fig. 3.3).

3.6.2 Seeds and Sowing

Bold and healthy seeds were hand dibbled on 02-08-2014 by adopting a spacing of 60 cm x 20 cm.

3.6.3 Gap Filling and Thinning

At 10 DAS, gap filling and thinning was done to maintain optimum plant population.
3.6.4 Fertilizers

Application of nitrogen as per the recommended dose of (120 kg ha\(^{-1}\)) was applied in three splits (50% as basal application, 25% at 30 DAS and 25% at 45 DAS) in the form of urea. Entire dose of phosphorus (60 kg P\(_2\)O\(_5\) ha\(^{-1}\)) in the form of single superphosphate (SSP) and potassium (50 kg K\(_2\)O ha\(^{-1}\)) in the form of muriate of potash (MOP) were applied as basal at the time of sowing.

3.6.5 Hand Weeding

First hand weeding was done at 20 DAS followed by a second hand weeding at 40 DAS using hand hoes in treatment T\(_2\) to remove weeds.

3.6.7 Herbicides Application

Atrazine and pendimethalin were sprayed using knapsack sprayer fitted with flat fan nozzle as per the treatments (T\(_3\), T\(_4\), T\(_8\) and T\(_9\)) one day after sowing as pre-emergence application.

Post-emergence herbicide topramezone was sprayed in treatments T\(_5\), T\(_7\), T\(_8\), and T\(_9\) by using knapsack sprayer fitted with flood jet nozzle on 20\(^{th}\) day after sowing. However, treatments T\(_6\) and T\(_7\), received topramezone spraying at 40 DAS. The spray volume used for the herbicide application was 500 L ha\(^{-1}\). The details of the herbicides used are presented in Table 3.3.

3.6.8 Irrigation

To ensure proper germination and plant stand, irrigation was given immediately after sowing. Subsequent irrigations were provided as need based. A total of four irrigations were given to supplement the rainfall during the crop growth period.

3.6.9 Plant Protection

Incidence of *Spodoptera litura* was noticed during the initial stages, which was controlled by spraying Chlorpyriphos @ 1.5 ml L\(^{-1}\) of water at 12 DAS. Carbofuran 3G granules @ 7.5 kg ha\(^{-1}\) were applied in the leaf whorls of the maize plants at 25 DAS to protect the crop against stem borer.
3.6.10 Harvesting

The crop was harvested at maturity when the cobs dried and the entire plant turned yellow. The border rows from each plot were harvested first, leaving the net plot. Later, the net plot area was harvested after separating the plants designated for recording biometric observations. Cobs harvested from net plot area were dried thoroughly under the sun. The stover was sun dried separately for recording the dry weights. Shelling of the cobs was done with a hand operated maize sheller.

3.7 BIOMETRIC OBSERVATIONS

3.7.1 Observations on Weeds

3.7.1.1 Weed density

Weed flora such as sedges, grasses and dicots were counted group wise at 30, 60, 90 DAS and at maturity in each plot from four randomly selected quadrants of 0.25 m² size. The total weed density was arrived by adding all the weed groups and expressed as number m⁻². The data was subjected to square root transformation $\sqrt{X + 0.5}$ to normalize their distribution (Gomez and Gomez, 1984).

3.7.1.2 Weed drymatter

Weed samples were collected from the quadrant of 0.25 m² from each plot at 30, 60, 90 DAS and at maturity. The samples were shade dried initially followed by oven drying at 60 °C to attain constant weight and was expressed in g m⁻².

3.7.1.3 Weed control efficiency

Based on the weed drymatter recorded at 30, 60, 90 DAS and at maturity, weed control efficiency (WCE) was calculated using the following formula and expressed in per centage (AICRPWC, 1988).

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

\[ \text{WCE} = \text{Weed control efficiency} \]

\[ \text{DWC} = \text{Dry weight of weeds in unweeded control plot} \]

\[ \text{DWT} = \text{Dry weight of weeds in treated plot} \]

### 3.7.1.4 Weed index

The weed index was calculated based on the maize kernel yield obtained from treatments using the formula suggested by Gill and Vijaykumar (1969).

\[
\text{W. I} = \frac{\text{X} - \text{Y}}{\text{X}} \times 100
\]

Where,

\[ \text{W. I=} \text{Weed index} \]

\[ \text{X=} \text{Yield from weed free plot} \]

\[ \text{Y=} \text{Yield from plot for which weed index is to be worked out} \]

### 3.8 OBSERVATIONS ON CROP

Five plants were labeled in each net plot for recording observations that did not involve destructive sampling. All observations during the crop growth were recorded on these labeled plants at 30, 60, 90 DAS and at maturity. For recording dry matter production which involved destructive sampling, five successive plants in the second row from the left border row in each plot were sampled each time.

#### 3.8.1 Pre-harvest Observations

#### 3.8.1.1 Crop injury score

Injury effects of the herbicides used if any, on maize crop in each treatment was visually assessed at 7 and 14 days after spraying of crop as per the phytotoxicity score card given by Rao (2000) and presented in Table 3.4.
Table 3.4. Qualitative description of treatment effects on crop in the visual scoring scale of 0-10 (equal to 0 to 100%)

<table>
<thead>
<tr>
<th>Effect</th>
<th>Rating</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>None</td>
<td>0</td>
<td>No injury, normal</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>Slight stunting, injury or discolour</td>
</tr>
<tr>
<td>Slight</td>
<td>2</td>
<td>Some stand loss, stunting/discolour</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>Injury more pronounced but not persistent</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>Moderate injury, recovery possible</td>
</tr>
<tr>
<td>Moderate</td>
<td>5</td>
<td>Injury more persistent, recovery doubtful</td>
</tr>
<tr>
<td></td>
<td>6</td>
<td>Near severe injury, stand loss</td>
</tr>
<tr>
<td></td>
<td>7</td>
<td>Severe injury, stand loss</td>
</tr>
<tr>
<td>Severe</td>
<td>8</td>
<td>Almost destroyed, a few plants surviving</td>
</tr>
<tr>
<td></td>
<td>9</td>
<td>Very few plants alive</td>
</tr>
<tr>
<td>Complete</td>
<td>10</td>
<td>Complete destruction</td>
</tr>
</tbody>
</table>

3.8.1.2 Plant population

Plant population at the start of the experiment i.e. 10 days after gap filling was recorded for each plot expressed as No. m⁻².

3.8.1.3 Plant height

Plant height was measured from ground level to the tip of the top most leaf before tasseling and up to the tip of the tassel after tasseling, at different crop growth stages i.e. at 30, 60, 90 DAS and at maturity in all the tagged plants, averaged and expressed in centimeters (cm).
3.8.1.4 Drymatter production

Five successive plants were sampled for the designated sum of destructive sampling. These plants were sun dried for 48 hours followed by oven drying at 60 °C till a constant weight was obtained. The dry weight of stems, leaves and cobs was summed up and expressed in kilogram hectare⁻¹.

3.8.1.5 Days to 50 per cent tasseling

The number of days taken from date of sowing to the stage when 50 per cent of plants have projected tassels out, in each treatment was considered as number of days to 50 per cent tasseling.

3.8.1.6 Days to 50 per cent silking

The number of days taken from date of sowing to the stage when 50 per cent of the plants showed extrusion of silks was counted and expressed as days to 50 per cent silking.

3.8.2 Post-harvest Observations

3.8.2.1 Number of cobs plant⁻¹

Total number of cobs harvested from the tagged plants was counted and expressed as average number of cobs plant⁻¹.

3.8.2.2 Number of kernel rows cob⁻¹

Number of kernel rows for each cob from the tagged plants was counted and expressed as average number of kernel rows per cob.

3.8.2.3 Number of kernels row⁻¹

Number of kernels for each row from the tagged plants was counted and expressed as average number of kernels per row.
3.8.2.4 Number of kernels cob$^{-1}$

Total number of kernels from five cobs was counted and expressed as average number of kernels per cob.

3.8.2.5 Weight of kernels cob$^{-1}$

The kernels obtained after shelling from five randomly selected cobs from net plot area were weighed and the mean value was worked out to obtain weight of kernels per cob.

3.8.2.6 Test weight (100 kernel weight)

A small sample of kernels was drawn from each net plot kernel yield. 100 kernels were counted and their weight was recorded in grams.

3.8.2.7 Kernel and stover yield

The cobs were harvested from the net plot area and the plants were cut at the ground level and dried in the sun. After thorough drying of the plants, the weights were recorded as stover yield and expressed as kg ha$^{-1}$. Shelling of the cobs was done with a hand operated maize sheller and weight of kernels was recorded. To this kernel weight, kernel yield of five plants, which were sampled for recording post-harvest observations, was added and expressed as kernel yield in kg ha$^{-1}$.

3.8.2.8 Harvest index

The ratio of economic yield to the total biological yield (kernel yield + stover yield) was calculated and expressed in per centage by using the following formula (Donald and Humblin, 1976).

\[
\text{Harvest index (\%) } = \frac{\text{Economic yield (kg ha}^{-1})}{\text{Biological yield (kg ha}^{-1})} \times 100
\]
3.9 NUTRIENT UPTAKE BY CROP AND WEEDS

The drymatter samples of maize crop collected at 30, 60, 90 DAS and at maturity and weeds collected at 30, 60 DAS were dried, ground into powder and analyzed for estimating nitrogen, phosphorus and potassium content by following standard methods as listed in the table.

Methods adopted for estimation of nutrient content in the crop and weeds

<table>
<thead>
<tr>
<th>Nutrient</th>
<th>Method</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nitrogen</td>
<td>Microkjeldal Distillation (Piper, 1966)</td>
</tr>
<tr>
<td>Phosphorus</td>
<td>Vanado-molybdo-phosphoric acid yellow colour method (Jackson, 1973)</td>
</tr>
<tr>
<td>Potassium</td>
<td>Flame photometer method (Jackson, 1973)</td>
</tr>
</tbody>
</table>

From the results of chemical analysis, the nutrient uptake was calculated using the formula

\[
\text{Nutrient uptake (kg ha}^{-1}) = \frac{\text{Nutrient concentration (\%)} \times \text{Weight of drymatter (kg ha}^{-1})}{100}
\]

3.10 ECONOMICS

The cost of cultivation for each treatment was worked out based on prevailing input costs. Similarly gross returns were calculated based on prevailing market price of the produce. The net returns were obtained after deducting the cost of cultivation from gross returns. The benefit-cost ratio was calculated using the following formula

\[
\text{Benefit Cost Ratio (BCR)} = \frac{\text{Net returns (Rs. ha}^{-1})}{\text{Cost of cultivation (Rs. ha}^{-1})}
\]
3.11 STATISTICAL ANALYSIS

Statistical analysis for the data recorded on weeds and maize crop was done following the analysis of variance technique for Randomized Block Design as suggested by Gomez and Gomez (1984). Statistical significance was tested by applying F-test at 0.05 level of probability and critical differences were calculated for those parameters which were found significant ($p \leq 0.05$) to compare the effects of different treatments.
Table 3.1. Weekly meteorological data recorded from the IMD observatory located at Agricultural College Farm, Bapatla during the crop growth period (30.07.2014 to 18.11.2014)

<table>
<thead>
<tr>
<th>Standard meteorological week</th>
<th>Date and month</th>
<th>Mean temperature (°C)</th>
<th>Mean RH (%)</th>
<th>Rain fall (mm)</th>
<th>No. of rainy days</th>
</tr>
</thead>
<tbody>
<tr>
<td>31</td>
<td>30 Jul. – 05 Aug.</td>
<td>35.0</td>
<td>26.3</td>
<td>56.5</td>
<td>1.0</td>
</tr>
<tr>
<td>32</td>
<td>06 Aug. – 12 Aug.</td>
<td>37.4</td>
<td>26.6</td>
<td>60.1</td>
<td>11.4</td>
</tr>
<tr>
<td>33</td>
<td>13 Aug. – 19 Aug.</td>
<td>35.6</td>
<td>25.5</td>
<td>75.4</td>
<td>10.2</td>
</tr>
<tr>
<td>34</td>
<td>20 Aug. – 26 Aug.</td>
<td>34.4</td>
<td>26.5</td>
<td>76.8</td>
<td>0.9</td>
</tr>
<tr>
<td>35</td>
<td>27 Aug. – 02 Sep.</td>
<td>33.1</td>
<td>25.3</td>
<td>69.6</td>
<td>57.9</td>
</tr>
<tr>
<td>36</td>
<td>03 Sep. – 09 Sep.</td>
<td>35.4</td>
<td>25.4</td>
<td>66.9</td>
<td>0.6</td>
</tr>
<tr>
<td>37</td>
<td>10 Sep. – 16 Sep.</td>
<td>32.5</td>
<td>23.9</td>
<td>82.1</td>
<td>22.4</td>
</tr>
<tr>
<td>38</td>
<td>17 Sep. – 23 Sep.</td>
<td>33.4</td>
<td>25.6</td>
<td>77.4</td>
<td>83.4</td>
</tr>
<tr>
<td>39</td>
<td>24 Sep. – 30 Sep.</td>
<td>33.3</td>
<td>24.8</td>
<td>76.0</td>
<td>3.0</td>
</tr>
<tr>
<td>40</td>
<td>01 Oct. – 07 Oct.</td>
<td>34.2</td>
<td>25.7</td>
<td>69.5</td>
<td>1.4</td>
</tr>
<tr>
<td>41</td>
<td>08 Oct. – 14 Oct.</td>
<td>36.8</td>
<td>24.4</td>
<td>79.6</td>
<td>1.2</td>
</tr>
<tr>
<td>42</td>
<td>15 Oct. – 21 Oct.</td>
<td>32.0</td>
<td>22.8</td>
<td>80.1</td>
<td>19.6</td>
</tr>
<tr>
<td>43</td>
<td>22 Oct. – 28 Oct.</td>
<td>30.6</td>
<td>21.6</td>
<td>76.3</td>
<td>141.2</td>
</tr>
<tr>
<td>44</td>
<td>29 Oct. – 04 Nov.</td>
<td>30.3</td>
<td>20.8</td>
<td>82.2</td>
<td>0</td>
</tr>
<tr>
<td>45</td>
<td>05 Nov. – 11 Nov.</td>
<td>30.5</td>
<td>22.0</td>
<td>85.7</td>
<td>34.5</td>
</tr>
<tr>
<td>46</td>
<td>12 Nov. – 18 Nov.</td>
<td>30.7</td>
<td>20.3</td>
<td>80.5</td>
<td>76.0</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
<td></td>
<td>464.7</td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td></td>
<td>33.4</td>
<td>24.2</td>
<td>74.7</td>
<td></td>
</tr>
</tbody>
</table>
Fig. 4.4. Plant height of maize as influenced by different weed control treatments
Fig. 4.5. Drymatter production (kg ha\(^{-1}\)) of maize as influenced by different weed control treatments
Fig. 4.6. Weed index (%) as influenced by different weed control treatments in maize
Fig. 4.7. Kernel yield and stover yield (kg ha\(^{-1}\)) of maize as influenced by different weed control treatments.
Fig. 4.1. Weed density (No. m\(^{-2}\)) as influenced by different weed control treatments in maize.

