

Weed Management in Maize - Berseem Cropping System Under Different Tillage Practices

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By

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CERTIFICATE - I

*This is to certify that the thesis entitled “**Weed management in maize - berseem cropping system under different tillage practices**” submitted in partial fulfilment of the requirements for the degree of **DOCTOR OF PHILOSOPHY in Agriculture (Agronomy)** of Rajmata Vijayaraje Scindia Krishi Vishwa Vidhyalaya, Gwalior is a record of the bona-fide research work carried out by **Mr. VINOD KUMAR WASNIK** under my guidance and supervision. The subject of the thesis has been approved by the student’s Advisory Committee and the Director of Instruction.*

No part of the thesis has been submitted for any other degree or diploma or has been published. All the assistance and help received during the course of this investigation has been acknowledged by the scholar.

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Abbreviations and Acronyms

Abbreviations/ Acronyms	Meaning
a.i.	Active ingredient
&	And
<i>et al.</i>	And co-workers
@	At the rate of
B: C	Benefit: cost ratio
cm	Centi meter
CT	Conventional tillage
CD	Critical difference
DAS	Days after sowing
ds/ m	Deci Siemens per metre
°C	Degree centigrade
E	East
EC	Electrical conductivity
Fig.	Figure
<i>fb</i>	Followed by
g	Gram
ha	Hectare
i.e.	In reference to; that is
kg	Kilogram
kg/ha	Kilogram per hectare
Max.	Maximum
m	Meter
m ²	Metre square
Min.	Minimum

<i>viz.</i>	Namely
N	Nitrogen
NS	Non significant
No.	Number
OC	Organic carbon
%	Percent
P ₂ O ₅	Phosphorus
K ₂ O	Potassium
q	Quintal
q/ha	Quintal per hectare
R.V.S.K.V.V.	Rajmata Vijayaraje Scindia Krishi Vishwa Vidhyalaya
RH	Relative humidity
₹	Rupees
pH	Soil reaction
SEm±	Standard error of mean
Temp.	Temperature
T	Tillage practices
WCE	Weed control efficiency
WI	Weed index
W	Weed management practices
Wt.	Weight
ZT	Zero tillage

Chapter - I

INTRODUCTION

Maize (*Zea mays* L.) is one of the most important cereal crops next to rice and wheat and occupies a prominent position in global agriculture. Predominantly in India it is a *kharif* season crop. Among the cereals due to its wider adaptability and highest genetic yield potential it is known as queen of cereals. Maize has diversified uses as human food, animal feed and fodder, poultry feed and industrial uses like beverages. Globally, maize is cultivated on an area of 185 million hectares with an average productivity of 5.6 tonnes/ha (DAC&FW, 2016). USA is the major producer of maize in the world, accounting for 34.7% of total world production. In India, it has occupied 8.69 million hectares area with production of 21.81 million tonnes and an average productivity of 2.51 tonnes/ha. Whereas, in Uttar Pradesh it is cultivated in an area of 0.68 million hectare (7.81% maize area) of India with 1.26 million tonnes production and an average productivity of 1.84 tonnes/ha (DAC&FW, 2016).

Berseem (*Trifolium alexandrinum* L.) is a premier winter season legume fodder and considered as king of fodder crop. In India, it is cultivated in an area of around 2 million hectares (Pandey and Roy, 2011). India is having highest area under berseem followed by Egypt and Pakistan (Muhammad *et al.* 2014). As compared to other forage crops its fodder is very nutritious, succulent and milk multiplier in nature. The multicut cultivar provides 80-85 t/ha green fodder in 5-6 cuttings. Berseem fodder has 20% crude protein, 62% total digestible nutrients with 65% digestibility and good palatability. The crop left for seed production after 3 cuts gives on an average 0.4-0.5 t/ha seed.

Maize – Berseem cropping system is very much popular in western Uttar Pradesh among dairy entrepreneurs. Berseem is considered as a promising crop for diversifying agriculture. Berseem in rotation with cereals and in integration with animals provides highest economic returns and gives livelihood security to millions of farm family (Upadhyay *et al.* 2011). Berseem

being a leguminous crop also improves the soil fertility and helps in increasing the yield of succeeding crop. Now a day's growing berseem in winter after maize is a profitable business. This encourages farmers to shift from the traditional cropping systems dominated by wheat and oil seeds to non-traditional systems containing forage crops especially berseem.

Tillage is an important practice in crop production as it provides favourable conditions for better crop growth and development. A soil tillage practice improves soil properties (physical, chemical and biological) and enables the plant to show their full yield potential and growth. Therefore, it is important that appropriate tillage practices should be applied to avoid the degradation of soil structure, to increase the crop yield as well as to maintain the ecosystem. In recent years, due to increase in energy and labour cost in crop production the conservation agriculture is receiving attention of researcher and policy maker. It is noticed that compared to conventional tillage, zero tillage improves physio-chemical and biological properties of soil, reduces the cost of production and increases economic returns (Bisen and Singh, 2008; Jha *et al.* 2011). This cropping practice also enhances the system diversity by stimulating biological processes in the soil, reduces soil erosion and leaching as well as reduces labour requirement by about 50%. Hence, to address the problem associated with faulty land utilization and to reduce the cost of crop production zero tillage is one of the better and viable options. Presently, conservation agriculture has been adopted over 250 million hectares globally and is fast gaining popularity in Asian countries. However, in India conservation agriculture adoption is still in the initial phase. Over the past few years, adoption of conservation agriculture has expanded to cover about 1.5 million hectares (Jat *et al.* 2012)

The success of conservation agriculture mainly depends on efficient weed management practices. The presence of weed seed in the upper layer of soil due to no tillage operation leads to their high infestation in conservation agriculture and so far, herbicides are the only answer to deal with this problem (Singh *et al.* 2014). Weeds are the major biotic constraint, which compete with crops for nutrients, water and light. Likewise, the quality of produce is also impaired by weed infestation. As per an estimate, the total

world food loss due to weeds is approximately 287 million tonnes, which accounts for nearly 11% of total food production. The infestation of composite weed flora reduces maize grain yield by 28-100% (Patel *et al.* 2006) and in berseem causes substantial yield reduction (30-40%), besides deteriorating the quality of green fodder (Jain, 1998). Hand weeding is considered as a popular and effective weed management method. The undependable labour availability and escalating wages in recent years have given impetus to the development and use of herbicides, which can control broad spectrum of weeds. Hence, under such a situation, use of herbicide is the only option to reduce the weed menace at least in the initial year of conservation agriculture. A considerable amount of research on conservation agriculture has been done in India under Maize - Wheat cropping system but almost no information is available particularly in Maize - Berseem cropping sequence. Thus, keeping these facts in view, the present research work on **“Weed management in Maize - Berseem cropping system under different tillage practices”** has been planned with the following objectives.

Objectives

1. To study the effect of tillage practices and weed control measures on growth and productivity of maize and berseem.
2. To work out suitable and economic weed control method for maize and berseem under different tillage practices.
3. To assess the effect of tillage and weed management on physical and chemical properties of soil.
4. To compute the system productivity and economics of different treatments.

Chapter - II

REVIEW OF LITERATURE

Maize - Berseem is one of the most important and dominant cropping systems in irrigated areas of India. The increasing fodder scarcity coupled with heavy demand of milk emphasizes the need for shift in cropping pattern. Replacement of *rabi* wheat with berseem crop under zero tillage condition provides an opportunity to use time and resources efficiently, but the main constraint in maximizing the yield in both the crops is weed infestation. Proper management of crop following appropriate weed management practices gives higher productivity and profitability.

In this chapter, an effort has been made to review the research work done so far pertaining to tillage practices and weed control measures on the productivity of maize and berseem.

2.1 Maize

2.1.1 Weed flora

Rao *et al.* (2009) observed that the major weed flora associated with zero-till sown maize were *Echinochloa colona* (L.) Link (41%), *Dinebra retroflexa* (vahl) Panzer (4%), *Panicum repens* (3%) and *Cynodon dactylon* (L.) pers. (2%), *Leptochloa chinensis* (L.) Nees (5%) (grasses), *Cyperus rotundus* L. (5%) (sedges), *Chrozophora rotleri* (Geisel) S.Juss. Ex Spreng. (15%), *Trianthema portulacastrum* L. (13%), *Digera arvensis* (4%), *Merremia emerginata* (Burm.f.) Hall. F. (3%), *Phyllanthus niruri* (3%) and *Euphorbia hirta* (2%) (Broad-leaved weeds).

Mukundam *et al.* (2011) reported *Cyperus rotundus*, *Trianthema portulacastrum*, *Digera arvensis*, *Phyllanthus niruri* and *Cynodon dactylon* as dominant weeds in maize field in clay loam soils of Bapatla.

The major weed flora in clay loam soils of Warangal were *E. colona* (13%), *D. retroflexa* (11%), *P. repens* (8%) and *L. chinensis* (7%) among the grasses, *C. rotundus* L. (8%) among sedges and *C. rotleri*. (11%), *T.*

portulacastrum (9 %), *D. arvensis* (9%), *M. emerginata* (12%), *P. niruri* (3%) and *E. hirta* (9%) among the broad-leaved weeds (Reddy et al. 2012).

Parameshwari (2013) found that in winter maize the predominant weed species in sandy loam soils of Hyderabad were *Echinochloa colona*, *Cyperus rotundus*, *Ageratum conyzoides* and *T. portulacastrum*.

Kiran and Rao (2014) revealed that zero till sown maize crop was infested with a total of 21 weed species, of which 7 were grasses, 3 sedges and 11 broad-leaved weeds.

Susha et al. (2014) noticed that major weed species present in maize field were *Achras racemosa* Heyne ex Roem & Ohwi, *Dactyloctenium aegyptium* (L.) P. Beauv, *Setaria glauca* (L.) Beauv, *Cyperus rotundus* (L.), *Trianthema portulacastrum* (L.), *Commelina benghalensis* (L.) and *Digera arvensis* (L.) Forsk.

Owla et al. (2015) reported that the predominant weed species of maize were *Eichnochloa colonum* (L.) Link, *Eichnochloa. crusgalli* (L.) Beauv. *Cynodon dactylon* (L.) Pers., *Digera arvensis* Forsk., *Phyllanthus niruri* Hook f., *Trianthema potulacstrum* L., *Amaranthus viridis* L., *Commelina benghalensis* L., *Portulaca oleracea* L. and *Parthenium hysterophorus* L.

Swetha et al. (2015) carried out an experiment at Professor Jayashankar Telangana State Agricultural University, Rajendranagar, Hyderabad, Telangana, wherein, they observed that the experimental field were infested with weeds *Cynodon dactylon*, *Digitaria sanguinalis*, *Dactyloctenium aegyptium*, *Echinocloa* spp, *Rottboellia exaltata*, *Parthenium hysterophorus*, *Commelina benghalensis*, *Amaranthus viridis*, *Euphorbia geniculata*, *Digera arvensis*, *Trianthema portulacastrum* and *Cyperus rotundus*.

Barla et al. (2016) stated that the experimental field was infested with broad-leaved weeds like *Alternenthara sessils*, *Commelina benghalensis*, *Commelina nudifolia*, *Ageratum conyzoides*, *Phyllanthus niruri*; among grassy weeds *Echinochloa colona*, *Echinochloa crusgalli*, *Digitaria sanguinalis*, *Paspalam distichum*, *Dactyloctenium aegyptium* and among

sedges *Cyperus rotundus*, *Cyperus iria* and *Fimbristylis miliacea* at Birsa Agricultural University, Ranchi, Jharkhand.

Das *et al.* (2016) observed major weed species in the experimental field during rainy season were *Ageratum conizoides*, *Alternanthera phyloxiroides*, *Bidens pilosa*, *Borrevia hispida*, *Galinsoga parviflora* and *Spilanthus acemella* among broad-leaved weeds; *Cynodon dactylon*, *Digitaria marginata*, *Digitaria sanguinalis*, *Panicum repens* and *Eleusine indica* among grasses and *Cyperus rotundus* and *Fimbristylis miliacea* among sedges.

2.1.2 Effect of tillage practices

2.1.2.1 Weed indices

Sarma and Gautam (2010) at Pantnagar recorded significantly lower total weed population (11.08 /m²) and weed dry weight (6.83 g/m²) under tilled plots than no-tilled plots.

Ramesh *et al.* (2014) conducted a field experiment on silty clay loam soil of Palampur during 2009 - 2011 and concluded that at 60 and 90 DAS zero tillage maize recorded significantly higher total weed count compared to conventional tillage.

Shekhar *et al.* (2014) found that adoption of ZT in wheat – maize cropping sequence has significantly increased the population of grassy and sedges weeds in both wheat and maize crops as compared to ZT-CT, CT-CT, CT-ZT and FIRB-bed.

2.1.2.2 Growth and development

Experimental results of Mukundam *et al.* (2011) under clay loam soil revealed that the maximum plant height of maize was noticed with conventional tillage than that under zero tillage. Similarly, Shekhar *et al.* (2014) reported the highest plant height (201.0 cm), dry matter (91.3 g/plant) and crop growth rate (15.4) with continuous adoption of conventional tillage.

Among different crop establishment methods significantly higher plant height and dry matter production of maize was observed when maize was grown after transplanted rice under zero-till condition (Parameswari, 2013).

2.1.2.3 Yield attributes and yield

Chopra and Angiras (2008) observed that conventional tillage produced significantly higher values of yield attributing characters (number of rows/cob and 1,000 grain weight) and also grain and stover yield of maize as compared to zero tillage.

Sarma and Gautam (2010) found significant improvement on yield attributes, grain and biological yield of maize due to tillage operation as compared to no-tillage. Significant decrease in grain (5.2 - 6.8%) and stover (4.6 - 7.4%) yield of maize were recorded under minimum tillage compared to conventional tillage (Sharma *et al.* 2010).

A field experiment conducted at Selakui, Dehradun during 2001- 04 to study the effect of tillage and mulching practices under artificially created varying land slopes on soil moisture conservation, productivity and nutrient uptake in maize - wheat cropping system indicated that lowest yield of maize was recorded under minimum tillage compared to conventional tillage (Singh *et al.* 2011).

In clay loam soil of Rajasthan College of Agriculture, Udaipur, Shekhar *et al.* (2014) recorded highest grain (3.55 t/ha) and stover (5.57 t/ha) yield of maize in wheat - maize cropping sequence with conventional tillage.

2.1.2.4 Economics

Ram *et al.* (2010) observed highest net returns and benefit: cost ratio in no-tillage - no-tillage due to low cost of cultivation. Maize grown under conventional tillage recorded highest net returns (15,901 ₹/ha) and benefit cost ratio (1.51) as compared to no-tillage (Sarma and Gautam, 2010).

Highest benefit: cost ratio was registered in zero-till maize with the application of atrazine 1.0 kg/ha *fb* topramezone 0.030 kg/ha at 30 DAS (Parameswari, 2013).

Ramesh *et al.* (2014) noticed that sowing of maize under zero tillage had the lowest cost of cultivation over conventional tillage, manual seed drill

and multi-crop planter due to less machinery use as the primary tillage was completely skipped.

2.1.3 Effect of weed control measures

2.1.3.1 Weed indices

Patel *et al.* (2006) conducted a field experiment at College of Agriculture Farm, Anand Agricultural University, Anand and recorded least weed density with hand weeding twice at 20 and 40 DAS.

Chopra and Angiras (2008) registered significantly lower count and dry matter of weeds and highest total weed control efficiency with the application of atrazine 1.5 kg/ha.

Pre-emergence application of atrazine 1.5 kg/ha followed by hand weeding at 30 DAS recorded the lowest weed dry weight and highest weed control efficiency at 60 DAS and at harvest (Rao *et al.* 2009).

Pasha *et al.* (2012) reported that pre-emergence application of atrazine 1.25 kg/ha + paraquat 0.75 kg/ha were found effective in reducing the weed density and weed dry matter.