Weed density (No. m\(^{-2}\)) as influenced by different weed control treatments in maize.
Fig. 4.2. Weed drymatter production (g m$^{-2}$) as influenced by different weed control treatments in maize.
Fig. 4.3. Weed control efficiency (%) as influenced by different weed control treatments in maize.
Fig. 4.9. Gross and net returns (Rs. ha\(^{-1}\)) of maize as influenced by different weed control treatments.
Fig. 4.8. Nutrient uptake (kg ha\(^{-1}\)) by maize at maturity as influenced by different weed control treatments in maize.
Chapter - IV

RESULTS AND DISCUSSION

Results and discussion of the present investigation entitled “Evaluation of pre and post emergence herbicides in kharif maize” conducted during kharif 2014 at the Agricultural College Farm, Bapatla are furnished here under appropriate sub heads.

4.1 SOIL AND WEATHER CONDITIONS DURING THE CROP GROWTH PERIOD

The crop was grown on sandy clay loam soil, which was medium in organic carbon, low in available nitrogen and high in available phosphorus and potassium (Table 3.2).

The sowing of the experiment was done on 02-08-2014. During the crop growth period, a total rainfall of 464.7 mm was received in 20 rainy days. The weekly mean maximum and minimum temperatures during the crop period ranged from 30.3 °C to 37.4 °C and 20.3 °C to 26.6 °C, respectively, while the average maximum and minimum temperatures during the crop growth period were 33.4 °C and 24.2 °C, respectively. The weekly mean relative humidity varied from 56.5 to 85.7 per cent with an average of 74.7 per cent. Much of the rainfall was not received during the critical periods of crop growth, so the crop was irrigated as and when required. Overall, the weather conditions prevailed during the crop period was normal (Table 3.1) in the region and was favourable to the crop.

4.2 OBSERVATIONS ON WEEDS

4.2.1 Weed Flora in Maize

The predominant weed species observed in the experimental field were *Cyperus rotundus* among sedges, *Trianthema portulacastrum*, *Cleome viscosa*, *Euphorbia hirta* and *Phyllanthus niruri* among dicots and *Cynodon dactylon*
among grasses. Vanaja (2007) and Srividya et al. (2011) have reported the similar weed flora in their experiments conducted in black soils of Krishna zone of Andhra Pradesh. The weed flora recorded in the experimental field are listed below.

<table>
<thead>
<tr>
<th>S.No</th>
<th>Botanical name</th>
<th>Common name</th>
<th>Family</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>Grasses</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td><em>Cynodon dactylon</em></td>
<td>Bermuda grass</td>
<td>Poaceae</td>
</tr>
<tr>
<td>2</td>
<td><em>Dactyloctenium aegyptium</em></td>
<td>Crow foot grass</td>
<td>Poaceae</td>
</tr>
<tr>
<td>3</td>
<td><em>Digitaria sanguinalis</em></td>
<td>Large crab grass</td>
<td>Poaceae</td>
</tr>
<tr>
<td>II</td>
<td>Sedges</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td><em>Cyperus rotundus</em></td>
<td>Purple nutsedge</td>
<td>Cyperaceae</td>
</tr>
<tr>
<td>III</td>
<td>Broad leaf weeds</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td><em>Borrella hispida</em></td>
<td>Button weed</td>
<td>Rubiaceae</td>
</tr>
<tr>
<td>2</td>
<td><em>Cleome viscosa</em></td>
<td>Wild mustard</td>
<td>Capparidaceae</td>
</tr>
<tr>
<td>3</td>
<td><em>Commelina benghalensis</em></td>
<td>Day flower</td>
<td>Commelinaceae</td>
</tr>
<tr>
<td>4</td>
<td><em>Digera muricata</em></td>
<td>False amaranth</td>
<td>Amaranthaceae</td>
</tr>
<tr>
<td>5</td>
<td><em>Euphorbia hirta</em></td>
<td>Garden spurge</td>
<td>Euphorbiaceae</td>
</tr>
<tr>
<td>6</td>
<td><em>Phyllanthus niruri</em></td>
<td>Stone breaker</td>
<td>Euphorbiaceae</td>
</tr>
<tr>
<td>7</td>
<td><em>Trianthema portulacastrum</em></td>
<td>Horse purslane</td>
<td>Aizoaceae</td>
</tr>
<tr>
<td>8</td>
<td><em>Tribulus terrestris</em></td>
<td>Puncture vine</td>
<td>Zygophyllaceae</td>
</tr>
<tr>
<td>9</td>
<td><em>Tridax procumbens</em></td>
<td>Mexican Daisy</td>
<td>Compositae</td>
</tr>
</tbody>
</table>

**4.2.2 Weed Density**

Perusal of data (Table 4.1 and Fig. 4.1) revealed that weed density was significantly influenced by different weed control treatments.

Among the weed control methods, hand weeding at 20 and 40 DAS (T2) resulted in the lowest weed density (3.9, 5.2, 6.2 and 5.5 m² at 30, 60, 90 DAS and maturity, respectively) throughout the crop growth period. This might be due to fact that the first hand weeding at 20 DAS eliminated all the early emerged weeds while the second hand weeding at 40 DAS removed the later germinated
weeds keeping the weed density below the critical level of competition. The current results are in conformity with the findings of Kolage et al. (2004), Tripathi et al. (2005), Patel et al. (2006), Selvakumar and Sundari (2006), Nagalakshmi et al. (2006), Walia et al. (2007) and Sandhyarani et al. (2013).

Hand weeding at 20 and 40 DAS was closely followed by sequential application of pre-emergence herbicides followed by post-emergence application of topramezone in reducing weed density. Among these treatments the lowest weed density was recorded in pre-emergence application of atrazine @ 1.0 kg a.i ha\(^{-1}\) fb topramezone spray @ 25 g a.i ha\(^{-1}\) at 20 DAS (POE). The better performance of this treatment might be due to the effective control of weeds achieved by atrazine upto 20 DAS and topramezone thereafter. The present findings are in conformity with the findings of Sreenivas and Satyanarayana (1994), Sinha et al. (2003), Aleem Ahmed et al. (2012) and Sonawane et al. (2014).

At 30 and 60 DAS among the herbicidal treatments the lowest weed density (5.5 and 6.1 m\(^{-2}\) at 30 and 60 DAS, respectively) was recorded with pre-emergence application of atrazine @ 1.0 kg a.i ha\(^{-1}\) fb topramezone spray @ 25 g a.i ha\(^{-1}\) at 20 DAS (T\(_9\)), which was on a par with pre-emergence application of pendimethalin @ 1.0 kg a.i ha\(^{-1}\) fb topramezone spray @ 25 g a.i ha\(^{-1}\) at 20 DAS (T\(_8\)) and topramezone spray @ 25 g a.i ha\(^{-1}\) (POE) at 20 and 40 DAS (T\(_7\)). The highest value (13.2 and 14.3 m\(^{-2}\) at 30 and 60 DAS, respectively) was observed in weedy check (T\(_1\)) than the other treatments. Persistence of atrazine for longer period might have resulted in less weed population in T\(_9\) treatment. The results are in conformity with findings of Rout and Satpathy (1996) and Saini and Angiras (1998).

At 90 DAS and at maturity, significantly superior trend continued for lowest weed density in hand weeding at 20 and 40 DAS (T\(_2\)), which was on a par with T\(_9\), T\(_7\) and T\(_8\) compared to atrazine @ 1.0 kg a.i ha\(^{-1}\) (PE) and pendimethalin @ 1.0 kg a.i ha\(^{-1}\) (PE) alone. This indicated that sequential application of herbicides had reduced the weed density compared to the application of pre-emergence herbicides alone.
Sequential application of pre-emergence herbicide followed by post-emergence herbicide markedly reduced the weed density compared to the application of pre-emergence herbicides only. This better performance might be due to maintenance of weed free condition for a long time which might have caused the reduced crop weed competition in the initial stages and control of the late emerged weeds by post-emergence herbicide. The highest weed density was recorded in weedy check (T1). The results are in agreement with the findings of Pandey et al. (2001), Tripathi et al. (2005), Patel et al. (2006), Malviya and Singh (2007), Srividya et al. (2011) and Aleem Ahmed et al. (2012).

4.2.3 Weed Drymatter Production

The data on dry weight of weeds at 30, 60, 90 DAS and at maturity presented in Table 4.2 and Fig. 4.2 revealed that drymatter of weeds was significantly reduced by all the weed control treatments compared to weedy check (T1).

Hand weeding at 20 and 40 DAS (T2) recorded the lowest weed drymatter at all the stages of crop growth i.e. 30, 60, 90 DAS and at maturity and was significantly lower compared to all other treatments. Removal of weeds that germinated along with crop and upto 20 DAS during the first hand weeding at 20 DAS and removal of weeds that germinated afterwards during the second hand weeding at 40 DAS and smothering of weeds by crop thereafter could be attributed to this. These results are in conformity with findings of Saini and Angiras (1998), Patel et al. (2006) and Sandhyarani et al. (2013).

Among the herbicidal treatments pre-emergence application of atrazine @ 1.0 kg a.i ha\(^{-1}\) fb topramezone spray @ 25 g a.i ha\(^{-1}\) at 20 DAS (T9) recorded the lowest weed drymatter (5.4 and 7.2 g m\(^{-2}\) at 30 and 60 DAS, respectively) which was on a par with T8, T7, and T5. The differences in weed drymatter among the treatments T4 and T3 were found non significant.

At 90 DAS and at maturity with the lowest weed drymatter (7.7 and 7.5 g m\(^{-2}\)) under hand weeding at 20 and 40 DAS (T2) found to be the superior and it was on a par with T7, T6, and T5 only. Weed drymatter in treatments T9, T8, T4 and T3 was statistically comparable.
Significantly superior results were obtained in the reduction of weed drymatter with atrazine as pre-emergence application followed by application of post-emergence herbicide compared to pendimethalin or topramezone alone could be attributed to the more persistence of atrazine resulting in maintenance of weed free condition for a long period, with reduced crop weed competition in the initial stages and control of the late emerged weeds by post-emergence herbicide. The results are in agreement with the findings of Sreenivas and Satyanarayana (1994), Mundra et al. (2002), Sinha et al. (2003), Kamble et al. (2005), Aleem Ahmed et al. (2012) and Ranjana Kumari et al. (2014).

4.2.4 Weed Control Efficiency

Data presented in Table 4.3 and Fig. 4.3 revealed that weed control efficiency was significantly influenced by different treatments.

The weed control efficiency recorded with hand weeding at 20 and 40 DAS (T₂) was the highest at all the stages of crop growth i.e. 74.5%, 73.6% 60.3% and 57.7% at 30, 60, 90 DAS and at maturity, respectively and was significantly superior to all the other weed control treatments. This could be attributed to the almost weed free condition achieved during the critical period of crop growth with hand weeding at 20 and 40 DAS. Higher weed control efficiency with hand weeding was also reported by Malviya and Singh (2007) and Sanodiya et al. (2014).

Hand weeding (T₂), was on a par with pre-emergence application of atrazine @ 1.0 kg a.i ha⁻¹ fb topramezone spray @ 25 g a.i ha⁻¹ at 20 DAS (T₉) and pre-emergence application of pendimethalin @ 1.0 kg a.i ha⁻¹ fb topramezone spray @ 25 g a.i ha⁻¹ at 20 DAS (T₈) and topramezone spray @ 25 g a.i ha⁻¹ at 20 and 40 DAS (T₇). This could be due to the fact that the initial weed population was effectively controlled by persistence activity of pre-emergence application of atrazine and later emerged weeds were controlled by the post-emergence herbicide. The results are in accordance with the findings of Paradkar and Sharma (1993), Sreenivas and Satyanarayana (1994), Mundra et al. (2002), Sinha et al. (2003), Kamble et al. (2005), Srividya et al. (2011), Aleem Ahmed et al. (2012) and Deshmukh et al. (2014).
However, in treatments, where only pre-emergence herbicides were applied, weed control efficiency was decreased as later emerged weeds and herbicide-resistant weeds persisted, resulting in reduced weed control efficiency. Similar results were also reported by Sinha et al. (2003) and Ramadevi (2013).

4.3 PRE HARVEST OBSERVATIONS ON CROP

4.3.1 Plant Height

Perusal of data on plant height of maize recorded at 30, 60, 90 DAS and at maturity are presented in Table 4.4 and depicted in Fig. 4.4 revealed that plant height increased continuously up to harvest and was affected significantly by different weed control treatments at all stages of crop growth. The highest plant height (64.5, 203.7, 228.1 and 232.5 cm at 30, 60, 90 DAS and at maturity, respectively) was recorded with hand weeding at 20 and 40 DAS (T2). Significant increase in plant height with hand weeding twice was also reported by Paradkar and Sharma (1993) and Srividya et al. (2011), Sunitha et al. (2011).

At 30 DAS among herbicidal treatments, the highest plant height (63.6 cm) was recorded with pre-emergence application of atrazine @ 1.0 kg a.i ha\(^{-1}\) fb post-emergence spray of topramezone @ 25 g a.i ha\(^{-1}\) at 20 DAS (T9) and was on a par with T4, T8, T3, T7 and T5 whereas, the lowest value of 49.2 cm was observed in weedy check (T1) than the other treatments at all stages of observation. At 30 DAS other pre-emergence herbicide treatments recorded significantly lower plant height compared to atrazine. This could be attributed to the more effective control of weeds achieved with atrazine when compared to pendimethalin as pre-emergence spray. The results are in agreement with the results reported by Rout and Satpathy (1996), Saini and Angiras (1998), Sinha et al. (2001) and Aleem Ahmed et al. (2012).

At 60, 90 DAS and at maturity, significantly superior trend was continued with regard to plant height in hand weeding at 20 and 40 DAS (T2) and was on a par with pre-emergence application of atrazine @ 1.0 kg a.i ha\(^{-1}\) fb topramezone spray @ 25 g a.i ha\(^{-1}\) at 20 DAS (T9), pre-emergence application of pendimethalin
@ 1.0 kg a.i ha\(^{-1}\) fb topramezone spray @ 25 g a.i ha\(^{-1}\) at 20 DAS (T\(_8\)) when compared to pre-emergence application of atrazine @ 1.0 kg a.i ha\(^{-1}\) and pre-emergence application of pendimethalin @ 1.0 kg a.i ha\(^{-1}\), post-emergence application of topramezone @ 25 g a.i ha\(^{-1}\) at 20 DAS alone indicating that sequential weed control to pre-emergence herbicide application is compulsory to control the weeds that emerge at later stages. This might be due to weed free situation persisting for nutrition, water, space and light availability throughout crop growth period, created as a result of herbicides application at critical period of crop weed competition, that enhanced the crop growth. The results are in concurrence with those reported by Sreenivas and Satyanarayana (1994), Sinha et al. (2001), Srividya et al. (2011), Aleem Ahmed et al. (2012) and Shantveerayya and Agasimani (2012).

Weedy check recorded significantly dwarf maize plants at all the stages due to increased weed density throughout crop growth period due to competition for growth factors, affecting growth and development of maize.

4.3.2 Drymatter Production

Perusal of data pertaining to the drymatter production of maize at 30, 60, 90 DAS and at maturity in Table 4.5 and Fig. 4.5 revealed that weed control treatments significantly influenced the drymatter production. The data also indicated that drymatter accumulation increased gradually with the increase in the age of the crop and the maximum drymatter accumulation was observed at the time of maturity.

Hand weeding at 20 and 40 DAS (T\(_2\)) resulted in the highest drymatter accumulation (4491, 7686 and 10175 kg ha\(^{-1}\) at 60, 90 DAS and at maturity, respectively).

At 30 DAS, among the herbicidal treatments, the highest drymatter accumulation (615 kg ha\(^{-1}\)) by maize was recorded in pre-emergence application of atrazine @ 1.0 kg a.i ha\(^{-1}\) fb topramezone spray @ 25 g a.i ha\(^{-1}\) at 20 DAS (T\(_9\)), which was on a par with T\(_4\), T\(_8\), and T\(_3\). The remaining herbicidal treatments were inferior to pre-emergence application of atrazine and pendimethalin @ 1.0 kg a.i ha\(^{-1}\).
At 60, 90 DAS and at maturity the highest drymatter accrual (4491, 7686 and 10175 kg ha\(^{-1}\)) was recorded with hand weeding at 20 and 40 DAS (T\(_2\)), which was on a par with pre-emergence application of atrazine @ 1.0 kg a.i ha\(^{-1}\) fb topramezone spray @ 25 g a.i ha\(^{-1}\) at 20 DAS (T\(_9\)) and pre-emergence application of pendimethalin @ 1.0 kg a.i ha\(^{-1}\) fb topramezone spray @ 25 g a.i ha\(^{-1}\) at 20 DAS (T\(_8\)). Significantly increased drymatter accrual in maize under these treatments could be attributed to less weed competition, maximum weed control efficiency, improved nutrient uptake, which might lead to the increased plant height and ultimately might have provided better growth environment to the crop as the weed density and drymatter recorded in these treatments was significantly less enabling the crop to put forth satisfactory growth. Similar results were also reported by Sinha et al. (2001), Srividya et al. (2011), Aleem Ahmed et al. (2012) and Shantveerayya and Agasimani (2012).

The lowest drymatter accumulation of 340, 2570, 3211 and 4486 kg ha\(^{-1}\) at 30, 60, 90 DAS and at maturity, respectively was recorded with the weedy check (T\(_1\)). The competition persistence between the crop and weeds from the initial stages itself, which continued upto harvest resulting in poor crop growth can be attributed to the lowest drymatter recorded in weedy check. Similar results were reported by Saini and Angiras (1998) and Sunitha et al. (2011).

### 4.3.3 Days to 50% Tasselling and 50% Silking

The data presented in table 4.6 revealed that days to 50% tasselling and 50% silking was significantly influenced by different weed control treatments.

Among the weed control treatments, hand weeding at 20 and 40 DAS (T\(_2\)) took the lowest number of days (53.0) to 50% tasseling and was statistically on a par with T\(_7\), T\(_9\) and T\(_8\) compared to rest of the treatments.

All the treatments including cultural (T\(_2\)), herbicidal treatments T\(_9\), T\(_8\), T\(_3\) and T\(_7\) were on a par with each other and took significantly less number of days to 50% silking over that of weedy check (T\(_1\)). Early tasseling and silking in these treatments might be due to better control of weeds in these plots which may have
facilitated more availability of nutrients to the crop compared to other weed management practices. Similar results were also reported by Sharma et al. (1998), Vanaja (2007) and Srividya (2010).

4.3.4 Crop Injury Score

Phytotoxic effect of herbicides on maize crop was presented in the form of score card in Table 4.7.

Among the herbicides, pre-emergence application of atrazine 1.0 kg a.i ha\(^{-1}\) (T\(_4\)) and pendimethalin 1.0 kg a.i ha\(^{-1}\) (T\(_3\)) were found to be safe as the crop was normal and phytotoxic symptoms were not recorded on crop at any stage of growth from germination to harvest. The results are in accordance with the findings of Ishrat et al. (2012).

Post-emergence spray of topramezone @ 25 g a.i ha\(^{-1}\) at 20 and at 40 DAS was found to be safe as the crop was normal and phytotoxic symptoms were not recorded on crop at any stage of growth from germination to harvest.

4.3.5 Plant Population

Data presented in Table 4.8 revealed that there were no significant differences in plant population due to different weed control treatments.

4.4 POST HARVEST OBSERVATIONS ON CROP

Data pertaining to yield attributing characters as influenced by various weed control treatments in the experiment are furnished in Table 4.8.

4.4.1 Number of Cobs Plant\(^{-1}\)

No variation in the number of cobs plant\(^{-1}\) due to different weed control treatments was recorded in maize as this character is mostly controlled by the genetic makeup and the treatments imposed had failed to influence significantly.

4.4.2 Cob Length

The results revealed that the cob length of maize was significantly influenced by different weed control treatments.
Among the weed control treatments, hand weeding at 20 and 40 DAS (T₂) recorded significantly greater cob length (18.4 cm) and was statistically on a par with T₉, T₈, T₃ and T₇ treatments that recorded the length of cobs in a descending (17.8, 17.1, 16.9 and 16.8 cm) order, respectively. All the weed control treatments were found to be significantly superior to that of weedy check (12.6 cm).

4.4.3 Number of Kernel Rows Cob⁻¹

Perusal of data revealed that number of kernel rows cob⁻¹ was significantly influenced by different weed control treatments.

The highest number of kernel rows cob⁻¹ (14.7) was recorded with hand weeding at 20 and 40 DAS (T₂). Kernel rows cob⁻¹ in other treatments recorded were on a par with hand weeding except weedy check, T₃, T₅ and T₆.

4.4.4 Number of Kernels Row⁻¹

Perusal of data revealed that the number of kernels row⁻¹ was significantly influenced by different weed control treatments.

Hand weeding at 20 and 40 DAS (T₂) recorded the highest number of kernels row⁻¹ (31.0). Pre-emergence application of atrazine @ 1.0 kg a.i ha⁻¹ fb topramezone spray @ 25 g a.i ha⁻¹ at 20 DAS (T₉), pre-emergence application of pendimethalin @ 1.0 kg a.i ha⁻¹ fb topramezone spray @ 25 g a.i ha⁻¹ at 20 DAS (T₈), recorded 30.3 and 28.8 kernels row⁻¹ respectively, which were on a par with T₂ treatment. The number of kernels row⁻¹ recorded in all other treatments were significantly lower compared to hand weeding. The lowest number of kernels row⁻¹ (22.2) was recorded in weedy check (T₁).

4.4.5 Total Number of Kernels Cob⁻¹

The results revealed that the number of kernels cob⁻¹ was significantly influenced by different weed control treatments.

The maximum number of kernels cob⁻¹ (456.4) was recorded with hand weeding at 20 and 40 DAS (T₂). Pre-emergence application of atrazine @ 1.0 kg a.i ha⁻¹ fb topramezone spray @ 25 g a.i ha⁻¹ at 20 DAS (T₉), pre-
emergence application of pendimethalin @ 1.0 kg a.i ha$^{-1}$ fb topramezone spray @ 25 g a.i ha$^{-1}$ at 20 DAS (T$_8$) with 436.4 and 422.0 kernels cob$^{-1}$ respectively, were found on a par with T$_2$ treatment. Treatments involving only pre-emergence application of pendimethalin (T$_3$), atrazine (T$_4$) and post-emergence application of topramezone @ 25 g a.i ha$^{-1}$ at 20 DAS (T$_5$) and topramezone @ 25 g a.i ha$^{-1}$ at 40 DAS (T$_6$) recorded significantly lower number of kernels cob$^{-1}$ compared to sequential application of either pre-emergence herbicides or post-emergence herbicide.

4.4.6 Weight of Kernels Cob$^{-1}$

The results revealed that the weight of kernels cob$^{-1}$ was significantly influenced by different weed control treatments.

Among the weed control treatments, hand weeding at 20 and 40 DAS (T$_2$) recorded significantly heavier kernels cob$^{-1}$ of 128.3 g over other treatments. With regard to the other herbicidal treatments, the highest kernel weight cob$^{-1}$ was recorded with the pre-emergence application of atrazine @ 1.0 kg a.i ha$^{-1}$ fb topramezone spray @ 25 g a.i ha$^{-1}$ at 20 DAS (T$_9$) and pre-emergence application of pendimethalin @ 1.0 kg a.i ha$^{-1}$ fb topramezone spray @ 25 g a.i ha$^{-1}$ at 20 DAS (T$_8$), which were on a par with each other.

The differences in weight of kernels cob$^{-1}$ among the treatments T$_7$, T$_4$, T$_5$ and T$_3$ were found non significant. All the weed control treatments were found to be significantly superior to that of weedy check (T$_1$) irrespective of increase in kernel weight cob$^{-1}$.

4.4.7 Test Weight (100-kernel weight)

The results revealed that the test weight of maize was significantly influenced by different weed control treatments.

Among the weed control treatments, hand weeding at 20 and 40 DAS (T$_2$) recorded significantly higher 100-kernel weight (26.9 g), which was statistically on a par with T$_9$, T$_8$ and T$_7$ treatments with 100-kernel weights of 26.7, 26.1 and 25.2 g, respectively. All the weed control treatments were found to be significantly superior to that of weedy check (20.9 g).
The better performance of these weed control treatments over weedy check with regard to yield attributes could be ascribed to higher accumulation of drymatter in plant, increased nutrient uptake by crop under optimum weed control achieved by these treatments that promoted the effective translocation of photosynthates from source to sink. Similar findings were reported by Saini and Angiras (1998), Singh et al. (2000), Ghodratollah Fathi (2005), Patel et al. (2006), Hussein et al. (2008), Deshmukh et al. (2008), Srividya (2010) and Aleem Ahmed et al. (2012).

4.4.8 Harvest Index

Data presented in Table 4.9 revealed that significant differences were not observed in harvest index due to different weed control treatments. However, higher (43.2%) and lower (39.1%) harvest indices were recorded with hand weeding at 20 and 40 DAS (T₂) and weedy check (T₁), respectively. The increased harvest index might be due to greater translocation of photosynthates as evidenced by higher yields. These results are in conformity with those reported by Srividya (2010) and Nagalakshmi et al. (2006).

4.4.9 Weed Index

The data on weed index indicating the extent of yield reduction due to competition from weeds are presented in Table 4.9 and Fig. 4.6. All the weed management treatments recorded lower weed index than weedy check.

The highest weed index (45.8%) was recorded in weedy check (T₁) indicating that uncontrolled weed competition during the crop period caused 45.8 per cent of yield loss. Slow growth of crop in the early stages offered much scope for the development of weeds besides competitiveness of weeds in utilizing the resources which resulted in more loss of yield in this treatment. These results are in conformity with the findings of Sharma et al. (2000), Pandey et al. (2002) and Patel et al. (2006).

Among the integrated weed control treatments, pre-emergence application of atrazine @ 1.0 kg a.i ha⁻¹ fb topramezone spray @ 25 g a.i ha⁻¹ at 20 DAS (T₉) and showering of pendimethalin @ 1.0 kg a.i ha⁻¹ fb topramezone spray @ 25 g a.i ha⁻¹ at 20 DAS (T₈) recorded a weed index of 13.9% and 18.1%,
respectively which were however significantly superior over rest of the remaining treatments. This clearly indicated that the sequential use of pre-emergence herbicides atrazine (T₉) and pendimethalin (T₈) followed by topramezone as post-emergence spray at 20 DAS was the most effective approach in controlling weeds and thus resulted in recording significantly lower values for weed index. These findings are in conformity with the findings of Sreenivas et al. (1992) and Shantveerayya and Agasimani (2012).

### 4.4.10 Kernel Yield

The data on kernel yield presented in Table 4.9 and Fig. 4.7 indicated significant differences in kernel yield due to different weed control treatments.

The maximum kernel yield obtained with hand weeding at 20 and 40 DAS (T₂) was significantly superior (5974 kg ha⁻¹) to rest of the treatments. The next best treatment was pre-emergence application of atrazine @ 1.0 kg a.i ha⁻¹ fb topramezone spray @ 25 g a.i ha⁻¹ at 20 DAS (T₉). However, it was statistically on a par with pre-emergence application of pendimethalin @ 1.0 kg a.i ha⁻¹ fb topramezone spray @ 25 g a.i ha⁻¹ at 20 DAS (T₈). Kernel yield of maize in treatments T₄, T₃ and T₆ was statistically comparable. The lowest kernel yield (2917 kg ha⁻¹) was recorded with weedy check (T₁).

Higher kernel yield observed under hand weeding at 20 and 40 DAS and integrated weed control treatments could be attributed to drastic decrease in weed population and drymatter accumulation by weeds, reduced crop weed competition. Further, improvement of soil physical condition, adequate nutrient uptake and better crop growth and yield attributes also contributed for higher yields. The lower yield in weedy check could be attributed to season long crop weed competition, poor weed control as evidenced by higher weed dry weight, which resulted in lower crop drymatter, decreased plant height, which finally resulted in reduced crop growth and lower yield attributing characters. These findings are in accordance with the findings of Pandey et al. (2001), Patel et al. (2006), Rao et al. (2009), Sandhyarani and Karunasagar (2013), Sonawane et al. (2014) and Aleem Ahmed et al. (2012).
4.3.11 Stover Yield

The data on stover yield presented in Table 4.9 and Fig. 4.7 indicated significant differences in stover yield due to different weed control treatments.

The highest stover yield obtained with hand weeding at 20 and 40 DAS (T\textsubscript{2}) was significantly superior (7837 kg ha\textsuperscript{-1}) to that of the other weed control treatments. Pre-emergence application of atrazine @ 1.0 kg a.i ha\textsuperscript{-1} fb topramezone spray @ 25 g a.i ha\textsuperscript{-1} at 20 DAS (T\textsubscript{9}) and pre-emergence application of pendimethalin @ 1.0 kg a.i ha\textsuperscript{-1} fb topramezone spray @ 25 g a.i ha\textsuperscript{-1} at 20 DAS (T\textsubscript{8}) recorded a stover yield of 7652 and 7291 kg ha\textsuperscript{-1}, respectively and were on a par with hand weeding at 20 and 40 DAS (T\textsubscript{2}). Stover yield of maize in treatments T\textsubscript{4}, T\textsubscript{3} and T\textsubscript{6} was statistically comparable. The lowest stover yield (4477 kg ha\textsuperscript{-1}) was recorded with weedy check (T\textsubscript{1}).

Higher stover yield under hand weeding twice and integrated weed control methods might be due to maintenance of weed free environment at critical stages of crop growth which led to complete utilization of nutrients and other growth factors by the crop plants, thus resulting in vigorous growth with greater drymatter accumulation by crop. This is in agreement with the findings of Vanaja (2007), Srividya (2010), Sandhyarani et al. (2013) and Sunitha et al. (2011).

Pre-emergence herbicides alone could not improve the stover yield as they failed to reduce the weed germination and growth during the later part of the critical period of crop growth for weed control. The lowest stover yield was recorded with the weedy check (T\textsubscript{1}) clearly reflecting the competition by unchecked weed growth to the crop and these results are in agreement with the results reported by Vanaja (2007), Srividya (2010), Sunitha et al. (2011), Sandhyarani et al. (2013) and Sonawane et al. (2014).

4.6 CHEMICAL ANALYSIS

4.6.1 Nutrient Uptake by Crop

Perusal of data on nutrient uptake by crop at 30, 60, 90 DAS and at maturity revealed that nutrient uptake was significantly influenced by different weed control treatments.
4.6.1.1 Nitrogen uptake by crop (kg ha\(^{-1}\))

Data presented in Table 4.10 and Fig. 4.8 revealed that nitrogen uptake by maize was significantly influenced by different treatments.