Reddy *et al.* (2012) recorded lowest density and dry weight of grasses, sedges and broad-leaved weeds at 30 DAS with tank mix application of atrazine + glyphosate (0.75 + 0.8 kg/ha).

Maximum reduction in weed density and dry matter of total weeds were recorded through pre-emergence application of atrazine + ethoxysulfuron (Choudhary *et al.* 2013).

Pre-emergence application of atrazine 1.0 kg/ha followed by topramazine 0.030 kg/ha at 30 DAS recorded highest weed control efficiency in zero-till maize (Parameswari, 2013). Kour *et al.* (2014) also observed lowest total weed density and weed biomass with pre-emergence application of atrazine @ 0.5 kg/ha.

Shekhar *et al.* (2014) advocated that two hand weeding provided significantly minimum density and dry weight of grassy, broad-leaved and sedges weeds compared to weedy check. Singh *et al.* (2015) found significantly lowest weed index with metribuzin + 1 HW.

Topramezone + atrazine @ 25.2 + 250 g/ha + MSO as post-emergence recorded significantly lower total number of weeds (31.56/m²) and weed dry matter (16.73 g/m²) in maize as compared to unweeded control (Swetha *et al.* 2015).

Barla *et al.* (2016) stated that application of atrazine + pendimethalin 0.50 + 0.50 kg/ha as pre-emergence significantly reduced weed density and weed dry matter. Weed free check had minimum weed population and dry weight at 30 and 60 DAS (Das *et al.* 2016).

2.1.3.2 Growth and development

Rao *et al.* (2009) recorded significantly higher plant height (245 cm) and crop dry matter (398 g) by hand weeding twice at 15 and 30 DAS. Similarly, higher plant height and crop dry matter was observed by Parameswari (2013) with hand weeding twice at 20 and 40 DAS.

Shekhar *et al.* (2014) carried out a field experiment at Rajasthan College of Agriculture, Udaipur and found highest plant height (202 cm) of maize under two hand weeding compared to weedy check.

2.1.3.3 Yield attributes and yield

Rao *et al.* (2009) recorded the highest maize grain yield with hand weeding twice at 15 and 30 DAS. Similar increase in grain and biological yield of maize with two hand weeding at 25 and 45 days after sowing were recorded by Sarma and Gautam (2010).

Two hand weeding at 3 and 6 weeks after sowing or intercultivation with power weeder at 4 weeks after sowing in maize recorded significantly higher maize grain yield under irrespective of tillage methods (Srividya *et al.* 2011).

Pasha *et al.* (2012) reported that tank mix application of atrazine 1.25 kg/ha + paraquat 0.75 kg/ha as pre-emergence produced significantly higher grains/cob, cob diameter and 100 grain weight.

In sandy loam soil of Hyderabad, Parameswari (2013) obtained highest yield attributes and yield of maize with two hand weeding at 20 and 40 DAS.

Pre-emergence application of atrazine @ 0.5 kg/ha recorded significantly higher grain yield (Kour *et al.* 2014). Sussha *et al.* (2014) found higher maize grain and stover yield in weed free check compared to rest of the weed control treatment.

Swetha *et al.* (2015) from a field experiment carried out during *Kharif*, 2014 at College Farm, College of Agriculture, Professor Jayashankar Telangana State Agricultural University, Rajendranagar, Hyderabad recorded maximum grain yield (6.58 t/ha) of maize in hand weeding at 20 and 40 DAS which was 60.5% higher over the un-weeded control.

Barla *et al.* (2016) conducted a field experiment on sandy loam soil of Birsa Agricultural University, Ranchi and registered lowest 100 seed weight, grain and straw yield of maize from weed check as compared to other weed control measures.

Das *et al.* (2016) registered highest number of cob length (15.4 cm), seeds per cob (285) and grain weight per cob (129 g) under weed free check.

2.1.3.4 Protein content

Highest protein content (10.06%) of maize was recorded with two hand weeding at 15 and 30 days after sowing followed by pre-emergence application of tank-mix atrazine + alachlor at Udaipur, (Choudhary *et al.* 2013).

2.1.3.5 Economics

Rao *et al.* (2009) recorded highest gross returns, net returns and benefit: cost ratio with two HW at 15 and 30 DAS and with pre-emergence application of atrazine 1.5 kg/ha *fb* HW at 30 DAS.

Choudhary *et al.* (2013) reported significantly greater benefit: cost ratio (2.19) by atrazine + alachlor application.

Parameswari (2013) concluded that gross returns (88,570 ₹/ha), net returns (50,820 ₹/ha) and benefit: cost ratio (2.35) were higher with HW twice at 20 and 40 DAS.

Susha *et al.* (2014) registered superiority on net returns and benefit: cost ratio by pre-emergence tank-mix application of pendimethalin 0.75 kg/ha + imazethapyr 0.050 kg/ha due to higher maize yield and lower cost of cultivation.

Owla *et al.* (2015) achieved enhanced net returns (37,340 ₹/ha) by pre-emergence application of atrazine + alachlor followed by hoeing.

Swetha *et al.* (2015) registered higher benefit: cost ratio (3.17) in tank mix spraying of topramezone + atrazine at 25.2 + 250 g/ha +MSO as post-emergence.

2.2 Berseem

2.2.1 Weed flora

Tiwana *et al.* (2002) stated that the major weed flora in berseem were *Cichorium intybus*, *Poa annua*, *Trianthema portulacastrum*, *Rumex dentatus* and *Lepidium sativa*.

The berseem experimental field weed flora was grouped in into two groups by Kumar and Dhar (2008) i.e. associated weed *Chicorium intybus* and other weeds *Cyperus rotundus* L., *Cynodon dactylon* L. Pers., *Melilotus indica* L., *Anagalis arvensis* L., *Desmodium tortuosum* (sw.) DC, *Spergula arvensis* L., *Rumex hongifolius* DC, *Tridax procumbens* L. and *Chenopodium album* L.

Revathi *et al.* (2012) observed *Cyperus rotundus*, *Cynodon dactylon* and *Dactylactenium aegyptium* among sedges and grasses; *Trianthema portulacastrum*, *Parthenium hysterophorus*, *Chicorium intybus*, *Digera arvensis*, *Euphorbia hirta*, *Trichodesma indicus* among broad leaved weed species and *Cuscuta chinensis* parastic weed in the experimental field of lucerne.

The most dominated weed species in berseem were *Cynodon dactylon* (28.5%), *Chloris barbata* (7.1%), *Digitaria longiflora* (10.7%), *Dactyloctenium aegyptium* (10.7%), *Cyperus rotundus* (42.9%), *Amaranthus viridis* (16.7%), *Euphorbia geniculata* (8.3%), *Celosia argentia* (4.2%), *Trianthema portulacastrum* (4.2%), *Commelina benghalensis* (12.5%),

Corchorus aestuans (4.2%), *Parthenium hysterophorus* (33.3%), *Tridax procumbens* (4.2%), *Portulaca oleracea* (4.2%) and *Cichorium intybus* (4.2%) (Pathan *et al.* 2013).

2.2.2 Effect of tillage practices

2.2.2.1 Weed indices

An investigation made by Kumar *et al.* (2015) during *Rabi* 2010 - 11 and 2011- 12 at the forage field situated at Ranchi Veterinary College campus under Birsa Agricultural University, Ranchi revealed that weed density and weed dry weight in oat field were decreased under zero tillage

2.2.2.2 Yield attributes and yield

Conventional tillage recorded highest green fodder yield of oat at first (10.9 t/ha) and second (24.5 t/ha) cut which remained at par with zero tillage (Kumar *et al.* 2015).

2.2.2.3 Crude protein yield

Kumar *et al.* (2015) reported highest crude protein and crude fiber in oat green fodder due to adoption of conventional tillage however it was at par with zero tillage.

2.2.3 Effect of weed control measures

2.2.3.1 Weed indices

Tiwana *et al.* (2002) noticed minimum dry matter of total weeds and highest weed control efficiency by application of butachlor @ 2.0 kg/ha.

Investigation made by Kumar and Dhar (2008) at Indian Grassland and Fodder Research Institute, Jhansi reported maximum total weed control efficiency (76 %) with pre-emergence application of imazethapyr @ 0.10 kg a.i. /ha.

Revathi *et al.* (2012) found lowest weed density, weed dry weight and highest weed control efficiency in lucerne at I cut, II cut and III cut under weed free check.

Minimum weed count, weed dry weight at harvest and minimum weed index for green fodder and seed yield of berseem were recorded with pre-

emergence application of oxyfluorfen 0.10 kg/ha followed by application of imazethapyr 0.10 kg/ha immediate after harvest of first cut (Pathan *et al.* 2013).

Jha *et al.* (2014) reported reduced weed density (6.17 /m²), weed dry weight (5.92 g/m²) and higher weed control efficiency (72.31%) by pre-emergence application of oxyfluorfen @ 0.100 kg a.i./ha + imazethapyr @ 0.150 kg a.i./ha immediate after harvest of 1st cut of berseem as compared to weedy check.

2.2.3.2 Growth and development

Jha *et al.* (2014) conducted a field experiment during *Rabi* 2011 - 12 and 2012 - 13 to find out most suitable weed management practices in berseem at Jabalpur and observed highest plant height of berseem in weed free plots.

2.2.3.3 Yield attributes and yield

Tiwana *et al.* (2002) achieved highest green (44.70 and 43.00 t/ha) and dry fodder (8.43 and 8.24 t/ha) yield of berseem when 10 % salt floatation and water floatation of berseem seed was followed to remove the weed seeds.

Kewat *et al.* (2005) reported highest green fodder (91.00 t/ha) and seed yield (5.71 q/ha) in berseem crop with the adoption of 10 per cent common salt seed treatment which was at par with application of butachlor @ 1.0 kg a.i./ha and imazethapyr @ 0.10 and 0.15 kg a.i./ha.

Kumar and Dhar (2008) recorded highest green fodder (88.20 t/ha) and dry matter yield (14.30 t/ha) of berseem from pre-emergence application of imazethapyr @ 0.15 kg a.i./ha being at par with imazethapyr @ 0.10 kg a.i./ha.

Mishra (2012) obtained maximum seed yield (461kg/ha) of lucerne at lower level of pendimethalin (500 g/ha) probably due to lower level of *Cuscuta* infestation. Revathi *et al.* (2012) also reported the highest total green fodder yield (33.54 t/ha) of lucerne over three cuts when imazethapyr was applied 75 g/ha at 12 days after sowing.

Weed free check registered significant superiority with respect to green fodder (47.27 t/ha), dry fodder (7.13 t/ha), seed (0.35 t/ha) and straw yield (1.34 t/ha) of berseem over other weed control approaches (Pathan *et al.* 2013). Similar observation was reported by Jha *et al.* (2014).

2.2.3.4 Crude protein yield

Tiwana *et al.* (2002) stated that the highest crude protein content (24.8 %) in berseem was registered with butachlor @ 1.0 kg/ha.

Significantly higher crude protein yield (2.6 t/ha) was recorded with the pre-emergence application of imazethapyr @ 0.10 kg a.i. /ha over other herbicide treatments and control (Kumar and Dhar, 2008).

Pathan *et al.* (2013) and Jha *et al.* (2014) recorded higher crude protein and crude fiber yield in berseem under weed free treatment.

2.2.3.5 Economics

Tamrakar *et al.* (2002) and Kewat *et al.* (2005) were obtained highest net monetary returns and benefit: cost ratio due to pre-emergence application of butachlor @ 2.0 kg/ha.

Kumar and Dhar (2008) registered higher net returns (28,695 ₹/ha) and benefit: cost ratio (1.86) with pre-emergence application of imazethapyr @ 0.10 kg a.i. /ha as compared to other treatments.

Maximum benefit: cost ratio (2.01) were realized by pre-emergence application of oxyflourfen 0.10 kg/ha *fb* imazethapyr 0.10 kg/ha immediate after harvest of 1st cut (Pathan *et al.* (2013).

Jha *et al.* (2014) revealed that the application of oxyfluorfen @ 0.100 kg a.i./ha + imazethapyr @ 0.150 kg a.i./ha recorded highest net profit of ₹ 84163/ha.

2.3 System productivity and economics

Highest total productivity of cropping systems in terms of maize grain equivalent yield was found under minimum tillage with mulching. Minimum tillage with mulching recorded 5.4% higher system productivity than conventional tillage (Prasad *et al.* 2014).

Saini *et al.* (2013) recorded highest maize equivalent yield (3.28 t/ha) with mechanical weedings at 20 and 40 days after sowing.

Conventionally tilled both rice and wheat produced 25.23, 11.9 and 11.4% higher mean rice equivalent yield compared to zero tilled rice and wheat; zero tilled rice and conventional tilled wheat and conventional tilled rice and zero tilled wheat (Surin *et al.* 2013).

Shekhar *et al.* (2014) observed highest net returns and wheat equivalent yield in wheat - maize cropping system under continuous adoption of conventional tillage.

2.4 Soil properties

Chopra and Angiras (2008) and Ram *et al.* (2010) recorded highest bulk density in 0-15 cm soil depth with zero tillage treatment.

Saha *et al.* (2010) found significant increase in soil organic carbon and microbial biomass with zero tillage + residue retention than conventional tillage.

Shekhar *et al.* (2014) obtained highest organic carbon content under continuous adoption of zero tillage at the end of second wheat - maize cropping sequence.

Chapter - III

MATERIAL AND METHODS

A field experiment entitled “**Weed management in Maize - Berseem cropping system under different tillage practices**” was conducted during *kharif* and *rabi* seasons of 2015-16 and 2016-17. The details of the material used and methods adopted during the course of investigation are given under the following heads.

3.1 Location of the experimental site

The experiment was conducted at Central Research Farm, Indian Grassland and Fodder Research Institute, Jhansi during 2015-16 (*Kharif - Rabi* season) and 2016-17 (*Kharif - Rabi* season). The farm is geographically situated at an altitude of 270 m above mean sea level on 25°27' N latitude and 78°33' E longitude. The region falls under Agro-climatic zone VIII Central Plateau and Hills region [Bundelkhand Agro climatic Zone (6)] of the Uttar Pradesh.

3.2 Weather during crop growth period

The weather parameters recorded at Meteorological Observatory, Central Research Farm, Indian Grassland and Fodder Research Institute, Jhansi during the crop growth period are presented in Table 3.1 and 3.2 and depicted in Fig. 3.1 and 3.2 for maize crop and Fig. 3.3 and 3.4 for berseem crop.

3.2.1 *Kharif* season (Maize crop)

The mean weekly maximum temperature in *kharif*, 2015 during maize crop period ranged from 31.7°C to 37.3°C with an average of 34.7°C and in *kharif*, 2016 it ranged from 30.3°C to 35.0°C with an average of 33.1°C. Likewise, the mean weekly minimum temperature for the corresponding period varied from 16.9°C to 25.3°C with an average of 22.9°C during 2015 and from 16.3°C to 26.5°C with an average of 23.6°C in 2016.

The mean relative humidity recorded at 7.30 hrs during the maize crop growth period ranged from 76 to 94% with an average of 86.1 % and 36 to

Table 3.1 Mean weekly meteorological data recorded during the crop growth period of maize *Kharif* 2015 and 2016

Standard Week No.	Date	Temperature (°C)				Relative humidity (%)				Sun-shine (hrs.)		Rainfall (mm)		Evaporation (mm)	
		Max.		Min.		Max.		Min.		2015	2016	2015	2016	2015	2016
		2015	2016	2015	2016	2015	2016	2015	2016						
28	9 July-15 July	33.0	32.5	25.2	26.5	90	93	68	79	5.0	3.5	18.4	26.4	6.3	6.3
29	16 July-22 July	33.0	31.1	25.3	25.8	94	92	78	74	3.8	3.0	101.8	28.4	5.9	5.3
30	23 July-29 July	31.7	32.7	24.0	25.7	92	93	75	80	6.2	4.6	51.4	171.6	6.0	5.2
31	30 July-5 Aug.	33	32.5	24.7	25.2	87	91	63	76	5.1	3.6	14.8	90.2	5.5	4.8
32	6 Aug.-12 Aug.	33.1	32.2	24.6	25.4	93	90	79	77	4.9	4.1	171.6	51.6	5.6	4.6
33	13 Aug.-19 Aug.	32.7	31	24.7	25	93	91	75	80	4.8	0.8	75.2	59	4.4	4.8
34	20 Aug.-26 Aug.	33.3	30.3	24.2	23.7	88	93	63	81	9.4	3	0	34.4	6.8	4.6
35	27 Aug.-2 Sept.	35	33.1	24.5	25.4	88	92	57	71	9.2	7	0	32.6	7.4	5.3
36	3 Sept.-9 Sept.	37	33.7	24.5	24.2	84	85	46	64	8.2	8.4	0	0	7.7	5.7
37	10 Sept.-16 Sept.	37.3	34.1	23.3	24	82	87	48	60	9.4	8.8	0	0	7.6	6.1
38	17 Sept.-23 Sept.	35.6	33.6	24.3	24.6	88	89	48	68	8.1	5.3	16.6	10.4	6.6	6.1
39	23 Sept.-30 Sept.	35.1	33.5	20.7	23	80	90	58	59	9.3	8.7	0	2.6	6.9	5.7
40	1 Oct.-7 Oct.	37.1	34.5	20.1	24.6	78	90	47	60	10	6.4	0	3	7	5.7
41	8 Oct.-14 Oct.	37.2	34.9	19.1	21.1	76	86	38	46	10.1	8.4	0	0	7	6.2
42	15 Oct.-21 Oct.	36.2	35	19.5	16.3	84	78	36	43	9.4	9.8	0	0	6.5	6
43	22 Oct.-28 Oct.	34.6	34.4	16.9	16.5	80	78	38	46	9.1	9.1	16.2	0	5.3	5.9

Source: Agro-met observatory, Central Research Farm, Indian Grassland and Fodder Research Institute, Jhansi

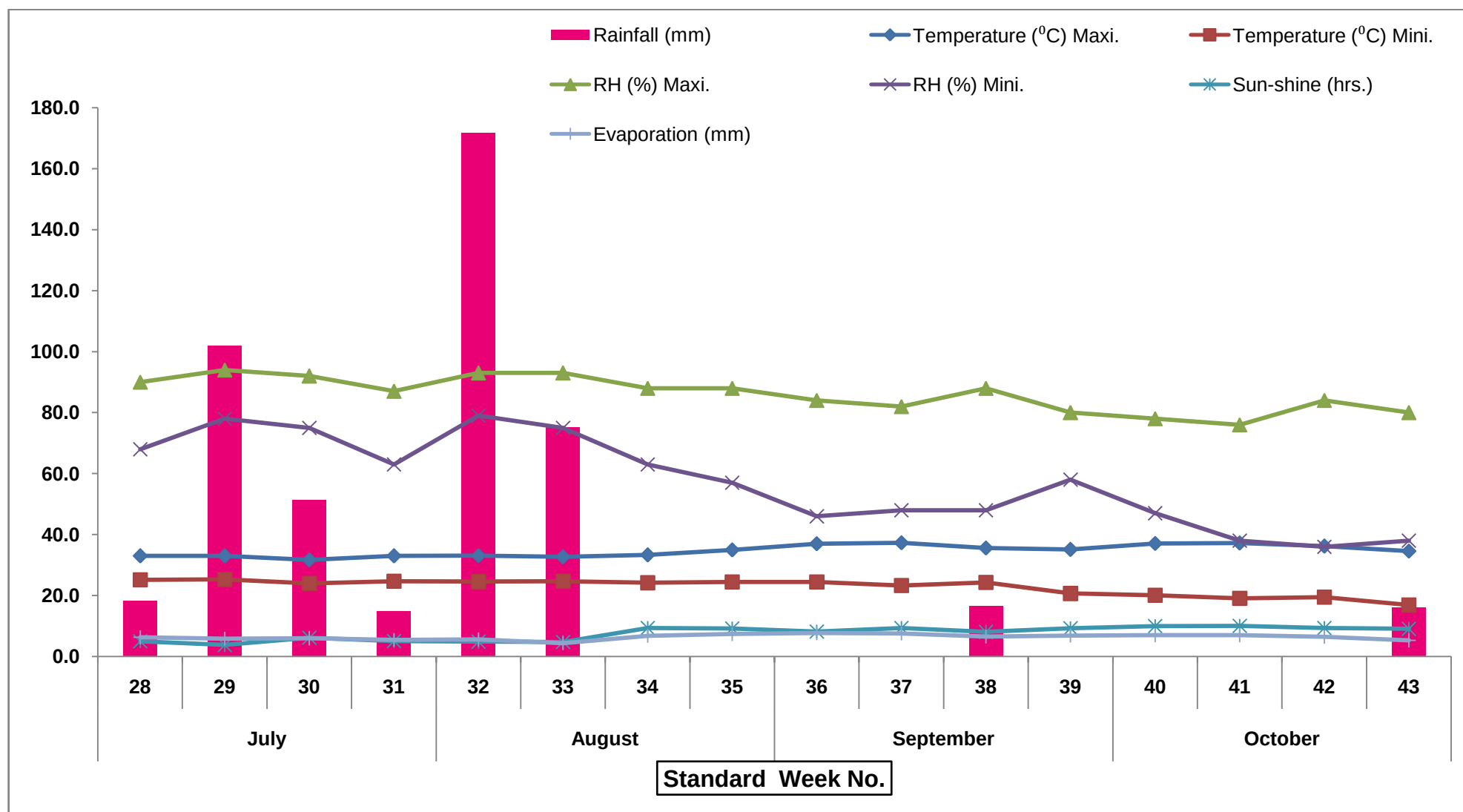


Fig. 3.1 Mean weekly meteorological data recorded during the crop growth period of maize *Kharif* 2015

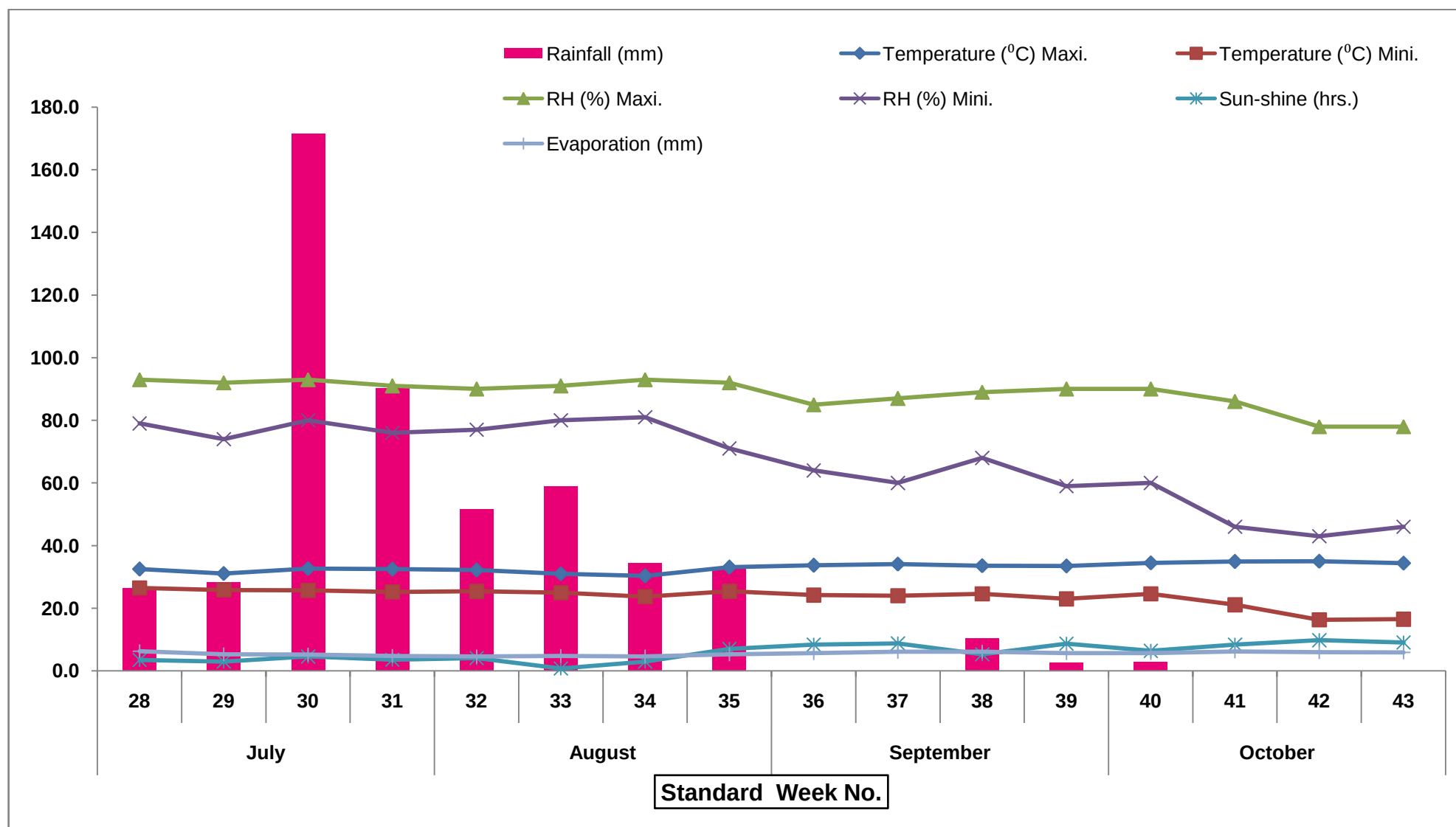


Fig. 3.2 Mean weekly meteorological data recorded during the crop growth period of maize *Kharif* 2016

Table 3.2 Mean weekly meteorological data recorded during the crop growth period of berseem *Rabi* 2015-16 and 2016-17

Standard Week No.	Date	Temperature (°C)				Relative humidity (%)				Sun-shine (hrs.)		Rainfall (mm)		Evaporation (mm)	
		Max.		Min.		Max.		Min.		15-16	16-17	15-16	16-17	15-16	16-17
		15-16	16-17	15-16	16-17	15-16	16-17	15-16	16-17						
45	5 Nov.-11 Nov.	31.3	31	17	12.6	88	81	43	40	7.4	9.6	3	0	4.2	4.3
46	12 Nov.-18 Nov.	31.2	30	14.6	11.6	88	84	40	43	8.4	9.5	0	0	3.7	3.6
47	19 Nov.-25 Nov.	28.3	30	10.7	11.5	88	87	39	40	7.6	9	0	0	3.2	3.6
48	26 Nov.-2 Dec.	28	29	13.8	11.8	84	87	54	50	6.3	8.5	4.4	0	3.6	3.4
49	3 Dec.-9 Dec.	27.1	23.8	10.2	9.6	88	92	42	56	7.4	6.4	0	0	3.1	2.8
50	10 Dec. -16 Dec.	25.1	26.7	9.2	8.9	88	86	42	46	7.6	7.9	0	0	2.6	2.8
51	17 Dec.-23 Dec.	21.4	25.8	5.2	7.4	89	87	49	52	8.3	8.3	0	0	2.9	2.8
52	24 Dec.-31 Dec.	23.4	25.5	6.7	8	87	88	43	62	8.5	6.9	0	0	3.1	2.7
1	1 Jan.-7 Jan.	25.5	21	8.2	7.8	86	91	46	69	8.8	6.6	0	0	3.5	2.4
2	8 Jan.-14 Jan.	26.1	19.7	8.8	6	82	91	48	77	8.7	7.2	0	3.6	3.9	2.1
3	15 Jan.-21 Jan.	15	20.6	6.8	6.4	92	90	81	58	3.7	7.3	8	0	2.7	2.3
4	22 Jan.-28 Jan.	22.5	24.4	5.5	9.5	91	89	56	53	6.8	8.2	0.4	22.2	2.9	2.7
5	29 Jan.-4 Feb.	25.4	23.3	9.2	10	83	91	48	57	8.7	7.2	0	0	3.7	3
6	5 Feb.-11 Feb.	24.3	24.4	8	8.7	83	89	44	54	9.9	7.8	0	0	3.7	2.9
7	12 Feb.-18 Feb.	25.6	25.5	10.6	9.6	83	87	49	46	8.2	8.3	0	0	3.8	3.6
8	19 Feb.-25 Feb.	29.5	30	12	10.6	79	81	39	41	8.9	8.5	0	0	4.1	4.4
9	26 Feb.-4 Mar.	30.1	29.7	12.6	11.5	83	80	42	43	10	8.6	0	0	4.9	5.2
10	5 Mar.-11 Mar.	31.3	28.1	15.6	10.9	82	76	46	44	9.1	8.9	0.4	0	5.3	4.8
11	12 Mar.-18 Mar.	31	28.7	15.2	10.5	85	80	42	35	8	9.5	7.4	0	5.5	4.9

12	19 Mar.-25 Mar.	34.8	33.8	15.1	16.1	80	80	32	37	10.4	9.1	0	0	7.3	6.3
13	26 Mar.-1 Apr.	36.3	38.7	16.5	18.8	73	69	29	31	9	9.4	0	0	7.5	8.7
14	2 Apr.-8 Apr.	38.8	39.9	20	19.6	65	64	28	32	9.3	9.9	0	0	8.6	9.5
15	9 Apr.-15 Apr.	39	38.2	20.6	17.2	52	66	23	29	10.2	9.7	0	0	10.4	9.5
16	16 Apr.-22 Apr.	41.5	42.8	24	23.6	37	56	22	28	9.9	9.2	0	0	12	11.2
17	23 Apr.-29 Apr.	40.5	40.2	22.1	23.3	47	46	24	28	10.7	8.9	0	0	11.9	12
18	30 Apr.-6 May	42.8	40.3	22.6	21.8	51	46	23	28	9.9	8.9	5.2	0	10.7	11.3
19	7 May-13 May	40	43.7	24.1	25.8	50	39	27	29	9	8.7	0	0	10.6	12.8
20	14 May-20 May	44.9	42.6	26.5	26.8	44	44	19	33	9.1	8.5	0	9.6	12.5	12.3

Source: Agro-met observatory, Central Research Farm, Indian Grassland and Fodder Research Institute, Jhansi