The highest nitrogen uptake by maize (72.1, 92.6 and 132.1 kg ha\(^{-1}\) at 60, 90 DAS and at maturity, respectively) was recorded in hand weeding at 20 and 40 DAS (T\(_{2}\)), which was significantly superior to the rest of weed control treatments.

At 30 DAS among the weed control treatments, the highest nitrogen uptake by crop (45.9 kg ha\(^{-1}\)) was recorded with pre-emergence application of atrazine @ 1.0 kg a.i ha\(^{-1}\) fb topramezone spray @ 25 g a.i ha\(^{-1}\) at 20 DAS (T\(_{9}\)), which was on a par with T\(_{4}\), T\(_{8}\), T\(_{3}\) and T\(_{2}\) treatments.

At 60 and 90 DAS, the highest nitrogen uptake by crop (72.1 and 92.6 kg ha\(^{-1}\), respectively) was recorded with hand weeding at 20 and 40 DAS (T\(_{2}\)) and it was on a par with T\(_{9}\), T\(_{8}\), T\(_{7}\) and T\(_{5}\) treatments.

At maturity, the highest total nitrogen uptake by crop (132.1 kg ha\(^{-1}\)) was recorded with hand weeding at 20 and 40 DAS (T\(_{2}\)), which was on a par with pre-emergence application of atrazine @ 1.0 kg a.i ha\(^{-1}\) fb topramezone spray @ 25 g a.i ha\(^{-1}\) at 20 DAS (T\(_{9}\)) and pre-emergence application of pendimethalin @ 1.0 kg a.i ha\(^{-1}\) fb topramezone spray @ 25 g a.i ha\(^{-1}\) at 20 DAS (T\(_{8}\)). Statistically no significant differences were found among the treatments T\(_{7}\), T\(_{5}\), T\(_{4}\) and T\(_{3}\). Whereas, the lowest value was observed in weedy check (T\(_{1}\)) at all the stages of observation.

4.6.1.2 Phosphorus uptake by crop (kg ha\(^{-1}\))

Data presented in Table 4.11 and Fig. 4.8 revealed that phosphorus uptake by maize was significantly influenced by different treatments.

The highest phosphorus uptake by maize (9.9, 16.1 and 34.6 kg ha\(^{-1}\) at 60, 90 DAS and at maturity, respectively) was recorded in hand weeding at 20 and 40 DAS (T\(_{2}\)), which was significantly superior to the rest of weed control treatments.
At 30 DAS among the weed control treatments, the highest phosphorus uptake by crop (6.3 kg ha\(^{-1}\)) was recorded with pre-emergence application of atrazine @ 1.0 kg a.i ha\(^{-1}\) fb topramezone @ 25 g a.i ha\(^{-1}\) at 20 DAS (T\(_9\)), which was on a par with atrazine @ 1.0 kg a.i ha\(^{-1}\) PE (T\(_4\)) and pre-emergence application of pendimethalin @ 1.0 kg a.i ha\(^{-1}\) PE fb topramezone spray @ 25 g a.i ha\(^{-1}\) at 20 DAS (T\(_8\)).

At 60, 90 DAS and at maturity, significantly superior trend continued for phosphorus uptake by crop in hand weeding at 20 and 40 DAS (T\(_2\)), which was on a par with pre-emergence application of atrazine @ 1.0 kg a.i ha\(^{-1}\) fb topramezone spray @ 25 g a.i ha\(^{-1}\) at 20 DAS (T\(_9\)) and pre-emergence application of pendimethalin @ 1.0 kg a.i ha\(^{-1}\) fb topramezone spray @ 25 g a.i ha\(^{-1}\) at 20 DAS (T\(_8\)). Statistically no significant differences were found among the treatments T\(_7\), T\(_4\) and T\(_5\). Whereas, the lowest value (2.3, 5.0, 7.9 and 16.8 kg ha\(^{-1}\) at 30, 60, 90 DAS and at maturity, respectively) was observed in weedy check (T\(_1\)).

### 4.6.1.3 Potassium uptake by crop (kg ha\(^{-1}\))

Data presented in Table 4.12 and Fig. 4.8 revealed that potassium uptake by maize was significantly influenced by different treatments.

The highest potassium uptake by maize (48.7, 73.4 and 117.4 kg ha\(^{-1}\) at 60, 90 DAS and at maturity, respectively) was recorded in hand weeding at 20 and 40 DAS (T\(_2\)), which was significantly superior to the rest of weed control treatments.

At 30 DAS among the weed control treatments, the highest potassium uptake by crop (31.3 kg ha\(^{-1}\)) was recorded with pre-emergence application of atrazine @ 1.0 kg a.i ha\(^{-1}\) fb topramezone spray @ 25 g a.i ha\(^{-1}\) at 20 DAS (T\(_9\)), which was on a par with T\(_4\), T\(_8\), T\(_3\) and T\(_2\).

At 60, 90 DAS and at maturity, significantly superior trend with regard to potassium uptake by crop was continued in hand weeding at 20 and 40 DAS (T\(_2\)), which was on a par with pre-emergence application of atrazine @ 1.0 kg a.i ha\(^{-1}\) fb topramezone spray @ 25 g a.i ha\(^{-1}\) at 20 DAS (T\(_9\)), pre-emergence application...
of pendimethalin @ 1.0 kg a.i ha\(^{-1}\) fb topramezone spray @ 25 g a.i ha\(^{-1}\) at 20 DAS (T\(_8\)) and topramezone spray @ 25 g a.i ha\(^{-1}\) at 20 and 40 DAS (T\(_7\)). Statistically no significant differences were found among the treatments T\(_5\), T\(_4\), T\(_6\) and T\(_3\). Whereas, the lowest value (19.5, 32.3, 48.8 and 85.4 kg ha\(^{-1}\) at 30, 60, 90 DAS and at maturity, respectively) was observed in weedy check (T\(_1\)).

The highest nitrogen, phosphorus and potassium uptake by crop was recorded with hand weeding at 20 and 40 DAS (T\(_2\)) and it was significantly superior to rest of the weed control treatments and statistically on a par with T\(_9\) and T\(_8\) treatments. This could be due to the fact that the initial weed population was better controlled by persistence activity of pre-emergence application of atrazine and later emerged weeds were controlled by the post-emergence herbicide, substantially more availability of these nutrients to crop. The least uptake of these nutrients was observed in weedy check due to minimum shoot drymatter production by the crop and maximum depletion of nutrients by weeds. The increased nutrient uptake in these treatments could be due to the effective weed control there by lesser weed competition during the critical period of crop growth, which resulted in increased biological yield. The findings are in conformity with the findings of Sreenivas and Satyanarayana (1996), Deshveer and Amarsingh (2002), Kamble \textit{et al.} (2005), Srividya \textit{et al.} (2011), Deshmukh \textit{et al.} (2014) and Sonawane \textit{et al.} (2014).

4.6.2 Nutrient Uptake by Weeds

Perusal of data on nutrient uptake by weeds at 30 and 60 DAS furnished in Table 4.13 revealed that the nutrient uptake was significantly influenced by different weed control treatments.

4.6.2.1 Nitrogen uptake by weeds (kg ha\(^{-1}\))

The highest nitrogen uptake by weeds (23.3 and 35.7 kg ha\(^{-1}\) at 30 and 60 DAS, respectively) was recorded in weedy check (T\(_1\)) indicating severe weed competition and the lowest nitrogen uptake (5.9 and 9.3 kg ha\(^{-1}\), respectively) with hand weeding at 20 and 40 DAS (T\(_2\)) which can be attributed to the effective weed
control achieved in this treatment. Pre-emergence application of atrazine @ 1.0 kg a.i ha$^{-1}$ fb topramezone spray @ 25 g a.i ha$^{-1}$ at 20 DAS (T$_9$) and pre-emergence application of pendimethalin @ 1.0 kg a.i ha$^{-1}$ fb topramezone spray @ 25 g a.i ha$^{-1}$ at 20 DAS (T$_8$) also recorded lesser nitrogen uptake by weeds and these two treatments were however on a par with hand weeding (T$_2$). This can be attributed to good weed control achieved in these treatments also. The nitrogen uptake by weeds in other treatments T$_6$, T$_3$, T$_4$ and T$_5$ was significantly higher when compared to T$_2$, T$_9$, T$_8$ and T$_7$ that could be attributed to lesser weed control in these treatments. These results are in agreement with the results reported by Nagalakshmi et al. (2006), Srividya et al. (2011), Sunitha et al. (2011) and Sonawane et al. (2014).

4.6.2.2 Phosphorus uptake by weeds (kg ha$^{-1}$)

The lowest phosphorus uptake by weeds (3.9 and 5.4 kg ha$^{-1}$ at 30 and 60 DAS, respectively) was recorded with hand weeding at 20 and 40 DAS and was significantly superior to all other treatments. It was followed by pre-emergence application of atrazine @ 1.0 kg a.i ha$^{-1}$ fb topramezone spray @ 25 g a.i ha$^{-1}$ at 20 DAS (T$_9$), pre-emergence application of pendimethalin @ 1.0 kg a.i ha$^{-1}$ fb topramezone spray @ 25 g a.i ha$^{-1}$ at 20 DAS (T$_8$) and topramezone spray @ 25 g a.i ha$^{-1}$ at 20 and 40 DAS (T$_7$). This can be attributed to higher level of weed control achieved in these treatments. The highest phosphorus uptake (15.5 and 18.3 kg ha$^{-1}$ at 30 and 60 DAS, respectively) was recorded in weedy check (T$_1$) indicating severe weed competition. The results are in agreement with the findings of Srividya et al. (2011), Sunitha et al. (2011) and Sonawane et al. (2014).

4.6.2.3 Potassium uptake by weeds (kg ha$^{-1}$)

The lowest potassium uptake by weeds (8.3 and 10.4 kg ha$^{-1}$ at 30 and 60 DAS, respectively) was recorded with hand weeding at 20 and 40 DAS (T$_2$) indicating effective weed control achieved with hand weeding. Pre-emergence application of atrazine @ 1.0 kg a.i ha$^{-1}$ fb topramezone spray @ 25 g a.i ha$^{-1}$ at 20 DAS (T$_9$) and pre-emergence application of pendimethalin @ 1.0 kg a.i ha$^{-1}$ fb
topramezone spray @ 25 g a.i ha\(^{-1}\) at 20 DAS (T\(_8\)) recorded lesser potassium uptake by weeds and these two treatments were on a par with hand weeding (T\(_2\)). The highest potassium uptake by weeds (27.3 and 38.4 kg ha\(^{-1}\) at 30 and 60 DAS, respectively) was recorded in weedy check (T\(_1\)) indicating severe competition suffered by crop due to weeds. The potassium uptake by weeds in other treatments T\(_6\), T\(_3\), T\(_4\) and T\(_5\) was significantly high when compared to T\(_2\), T\(_9\), T\(_8\) and T\(_7\) could be attributed to lower weed control in these treatments. The findings are in agreement with the results reported by Srividya \textit{et al.} (2011), Sunitha \textit{et al.} (2011) and Sonawane \textit{et al.} (2014).

**4.7 ECONOMICS**

The data on economics of various treatments as influenced by various weed control treatments are presented in Table 4.14 and Fig. 4.9.

The highest gross returns (Rs. 81581 ha\(^{-1}\)) was recorded in hand weeding at 20 and 40 DAS (T\(_2\)). Hand weeding treatment (T\(_2\)) was followed by pre-emergence application of atrazine @ 1.0 kg a.i ha\(^{-1}\) fb topramezone spray @ 25 g a.i ha\(^{-1}\) at 20 DAS (T\(_9\)) and pre-emergence application of pendimethalin @ 1.0 kg a.i ha\(^{-1}\) fb topramezone spray @ 25 g a.i ha\(^{-1}\) at 20 DAS (T\(_8\)) with a gross returns of Rs. 76977 ha\(^{-1}\) and Rs. 72312 ha\(^{-1}\), respectively. The better gross returns in the treatments T\(_2\), T\(_9\) and T\(_8\) can be attributed to the better weed control achieved in these treatments resulting in higher kernel yield. The gross returns recorded in T\(_3\), T\(_4\), T\(_5\), T\(_6\) and T\(_7\) was less when compared to T\(_2\), T\(_9\) and T\(_8\). The lowest gross returns was Rs. 40160 ha\(^{-1}\) recorded in weedy check (T\(_1\)) indicating the severe crop weed competition resulting in decreased kernel yield.

Even though the highest gross returns (Rs. 81581 ha\(^{-1}\)) was recorded in hand weeding, the highest net returns (Rs. 51340 ha\(^{-1}\)) was recorded in pre-emergence application of atrazine @ 1.0 kg a.i ha\(^{-1}\) fb topramezone spray @ 25 g a.i ha\(^{-1}\) at 20 DAS (T\(_9\)) and was followed by hand weeding at 20 and 40 DAS (T\(_2\)) with Rs. 47744 ha\(^{-1}\) and pre-emergence application of pendimethalin @ 1.0 kg a.i ha\(^{-1}\) fb topramezone spray @ 25 g a.i ha\(^{-1}\) at 20 DAS (T\(_8\)) with Rs. 45790 ha\(^{-1}\), because of the differences in cost of cultivation. The lower cost of herbicides in T\(_9\) decreased the cost of cultivation there by increased the net returns, where as the higher cost of labour increased the cost of cultivation in hand weeding (T\(_2\)) leads to reduced net returns.
Even though other weed control treatments recorded better gross and net returns than the weedy check, they were inferior to the treatments $T_9$, $T_2$ and $T_8$.

The highest benefit cost ratio (2.00) was recorded in the treatment $T_9$ and was closely followed by the treatment $T_8$ with 1.73 and treatment $T_2$ with 1.41 which indicated the cost effectiveness of herbicides when compared to hand weeding. These results are in agreement with Sreenivas and Satyanarayana (1994), Aleem Ahmed et al. (2012), Deshmukh et al. (2014) and Ranjana Kumari et al. (2014).
Chapter - II

REVIEW OF LITERATURE

Maize crop mostly grown as rainfed during *kharif* faces a forbidden problem of weeds and compete severely for growth resources. This season is encountered by dual problem of heavy rains and acute labour scarcity, thus rendering difficult to control the weeds by conventional and other methods. With no other option left but for chemical weed control as an alternative, it was initiated to timely and effectively curb the weeds for greater scope of minimizing the cost of weed control irrespective of the season.

Emphasis has been made for collecting and identifying the magnitude of weed flora and the losses it causes besides the evaluation of pre and post emergence herbicides in *kharif* maize. The review of literature related to these aspects is cited in this chapter under the following sub-heads.

2.1 WEED FLORA IN MAIZE

Prusty (1988) at IARI, New Delhi observed that *Trianthema monogyna* among broad leaf weeds, *Dactyloctenium aegypticum* and *Echinochloa crusgalli* among grassy weeds, *Cyperus rotundus* among sedges were the dominant weeds in maize fields.

Ramachandraprasad et al. (1990) at Hebbal, Banglore observed that the major weed flora such as *Cyperus rotundus*, *Cynodon dactylon*, *Digitaria marginata*, *Dactyloctenium aegypticum*, *Eragrostis pilosa*, *Eragrostis riparia*, *Panicum* spp., *Ageratum conyzoides*, *Amaranthus viridis*, *Acanthospermum hispidum*, *Mimosa pudica*, *Phyllanthus niruri*, *Portulaca oleracea* and *Cleome monophylla* were associated with maize.