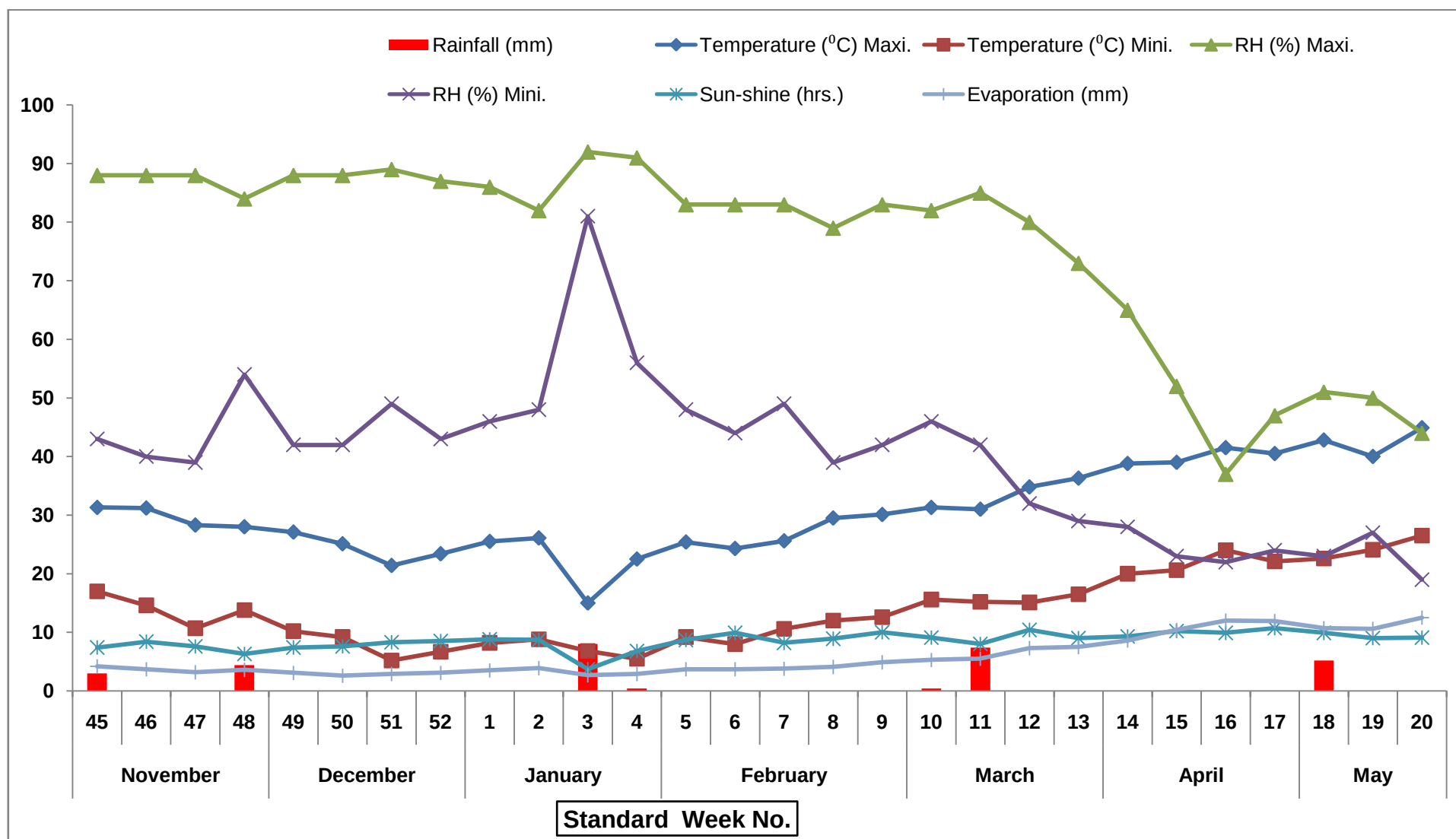


Fig. 3.3 Mean weekly meteorological data recorded during the crop growth period of berseem *Rabi* 2015-16

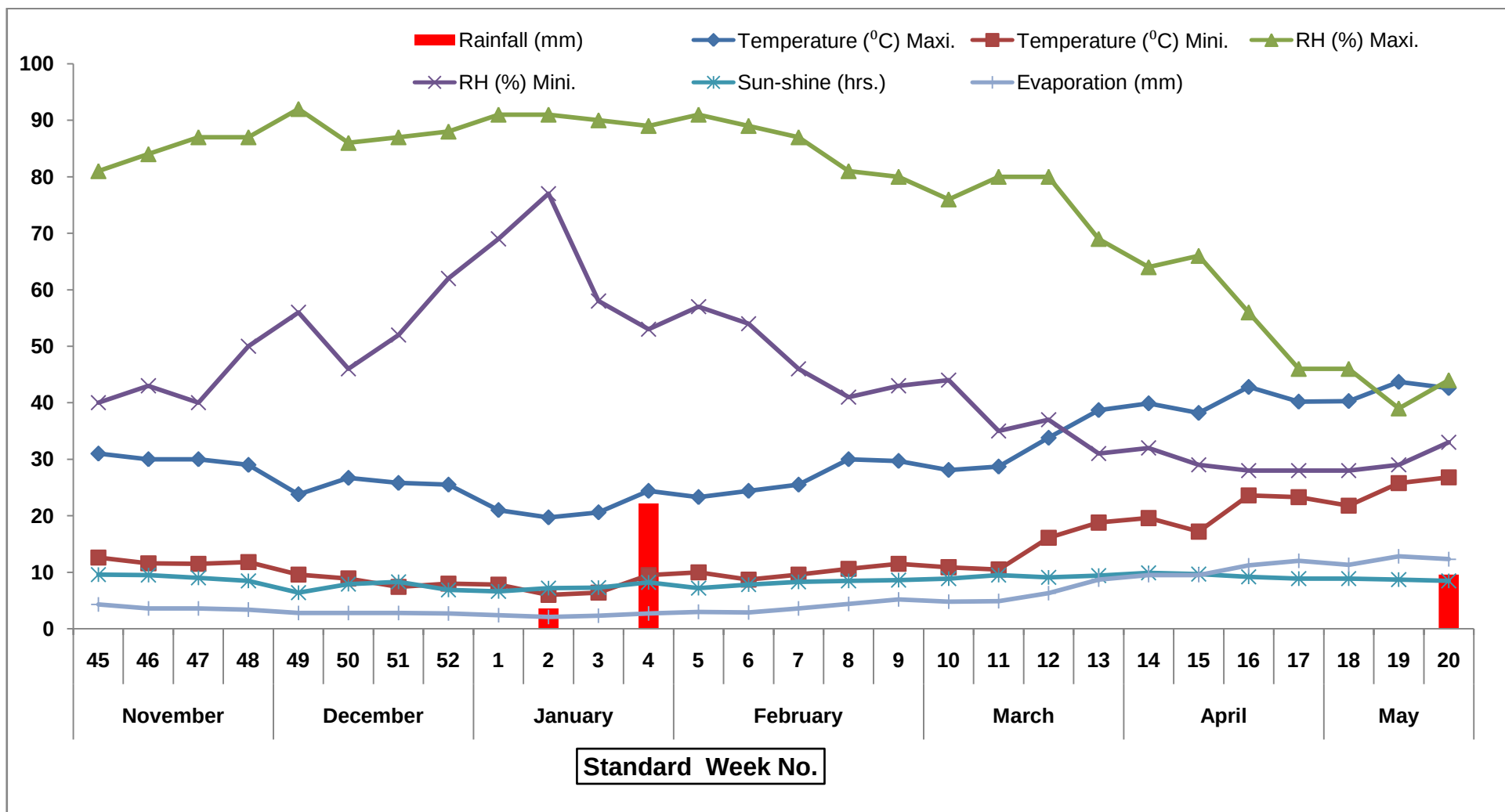


Fig. 3.4 Mean weekly meteorological data recorded during the crop growth period of berseem *Rabi* 2016-17

79 % with a mean of 57.3% at 14:30 hrs in 2015 and 78 to 93% with an average of 88.6% and 43 to 81% with a mean of 66.5% respectively during 2016. The mean bright sunshine hours varied from 3.8 to 10.1 with an average of 7.6 hours in the year 2015 and 0.8 to 9.8 with a mean of 5.9 hours in the year 2011.

The total precipitation received during the cropping period was 466.0 mm and 510.2 mm in 2015 and 2016 respectively. The evaporative demand of atmosphere as reflected by pan evaporation (USWB-class A pan) ranged from 4.4 to 7.7 mm with an average of 6.4 mm during 2015 and from 4.6 to 6.3 mm with an average of 5.5 mm in the year 2016.

3.2.2 *Rabi* season (Berseem crop)

The mean weekly maximum temperature in 2015-16 during berseem cropping period ranged from 15.0°C to 44.9°C with an average of 30.74°C and in *rabi*, 2016-17 from 19.7°C to 43.7°C with a mean of 30.62°C. Likewise, the weakly minimum temperature for the corresponding period varied from 5.2°C to 26.5°C with an average 13.98°C during 2015-16 and from 6.0°C to 26.8°C with an average of 13.34°C during 2016-17.

The mean relative humidity during the crop growing period at 7: 30 hours ranged from 37 to 92% with an average of 76.0% during 2015-16 and 39 to 92% with an average of 76.68% during 2016-17. At 14:30 hours it ranged from 19 to 81% with a mean of 40.0% during 2015-16 and from 28.0 to 77.0% with a mean of 44.32% during 2016-17. The total precipitation received during cropping period were 28.8 mm and 35.4 mm in 2015-16 and 2016-17, respectively.

The sunshine hours varied from 3.7 to 10.7 with an average 8.56 hours during 2015-16 and from 6.4 to 9.9 hours with a mean of 8.45 hours during 2016-17. The pan evaporation during maize cropping period ranged from 2.6 to 12.5 mm with an average of 5.78 in 2015-16 and from 2.1 to 12.8 mm with a mean of 5.64 mm in 2016-17.

3.3 Characteristics of the experimental site

3.3.1 Physical and chemical properties

Soil samples were drawn at random before sowing of the crop from 0-15 cm soil depth from the experimental site and were analyzed for their physico-chemical properties by adopting standard procedures and the results are presented in Table 3.3.

Table 3.3 Mechanical, physical and chemical properties of experimental site soil

	Characteristic	Contents	Method employed
(A)	Mechanical composition		
(i)	Sand (%)	45.53	Hydrometer method
(ii)	Silt (%)	26.51	Bouyoucos (1962)
(iii)	Clay (%)	28.63	
	Texture class	Clay loam	Triangular diagram USDA (1971)
(B)	Physical properties		
(i)	Bulk density (Mg/ m ³)	1.26	Black (1965)
(ii)	Particle density (Mg/ m ³)	2.37	Black (1965)
(C)	Chemical properties		
(i)	Organic carbon (%)	0.52	Walkely and Black (1947)
(ii)	Available nitrogen (kg/ha)	230.98	Alkaline KMnO ₄ method Subbiah and Asija (1956)
(iii)	Available phosphorus (kg/ha)	15.15	Olsen's method Olsen <i>et al.</i> (1954)
(iv)	Available potassium (kg/ha)	137.83	Flame photometer method Jackson (1973)
(v)	EC (dS/ m at 25°C)	0.34	Conductivity bridge method Richards (1968)
	pH	7.15	pH meter
(vi)	(1:2 soil : water ratio)		Piper (1950)

3.4 Previous crop history

The cropping history of the experimental site for the previous year is summarized in Table 3.4.

Table 3.4 Previous crop history of the experimental site

S.No	Year	Season	Cropping patterns
1.	2013-14	<i>Kharif</i>	Sorghum
		<i>Rabi</i>	Berseem
		<i>Summer</i>	Fallow
2.	2014-15	<i>Kharif</i>	Cowpea
		<i>Rabi</i>	Berseem
		<i>Summer</i>	Fallow
3.	2015-16	<i>Kharif</i>	Experimental maize crop
		<i>Rabi</i>	Experimental berseem crop
4.	2016-17	<i>Kharif</i>	Experimental maize crop
		<i>Rabi</i>	Experimental berseem crop

3.5 Experimental details

3.5.1 Treatments

A. Tillage practices	Symbol
(i) Conventional (Maize) – Conventional (Berseem)	T ₁ = CT - CT
(ii) Conventional (Maize) – Zero (Berseem)	T ₂ = CT - ZT
(iii) Zero (Maize) – Zero (Berseem)	T ₃ = ZT - ZT
(iv) Zero (Maize) – Conventional (Berseem)	T ₄ = ZT - CT
B. Weed control measures	
(i) Atrazine @ 1.0 kg a.i./ha (pre-emergence) (Maize) – Pendimethalin + Imazethapyr @ 0.75 kg a.i./ha (pre-emergence) (Berseem)	W ₁
(ii) 2,4-D @ 0.75 kg a.i./ha (20 DAS) (Maize) – Imazethapyr @ 0.1 kg a.i./ha (20 DAS) (Berseem)	W ₂
(iii) Two hand weeding at 20 and 40 DAS (Maize) –	W ₃

Four hand weeding at 20, 40, 60 and 80 DAS
(Berseem)

(iv) Weedy check (Maize) – Weedy check (Berseem) W₄

3.5.2 Other Experimental Details

- | | | | |
|-------|--------------|---|------------------------------|
| (i) | Design | : | Split plot design |
| | Main plot | : | Tillage practices |
| | Sub plot | : | Weed control measures |
| (ii) | Replications | : | 3 |
| (iii) | Plot size | : | Maize |
| | Gross plot | : | 4.6 m x 4.4 m |
| | Net plot | : | 4.1 m x 3.0 m |
| | | : | Berseem |
| | Gross plot | : | 4.6 m x 4.4 m |
| | Net plot | : | 4.1 m x 3.6 m |
| (iv) | Varieties | : | Maize : HM 11 (Hybrid) |
| | | : | Berseem : Warden |
| (v) | Spacing | : | Maize : 60 cm x 25 cm |
| | | : | Berseem : 40 cm x solid rows |

3.6 Description of varieties / hybrids

Maize: Late duration single cross maize hybrid, HM 11 was used as test crop for present investigation. Across the country except Himalayan belt, it is suitable for both *kharif* and *rabi* seasons. It has an yield potential of 5.5-6 t/ha.

Berseem: The variety Warden was developed through selection by IGRI, Jhansi from the large genetically diverse polyploid material. The plant habit is erect and flower colour is white. It matures in 160-170 days and have 0.3-0.4 t/ha seed yield potential.

3.7 Field preparation

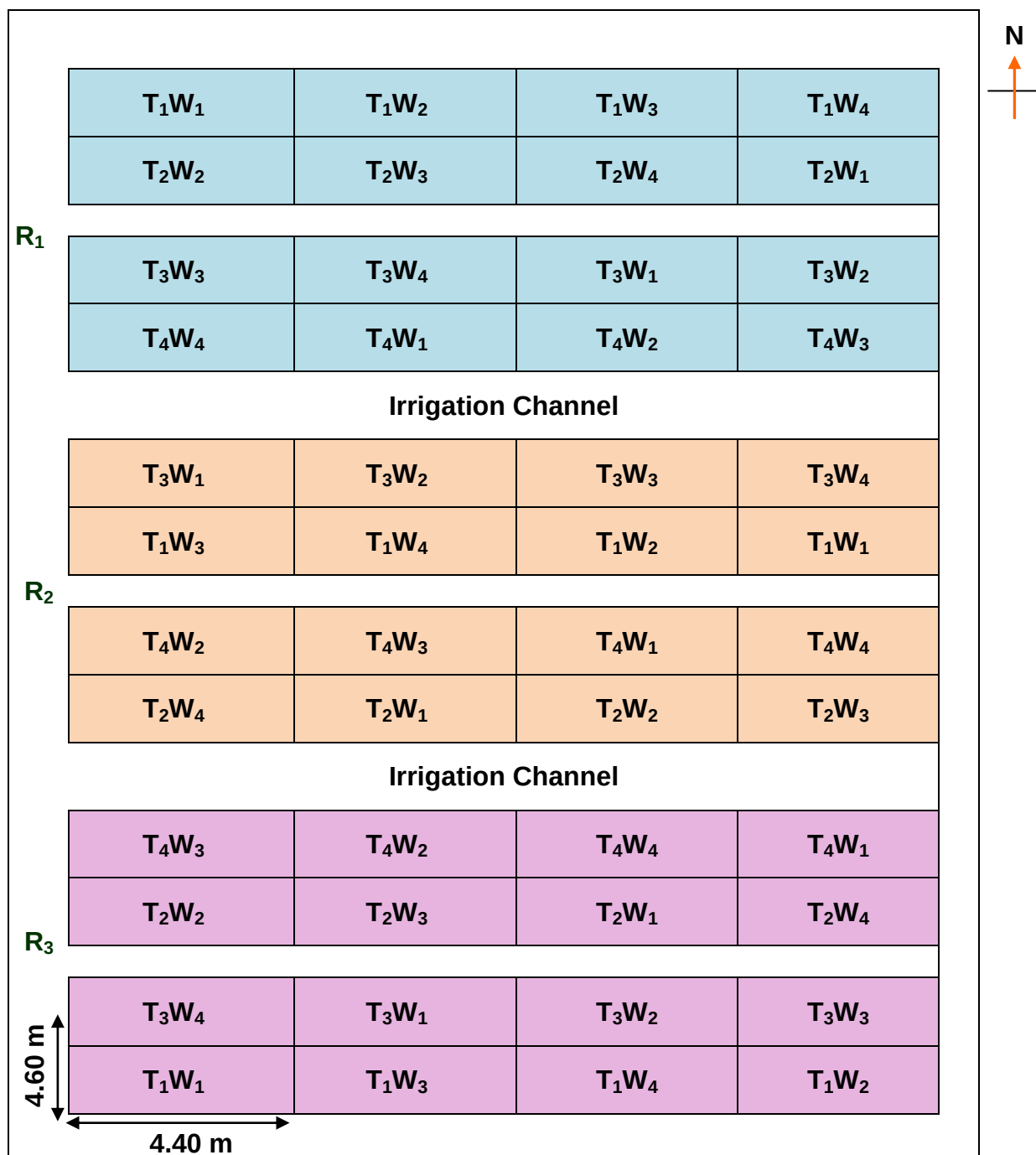


Fig. 3.5 Layout plan of the experiment

As per the treatment experimental field under conventional tillage was prepared by ploughing once with tractor drawn disc plough followed by cross cultivation and planking to obtain thoroughly pulverized seed bed. Under zero tillage crop were planted by direct seeding in to dead residue of the previous crop without field preparation using zero till ferti-seed drill having inverted T-type furrow openers.

Table 3.5 Schedule of field operations during crop growth periods

S.No.	Operations	Date	
		2015-16	2016-17
A.	Maize		
1.	Tillage operation as per treatment	07.07.2015	09.07.2016
2.	Layout and bunding	08.07.2015	10.07.2016
3.	Fertilizer application & sowing	10.07.2015	12.07.2016
4.	Irrigation		
	I - Irrigation	15.09.2015	17.09.2016
	II - Irrigation	29.09.2015	01.10.2016
5.	Herbicide spray (As per treatment)		
(i)	Atrazine 2 DAS	12.07.2015	14.07.2016
(ii)	2,4-D 20 DAS	30.07.2015	01.08.2016
6.	Hand weeding (As per treatment)		
(i)	20 DAS	30.07.2015	01.08.2016
(ii)	40 DAS	19.08.2015	21.08.2016
7.	Top dressing of urea		
(i)	Knee high stage	09.08.2015	11.08.2016
(ii)	At 50 per cent tasseling stage	03.09.2015	03.09.2016
8.	Harvesting	21.10.2015	23.10.2016
9.	Shelling and processing	31.10.2015	02.11.2016
B.	Berseem		
1.	Tillage operation as per treatment	07.11.2015	10.11.2016
2.	Layout and bunding	08.11.2015	11.11.2016
3.	Fertilizer application & sowing	10.11.2015	13.11.2016
4.	Irrigation		
	I - Irrigation	10.11.2015	13.11.2016
	II - Irrigation	18.11.2015	21.11.2016

	III - Irrigation	28.11.2015	01.10.2016
	IV - Irrigation	17.12.2015	20.12.2016
	V - Irrigation	16.01.2016	19.01.2017
	VI - Irrigation	13.02.2016	16.02.2017
	VII - Irrigation	04.03.2016	07.03.2017
	VIII - Irrigation	20.03.2016	23.03.2017
	IX - Irrigation	05.04.2016	08.04.2017
	X - Irrigation	15.04.2016	18.04.2017
5.	Herbicide spray (As per treatment)		
(i)	Pendimethalin + Imazethapyr 3 DAS	13.11.2015	16.11.2016
(ii)	Imezathyper 20 DAS	30.11.2015	03.12.2016
6.	Hand weeding (As per treatment)		
(i)	20 DAS	30.11.2015	03.12.2016
(ii)	40 DAS	20.12.2015	23.12.2016
(iii)	60 DAS	09.01.2016	12.01.2017
(iv)	80 DAS	29.01.2016	01.02.2017
7.	Green fodder harvesting		
(i)	First cut	04.01.2016	07.01.2017
(ii)	Second cut	29.01.2016	01.02.2017
(iii)	Third cut	23.02.2016	26.02.2017
8.	Seed harvesting	06.05.2016	09.05.2017
9.	Threshing and winnowing	09.05.2016	13.05.2017

3.8 Cultivation details of maize and berseem crop

3.8.1 Seeds and sowing

3.8.1.1 Maize

The maize crop was sown with onset of monsoon rain on 10th and 12th July, during 2015 and 2016, respectively using 20 kg seed/ha. In conventionally prepared field, furrows were opened at 60 cm apart and seeds were placed manually using 25 cm plant to plant spacing at a depth of 3-4 cm. whereas, in zero tillage crop was planted by direct seeding using zero till ferti-seed drill at 60 cm row spacing.

3.8.1.2 Berseem



Plate 3.1 View of maize experimental field

The berseem crop was sown on 10th and 13th November during both the years using 20 kg seed/ha. In conventionally prepared field, furrows were opened at 40 cm apart and seeds were placed manually using no plant to plant spacing at a depth of 2-3 cm. Whereas, in zero tillage crop was planted by direct seeding using zero till ferti-seed drill at 40 cm row spacing.

3.8.2 Thinning

After emergence of seedlings, excess seedlings were thinned out at 15 days after sowing to maintain one healthy seedling per hill.

3.8.3 Fertilizer application

3.8.3.1 Maize

A fertilizer schedule 150 kg N, 60 kg P₂O₅ and 40 kg K₂O/ha were applied through urea, single super phosphate and muriate of potash. Entire dose of phosphorus and potash were applied as basal. Nitrogen was applied in three splits, 1/3rd at sowing, 1/3rd at knee high stage and 1/3rd at tasseling stages by placement method.

3.8.3.2 Berseem

The recommended dose of fertilizers (20 kg N, 60 kg P₂O₅ and 40 kg K₂O/ha) were applied through urea, single super phosphate and muriate of potash. The entire quantity of nitrogen, phosphorus and potassium were applied as basal dose.

3.8.4 Water management

3.8.4.1 Maize

First irrigation was given immediately after sowing of crop. Subsequent irrigations were provided based on the need coinciding with the critical stage of crop growth.

3.8.4.2 Berseem

The berseem crop was immediately irrigated after sowing of crop. Subsequent irrigations were provided at 10-12 days interval based on the need coinciding with the critical stage of crop growth.

3.8.5 Weed management



Plate 3.2 View of berseem experimental field

3.8.5.1 Maize

As per the treatment schedule, atrazine @ 1.0 kg a.i./ha was applied as a pre-emergence herbicide at 2 days after sowing and 2, 4-D was @ 0.75 kg a.i./ha applied at 20 days after sowing as post-emergence herbicide. In weed free treatment hand weeding twice at 20 and 40 days after sowing was done. In weedy check plots no weed control operation was done.

3.8.5.2 Berseem

As per treatment schedule, pendimethalin + Imazethapyr @ 0.75 kg a.i./ha was applied as a pre-emergence herbicide at 3 days after sowing and imazethapyr @ 0.100 kg a.i./ha was applied at 20 days after sowing as post-emergence herbicide. In weed free plot four hand weeding at 20, 40, 60 and 80 days after sowing was done. Weedy check plots were kept undisturbed.

3.8.6 Harvesting

3.8.6.1 Maize

The crop was harvested at physiological maturity when the cob husk dried and entire plants turned yellow. The border rows of each plot were harvested first and later net plot area was harvested. The cobs harvested from net plot were dried thoroughly under sun and shelling was done manually.

3.8.6.2 Berseem

Harvesting was taken up when the crop straw turned yellow. The plants from the net plot area were harvested at ground level and kept in the field itself for drying. The seeds were sun dried to 14 % moisture content, winnowed, cleaned and their weight were recorded.

3.9 Observations recorded

3.9.1 Weed studies

3.9.1.1 Weed density (No. /m²)

The weeds were counted at 30 and 60 days after sowing and at harvest for maize crop and at 25, 45, 65 and 85 days after sowing for berseem crop. Weeds from an area of 0.25 m² using 0.5 m x 0.5 m quadrat

were species wise (grassy weeds, broad leaf weeds and sedges) counted and then expressed as no. /m². The mean data were subjected to square root transformation $\sqrt{(X + 0.5)}$ to normalize their distribution (Gomez and Gomez, 1984).

3.9.1.2 Weed dry weight (g/m²)

Samples of weeds were collected from each plot from the 0.25 m² area at 30 and 60 days after sowing and at harvest for maize crop and at 25, 45, 65 and 85 days after sowing for berseem crop. The samples were sun dried for two days, and then oven dried at 65°C to obtain constant weight. The dry weight recorded was expressed in g/m².

3.9.1.3 Weed control efficiency (%)

Weed control efficiency was worked out on the basis of weed dry matter recorded in each treatment at 30 and 60 days after sowing and at harvest for maize crop and at 25, 45, 65 and 85 days after sowing for berseem crop using the formula suggested by Sankaran and Mani (1974).

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

WCE - Weed control efficiency in percentage

DWC - Dry weight of weeds in un-weeded check

DWT - Dry weight of weeds in weed control treatment

3.9.1.4 Weed index (%)

Weed index was worked out on the basis of economic produce recorded in each treatment as out lined by Gill and Vijayakumar (1966).

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

WI - Weed index

X - Yield from minimum competition plot

Y- Yield from treatment

3.10 Crop studies

3.10.1 Maize

3.10.1.1 Growth and development parameters

3.10.1.1.1 Plant height (cm)

Plant height was measured from the base of each five tagged plants to the tip of the longest leaf at 30 and 60 days after sowing, tip of the tassel at harvest.

3.10.1.1.2 Dry matter production (g/ plant)

Five plants were selected at randomly from each plot and removed periodically at 30, 60 days after sowing and at harvest. Root portion from the sample was separated, air dried and then oven dried at 65°C for 72 hours. From the dry weight of samples dry matter was expressed in g/plant.

3.10.1.1.3 Days to 50 % silking

The number of days taken by 50 per cent of the plants in net plot in each treatment from date of emergence to the silking was considered as days to 50 per cent silking.

3.10.1.1.4 Days to physiological maturity

Number of days taken by 50 per cent of plants in each treatment from emergence to a stage of black layer formation at base of grain was considered as days to physiological maturity. It was 10-15 days prior to normal harvest.

3.10.1.2 Yield attributes and yield

3.10.1.2.1 Grains/cob

The total number of grains per cob of five randomly selected cobs was counted and expressed on per unit cob basis.

3.10.1.2.2 100 grain weight (g)

Hundred grains were randomly drawn from the composite sample of grain harvest of net plot area in each treatment and their weight was recorded and expressed in grams.

3.10.1.2.3 Shelling percentage

The shelling percentage was calculated by using the following formula.

$$\text{Shelling percentage (\%)} = \frac{\text{Grain weight per cob}}{\text{Cob weight with grains}} \times 100$$

3.10.1.2.4 Grain yield (q/ha)

Seeds from the net plot area were thoroughly sun dried to 14 % moisture content, weighed and expressed in q/ha.

3.10.1.2.5 Stover yield (q /ha)

Stover obtained from the net plot area was thoroughly sun dried until a constant weight was obtained and expressed in q/ha.

3.10.2 Berseem

3.10.2.1 Growth and development parameters

3.10.2.1.1 Dry weight (g)

The 500 g green fodder samples were harvested upto the ground level from each of the plots at 1st, 2nd and 3rd cut. The samples were shade dried and then oven dried at 65°C to constant weight and expressed as dry weight in gram.

3.10.2.1.2 Plant height (cm)

Plant height was measured from the base of each tagged plant upto tip of the head at harvest and expressed in centimeters.

3.10.2.2 Yield attributes and yield

3.10.2.2.1 Effective tillers (No. /m²)

The number of head bearing every tiller was counted from one square meter area and expressed as number of effective tillers/m².

3.10.2.2.2 Test weight (g)

Thousand seed were randomly drawn from the composite sample of seed harvest of net plot area in each treatment (dried to 14 % moisture content) were weighed and expressed in grams.

3.10.2.2.3 Green fodder yield (q/ha)

Crop harvested from the net plots at 1st, 2nd and 3rd cut was bundled and weighed to obtain green fodder yield and expressed in q/ha.

3.10.2.2.4 Seed yield (q/ha)

The harvested seed in net plot area were dried to 14 % moisture content. After thorough drying, it was weighed and expressed as q/ha.

3.10.2.2.5 Straw yield (q/ha)

The straw yield of the net plot area of each plot was weighed after threshing and expressed in q/ha.

3.10.2.2.6 Dry matter yield (q/ha)

With the help of dry matter percentage data of the samples and net plot green fodder yield of different treatments, dry matter yield quintal per hectare was computed.

3.11 Maize equivalent yield (q /ha)

Maize grain equivalent yield was computed using the following formula.

$$\text{MEY (q/ha)} = \frac{\text{EYB (q/ha)} \times \text{Price of berseem/q}}{\text{Price of maize/q}} + \text{MGY (q/ha)}$$

MEY – Maize equivalent yield

EYB – Economic yield of berseem

MGY – Maize grain yield

3.12 Plant Analysis

3.12.1 Crude protein percent and yield

The nitrogen content of the oven dried samples of fodder was determined as per Wright, 1939. The crude protein percentage was worked

out by multiplying nitrogen percentage with 6.25 constant. The production of crude protein yield was calculated as under the below given formula.

$$\text{Crude protein yield (q/ha)} = \frac{\text{Crude protein percent} \times \text{dry matter (q/ha)}}{100}$$

3.13 Economics

3.13.1 Gross returns (₹/ha)

Gross monetary returns were calculated by multiplying the economics of yield of each crop (maize and berseem) in each treatment by the prevailing market price. It was expressed as rupees per hectare.

3.13.2 Net returns (₹/ha)

Net returns were calculated by subtracting cost of cultivation of crop (maize and berseem) from gross returns for each treatment. It was expressed as rupees per hectare per crop basis or crop rotation basis.

3.13.3 Benefit: cost ratio

Benefit: cost ratio was worked out for different treatments by dividing the gross returns by corresponding cost of cultivation of each crop.

3.14 Soil analysis

In Maize - Berseem cropping sequence soil samples were collected from each plot up to 15 cm depth at initial and also after harvest of berseem. Soil samples were analyzed for soil physical and chemical properties as per method furnished in Table 3.3.

3.14.1 Soil pH

The pH of the soil was determined in 1: 2.5 soil water suspension using glass electrode digital pH meter (Jackson, 1973).

3.14.2 Electrical conductivity (EC)

The electrical conductivity of the soil was determined 1: 2 soil water extract using conductivity meter method given by Jackson (1973) and was expressed as dS/m.

3.14.3 Organic carbon (%)

The organic carbon percentage of the soil was estimated by using the rapid titration procedure given by Walkley and Black (1947).

3.14.4 Bulk and Particle density

The bulk and particle density of soil was analysed as per procedure given by Black (1965).

3.14.5 Available nitrogen (kg/ha)

The available nitrogen (kg/ha) was determined by alkaline permanganate method given by Subbiah and Asija (1956).

3.14.6 Available phosphorus (kg/ha)

Available phosphorus of the soil samples was extracted with Olsen's extractant (0.5 M NaHCO_3). Phosphorus in the extract was estimated colorimetrically by ascorbic acid method (Olsen *et al.* 1954).

3.14.7 Available potassium (kg/ha)

The available potassium of soil samples was extracted by neutral ammonium acetate solution and were determined using flame photometer (Jackson 1973).