Singh and Patel (1991) from Shillong listed *Digitaria marginata*, *Panicum psilopodium*, *Galinsoga parviflora*, *Bidens pilosa*, *Ageratum conyzoides*, *Cynodon dactylon* and *Eupatorium odoratum* as predominant weeds in maize.
Sharma and Nayital (1993) revealed that *Dactyloctenium aegypticum, Digitaria sanguinalis, Eleusine indica, Cyperus rotundus, Cynodon dactylon, Commelina benghalensis, Amaranthus viridis* and *Polygonum* sp. were the dominant weeds in maize.

*Echinochloa colonum, Echinochloa crusgalli, Cynodon dactylon, Cyperus iria, Cyperus esculentus, Commelina benghalensis* and *Ageratum conyzoides* were dominant weed species of maize at Palampur, Himachal Pradesh (Saini and Angiras, 1998).

Reddy *et al.* (2000) from Hyderabad reported that *Cyperus rotundus, Cynodon dactylon, Panicum repens, Commelina benghalensis, Celosia argentea, Amaranthus polygamus, Euphorbia geniculata, Cleome viscosa, Digera arvensis* were the dominant weeds in maize both during *kharif* and *rabi* seasons.

At Udaipur in Rajasthan, Shekhawat *et al.* (2001) noticed that the important weed species in maize fields were *Echinochloa crusgalli, Echinochloa colona, Portulaca oleracea, Phyllanthus niruri, Commelina benghalensis, Cynodon dactylon, Digera arvensis* and *Cyperus rotundus*.

Pandey *et al.* (2002) from Almora (Uttaranchal) reported that *Echinochloa colonum, Brachiaria ramosa* and *Panicum repens* among grassy weeds, *Ageratum conyzoides, Euphorbia geniculata* and *Oxalis latifolia* among non grassy weeds and *Cyperus rotundus* among sedges were dominant weeds in maize.

Weeds such as *Cyperus rotundus, Cynodon dactylon, Sorghum halepense, Chenopodium album, Convolvulus arvensis, Anagallis arvensis, Cannabis sativa* and *Melilotus alba* were found to be dominant in winter maize of North Bihar (Sinha *et al.*, 2003).

Kamble *et al.* (2005) of Yavatmal opined that broad leaved weeds such as *Commelina benghalensis, Amaranthus viridis, Euphorbia hirta, Lagasca mollis, Parthenium hysterophorus* and *Cyperus rotundus, Cyperus iria* as sedges and *Cynodon dactylon* as narrow leaf grassy weed were associated with maize.
Chalka and Nepalia (2006) from Udaipur, Rajasthan noticed that maize was infested with a mixed flora of weeds, chiefly comprising of *Echinochloa crus-galli*, *Echinochloa colonum*, *Portulaca oleracea*, *Commelina benghalensis*, *Digera arvensis*, *Trianthema portulacastrum* and *Phyllanthus niruri*.

Sharma and Gautam (2006) from Pantnagar (Uttarakhand) reported that *Cynodon dactylon*, *Cyperus rotundus*, *Echinochloa colonum*, *Echinochloa crus-galli*, *Agropyron repens*, *Parthenium hysterophorus*, *Digitaria sanguinalis*, *Eclipta alba*, *Euphorbia hirta* and *Commelina benghalensis* were dominant weeds in maize.

Malviya and Singh (2007) from Faizabad, Uttar Pradesh noticed that maize was infested with a mixed flora of weeds chiefly consisting of *Cyperus rotundus*, *Cynodon dactylon*, *Eclipta alba*, *Solanum nigrum*, *Digera arvensis*, *Phyllanthus niruri*, *Echinochloa colonum* and *Commelina benghalensis*.

The weed flora consisting of *Cynodon dactylon*, *Cyperus rotundus*, *Trianthema portulacastrum*, *Phyllanthus niruri*, *Digera arvensis*, *Euphorbia hirta*, *Aristolochia bracteata*, *Commelina benghalensis*, *Sida acuta* and *Cleome viscosa* were dominant in maize on clay loam soils of Bapatla (Vanaja, 2007).

Chopra and Angiras (2008) from Palampur (Himachal Pradesh) reported that *Digitaria sanguinalis*, *Echinochloa colonum*, *Panicum dichotomiflorum*, *Commelina benghalensis*, *Cyperus iria*, *Brachiaria ramosa*, *Cynodon dactylon* and *Ipomoea purpurea* were dominant weeds of maize.

Mahadevaiah *et al.* (2010) of Tirupati (Andhra Pradesh) observed that *Cynodon dactylon*, *Digitaria sanguinalis* and *Dactyloctenium aegyptium* among the grasses, *Cyperus rotundus* as sedge, *Commelina benghalensis* and *Trichodesma indicum* among broad leaved weeds were dominant weeds in baby corn.

In a study conducted by Srividya *et al.* (2011) at Agricultural College, Bapatla, weed species viz., *Cyperus rotundus*, *Phyllanthus niruri*, *Digera arvensis* and *Cynodon dactylon* were found dominant in maize.
The weeds such as *Digitaria sanguinalis* and *Dactyloctenium aegyptium* among grasses, sedge like *Cyperus rotundus*, broad leaved weeds like *Cleome viscosa, Borrella hispida, Celosia argentea, Merrinia aegyptia* and *Trichodesma indicum* were dominant in sweet corn in Tirupati (Sandhyarani *et al.*, 2011).

Aleem Ahmed *et al.* (2012) conducted a field experiment at College of Agriculture, Rajendranagar, Hyderabad on sandy loam soils and reported that the major weed flora associated with maize crop in the experimental site consisted of four monocots viz., *Cyperus rotundus, Cynodon dactylon, Digitaria sanguinalis, Dactyloctenium aegyptium* and eight dicots viz., *Parthenium hysterophorus, Commelina benghalensis, Amaranthus viridis, Euphorbia geniculata, Celosia argentea, Digera arvensis, Trichodesma indicum* and *Lagasca mollies.*

The weed flora consisting of *Cynodon dactylon, Echinochloa crusgalli, Cyperus rotundus, Trianthema portulacastrum, Phyllanthus niruri, Digera arvensis, Physalis minima, Euphorbia hirta, Aristolochia bracteata, Meremmia everta, Commelina benghalensis, Sida acuta* and *Cleome viscosa* were dominant in maize on clay loam soils of Bapatla (Praveena, 2013).

In a study conducted by Ramadevi (2013) in baby corn on sandy clay loam soils of Bapatla, weed species such as *Cyperus rotundus* among sedges, *Trianthema portulacastrum, Cleome viscosa, Euphorbia hirta, Phyllanthus niruri* and *Digera arvensis* among the dicots and *Cynodon dactylon* among grasses were found significant.

Sakthivel *et al.* (2014) reported that on sandy loam soils of Tamil Nadu Agricultural University, Coimbatore the major weed species associated with maize were *Trianthema portulacastrum, Digera arvensis, Cleome gynandra, Parthenium hysterophorus, Datura metal, Dactyloctenium aegyptium, Setaria verticillata* and *Cyperus rotundus.*

### 2.2 CRITICAL PERIOD OF CROP WEED COMPETITION

The period during which maximum yield loss occurs to the crop due to weeds is known as critical period of crop weed competition. Weeds must be removed at any cost during this period, otherwise yields will be drastically reduced.
Nayital et al. (1989) observed that critical period of crop weed competition in maize was from 20 to 60 DAS on sandy loam soils of Bajaura.

The first 20-40 DAS was the critical period of crop weed competition in maize on sandy soils of Shillong (Varshney, 1991).

Sharma and Nayital (1993) noticed that the most critical period of crop weed competition in maize was between 4-5 WAS in sandy loam soils of Bajaura (Kullu).

Porwal (2000) observed that in the rainy season, emergence of weeds along with the crop were simultaneous and found that the first 20 – 30 days were the most critical period for crop weed competition.

The critical period of weed competition coincided with early stages of the crop i.e. 15 to 45 DAS on clay loam soils of Tamil Nadu (Suresh Kumar and Sundari, 2002).

Dogan et al. (2004) from Turkey reported that weed control should be carried out between 3-4 and 7-10 leaf stages in the maize to obtain maximum grain yield.

Kamble et al. (2005) reported that the critical stage of crop weed competition in maize crop is 30 to 45 days after sowing.

Nagalakshmi et al. (2006) observed that the critical period of crop weed competition in maize was from 3-4 weeks after sowing on clay loam soils of Bapatla (Andhra Pradesh).

Ghanizadeh et al. (2009) from Sushtar, Iran stated that critical period for weed control in maize was from 5-9 leaf stage (17-36 DAS).

2.3 YIELD LOSSES CAUSED BY WEEDS

Season long infestation of composite weed flora in maize field reduced the grain yield by 28-100% (Angiras and Singh, 1989 and Pandey et al., 2001) at various maize growing locations of Palampur and Almora, respectively.
Sharma and Nayital (1993) found that yield loss in maize due to unchecked weed growth was 61.3% as compared to weed free check on sandy loam soils of Bajaura (Kullu).

Kandaswamy and Chandrasekhar (1998) found that yield loss in maize due to uncontrolled weed growth was 45.9 per cent as compared to weed free check on dry lands of Tamil Nadu.

In an experiment at Punjab Agricultural University, Ludhiana Sharma et al. (2000) observed that yield losses due to unchecked weed growth ranged from 32.4 to 42.3% in rainfed maize on sandy loam soils.

Pandey et al. (2002) reported that season long weed infestation reduced the baby corn yield by 44% under rainfed conditions in Almora, Uttaranchal.

In an experiment conducted by Walia et al. (2005) at Punjab Agricultural University, Ludhiana the yield loss recorded due to unchecked weed growth was upto 56% in rainfed maize on sandy loam soils.

Maize being a rainy season and widely spaced crop gets infested with variety of weeds and subjected to heavy weed competition, which often inflicts huge losses ranging from 28-100 per cent in maize (Patel et al. 2006).

Malviya and Singh (2007) reported that season long weed competition reduced the grain yield of maize by 70.24% compared with the weed free conditions on silty loams of Uttar Pradesh.

Rao et al. (2009) reported 41% yield loss due to unchecked weed growth in zero tillage maize on clay loam soils of Lam, Guntur

Sunitha et al. (2010) observed that yield loss due to uncontrolled weed growth in sweet corn was to an extent of 40-42% on sandy loam soils of Tirupati

Patil et al. (2014) at TCA farm, Dholi, Muzzffarpur observed that yield loss due to unchecked weed growth was upto 58% in rabi maize.
2.4 WEED CONTROL METHODS

2.4.1 Physical Methods

In spite of effective alternate methods of weed control, weed management through physical means comprising hand weeding is still considered as an effective method of weed control since it removes every blade of unwanted grass growing among the crop plants (Gupta, 1998).

Hand weeding thrice at 30, 60 and 90 DAS gave season long weed control in maize on sandy loam soils of Hisar (Sangwan et al., 1989).

Hand weeding twice at 2 and 4 WAS controlled the weeds more effectively as compared to weedy check in maize on sandy loam soils of Punjab (Brar et al., 1991).

Prasad and Rafey (1996) reported that hand weeding at 15 and 30 days after sowing recorded the lowest weed density and was on a par with pre-emergence application of pendimethalin @ 1.0 kg a.i ha⁻¹.

Intodia et al. (1996) stated that hoeing and weeding at 20 and 40 DAS recorded significantly lower weed drymatter than with pre-emergence application of various herbicides.

Rout and Satpathy (1996) reported that hand weeding twice at 21 and 42 DAS effectively controlled the weeds in maize on sandy loam soils of Umerkote, Orissa.

Hand weeding twice at 15 and 30 DAS was more effective in reducing weed population over the weedy check in maize (Pandey et al., 2000 and Tripathi et al., 2005).

Hand weeding at 15 and 35 DAS recorded the lowest weed population and dry weight of weeds in maize on sandy loam soils of Bajaura (Reddy et al., 2000 and Shinde et al., 2001).
Reddy et al. (2002) reported that hand weeding twice at 25 and 45 DAS effectively controlled the weeds and reduced the weed biomass in maize on clay loam soils of Annamalai University, Tamil Nadu.

In an experiment conducted on clay loam soils of Coimbatore the lowest weed drymatter production was recorded with two hand weedings at 3 and 6 weeks after sowing in maize (Audi Reddy et al., 2004).

Hand weeding twice at 25 and 40 DAS significantly reduced the weed population and dry weight of weeds as compared to weedy check in maize. (Subramanyam et al., 2001, Kolage et al., 2004 and Sharma and Gautam, 2006).

Two hand weedings at 20 and 40 DAS proved better in reducing weed drymatter and weed population which in turn increased the plant growth characters of maize (Patel et al., 2006, Selvakumar and Sundari, 2006 and Walia et al., 2007).

Sharma and Gautam (2010) recorded that maximum grain yield of maize with two hand weedings under conventional as well as no till system as compared to other treatments at Pantnagar (Uttarakhand).

In an experiment conducted on sandy loam soils at Agricultural college, Rajendranagar, Hyderabad the lowest weed density, drymatter production and the highest weed control efficiency was recorded with intercultivation at 20 DAS followed by hand weeding at 30 DAS in maize (Aleem Ahmed et al., 2012).

Sandhyarani and Karunasagar (2013) conducted an experiment during rabi season at Tirupati on sandy loam soils and reported that growth and yield parameters of sweet corn viz., plant height, leaf area index, drymatter production, green cob and green fodder yield were highest with hand weeding twice at 20 and 40 DAS.

Deshmukh et al. (2014) observed that atrazine @ 1.0 kg a.i ha\(^{-1}\) followed by mechanical or hand weeding at 30 DAS had effectively controlled weed drymatter accumulation, increasing weed control efficiency and grain yield in kharif maize at Punjabrao Deshmukh Krishi Vidyapeeth, Akola.
2.4.2 Chemical Methods

2.4.2.1 Pre-emergence application of atrazine

Atrazine accumulates in chloroplasts and interferes at or close to light reaction II of photosynthesis blocking the electron transport. A block in the electron transport system by atrazine leads to potentially harmful oxidized chlorophyll molecules because of the continuous light activated loss of electrons and deficiency of NADPH₂ required to keep carotenoids and in turn the chlorophyll in a reduced state. It is also postulated that such effects can be accompanied by formation of secondary phytotoxic agents. The immediate phytotoxicity symptom of s-triazines in plants i.e. chlorosis of actively photosynthesizing leaves, margin inwards supports the above hypothesis. Plant starvation due to hampered food synthesis may further aid in ultimate mortality of the affected plant.

Shakoor et al. (1986) reported the lowest weed drymatter ha⁻¹ with the application of atrazine @ 3.0 kg a.i ha⁻¹ in maize crop on sandy loam soils of Pakistan.

Pre-emergence application of atrazine @ 1.0 kg a.i ha⁻¹ + post-emergence application of glyphosate @ 1.0 kg a.i ha⁻¹ recorded the lowest weed drymatter which was on a par with atrazine @ 1.0 kg a.i ha⁻¹ + 2,4-D Na salt @ 0.5 kg a.i ha⁻¹ in maize at Rajendranagar, Hyderabad (Sreenivas and Satyanarayana, 1994).