3.15 Statistical analysis

The data collected for above mentioned characters were subjected to the analysis of variance for each character separately as per standard statistical procedure for split-plot design suggested by the Fisher, 1958. Wherever treatment differences were found significant (F test) critical differences were worked out at five percent probability level and the values were furnished. Treatment differences that were non-significant were denoted by 'NS'. The skeleton of analysis of variance is presented in the Table 3.6 to 3.7

Table 3.6 Skeleton of Analysis of variance for the individual year

Sources of variation	d.f.	SS	MSS	F _{cal.}	F _{tab.}
Replication	2	SS (R)	MS (R)	MS (R)/Ea	
Tillage practices (T)	3	SS (T)	MS (T)	MS (T)/Ea	F _{5%} (3,6)
Error (a)	6	SS Error (a)	Ea	-	-
Weed control (W)	3	SS (W)	MS (W)	MS (W)/Eb	F _{5%} (3,24)
T*W	9	SS (TxW)	MS (TxW)	MS (TxW)/Eb	F _{5%} (9,24)
Error (b)	24	SS Error (b)	Eb	-	
Total	47				

Table 3.7 Skeleton of Analysis of variance for pooled analysis

Sources of variation	d.f.	SS	MSS	F _{cal.}	F _{tab.}
Year (Y)	1	SS (Y)	MS (Y)	MS (Y)/ MS (Replication within year)	
Replication within year	4	SS (Replication within year)	MS (Replication within year)		
Tillage practices (T)	3	SS (T)	MS (T)	MS (T)/Ea	
Y*T	3	SS (YxT)	MS (YxT)	MS (YxT)/Ea	
Error (a)	12	SS Error (a)	Ea		
Weed control (W)	3	SS (W)	MS (W)	MS (W)/Eb	
Y*W	3	SS (YxW)	MS (YxW)	MS (YxW)/Eb	
T*W	9	SS (TxW)	MS (TxW)	MS (TxW)/Eb	
Y* T* W	9	SS (YxFxW)	MS (YxFxW)	MS (YxFxW)/Eb	
Error (b)	48	SS Error (b)	Eb		
Total	95				

Mean sum of square for individual years calculated as under:

$$MS (R) = \frac{SSR}{R - 1}$$

$$MS (T) = \frac{SST}{T - 1}$$

$$Ea = \frac{SSEa}{(R - 1)(T - 1)}$$

$$MS (W) = \frac{SSW}{W - 1}$$

$$MS (T \times W) = \frac{SS (T \times W)}{(T - 1)(W - 1)}$$

$$Eb = \frac{SSEb}{T (R - 1)(W - 1)}$$

Mean sum of square for pooled analysis calculated as under:

$$MS (Y) = \frac{SSY}{Y - 1}$$

$$MS (R) = \frac{SSR}{Y(R - 1)}$$

$$MS (T) = \frac{SST}{T - 1}$$

$$MS (Y \times T) = \frac{SS (Y \times T)}{(Y - 1)(T - 1)}$$

$$Ea = \frac{SSEa}{Y (R - 1)(T - 1)}$$

$$MS (W) = \frac{SSW}{W - 1}$$

$$MS (Y \times W) = \frac{SS (Y \times W)}{(Y - 1)(W - 1)}$$

$$MS (T \times W) = \frac{SS (T \times W)}{(T - 1)(W - 1)}$$

$$MS (Y \times T \times W) = \frac{SS (Y \times T \times W)}{(Y - 1)(T - 1)(W - 1)}$$

$$Eb = \frac{SSEb}{Y T (R - 1)(W - 1)}$$

Standard errors for the difference between any two treatments mean S.E (m):

For individual year:-

(i) S.E. for the difference between any two tillage practices means:

$$S. E. (T) = \sqrt{2Ea/RW}$$

$$C.D. (at 5\%) = S.E. (T) \times t 5\% (error a d.f.)$$

(ii) S.E. for the difference between any two weed control means:

$$S. E. (W) = \sqrt{2Eb/RT}$$

$$C.D. (at 5\%) = S.E. (W) \times t 5\% (error b d.f.)$$

(iii) S.E. for the difference between any two weed control means at the same level of tillage practices:

$$S.E. (T \times W) = \sqrt{2Eb/R}$$

$$C.D. (at 5\%) = S.E. (T \times W) \times t_{5\%} \text{ (error b d.f.)}$$

(iv) S.E. for the difference between any two tillage practices means at the same or different levels of weed control:

$$S.E. (T \times W) = \sqrt{2[W - 1] Eb + Ea / RW}$$

$$C.D. (at 5\%) = S.E. (T \times W) \times t_{\text{tab.}}$$

Where,

$$t_{\text{tab.}} = \frac{(W - 1)Eb \times t_b + Ea \times t_a}{(W - 1)Eb + Ea}$$

For pooled analysis:-

(i) S.E. for the difference between any two tillage practices means:

$$S.E. (T) = \sqrt{2Ea/YRW}$$

$$C.D. (at 5\%) = S.E. (T) \times t_{5\%} \text{ (error a d.f.)}$$

(ii) S.E. for the difference between any two weed control means:

$$S.E. (W) = \sqrt{2Eb/YRT}$$

$$C.D. (at 5\%) = S.E. (W) \times t_{5\%} \text{ (error b d.f.)}$$

(iii) S.E. for the difference between any two weed control means at the same level of tillage practices:

$$S.E. (T \times W) = \sqrt{2Eb/YR}$$

$$\text{C.D. (at 5\%)} = \text{S.E. (T x W)} \times t_{5\% \text{ (error b d.f.)}}$$

(iv) S.E. for the difference between any two tillage practices means at the same or different levels of weed control:

$$\text{S.E. (T x W)} = \sqrt{2 [(W - 1)E_b + E_a/YRW]}$$

$$\text{C.D. (at 5\%)} = \text{S.E. (T x W)} \times t_{\text{tab.}}$$

Where,

$$t_{\text{tab.}} = \frac{(W - 1)E_b \times t_b + E_a \times t_a}{(W - 1)E_b + E_a}$$

Where, t (a) and t (b) are tabulated 't' values at error (a) and error (b) d.f., respectively and Y, R, T and W are the number of year, replication, tillage practices and weed control measures, respectively.

Chapter - IV

EXPERIMENTAL FINDINGS

The results obtained from the experiment entitled “**Weed management in Maize – Berseem cropping system under different tillage practices**” conducted during the year of 2015-16 and 2016-17, data pertaining to effect of different tillage practices and weed control measures on weeds and crop were statically analyzed and after the evaluation with the help of suitable tables and graphs they are presented in this chapter.

4.1 Maize

4.1.1 Weed studies

4.1.1.1 Weed flora

Weed flora of the experimental field consisted of five species of grasses, fourteen species of broad leaved weeds and one species of sedge (Table 4.1). Among the grasses, *Echinochloa colona* and *Echinochloa crusgalli* were predominant. The *Celosia argentea*, *Commelina diffusa*, *Digera arvensis*, *Corchorus olitorius* and *Trianthema portulacastrum* were the major broad leaved weeds while only *Cyperus rotundus* was observed among the sedges.

4.1.1.2 Weed density (No. /m²)

Data pertaining to grassy, broad leaf, sedges and total weed density at 30 and 60 DAS and at harvest influenced by tillage practices and weed control measures are presented in Table 4.2 to 4.4 and depicted graphically in Figure 4.1.

4.1.1.2.1 Grassy weeds

Conventional tillage recorded the lowest grassy weed population compared to zero tillage; both the conventional tillage and zero tillage were at par during first year. However, during second year highest grassy weed population were recorded in zero tillage - zero tillage, which was significantly higher over conventional tillage - conventional tillage, conventional tillage -

Table 4.1 Weed flora of the maize experimental field

S. No.	Botanical Name	Common Name	Family	Life Cycle
A. Grassy weeds				
1.	<i>Cynodon dactylon</i> (L.) Pers	Bermuda grass	Poaceae	Perennial
2.	<i>Dactyloctenium aegyptium</i> (L.) Beauv	Crow foot grass	Poaceae	Annual
3.	<i>Digitaria sanguinalis</i> (L.) Scop	Crab grass	Poaceae	Annual
4.	<i>Echinochloa colona</i> (L.) Link	Jungle rice	Poaceae	Annual
5.	<i>Echinochloa crusgalli</i> (L.) Beauv	Barnyard millet	Poaceae	Annual
B. Broad leaf weeds				
1.	<i>Alternanthera polygonoides</i> (L.) R.Br.	Joy weeds	Amaranthaceae	Annual
2.	<i>Celosia argentea</i> Linn	White cocks comb	Amaranthaceae	Annual
3.	<i>Commelina benghalensis</i> Linn	Tropical spider wart	Commelinaceae	Annual
4.	<i>Commelina diffusa</i> L.	Spreading dayflower	Commelinaceae	Annual
5.	<i>Corchorus olitorius</i>	Wild jute	Tiliaceae	Annual
6.	<i>Corchorus trilocularis</i>	Wild jute	Tiliaceae	Annual
7.	<i>Digera arvensis</i>	Kali gandhari	Amaranthaceae	Annual
8.	<i>Euphorbia hirta</i>	Pill pad spurge	Euphorbiaceae	Annual
9.	<i>Leucas aspera</i> Link	Thumbai	Lamiaceae	Annual

10.	<i>Phyllanthus niruri</i>	Stonebreaker	Phyllanthaceae	Annual
11.	<i>Physalis minima</i> L.	Native gooseberry	Solanaceae	Annual
12.	<i>Trianthema portulacastrum</i> L.	Black pigweed	Aizoaceae	Annual
13.	<i>Trichodesma indicum</i>	Hetamundia	Boraginaceae	Annual
14.	<i>Tridax procumbens</i>	Tridax	Compositae	Annual
C. Sedges				
1.	<i>Cyperus rotundus</i> L.	Purple nut sedge	Cyperaceae	Perennial

Table 4.2 Effect of tillage practices and weed control measures on weed density in maize at 30 days after sowing

Treatments	Weed density (No. /m ²)											
	Grassy			Broad leaf			Sedges			Total		
	2015	2016	Pooled	2015	2016	Pooled	2015	2016	Pooled	2015	2016	Pooled
Tillage practices												
CT (Maize) - CT (Berseem)	4.56 (30.50)	3.58 (25.29)	4.07 (27.90)	3.61 (16.92)	3.35 (16.21)	3.38 (16.56)	2.58 (8.08)	2.39 (7.58)	2.49 (7.83)	6.29 (55.50)	5.43 (49.08)	5.86 (52.29)
CT (Maize) - ZT (Berseem)	4.71 (31.50)	4.04 (28.67)	4.38 (30.08)	3.66 (17.33)	3.21 (15.67)	3.43 (16.50)	2.77 (9.25)	2.63 (8.83)	2.70 (9.04)	6.49 (58.08)	5.73 (53.17)	6.11 (55.63)
ZT (Maize) - ZT (Berseem)	5.38 (37.25)	6.11 (47.17)	5.74 (42.21)	3.44 (15.00)	2.91 (12.75)	3.17 (13.88)	3.06 (11.75)	3.16 (13.00)	3.11 (12.38)	7.00 (64.00)	7.43 (72.92)	7.22 (68.46)
ZT (Maize) - CT (Berseem)	5.21 (35.17)	5.70 (40.67)	5.45 (37.92)	3.48 (15.29)	3.06 (13.25)	3.27 (14.27)	2.85 (10.00)	2.92 (11.67)	2.88 (10.83)	6.81 (60.46)	7.04 (65.58)	6.92 (63.02)
S.Em. ±	0.05	0.04	0.03	0.06	0.04	0.03	0.06	0.05	0.04	0.05	0.06	0.04
C.D. (P = 0.05)	0.16	0.15	0.10	NS	0.13	0.10	0.22	0.17	0.12	0.18	0.19	0.12
Weed control measures												
Atrazine @ 1.0 kg a.i./ha	3.14 (9.50)	2.62 (7.75)	2.88 (8.63)	2.74 (7.00)	2.23 (4.50)	2.48 (5.75)	1.86 (3.00)	1.62 (2.33)	1.74 (2.67)	4.45 (19.50)	3.77 (14.58)	4.11 (17.04)
2,4-D @ 0.75 kg a.i./ha	4.05 (16.17)	4.21 (18.50)	4.13 (17.33)	2.44 (5.50)	1.90 (3.17)	2.17 (4.33)	2.40 (5.33)	2.54 (6.17)	2.47 (5.75)	5.23 (27.00)	5.24 (27.83)	5.23 (27.42)
Hand weeding (20 and 40 DAS)	2.53 (6.17)	2.13 (5.83)	2.33 (6.00)	2.01 (3.58)	1.40 (1.50)	1.71 (2.54)	1.62 (2.17)	1.35 (1.42)	1.48 (1.79)	3.50 (11.92)	2.84 (8.75)	3.17 (10.33)
Weedy check	10.15 (102.58)	10.47 (109.71)	10.31 (106.15)	6.99 (48.46)	7.00 (48.71)	7.00 (48.58)	5.37 (28.58)	5.59 (31.17)	5.48 (29.88)	13.42 (179.63)	13.77 (189.58)	13.60 (184.60)
S.Em. ±	0.08	0.06	0.05	0.05	0.05	0.04	0.07	0.07	0.05	0.07	0.05	0.04
C.D. (P = 0.05)	0.24	0.18	0.15	0.15	0.16	0.11	0.19	0.21	0.14	0.20	0.14	0.12

Values are $\sqrt{(X + 0.5)}$ transformed and original values are in parenthesis

zero tillage and zero tillage - conventional tillage. Based on two years pooled, minimum grassy weed population (4.07, 4.92 and 4.94 /m²) was recorded in conventional tillage - conventional tillage treatment at 30 and 60 DAS and at harvest respectively which was significantly lower compared to other tillage practices.

Weed management practices significantly influenced the population of grassy weeds at all stages of observation during both the years over weedy check. Among all weed management treatments lowest population of grassy weeds was recorded in hand weeding twice at 20 and 40 DAS followed by atrazine @ 1.0 kg a.i./ha and 2,4-D @ 0.75 kg a.i./ha. On pooled basis, maximum population of grassy weeds (10.31, 10.87 and 10.63 /m²) at 30 and 60 DAS and at harvest was recorded from weedy check.

4.1.1.2.2 Broad leaf weeds

Different tillage system failed to record variation in broad leaf weeds population recorded at 30 and 60 DAS and at harvest during first year. Whereas, during second year significantly lower broad leaf weeds population was recorded under zero tillage - zero tillage adoption.

Alike grassy weeds, all the weed control approaches had significant influence on broad leaved weed density in maize during both the years. At 30 and 60 DAS and at harvest hand weeding twice at 20 and 40 DAS resulted in significantly lower broad leaved weed density. On pooled basis, maximum population of broad leaf weeds (7.00, 7.24 and 6.94 /m²) at 30 and 60 DAS and at harvest was recorded from weedy check.

4.1.1.2.3 Sedges

Similarly, like grassy weeds the lowest sedges weed population was recorded in conventional tillage compared to zero tillage. Both the conventional tillage and zero tillage were at par during first year. But, during second year the highest sedges weed population were recorded in zero tillage - zero tillage, which was significantly highest over conventional tillage - conventional tillage, conventional tillage - zero tillage and zero tillage - conventional tillage. According to two years pooled data, minimum sedges

Table 4.3 Effect of tillage practices and weed control measures on weed density in maize at 60 days after sowing

Treatments	Weed density (No. /m ²)											
	Grassy			Broad leaf			Sedges			Total		
	2015	2016	Pooled	2015	2016	Pooled	2015	2016	Pooled	2015	2016	Pooled
Tillage practices												
CT (Maize) - CT (Berseem)	5.29 (36.00)	4.55 (31.13)	4.92 (33.56)	3.84 (18.50)	3.66 (18.00)	3.75 (18.25)	2.82 (9.58)	2.58 (8.42)	2.70 (9.00)	7.05 (64.08)	6.34 (57.54)	6.69 (60.81)
CT (Maize) - ZT (Berseem)	5.43 (37.83)	5.21 (35.83)	5.32 (36.83)	3.91 (9.33)	3.51 (16.75)	3.71 (18.04)	3.04 (11.00)	2.90 (10.25)	2.97 (10.63)	7.29 (68.17)	6.86 (62.83)	7.07 (65.50)
ZT (Maize) - ZT (Berseem)	6.03 (44.58)	6.55 (54.83)	6.29 (49.71)	3.61 (16.25)	3.22 (14.67)	3.42 (15.46)	3.42 (13.45)	3.78 (18.83)	3.60 (16.14)	7.77 (74.29)	8.19 (88.33)	7.98 (81.31)
ZT (Maize) - CT (Berseem)	5.82 (41.67)	5.98 (46.08)	5.90 (43.88)	3.73 (17.42)	3.45 (16.50)	3.59 (16.96)	3.17 (12.04)	3.16 (13.13)	3.17 (12.58)	7.55 (71.13)	7.53 (75.71)	7.54 (73.42)
S.Em. ±	0.09	0.07	0.06	0.06	0.06	0.04	0.10	0.03	0.05	0.05	0.08	0.05
C.D. (P = 0.05)	0.31	0.24	0.17	NS	0.19	0.13	0.33	0.11	0.15	0.18	0.27	0.15
Weed control measures												
Atrazine @ 1.0 kg a.i./ha	3.90 (14.75)	3.38 (11.42)	3.64 (13.08)	3.11 (9.21)	2.75 (7.08)	2.93 (8.15)	2.17 (4.25)	1.89 (3.13)	2.03 (3.69)	5.36 (28.21)	4.67 (21.63)	5.01 (24.92)
2,4-D @ 0.75 kg a.i./ha	4.66 (21.42)	4.94 (24.58)	4.80 (23.00)	2.62 (6.42)	2.15 (4.17)	2.39 (5.29)	2.75 (7.20)	2.90 (8.17)	2.82 (7.69)	5.94 (35.04)	6.05 (36.92)	6.00 (35.98)
Hand weeding (20 and 40 DAS)	3.38 (11.08)	2.89 (8.42)	3.14 (9.75)	2.15 (4.17)	1.68 (2.42)	1.91 (3.29)	1.91 (3.21)	1.57 (2.08)	1.74 (2.65)	4.34 (18.46)	3.62 (12.92)	3.98 (15.69)
Weedy check	10.64 (112.83)	11.09 (123.46)	10.87 (118.15)	7.21 (51.71)	7.26 (52.25)	7.24 (51.98)	5.64 (31.42)	6.07 (37.25)	5.85 (34.33)	14.01 (195.96)	14.57 (212.96)	14.29 (204.46)
S.Em. ±	0.07	0.04	0.04	0.08	0.04	0.05	0.06	0.06	0.04	0.03	0.04	0.03
C.D. (P = 0.05)	0.20	0.13	0.11	0.25	0.11	0.13	0.19	0.16	0.12	0.10	0.13	0.08

Values are $\sqrt{(X + 0.5)}$ transformed and original values are in parenthesis

weeds population (2.49, 2.70 and 2.64 /m²) was recorded in conventional tillage - conventional tillage treatment at 30 and 60 DAS and at harvest ,respectively which was significantly lower compared to other tillage practices treatment.

During both the years, sedges weed density in maize was significantly influenced by all the weed control treatments. Between the weed control measures treatments, the lowest sedges weeds population was recorded in hand weeding twice at 20 and 40 DAS followed by atrazine @ 1.0 kg a.i./ha. Based on pooled basis, maximum population of sedges weeds (5.48, 5.85 and 5.65 /m²) was recorded from weedy check.

4.1.1.2.4 Total weed density

The data pertaining to total weed density at 30 and 60 DAS and at harvest as influenced by different tillage practices and weed control measures.

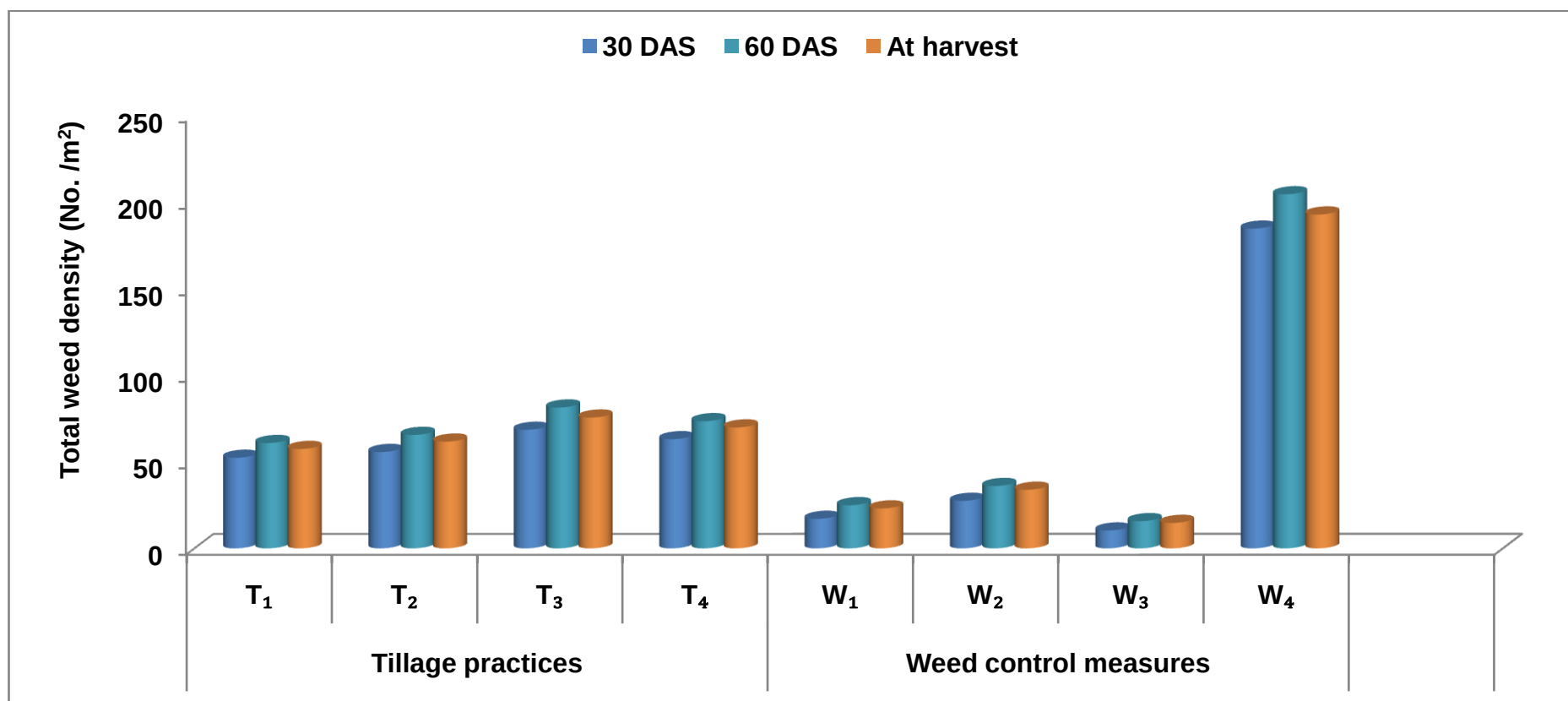
The perusal of the data revealed that conventional tillage - conventional tillage resulted significantly lower total weed density compared to conventional tillage - zero tillage, zero tillage - zero tillage and zero tillage - conventional tillage at 30 and 60 DAS and at harvest during 2015 and 2016. As per two years pooled data, conventional tillage - conventional tillage adopted treatment recorded the lowest total weed density (5.86, 6.69 and 6.60 /m²) over conventional tillage - zero tillage (6.11, 7.07 and 6.82 /m²), zero tillage - zero tillage (7.22, 7.98 and 7.70 /m²) and zero tillage - conventional tillage (6.92, 7.54 and 7.29 /m²) at 30 and 60 DAS and at harvest, respectively.

All the weed management practices in maize significantly reduced the total weed density over weedy check. During both the years, at 30 and 60 DAS and at harvest significantly lower weed density was observed with hand weeding twice at 20 and 40 DAS. Pooled data of two years investigation revealed that highest total weed density at 30 and 60 DAS and at harvest was recorded in weedy check (13.60, 14.29 and 13.88 /m²) as compared to hand weeding twice at 20 and 40 DAS (3.17, 3.98 and 3.87 /m²), atrazine @

Table 4.4 Effect of tillage practices and weed control measures on weed density in maize at harvest

Treatments	Weed density (No. /m ²)											
	Grassy			Broad leaf			Sedges			Total		
	2015	2016	Pooled	2015	2016	Pooled	2015	2016	Pooled	2015	2016	Pooled
Tillage practices												
CT (Maize) - CT (Berseem)	5.12 (34.38)	4.75 (30.46)	4.94 (32.42)	3.61 (16.58)	3.59 (16.46)	3.60 (16.52)	2.78 (9.17)	2.51 (7.75)	2.64 (8.46)	6.79 (60.13)	6.41 (54.67)	6.60 (57.40)
CT (Maize) - ZT (Berseem)	5.26 (36.50)	5.10 (34.75)	5.18 (35.63)	3.70 (17.42)	3.35 (15.42)	3.53 (16.42)	2.92 (9.83)	2.73 (9.33)	2.82 (9.58)	7.00 (63.75)	6.63 (59.50)	6.82 (61.63)
ZT (Maize) - ZT (Berseem)	5.82 (41.83)	6.41 (51.17)	6.12 (46.50)	3.43 (14.75)	3.04 (13.45)	3.24 (14.10)	3.30 (12.75)	3.63 (17.08)	3.46 (14.92)	7.47 (69.33)	7.93 (81.70)	7.70 (75.52)
ZT (Maize) - CT (Berseem)	5.64 (39.50)	5.82 (44.42)	5.73 (41.96)	3.60 (16.33)	3.28 (15.17)	3.44 (15.75)	3.08 (11.38)	3.01 (12.83)	3.04 (12.10)	7.30 (67.21)	7.29 (72.42)	7.29 (69.81)
S.Em. ±	0.05	0.05	0.03	0.08	0.06	0.05	0.07	0.06	0.04	0.03	0.03	0.02
C.D. (P = 0.05)	0.16	0.16	0.10	NS	0.22	0.16	0.24	0.19	0.14	0.10	0.10	0.06
Weed control measures												
Atrazine @ 1.0 kg a.i./ha	3.68 (13.08)	3.38 (11.25)	3.53 (12.17)	2.98 (8.42)	2.68 (6.75)	2.83 (7.58)	2.11 (4.04)	1.73 (2.58)	1.92 (3.31)	5.10 (25.54)	4.58 (20.58)	4.84 (23.06)
2,4-D @ 0.75 kg a.i./ha	4.49 (19.83)	4.87 (24.00)	4.68 (21.92)	2.40 (5.33)	2.03 (3.67)	2.21 (4.50)	2.72 (7.08)	2.81 (7.75)	2.77 (7.42)	5.71 (32.25)	5.92 (35.42)	5.82 (33.83)
Hand weeding (20 and 40 DAS)	3.20 (9.92)	3.04 (8.92)	3.12 (9.42)	2.02 (3.67)	1.60 (2.29)	1.81 (2.98)	1.80 (2.83)	1.46 (1.75)	1.63 (2.29)	4.10 (16.42)	3.65 (12.95)	3.87 (14.69)
Weedy check	10.48 (109.38)	10.79 (116.63)	10.63 (113.00)	6.93 (47.67)	6.95 (47.79)	6.94 (47.73)	5.43 (29.17)	5.88 (34.92)	5.65 (32.04)	13.66 (186.21)	14.10 (199.33)	13.88 (192.77)
S.Em. ±	0.06	0.08	0.05	0.08	0.06	0.05	0.08	0.08	0.06	0.06	0.07	0.05
C.D. (P = 0.05)	0.17	0.22	0.14	0.22	0.18	0.14	0.24	0.24	0.17	0.16	0.21	0.13

Values are $\sqrt{(X + 0.5)}$ transformed and original values are in parenthesis



T₁ - Conventional tillage – Conventional tillage
 T₂ - Conventional tillage – Zero tillage
 T₃ - Zero tillage – Zero tillage
 T₄ - Zero tillage – Conventional tillage

W₁ - Atrazine @ 1.0 kg a.i./ha
 W₂ - 2,4-D @ 0.75 kg a.i./ha
 W₃ - Hand weeding (20 and 40 DAS)
 W₄ - Weedy check

Fig. 4.1 Effect of tillage practices and weed control measures on mean total weed density in maize at 30, 60 DAS and at harvest

1.0 kg a.i./ha (4.11, 5.01 and 4.84 /m²) and 2,4-D @ 0.75 kg a.i./ha (5.23, 6.00 and 5.82 /m²).

4.1.1.3 Weed dry weight (g/m²)

The data on grassy, broad leaf, sedges and total weed dry weight at 30 and 60 DAS and at harvest influenced by tillage practices and weed control measures are presented in Table 4.5 to 4.7 and exhibited in Figure 4.2.

4.1.1.3.1 Grassy weeds

During first year, conventional tillage recorded the lowest grassy weed dry weight compared to zero tillage; both the conventional tillage and zero tillage were at par. However, during second year the highest grassy weed dry matter was recorded in zero tillage - zero tillage, which was significantly higher over conventional tillage - conventional tillage, conventional tillage - zero tillage and zero tillage - conventional tillage. Two years pooled data indicated that, minimum grassy weed dry matter (2.29, 3.00 and 3.80 g/m²) was observed in conventional tillage - conventional tillage treatment at 30 and 60 DAS and at harvest respectively which was significantly lower compared to other tillage practices.

Across the years, grassy weed dry weight observation at all stages were significantly influenced by different weed control measure over weedy check. Among weed control treatments the lowest dry matter of grassy weeds was recorded in hand weeding twice at 20 and 40 DAS followed by application of atrazine @ 1 kg a.i./ha and 2,4-D @ 0.75 kg a.i./ha . Based on pooled value, the highest dry weight of grassy weeds (5.51, 6.58 and 7.37 g/m²) at 30 and 60 DAS and at harvest was registered in weedy check.

4.1.1.3.2 Broad leaf weeds

A critical analysis of data revealed that during first year different tillage system failed to record significant variation in broad leaf weeds dry weight recorded at 30 and 60 DAS and at harvest. However, during second year broad leaf weeds dry weight was significantly lower under zero tillage - zero tillage.