Pre-emergence application of atrazine @ 1.5 kg a.i ha⁻¹ followed by its post-emergence application @ 0.75 kg a.i ha⁻¹ at 30 DAS was found effective in controlling all the weed species in maize (Saini and Angiras, 1998).

Pre-emergence application of atrazine @ 1.0 kg a.i ha⁻¹ was the most effective herbicide in controlling weeds from early stages of crop growth (Porwal, 2000; Sharma et al., 2000).

Pre-emergence application of atrazine @ 1.5 kg a.i ha⁻¹ proved effective in controlling grasses as well as broad leaved weeds from early growth stages of maize (Sinha et al., 2001).
Sinha et al. (2003) observed that pre-emergence application of atrazine @ 1.5 kg a.i ha\(^{-1}\) followed by post-emergence application of 2,4-D @ 0.8 kg a.i ha\(^{-1}\) resulted in significant reduction in weed count and drymatter of weeds over unweeded control in maize on silt loam soils of Bihar.

At Nigeria, the new formulation doses of atrazine from 1.0 to 3.5 kg a.i ha\(^{-1}\) recorded 85 to 98% control of Commelina benghalensis, Passiflora foetida and Talinum triangulare at 4 weeks after treatment (Chikoye et al., 2006).

Chopra and Angiras (2008) reported that pre-emergence application of atrazine @ 1.5 kg a.i ha\(^{-1}\) reduced the weed density and weed drymatter in maize on silty clay loam soils of Palampur.

Deshmukh et al. (2008) opined that pre-emergence application of atrazine @ 1.0 kg a.i ha\(^{-1}\) was found effective in suppressing weeds and found significantly superior to weedy check in maize crop.

Sunitha et al. (2011) registered the highest green cob, fodder yield and yield attributes with pre-emergence application of atrazine @ 1.0 kg a.i ha\(^{-1}\) followed by hand weeding at 30 DAS in sweet corn on sandy loam soils at Tirupati, Andhra Pradesh.

Aleem Ahmed et al. (2012) reported that weed menace in maize during kharif season can be managed efficiently through the integration of pre-emergence application of atrazine @ 1.0 kg a.i ha\(^{-1}\) followed by topramezone @ 40 ml a.i ha\(^{-1}\) as post-emergence spray at 30 DAS on sandy loam soils of Rajendranagar.

Arvadiya et al. (2012) reported that pre-emergence application of atrazine 1.0 kg a.i ha\(^{-1}\) + hand weeding at 40 DAS recorded higher net return and benefit cost ratio on clay soils of Navasari Agricultural University, Navasari.

According to recommendations of Integrated Weed Management unit, Lam Farm, Guntur application of atrazine @ 2.5-3.5 kg ha\(^{-1}\) immediately or within 3 DAS was found effective in controlling broad spectrum of weeds in kharif maize (Anon., 2013).
2.4.2.2 Pre-emergence application of pendimethalin

Pendimethalin inhibits both cell division and cell elongation in root and shoot meristems of the susceptible plants. The growth is inhibited directly following absorption through hypocotyl and shoot region. The plants die shortly after germination or emergence from the soil.

Thakur and Singh (1989) stated that application of pendimethalin @ 1.5 kg a.i ha\(^{-1}\) effectively controlled the weeds right from emergence of maize crop at Bajaura (Kullu).

Paradkar and Sharma (1993) reported that integration of herbicides viz., atrazine or pendimethalin @ 1.0 kg a.i ha\(^{-1}\) followed with hand weeding at 30 DAS gave consistent and effective weed control than herbicides alone on clay loam soils of Chindwara (Madhya Pradesh).

Pre-emergence application of pendimethalin @ 1.5 kg a.i ha\(^{-1}\) proved on a par with two hand weedings (30 and 60 DAS) in reducing weed population in *rabi* maize on sandy loam soils of North Bihar (Prasad and Rafey, 1996).

Pre-emergence application of pendimethalin @ 1.25 kg a.i ha\(^{-1}\) effectively reduced the weed count over weedy check in maize on loamy clay soils of Almora (Pandey et al., 1999).

Patel et al. (2006) from Anand (Gujarat) reported more than 98% weed control efficiency in maize with combined pre-emergence application of atrazine + pendimethalin (0.5 + 0.25 kg a.i ha\(^{-1}\)) on sandy loam soils.

Singh et al. (2012) from Wadura (Maharashtra) reported that the highest weed control efficiency (74.1%) in maize was recorded with atrazine @ 0.5 kg a.i ha\(^{-1}\) followed by pendimethalin @ 1.0 kg a.i ha\(^{-1}\) (71%) and the lowest under one hand weeding (60%).
2.4.2.3 Post-emergence application of topramezone

Topramezone is a new, highly selective herbicide of pyrazolone structure for the post-emergence control of broadleaf and grass weeds in corn (Porter et al., 2005). Its efficacy is the result of the inhibition of HPPD (4-hydroxyphenylpyruvate dioxygenase, an enzyme in the plastoquinone biosynthetic pathway), and indirectly the carotenoid biosynthetic pathway. As a result, oxidative degradation of chlorophyll and membrane structure occurs, leading to pronounced whitening or “bleaching” of sensitive weeds. These bleaching effects will be visible on new growth within five days of treatment. Ultimately, growth is inhibited. Under the influence of light, chlorotic tissues become necrotic, and sensitive plants usually die within 7-14 days after treatment. The compound is distributed within the plants systemically through acropetal and basipetal movement. Adjuvants enhance leaf absorption and distribution of topramezone.

Soltani et al. (2007) studied the tolerance of eight sweet corn hybrids to topramezone applied as post-emergence at 0, 50, 75, 100, 150, and 300 g a.i ha\(^{-1}\) at 4-5 sweet corn leaf stage. The herbicide did not cause any morphological injury but reduced the plant height, cob size, or marketable yield of sweet corn hybrids at 7\(^{th}\) day after treatment and resulted in minimal injury (less than 5\%) at 300 g a.i ha\(^{-1}\) in all hybrids on Brookston clay loam soils at Ontario.

Thomas et al. (2010) resorted to post-emergence application of topramezone @ 50 g a.i ha\(^{-1}\) at 2-4, 4-6 and 6-8 maize leaf stage. In both the years, plant height, cob number and yield were not affected with the use of herbicide at these growth stages and yields were similar with that of hand weeded plots, on sandy clay loam soils at the Nagref-Cereal Institute at Thessaloniki, Greece.

Aleem Ahmed et al. (2012) reported that weed menace in maize during kharif season can be managed efficiently through the integration of pre-emergence application of atrazine @ 1.0 kg a.i ha\(^{-1}\) followed by topramezone @ 40 ml a.i ha\(^{-1}\) as post-emergence spray at 25 DAS on sandy loam soils of Rajendranagar.
Kumar *et al.* (2013) reported that in zero tillage maize glyphosate pre-plant incorporation followed by topramezone+atrazine @ (40 ml + 500 g a.i/ha) as post-emergence application at 30 DAS resulted in significantly higher mean grain yield (6360 kg ha\(^{-1}\)) as compared to un-weeded check on sandy loam soils of Sabour, Bihar.

Zhang *et al.* (2013) observed that post-emergence application of topramezone @ 25 g a.i ha\(^{-1}\) at 2-3 and 4-5 leaf stage of weeds. Topramezone could effectively control broadleaved and grass weeds when its dose was reduced by 67% without sacrificing the total weed control efficacy and grain yield in summer maize on sandy loam soils of North China Plain.

### 2.4.2.4 Weed control rating and crop toxicity rating

James and Brad (2006) at Agricultural Experimentation Station, USA reported that less rainfall may reduce weed germination and emergence, while increased the herbicide persistence in the soil, which resulted in greater weed control ratings.

Ishrat *et al.* (2012) reported that there was no toxic effect to maize with pre-emergence application of atrazine @ 1.25 kg a.i ha\(^{-1}\) on clay loam soils of Karnataka.

### 2.5 WEED DENSITY AND DRY WEIGHT

Balyan and Bhan (1987) noticed that pre-emergence application of atrazine @ 0.5 kg a.i. ha\(^{-1}\) reduced the dry weight of dominant weeds like *Trianthema portulacastrum* and *Echinocloa colonum* in maize on sandy loam soils of Hisar.

Angiras and Singh (1989) reported that hand weeding twice at 30 and 60 DAS significantly reduced the weed population and weed dry weight as compared to weedy check in maize.

Rout and Satpathy (1996) from Orissa reported that pre-emergence application of herbicides viz., atrazine, metolachlor and alachlor @ 1.25 kg a.i ha\(^{-1}\) were more than 90% efficient in reducing the dry weight of weeds in rainfed maize.
Saini and Angiras (1998) reported that atrazine @ 1.5 kg a.i ha\(^{-1}\) was the most effective for weed control in maize compared to pendimethalin @ 0.75 kg a.i ha\(^{-1}\) and metolachlor @ 1.5 kg a.i ha\(^{-1}\) on silt loam soils of Himachal Pradesh.

Pre-emergence application of atrazine @ 0.5 kg a.i ha\(^{-1}\) followed by intercultivation at 35 DAS resulted in the lowest weed dry weight on clay loam soils of Udaipur (Mundra et al., 2002).

Pre-emergence application of atrazine @ 0.5 kg a.i ha\(^{-1}\) followed by one hoeing at 20 DAS resulted in the lowest weed dry weight on clay loam soils of Yavatmal in *kharif* maize (Kamble et al., 2005).

Tripathi et al. (2005) reported that atrazine @ 0.5 kg a.i ha\(^{-1}\) could provide effective control of weeds when it was supplemented with one hand weeding at 20 DAS in maize on sandy loam soils of Kanpur.

Nagalakshmi et al. (2006) reported the lowest weed density and dry matter accumulation with two hand weedings at 21 and 42 DAS in maize on clay loam soils of Agricultural college, Bapatla.

Patel et al. (2006) from Anand (Gujarat) registered the lowest weed density and dry matter with hand weeding at 20 and 40 DAS on sandy loam soils.

Srividya et al. (2011) opined that application of either atrazine @ 1.25 kg a.i ha\(^{-1}\) or pendimethalin @ 1.5 kg a.i ha\(^{-1}\) in combination with directed spray of paraquat @ 0.6 kg a.i ha\(^{-1}\) in between rows at three weeks after sowing recorded significantly lower weed density and dry matter comparable with that of two hand weedings and intercultivation with power weeder at 4 WAS on clay loam soils of Bapatla.

Pre-emergence application of atrazine @ 1.0 kg a.i ha\(^{-1}\) followed by hand weeding at 40 DAS resulted in the lowest weed dry weight in sweet corn on heavy black soils of Navasari Agricultural University, Navasari (Arvadiya et al., 2012).
Sandhyarani and Karunasagar (2013) reported the lowest weed density and dry weight with two hand weedings at 20 and 40 DAS in maize on sandy loam soils at Tirupati.

At crop research centre, RAU (Pusa), Ranjana Kumari et al. (2014) recorded the lowest weed density and dry weight accumulation with pre-emergence application of atrazine @ 1.0 kg a.i ha\(^{-1}\) followed by working with power weeder at 45 DAS in summer maize.

Amandeep et al. (2014) recorded significantly lower weed drymatter with pre-emergence tank mix application of atrazine 0.75 kg a.i ha\(^{-1}\) + pendimethalin 0.75 kg a.i ha\(^{-1}\) at University Seed Farm, Nabha (Punjab).

Deshmukh et al. (2014) observed that atrazine @ 1.0 kg a.i ha\(^{-1}\) followed by mechanical or hand weeding at 30 DAS controlled the weed density and drymatter in kharif maize at Punjabrao Deshmukh Krishi Vidyapeeth, Akola.

Pre-emergence application of atrazine @ 0.75 kg a.i ha\(^{-1}\) followed by 2,4-D @ 0.5 kg a.i ha\(^{-1}\) recorded the lowest weed density and it was on a par with hand weeding at 20 and 40 DAS in maize on clay soils of Akola, Maharashtra (Sonawane et al., 2014).

2.6 WEED CONTROL EFFICIENCY

Weed control efficiency is a parameter derived out of weed dry weight per unit area for studying treatments performance in weed control research. Weed control efficiency compares different weed control treatments on the basis of their effect on weed dry weight.

Paradkar and Sharma (1993) reported that hand weeding twice at 15 and 30 DAS gave the highest weed control efficiency (97.3%) but it was statistically on a par with pre-emergence application of atrazine @ 1.0 kg a.i ha\(^{-1}\) followed by one hand weeding at 30 DAS (96.5%) in maize crop on clay loam soils of Chindwara (Madhya Pradesh).

Sreenivas and Satyanarayana (1994) recorded the lowest weed density and the highest weed control efficiency (61.2%) with pre-emergence application of atrazine @ 1.0 kg a.i ha\(^{-1}\) followed by post-emergence application of 2,4-D Na salt @ 0.5 kg a.i ha\(^{-1}\) at 30 DAS in kharif maize at Rajendranagar, Hyderabad.
Hand weeding twice at 20 and 40 DAS and pre-emergence application of metolachlor @ 1.25 kg a.i. ha$^{-1}$ gave maximum weed control efficiency of 82.7 and 82.3% respectively, in maize at Bajaura (Thakur, 1994).

Prasad and Rafey (1996) recorded the highest weed control efficiency with two hand weedings which was comparable with pre-emergence application of pendimethalin @ 0.75 kg a.i. ha$^{-1}$.

Porwal (1998) noticed that the highest weed control efficiency of 69.5% was achieved with pre-emergence application of atrazine @ 1.0 kg a.i. ha$^{-1}$ followed by hand weeding twice in maize.

Pandey et al. (2000) found that two weedings each at 15 and at 30 DAS gave the highest weed control efficiency of 87.9% in maize on loamy clay soils of Almora.

Pre-emergence application of atrazine @ 0.5 kg a.i. ha$^{-1}$ followed by intercultivation at 35 DAS resulted in the highest weed control efficiency (75%) on clay loam soils of Udaipur (Mundra et al., 2002).

Pandey et al. (2002) registered that the highest weed control efficiency of 93.3% was achieved with hand weeding at 15 DAS followed by earthing up at 30 DAS in baby corn on loamy clay soils of Almora, Uttaranchal.

Sinha et al. (2003) noticed that the lowest weed density and the highest weed control efficiency (44.1%) was achieved with pre-emergence application of atrazine @ 1.5 kg a.i. ha$^{-1}$ followed by post-emergence application of 2,4-D @ 0.8 kg a.i. ha$^{-1}$ in maize on silt loam soils of Bihar.

The maximum weed control efficiency (95.02%) was observed in weed free check followed by pre-emergence spraying of atrazine @ 1.0 kg a.i. ha$^{-1}$ (84.98%) in kharif maize crop on the clayey soils of Rahuri (Kolage et al., 2004).

Kamble et al. (2005) recorded the highest weed control efficiency (50.3%) with pre-emergence application of atrazine @ 0.5 kg a.i. ha$^{-1}$ followed by one hoeing at 20 DAS on clay loam soils of Yavatmal in kharif maize.
In an experiment conducted on sandy clay loam soils of Tamil Nadu by Ramesh and Nadanassababady (2005) pre-emergence application of atrazine @ 0.25 kg ha\(^{-1}\) at 3 DAS followed by handweeding at 40 DAS resulted in greater weed control efficiency (87.1%) than other treatments in maize.

Selvakumar and Sundari (2006) at Annamalai University noticed the highest weed control efficiency of 69.5% with pre-emergence application of pendimethalin @ 1.0 kg a.i ha\(^{-1}\) followed by hand weeding at 30 DAS in maize on clay loam soils of Tamil Nadu.

Malviya and Singh (2007) reported the highest weed control efficiency of 71.7% with two hand weedings at 20 and 40 DAS in maize on silty loam soils of Faizabad, Uttar Pradesh.

From the experimental results on clay soils of Agricultural University, Parbhani by Deshmukh et al. (2008) indicated that pre-emergence application of atrazine @ 1.0 kg a.i ha\(^{-1}\) resulted in a weed control efficiency of 83.27% in maize.

Sunitha et al. (2010) reported the highest weed control efficiency (81.9%) with pre-emergence application of atrazine @ 1.0 kg a.i ha\(^{-1}\) followed by hand weeding at 30 DAS in sweet corn on sandy loam soils at Tirupati.

Aleem Ahmed et al. (2012) observed that the weed density and weed dry matter production significantly reduced and thereby increased the weed control efficiency (89.2%) with intercultivation at 20 DAS followed by hand weeding at 30 DAS. The next best treatment was the pre-emergence application of atrazine @ 1.0 kg a.i. ha\(^{-1}\) followed by intercultivation at 20 DAS, which were statistically on a par with pre-emergence application of atrazine @ 1.0 kg a.i ha\(^{-1}\) followed by topramezone @ 40 ml a.i ha\(^{-1}\) as post-emergence spray (85.3%) at 25 DAS in kharif maize on sandy loam soils of Rajendranagar.

The highest weed control efficiency of 68.1% was achieved with hand weeding twice at 20 and 40 DAS which was at par with atrazine @ 1.0 kg a.i ha\(^{-1}\) followed by mechanical weeding at 30 DAS (61.2%) in maize at Agricultural University, Akola, Maharashtra (Deshmukh et al., 2014).
2.7 WEED INDEX

Weed index is a parameter derived from crop yields obtained across the treatments of weed control research. It is a measure of the crop yield loss accrued across treatments in comparison to weed free plot or in certain cases the minimum weed infested plot like two or three hand weedings adopted in an experiment. It is the ultimate parameter towards appraisal of the superiority or inferiority of several treatments and is worked out in almost all weed control experiments.

From an experiment conducted on sandy soils at Hyderabad, Sreenivas et al. (1992) reported significantly higher crop drymatter production and lower weed index in maize with atrazine @ 1.0 kg a.i ha\(^{-1}\) (pre-emergence) followed by 2,4-D @ 0.5 kg a.i ha\(^{-1}\) (post-emergence) over farmers practice.

Kelage et al. (2004) noticed the lowest weed index of 1.41% in kharif maize with pre-emergence spraying of atrazine @ 1.0 kg a.i. ha\(^{-1}\) on clay soils of Rahuri.

Nagalakshmi et al. (2006) reported the lowest weed index and the highest weed control efficiency (82.6%) with two hand weedings in maize on clay loam soils at Agricultural college, Bapatla.

Arvadiya et al. (2012) observed the lowest weed index and the highest weed control efficiency (90.6%) under weed free check followed by atrazine 1.0 kg a.i ha\(^{-1}\) + hand weeding at 40 DAS in sweet corn on clay soil of Gujarat.

Sanodiya et al. (2014) noticed lower weed index and the highest weed control efficiency with hand weeding at 20 and 40 DAS in maize due to reduced competition by weeds at Jabalpur, Madhya Pradesh.

2.8 PLANT CHARACTERS

Controlling of weeds by different weed control treatments effects growth and development of crop.
Balyan and Bhan (1987) recorded significantly taller plants with higher drymatter production with pre-emergence application of atrazine @ 0.5 kg a.i ha\(^{-1}\) over unweeded control in maize on sandy loam soils of Hissar.

An experiment conducted on clay loam soils of Chindwara (Madhya Pradesh) revealed that hand weeding twice at 15 and 30 DAS exhibited significant increase in plant height of maize (234.2 cm), but was on a par with pre-emergence application of atrazine @ 1.0 kg a.i ha\(^{-1}\) + one hand weeding at 30 DAS (Paradkar and Sharma, 1993).

Anil Dixit and Gautam (1996) reported that application of atrazine @ 0.75 kg a.i ha\(^{-1}\) as pre-emergence and 0.25 kg a.i ha\(^{-1}\) at knee high stage and at tasseling stage resulted in significantly greater growth characters viz., plant height, drymatter production plant\(^{-1}\) and number of leaves plant\(^{-1}\) over pre-emergence application of atrazine @ 0.75 kg a.i ha\(^{-1}\) alone in maize on sandy loam soils of New Delhi.

Pandey et al. (2000) recorded significantly increased plant height of 218.8 cm with hand weeding twice at 15 and 30 DAS over weedy check, but was statistically on a par with application of atrazine @ 0.625 kg a.i ha\(^{-1}\) + alachlor @ 1.0 kg a.i ha\(^{-1}\).

Sharma et al. (2000) registered maximum plant height (219 cm) of maize crop with pre-emergence application of atrazine @ 1.0 kg a.i ha\(^{-1}\) over post-emergence application on sandy loam soils of PAU, Ludhiana (Punjab).

Shinde et al. (2001) opined that drymatter produced plant\(^{-1}\) of maize was significantly higher under weed free condition (307.4 g plant\(^{-1}\)), but was at par with hand weeding twice at 20 and 40 DAS and pre-emergence application of atrazine @ 1.0 kg a.i ha\(^{-1}\) on alkaline soils of Rahuri.

Sinha et al. (2001) from Bihar recorded significantly the highest drymatter accumulation (92.0 g plant\(^{-1}\)) and taller plants (172.4 cm) with pre-emergence application of atrazine @ 1.5 kg a.i ha\(^{-1}\) followed by 2,4-D @ 0.8 kg a.i ha\(^{-1}\) and it was on a par with hand weeding at 25 and 45 DAS in maize on silt loam soils.
Srividya et al. (2011) stated that application of either atrazine @ 1.25 kg a.i ha⁻¹ or pendimethalin @ 1.5 kg a.i ha⁻¹ in combination with directed spray of paraquat @ 0.6 kg a.i ha⁻¹ in between rows at three WAS recorded significantly taller plants comparable with that of two hand weedings and intercultivation with power weeder at 4 WAS on clay loam soils of Bapatla.

Sunitha et al. (2011) recorded significantly higher drymatter production (7044 kg ha⁻¹) and plant height (141.6 cm) with pre-emergence application of atrazine @ 1.0 kg a.i ha⁻¹ + hand weeding at 30 DAS and it was on a par with hand weeding twice at 15 and 30 DAS in sweet corn on sandy loam soils at Tirupati.

Aleem Ahmed et al. (2012) from Rajendranagar recorded significantly the highest plant height (208.6 cm) and plant drymatter production (78.3 plant⁻¹) with intercultivation at 20 DAS followed by hand weeding at 30 DAS, which was on a par with pre-emergence application of atrazine @ 1.0 kg a.i. ha⁻¹ followed by intercultivation at 20 DAS and pre-emergence application of atrazine @ 1.0 kg a.i ha⁻¹ followed by topramezone @ 40 ml a.i ha⁻¹ as post-emergence spray at 25 DAS in kharif maize on sandy loam soils.

Shantveerayya and Agasimani (2012) recorded significantly taller plants (201 cm) and the highest drymatter production (309.8 g plant⁻¹) with pre-emergence application of atrazine @ 0.75 kg a.i ha⁻¹ followed by 2,4-D @ 1.0 kg a.i ha⁻¹ over unweeded control (208 g plant⁻¹) in maize on black soils of Dharwad.

2.9 YIELD ATTRIBUTES AND YIELD

Pre-emergence application of atrazine @ 0.5 kg a.i ha⁻¹ and hand weeding at 3 and 5 WAS recorded higher number of cobs plant⁻¹ and grains cob⁻¹, which were on a par with weed free conditions in sandy loam soils of Hissar (Balyan and Bhan, 1987).

In an experiment on sandy loam soils at Solan, the highest maize grain yield of 6800 kg ha⁻¹ was obtained with pre-emergence application of pendimethalin @ 1.5 kg a.i ha⁻¹ followed by hand weeding twice at 21 and 42 DAS and was significantly higher over unweeded check (Thakur and Singh, 1989).
In a field trial at Ludhiana, Brar et al. (1991) revealed that hand weeding twice at two and four WAS produced the maximum number of cobs ha\(^{-1}\) and maximum cob length, which was on a par with pre-emergence application of atrazine @ 1.0 kg a.i ha\(^{-1}\) in maize on loamy sand soils.

Sreenivas et al. (1992) observed a significant increase in yield of maize (5500 kg ha\(^{-1}\)) by the application of atrazine @ 1.0 kg a.i ha\(^{-1}\) + 2,4-D Na salt @ 0.5 kg a.i ha\(^{-1}\) over farmers practice i.e. intercultivation at 20 DAS followed by hand weeding at 30 DAS (4530 kg ha\(^{-1}\)) on sandy loam soils of Rajendranagar.

Paradkar and Sharma (1993) reported that significantly greater number of cobs and the highest grain yield were obtained with pre-emergence application of atrazine @ 1.0 kg a.i ha\(^{-1}\) + hand weeding at 30 DAS over other herbicide treatment combinations in maize on clay loam soils of Chindwara (Madhya Pradesh).

Sreenivas and Satyanarayana (1994) reported that the yield obtained (5500 kg ha\(^{-1}\)) by the pre-emergence application of atrazine @ 1.0 kg a.i ha\(^{-1}\) followed by 2,4-D Na salt @ 0.5 kg a.i ha\(^{-1}\) at 30 DAS was at par with that of application of atrazine @ 1.0 kg a.i ha\(^{-1}\) followed by glyphosate @ 1.0 kg a.i ha\(^{-1}\) as post-emergence directed spray in maize during rainy season at Rajendranagar, Hyderabad.

Application of atrazine @ 0.75 kg a.i ha\(^{-1}\) as pre-emergence and @ 0.25 kg a.i ha\(^{-1}\) each at knee high stage and tasseling stages resulted in significantly higher yield attributing characters like cob length (17.3cm), test weight (269 g) and grain yield (7230 kg ha\(^{-1}\)) in maize over application of atrazine alone @ 0.75 kg a.i ha\(^{-1}\) as pre-emergence on sandy loam soils of New Delhi (Anil Dixit and Gautam, 1996).

Saini and Angiras (1998) found that pre-emergence application of atrazine @ 1.5 kg a.i ha\(^{-1}\) followed by post-emergence application of atrazine @ 0.75 kg a.i ha\(^{-1}\) provided significantly higher yield attributes and yield on silty loam soils of Himachal Pradesh.
Sharma et al. (1998) reported significantly higher grain yield (4491 kg ha\(^{-1}\)) stover yield (8376 kg ha\(^{-1}\)) and grains cob\(^{-1}\) (410.48) by application of metolachlor @ 1.5 kg a.i ha\(^{-1}\) and atrazine @ 0.75 kg a.i ha\(^{-1}\) in maize over the other herbicidal treatments on sandy loam soils at Bajaura (Himachal Pradesh).

Pandey et al. (1999) observed significant increase in number of cobs ha\(^{-1}\), cob length and diameter with pre-emergence application of atrazine or pendimethalin @ 1.25 kg a.i ha\(^{-1}\) than with weedy check.

Atrazine @ 1.0 kg a.i ha\(^{-1}\) applied at 30 DAS resulted in significantly higher grain yield (3890 kg ha\(^{-1}\)) than pre-emergence application of atrazine @ 1.0 kg a.i ha\(^{-1}\) (3590 kg ha\(^{-1}\)) due to effective weed control during the active growth period in maize on clay loam soils of Banswara in Southern Rajasthan (Porwal, 2000).

Sinha et al. (2001) recorded the highest kernel weight cob\(^{-1}\) (132.9 g) and kernels cob\(^{-1}\) (353.3) with hand weeding twice at 25 and 45 DAS in maize on silt loam soils at Bihar.

The highest grain and stover yields were recorded with pre-emergence application of atrazine @ 1.0 kg a.i ha\(^{-1}\) + metolachlor @ 1.0 kg a.i ha\(^{-1}\) with one hand weeding at 40 DAS on wet land in Tirupati (Subramanyam et al., 2001).

Pandey et al. (2002) recorded the highest corn weight, corns plant\(^{-1}\), corn length, girth and green fodder and cob yield was with hand weeding at 15 DAS + earthing up at 30 DAS in baby corn on loamy clay soils of Almora, Uttaranchal.

Pre-emergence application of atrazine @ 0.5 kg a.i ha\(^{-1}\) combined with intercultivation at 35 DAS resulted in maximum values of yield components which were statistically on a par with intercultivation at 20 and 35 DAS on clay loam soils of Chindwara, Madhya Pradesh (Mundra et al., 2003).

Ghodratollah Fathi et al. (2005) reported that increased number of kernel rows cob\(^{-1}\) (15), kernels row\(^{-1}\) (44) was achieved with hand weeding at 15 and 45 DAS in maize on sandy loam soils of Ramin Agricultural Research and Education centre of Shahid, Iran.
Tripathi *et al.* (2005) reported that on sandy loam soils of Kanpur higher grain yield of maize (3230 kg ha\(^{-1}\)) was recorded by hand weeding twice at 15 and at 30 DAS and was on a par with the application of atrazine @ 0.5 kg a.i ha\(^{-1}\) followed by one hand weeding at 30 DAS (3146 kg ha\(^{-1}\)).

Patel *et al.* (2006) reported that atrazine @ 0.5 kg a.i ha\(^{-1}\) in combination with pendimethalin @ 0.25 kg a.i ha\(^{-1}\) as pre-emergence application recorded the maximum number of grains cob\(^{-1}\) (456) and test weight (20.4 g) in *kharif* maize on sandy loam soils of Gujarat.

Walia *et al.* (2007) reported that on loamy sand of Ludhiana tank mix application of atrazine + pendimethalin @ 0.5 + 0.5 kg a.i ha\(^{-1}\) followed by hand weeding at 15 and 30 DAS resulted in significantly higher yields (5156 kg ha\(^{-1}\)) over the application of atrazine @ 1.0 kg a.i ha\(^{-1}\) as pre-emergence (4625 kg ha\(^{-1}\)) in maize.

Chopra and Angiras (2008) reported that atrazine @ 1.5 kg a.i ha\(^{-1}\) resulted in significant increase in all the yield attributes of maize crop and thereby its grain yield over weedy check on silty clay loam soils of Palampur.

Hussein *et al.* (2008) reported that more number of kernels cob\(^{-1}\) (529) and kernel weight cob\(^{-1}\) (129.6 g) with hand weeding twice at three and six WAS in maize on sandy soils of Egypt.

On sandy loam soils of Tirupati, pre-emergence application of atrazine @ 1.0 kg a.i ha\(^{-1}\) followed by hand weeding at 30 DAS resulted in significantly higher yields over other treatments in baby corn (Mahadevaiah *et al.*, 2010).

The highest green cob weight (219.0 g) was recorded with hand weeding twice at 15 and 30 DAS in sweet corn on sandy loam soils at Tirupati (Sunitha *et al.*, 2010).

Sunitha *et al.* (2011) reported the highest green cob, fodder yield and yield attributes with pre-emergence application of atrazine @ 1.0 kg a.i ha\(^{-1}\) followed by hand weeding at 30 DAS in sweet corn on sandy loam soils at Tirupati, Andhra Pradesh.
In an experiment on sandy loam soils at Rajendranagar, the highest maize grain yield (5122 kg ha\(^{-1}\)), stover yield (7934 kg ha\(^{-1}\)), grains cob\(^{-1}\) (424.1), test weight (21.0), was obtained with intercultivation at 20 DAS followed by hand weeding at 30 DAS, which was however on a par with pre-emergence application of atrazine @ 1.0 kg a.i. ha\(^{-1}\) followed by intercultivation at 20 DAS and pre-emergence application of atrazine @ 1.0 kg a.i ha\(^{-1}\) followed by topramezone @ 40 ml a.i ha\(^{-1}\) as post-emergence spray at 25 DAS (Aleem Ahmed et al., 2012).

Pre-emergence application of atrazine @ 1.0 kg a.i ha\(^{-1}\) followed by hand weeding at 40 DAS recorded the highest green fodder and green cob yield at Navasari Agricultural University, Navasari (Arvadiya et al., 2012).

Kumar et al. (2013) stated that zero tillage-glyphosate pre-plant incorporation followed by topramezone+atrazine @ (40 ml + 500 g a.i ha\(^{-1}\)) as post-emergence application at 30 DAS resulted in significantly higher yield attributing characters viz., cob length (15.6 cm), grain rows cob\(^{-1}\) (14), grains row\(^{-1}\) (40) over un-weeded check in kharif maize on sandy loam soils of Sabour, Bihar.

Sandhyarani and Karunasagar (2013) conducted an experiment during rabi season at Tirupati on sandy loam soils and reported that growth and yield parameters of sweet corn viz., plant height, leaf area index, drymatter production, green cob and green fodder yield were highest with hand weeding twice at 20 and 40 DAS.

Sonawane et al. (2014) reported the highest green fodder yield with pre-emergence application of atrazine @ 0.75 kg a.i ha\(^{-1}\) followed by 2,4-D @ 0.5 kg a.i ha\(^{-1}\) and it was on a par with hand weeding at 20 and 40 DAS in maize on clay soils at Akola, Maharashtra.

### 2.10 EFFECT OF WEED CONTROL METHODS ON NUTRIENT UPTAKE

Thakur and Singh (1990) reported that total nitrogen uptake by maize crop (218 kg ha\(^{-1}\)) was significantly higher with pendimethalin @ 1.5 kg a.i ha\(^{-1}\) over weedy check (121.5 kg ha\(^{-1}\)) on clay loam soils of Himachal Pradesh.
Sreenivas and Satyanarayana (1994) reported significantly higher uptake of nitrogen (206.3 kg ha⁻¹), phosphorus (40.3 kg ha⁻¹) and potassium (183.2) by maize with pre-emergence application of atrazine @ 1.0 kg ha⁻¹ followed by post-emergence application of 2,4-D @ 0.5 kg a.i ha⁻¹ at Rajendranagar, Hyderabad.

Jat et al. (1996) reported that the maximum nitrogen, phosphorus and potassium uptake by maize was recorded with two manual weedicings and the highest nitrogen, phosphorus and potassium uptake by weeds was recorded in unweeded check on clay loam soils of Rajasthan.

Deshveer and Amarsingh (2002) recorded significantly higher nitrogen uptake by maize crop in weed free condition (54.86 kg ha⁻¹) and it was on a par with pre-emergence application of pendimethalin @ 1.0 kg a.i ha⁻¹ (52.93 kg ha⁻¹) on heavy texture soils of Bharatpur.

Mundra et al. (2002) from Udaipur reported significantly higher uptake of nitrogen (143.9 kg ha⁻¹), phosphorus (32.0 kg ha⁻¹) by maize with atrazine @ 0.5 kg a.i ha⁻¹ followed by intercultivation at 35 DAS on clay loam soils.

Nagalakshmi et al. (2006) from Bapatla (Andhra Pradesh) reported higher uptake of nitrogen (30.43 kg ha⁻¹) by weeds was recorded in weedy check on clay loam soils.

Srividya et al. (2011) reported that weed free check and intercultivation with power weeder, pre-emergence application of atrazine @ 1.5 kg a.i ha⁻¹ in combination with paraquat recorded significantly higher nitrogen, phosphorus and potassium uptake by maize over the application of atrazine or pendimethalin alone. The highest nitrogen, phosphorus and potassium uptake by weeds was recorded in weedy check.

Sunitha et al. (2011) from Tirupati (Andhra Pradesh) reported that the lowest uptake of nitrogen, phosphorus and potassium by sweet corn in weedy check. The highest nitrogen, phosphorus and potassium uptake by weeds was recorded in weedy check.
Sonawane et al. (2014) noticed significantly higher nitrogen, phosphorus and potassium uptake by maize with application of atrazine @ 0.75 kg a.i ha\(^{-1}\) followed by 2,4-D @ 0.5 kg a.i ha\(^{-1}\) at Akola, Maharashtra. The highest nitrogen, phosphorus and potassium uptake by weeds was recorded in weedy check.

### 2.11 ECONOMICS OF WEED CONTROL TREATMENTS

Recommendation of any weed control measure can be finalized by judging its efficiency of weed control and economic feasibility.

Sreenivas and Satyanarayana (1994) stated that atrazine @ 1.0 kg a.i ha\(^{-1}\) + 2,4-D @ 0.5 kg a.i ha\(^{-1}\) recorded the highest net returns (Rs. 21,529 ha\(^{-1}\)) in kharif maize at Rajendranagar, Hyderabad.

Padmavathi and Gopalaswamy (1995) stated that hand weeding twice recorded the highest net return of Rs. 6196 and 5132 ha\(^{-1}\) and BCR of 1.57 and 1.24 during kharif and rabi seasons, respectively in maize on clay loam soils of Coimbatore.

Pre-emergence application of atrazine @ 0.25 kg a.i. ha\(^{-1}\) + hand weeding once at 40 DAS enhanced B: C ratio (2.59) over weedy check (Kandaswamy and Chandrasekhar, 1998).

Net return per rupee invested was significantly more (1.48) with pre-emergence application of pendimethalin @ 1.0 kg a.i ha\(^{-1}\) over hand weeding and no weeding due to the lowest cost involved under herbicidal treatment in maize on clay loam soils of Bihar (Sinha et al., 1999).

The highest BCR of 1.83 and net return of Rs. 20,872 ha\(^{-1}\) were recorded with pre-emergence application of atrazine @ 1.0 kg a.i. ha\(^{-1}\) + metolachlor @ 1.0 kg a.i. ha\(^{-1}\) followed by one hand weeding at 40 DAS in maize on sandy loam soils of Tirupati (Subramanyam et al., 2001).

Kamble et al. (2005) noticed that pre-emergence application of atrazine @ 0.5 kg a.i ha\(^{-1}\) + one hoeing at 20 DAS was the most economical and effective method in controlling weeds besides recording higher benefit cost ratio (3.68) in kharif maize at Yavatmal.
Sunita et al. (2011) reported the highest net return and BCR with pre-emergence application of atrazine @ 1.0 kg a.i ha\(^{-1}\) followed by hand weeding at 30 DAS in sweet corn on sandy loam soils at Tirupati, Andhra Pradesh.

Aleem Ahmed et al. (2012) noticed that pre-emergence application of atrazine @ 1.0 kg a.i ha\(^{-1}\) followed by topramezone @ 40 ml a.i ha\(^{-1}\) as post-emergence spray at 25 DAS was the most economical and effective method in controlling weeds besides recording higher benefit cost ratio (1.88) in kharif maize on sandy loam soils of Rajendranagar.

Kumar et al. (2013) stated that zero tillage-glyphosate pre-plant incorporation followed by topramezone+atrazine @ (40 ml + 500 g a.i ha\(^{-1}\)) as post-emergence application at 30 DAS recorded the highest net return (Rs. 34,856 ha\(^{-1}\)) and benefit cost ratio (1.21) as compared to rest of the weed control methods in kharif maize on sandy loam soils of Sabour, Bihar.

The highest net returns of Rs. 48,870 ha\(^{-1}\) and benefit cost ratio (2.64) were recorded with pre-emergence tank mix application of atrazine 0.75 kg a.i ha\(^{-1}\) + pendimethalin 0.75 kg a.i ha\(^{-1}\) which make these herbicides economically feasible and cost effective for controlling weeds in kharif maize at Punjab (Amandeep et al., 2014).

Patil et al. (2014) recorded the highest benefit cost ratio (2.7) with atrazine @ 1.0 kg a.i ha\(^{-1}\) followed by mechanical or hand weeding at 30 DAS over hand weeding twice at 20 and 40 DAS in maize at Akola, Maharashtra.
Chapter - V

SUMMARY AND CONCLUSIONS

The salient findings of the study on “Evaluation of pre and post emergence herbicides in kharif maize” were summarized in this chapter. The experiment was conducted on sandy clay loam soil at Agricultural College Farm, Bapatla during kharif 2014 by adopting Randomized Block Design with nine treatments replicated thrice. The treatments consisted of T1-Weedy check; T2-Hand weeding at 20 and 40 DAS; T3-Pendimethalin @ 1.0 kg a.i ha$^{-1}$ (PE); T4-Atrazine @ 1.0 kg a.i ha$^{-1}$ (PE); T5-Topramezone @ 25 g a.i ha$^{-1}$ at 20 DAS (POE); T6-Topramezone @ 25 g a.i ha$^{-1}$ at 40 DAS (POE); T7-Topramezone @ 25 g a.i ha$^{-1}$ at 20 and 40 DAS (POE); T8-Pendimethalin @ 1.0 kg a.i ha$^{-1}$ (PE) fb topramezone @ 25 g a.i ha$^{-1}$ at 20 DAS (POE); T9-Atrazine @ 1.0 kg a.i ha$^{-1}$ (PE) fb topramezone @ 25 g a.i ha$^{-1}$ at 20 DAS (POE).

The predominant weed species observed in the experimental field were Cyperus rotundus among sedges, Trianthema portulacastrum, Cleome viscosa, Euphorbia hirta and Phyllanthus niruri among dicots and Cynodon dactylon, Panicum repens and Dactyloctenium aegyptium among grasses.

The lowest density and dry weight of weeds and the highest weed control efficiency were recorded with hand weeding at 20 and 40 DAS (T2). Among the herbicidal treatments, pre-emergence application of atrazine @ 1.0 kg a.i ha$^{-1}$ fb topramezone spray @ 25 g a.i ha$^{-1}$ at 20 DAS (T9) and pre-emergence application of pendimethalin @ 1.0 kg a.i ha$^{-1}$ fb topramezone spray @ 25 g a.i ha$^{-1}$ at 20 DAS (T8) recorded lower values for weed density and drymatter and were next to hand weeding treatment (T2) indicating efficiency of these treatments in controlling the weeds during the critical growth period of maize for weed competition. The highest density and drymatter of weeds was recorded in weedy check (T1).
Even though, plant height and dry matter accumulation in maize at 30, 60, 90 DAS and at maturity were the highest under hand weeding at 20 and 40 DAS (T2), pre-emergence application of atrazine @ 1.0 kg a.i ha\(^{-1}\) fb topramezone spray @ 25 g a.i ha\(^{-1}\) at 20 DAS (T9) and pre-emergence application of pendimethalin @ 1.0 kg a.i ha\(^{-1}\) fb topramezone spray @ 25 g a.i ha\(^{-1}\) at 20 DAS (T8) were on a par with T2 reflecting good weed control achieved in these treatments. Uptake of nutrients by maize was the highest with hand weeding at 20 and 40 DAS (T2). Pre-emergence application of atrazine @ 1.0 kg a.i ha\(^{-1}\) fb topramezone spray @ 25 g a.i ha\(^{-1}\) at 20 DAS (T9) and pre-emergence application of pendimethalin @ 1.0 kg a.i ha\(^{-1}\) fb topramezone spray @ 25 g a.i ha\(^{-1}\) at 20 DAS (T8) recorded comparable nutrient uptake by maize with hand weeding (T2) indicating effective weed control among these treatments. Significant increase in nitrogen, phosphorus and potassium uptake by weeds was recorded in weedy check (T1) over other weed control treatments indicating the severe weed competition offered by weeds to maize.

The effect of various weed control treatments on yield and yield attributes of maize were found to be the same as on plant height and dry matter accumulation. Among various treatments, sequential application of atrazine @ 1.0 kg a.i ha\(^{-1}\) (PE) fb topramezone spray @ 25 g a.i ha\(^{-1}\) at 20 DAS (T9) and pre-emergence application of pendimethalin @ 1.0 kg a.i ha\(^{-1}\) fb topramezone spray @ 25 g a.i ha\(^{-1}\) at 20 DAS (T8) recorded the higher kernel yield of 5627 kg ha\(^{-1}\) and 5282 kg ha\(^{-1}\), respectively and these treatments were statistically on a par with hand weeding at 20 and 40 DAS which recorded the highest kernel yield (5974 kg ha\(^{-1}\)). Similar trend was observed in stover yield under different weed control treatments.

Even though, hand weeding at 20 and 40 DAS recorded the highest gross returns (Rs. 81581 ha\(^{-1}\)), sequential application of atrazine @ 1.0 kg a.i ha\(^{-1}\) (PE) fb topramezone spray @ 25 g a.i ha\(^{-1}\) at 20 DAS (T9) and pre-emergence application of pendimethalin @ 1.0 kg a.i ha\(^{-1}\) fb topramezone spray @ 25 g a.i ha\(^{-1}\) at 20 DAS (T8) recorded a net profit of Rs. 51340 ha\(^{-1}\) and
Rs. 45790 ha\(^{-1}\) with a returns per rupee investment of 2.00 and 1.73, respectively and were found to be superior to even hand weeding at 20 and 40 DAS which recorded a net return of Rs. 47744 ha\(^{-1}\) with a returns per rupee investment of 1.41, as the lower cost of herbicides reduced the cost of cultivation and contributed to the highest net returns.

**CONCLUSIONS**

Based on the results of present investigation, the following conclusions have been drawn.

- Pre-emergence application of either atrazine or pendimethalin @ 1.0 kg a.i ha\(^{-1}\) fb post-emergence application of topramezone @ 25 g a.i ha\(^{-1}\) at 20 DAS resulted in better growth, yield attributes and yield of maize as well as increased weed control efficiency besides achieving reduced weed density and dry weight of weeds and these two treatments were comparable with hand weeding at 20 and 40 DAS.

- Hand weeding at 20 and 40 DAS even though recorded the highest kernel yield and gross income, pre-emergence application of atrazine @ 1.0 kg a.i ha\(^{-1}\) fb topramezone spray @ 25 g a.i ha\(^{-1}\) at 20 DAS (T\(_9\)) was found to be the most cost effective weed control measure in maize with the highest BCR.

**Future line of work:** Effectiveness of new post-emergence broad spectrum selective herbicides other than topramezone may be evaluated for control all groups of weeds in maize as topramezone failed to control sedges.