Table 4.5 Effect of tillage practices and weed control measures on weed dry weight in maize at 30 day after sowing

Treatments	Weed dry weight (g/m ²)											
	Grassy			Broad leaf			Sedges			Total		
	2015	2016	Pooled	2015	2016	Pooled	2015	2016	Pooled	2015	2016	Pooled
Tillage practices												
CT (Maize) - CT (Berseem)	2.50 (8.43)	2.08 (7.12)	2.29 (7.78)	1.93 (4.35)	1.82 (4.17)	1.87 (4.26)	0.757 (0.076)	0.746 (0.059)	0.751 (0.068)	3.07 (12.85)	2.66 (11.35)	2.86 (12.10)
CT (Maize) - ZT (Berseem)	2.60 (8.82)	2.29 (8.05)	2.44 (8.43)	1.98 (4.49)	1.74 (4.01)	1.86 (4.25)	0.764 (0.088)	0.761 (0.082)	0.763 (0.085)	3.19 (13.40)	2.76 (12.15)	2.98 (12.77)
ZT (Maize) - ZT (Berseem)	2.94 (10.58)	3.34 (13.62)	3.14 (12.10)	1.85 (3.97)	1.66 (3.48)	1.76 (3.72)	0.787 (0.125)	0.806 (0.161)	0.796 (0.143)	3.41 (14.67)	3.67 (17.26)	3.54 (15.97)
ZT (Maize) - CT (Berseem)	2.84 (9.78)	3.10 (11.54)	2.97 (10.66)	1.91 (4.19)	1.87 (4.02)	1.89 (4.10)	0.777 (0.109)	0.789 (0.133)	0.783 (0.121)	3.35 (14.08)	3.56 (15.68)	3.45 (14.88)
S.Em. ±	0.03	0.02	0.02	0.03	0.03	0.02	0.003	0.002	0.002	0.02	0.02	0.01
C.D. (P = 0.05)	0.11	0.08	0.06	NS	0.09	0.06	0.010	0.006	0.005	0.06	0.09	0.05
Weed control measures												
Atrazine @ 1.0 kg a.i./ha	1.77 (2.68)	1.55 (2.22)	1.66 (2.45)	1.48 (1.70)	1.29 (1.19)	1.38 (1.44)	0.731 (0.034)	0.723 (0.024)	0.727 (0.029)	2.21 (4.42)	1.92 (3.43)	2.07 (3.92)
2,4-D @ 0.75 kg a.i./ha	2.23 (4.56)	2.33 (5.29)	2.28 (4.92)	1.36 (1.38)	1.17 (0.90)	1.27 (1.14)	0.748 (0.060)	0.756 (0.071)	0.752 (0.066)	2.54 (6.00)	2.54 (6.26)	2.54 (6.13)
Hand weeding (20 and 40 DAS)	1.48 (1.74)	1.32 (1.60)	1.40 (1.67)	1.15 (0.83)	0.94 (0.42)	1.04 (0.62)	0.721 (0.020)	0.714 (0.009)	0.717 (0.015)	1.75 (2.59)	1.47 (2.03)	1.61 (2.31)
Weedy check	5.39 (28.63)	5.62 (31.22)	5.51 (29.93)	3.68 (13.09)	3.69 (13.17)	3.69 (13.13)	0.885 (0.284)	0.909 (0.330)	0.897 (0.307)	6.52 (42.00)	6.72 (44.72)	6.62 (43.36)
S.Em. ±	0.04	0.03	0.03	0.05	0.04	0.03	0.003	0.001	0.001	0.03	0.04	0.02
C.D. (P = 0.05)	0.13	0.09	0.08	0.15	0.12	0.09	0.008	0.004	0.004	0.07	0.12	0.07

Values are $\sqrt{(X + 0.5)}$ transformed and original values are in parenthesis

During both the years, like grassy weeds all the weed management practices had significant influence on broad leaf weeds dry matter in maize. Hand weeding twice at 20 and 40 DAS followed by post-emergence application of 2,4-D @ 0.75 kg a.i./ha and pre-emergence application of atrazine @ 1.0 kg a.i./ha recorded significantly lower broad leaf weed dry matter at 30 and 60 DAS and at harvest. On pooled basis, the highest dry matter of broad leaf weeds (3.69, 4.26 and 4.68 g/m²) at 30 and 60 DAS and at harvest was recorded from weedy check.

4.1.1.3.3 Sedges

Similar to grassy weeds, the lowest sedges weed dry weight was recorded in conventional tillage compared to zero tillage. During first year both the conventional tillage and zero tillage treatment were on par. However, during second year the highest sedges weed dry weight was recorded in zero tillage - zero tillage, which was significantly highest over conventional tillage - conventional tillage, conventional tillage - zero tillage and zero tillage - conventional tillage. In pooled data, the lowest sedges weed dry weight (0.751, 1.63 and 2.40 g/m²) was recorded in conventional tillage -conventional tillage treatment at 30 and 60 DAS and at harvest.

During both the years, Sedges weed dry weight in maize was significantly influenced by all the weed control treatments. Among all the weed control measures the lowest sedges weed dry weight was recorded in hand weeding twice at 20 and 40 DAS followed by atrazine @ 1.0 kg a.i./ha and 2,4-D @ 0.75 kg a.i./ha. Based on pooled value, maximum dry weight of sedges weeds (0.897, 3.21 and 3.91 g/m²) at 30 and 60 DAS and at harvest was recorded from weedy check.

4.1.1.3.4 Total weeds dry weight

The total weed dry weight at 30 and 60 DAS and at harvest was significantly influenced by different tillage practices and weed control treatments.

The data revealed that during 2015 and 2016 conventional tillage - conventional tillage resulted in significantly lower total weed dry weight

Table 4.6 Effect of tillage practices and weed control measures on weed dry weight in maize at 60 day after sowing

Treatments	Weed dry weight (g/m ²)											
	Grassy			Broad leaf			Sedges			Total		
	2015	2016	Pooled	2015	2016	Pooled	2015	2016	Pooled	2015	2016	Pooled
Tillage practices												
CT (Maize) - CT (Berseem)	3.20 (12.65)	2.80 (11.02)	3.00 (11.84)	2.32 (6.21)	2.23 (6.13)	2.27 (6.17)	1.68 (2.91)	1.57 (2.56)	1.63 (2.73)	4.16 (21.77)	3.77 (19.72)	3.96 (20.74)
CT (Maize) - ZT (Berseem)	3.30 (13.52)	3.25 (13.44)	3.28 (13.48)	2.35 (6.50)	2.14 (5.64)	2.25 (6.07)	1.77 (3.25)	1.73 (3.10)	1.75 (3.18)	4.30 (23.27)	4.13 (22.18)	4.21 (22.73)
ZT (Maize) - ZT (Berseem)	3.72 (16.72)	3.88 (18.74)	3.80 (17.73)	2.21 (5.61)	2.00 (5.02)	2.10 (5.23)	1.96 (3.90)	2.04 (4.85)	2.00 (4.37)	4.63 (26.06)	4.71 (28.60)	4.67 (27.33)
ZT (Maize) - CT (Berseem)	3.63 (15.76)	3.72 (17.34)	3.68 (16.55)	2.25 (5.84)	2.14 (5.72)	2.19 (5.78)	1.80 (3.39)	1.89 (4.13)	1.85 (3.76)	4.52 (24.99)	4.57 (27.19)	4.54 (26.09)
S.Em. ±	0.03	0.03	0.02	0.03	0.03	0.02	0.05	0.02	0.02	0.03	0.04	0.02
C.D. (P = 0.05)	0.11	0.11	0.07	NS	0.10	0.07	0.16	0.06	0.07	0.11	0.12	0.07
Weed control measures												
Atrazine @ 1.0 kg a.i./ha	2.41 (5.35)	2.11 (4.15)	2.26 (4.75)	1.89 (3.09)	1.71 (2.42)	1.80 (2.75)	1.32 (1.26)	1.19 (0.92)	1.25 (1.09)	3.19 (9.69)	2.81 (7.48)	3.00 (8.59)
2,4-D @ 0.75 kg a.i./ha	2.86 (7.77)	3.02 (8.84)	2.94 (8.30)	1.62 (2.15)	1.38 (1.42)	1.50 (1.79)	1.61 (2.13)	1.67 (2.35)	1.64 (2.24)	3.53 (12.05)	3.59 (12.61)	3.56 (12.33)
Hand weeding (20 and 40 DAS)	2.11 (4.03)	1.83 (3.03)	1.97 (3.53)	1.37 (1.40)	1.14 (0.82)	1.26 (1.11)	1.20 (0.95)	1.04 (0.60)	1.12 (0.77)	2.61 (6.37)	2.21 (4.45)	2.41 (5.41)
Weedy check	6.47 (41.51)	6.69 (44.52)	6.58 (43.01)	4.24 (17.52)	4.28 (17.84)	4.26 (17.60)	3.10 (9.10)	3.33 (10.78)	3.21 (9.94)	8.27 (67.97)	8.57 (73.14)	8.42 (70.55)
S.Em. ±	0.05	0.03	0.03	0.04	0.02	0.02	0.03	0.03	0.02	0.03	0.03	0.02
C.D. (P = 0.05)	0.16	0.09	0.09	0.13	0.06	0.07	0.09	0.08	0.06	0.10	0.08	0.06

Values are $\sqrt{(X + 0.5)}$ transformed and original values are in parenthesis

compared to conventional tillage - zero tillage, zero tillage - zero tillage and zero tillage - conventional tillage at 30 and 60 DAS and at harvest. Based on two years pooled data, conventional tillage - conventional tillage recorded the lowest total weed dry weight (2.86, 3.96 and 5.24 g/m²) over conventional tillage - zero tillage (2.98, 4.21 and 5.40 g/m²), zero tillage - zero tillage (3.63, 4.74 and 5.93 g/m²) and zero tillage - conventional tillage (3.54, 4.54 and 5.87 g/m²) at 30 and 60 DAS and at harvest.

In maize, all the weed management practices significantly reduced the total weed dry weight over weedy check. During both the years, at 30 and 60 DAS and at harvest the significantly lower weed dry weight was observed with hand weeding twice at 20 and 40 DAS. Two years pooled data of investigation revealed that highest total weed dry weight at 30 and 60 DAS and at harvest was recorded in weedy check treatment (6.62, 8.42 and 9.52 g/m²) as compared to hand weeding twice at 20 and 40 DAS (2.65, 3.63 and 4.85 g/m²), atrazine @ 1.0 kg a.i./ha (2.20, 3.09 and 4.28 g/m²) and 2,4-D @ 0.75 kg a.i./ha (2.65, 3.63 and 4.85 g/m²).

4.1.1.4 Weed control efficiency (%)

Weed control efficiency at 30 and 60 DAS and at harvest was influenced by different weed control measures are presented in Table 4.8.

In maize, among all weed control treatments, maximum weed control efficiency was recorded with hand weeding twice at 20 and 40 DAS followed by pre-emergence application of atrazine @ 1.0 kg a.i./ha and post-emergence application of 2,4-D @ 0.75 kg a.i./ha.

4.1.1.5 Weed index (%)

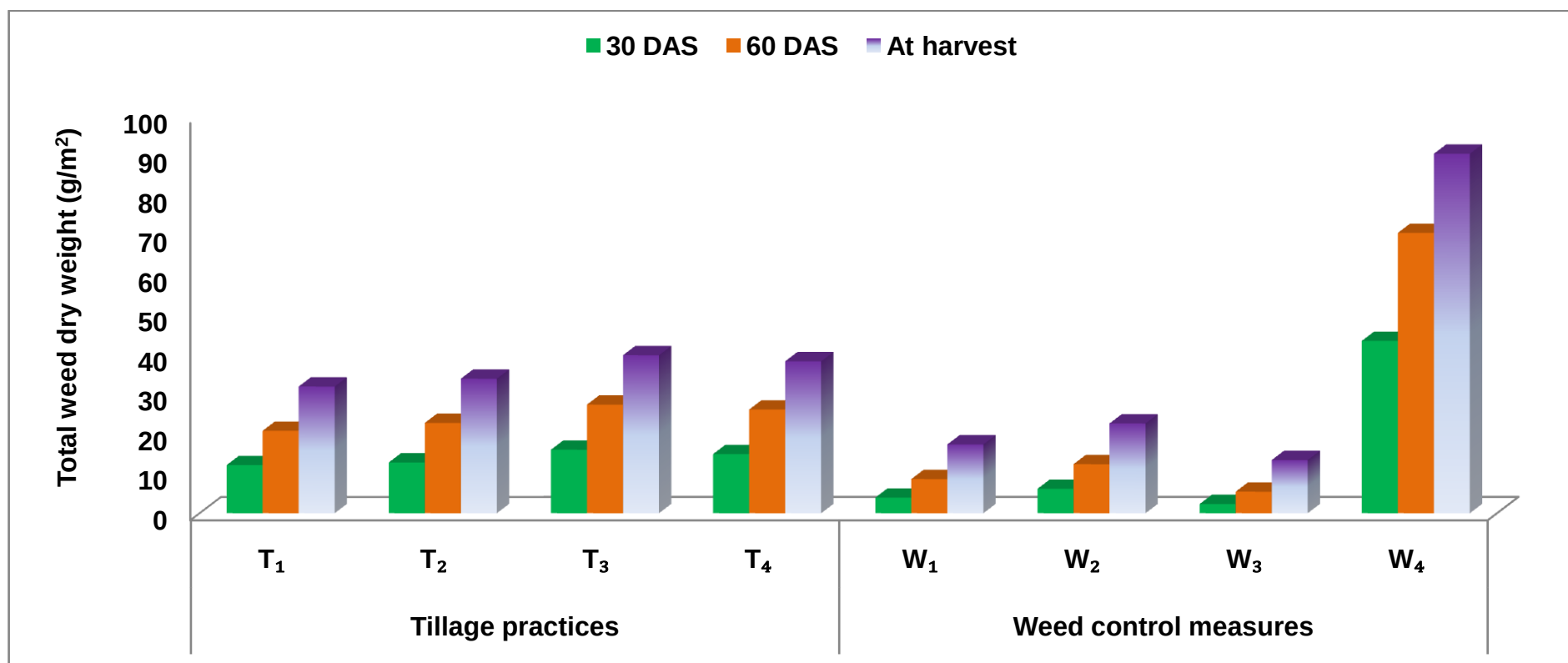
The weed index calculated in respect to reduction in yield due to weed competition compare to the highest yield producing treatment is presented in Table 4.8.

During 2015 and 2016, among all weed control measures, pre-emergence application of atrazine @ 1.0 kg a.i./ha recorded the lowest weed index (13.26 and 12.92 %) followed by post-emergence application of 2,4-D @ 0.75 kg a.i./ha (25.06 and 28.27%). Whereas, highest weed index (37.27 and 41.92%) was recorded from weedy check treatment.

Table 4.7 Effect of tillage practices and weed control measures on weed dry weight in maize at harvest

Treatments	Weed dry weight (g/m ²)											
	Grassy			Broad leaf			Sedges			Total		
	2015	2016	Pooled	2015	2016	Pooled	2015	2016	Pooled	2015	2016	Pooled
Tillage practices												
CT (Maize) - CT (Berseem)	3.92 (18.11)	3.68 (16.12)	3.80 (17.12)	2.89 (9.02)	2.84 (8.97)	2.87 (9.00)	2.50 (6.19)	2.30 (5.34)	2.40 (5.77)	5.39 (33.33)	5.10 (30.42)	5.24 (31.88)
CT (Maize) - ZT (Berseem)	4.04 (19.37)	3.86 (17.81)	3.95 (18.59)	2.93 (9.24)	2.76 (8.68)	2.84 (8.96)	2.57 (6.53)	2.47 (6.06)	2.52 (6.30)	5.53 (35.14)	5.27 (32.55)	5.40 (33.85)
ZT (Maize) - ZT (Berseem)	4.38 (22.03)	4.73 (26.16)	4.55 (24.09)	2.79 (8.27)	2.45 (6.68)	2.62 (7.48)	2.68 (7.20)	2.90 (9.18)	2.79 (8.19)	5.76 (37.50)	5.99 (42.02)	5.87 (39.76)
ZT (Maize) - CT (Berseem)	4.25 (20.83)	4.42 (23.62)	4.34 (22.23)	2.85 (8.80)	2.68 (8.10)	2.77 (8.45)	2.66 (7.05)	2.74 (8.09)	2.70 (7.57)	5.69 (36.68)	5.77 (39.81)	5.73 (38.24)
S.Em. ±	0.03	0.02	0.02	0.04	0.04	0.03	0.02	0.04	0.02	0.02	0.03	0.02
C.D. (P = 0.05)	0.10	0.08	0.06	NS	0.13	0.09	0.07	0.15	0.07	0.06	0.09	0.05
Weed control measures												
Atrazine @ 1.0 kg a.i./ha	3.03 (8.71)	2.85 (7.75)	2.94 (8.23)	2.50 (5.77)	2.30 (4.79)	2.40 (5.28)	2.17 (4.20)	1.97 (3.39)	2.07 (3.80)	4.38 (18.67)	4.05 (15.94)	4.21 (17.31)
2,4-D @ 0.75 kg a.i./ha	3.52 (11.97)	3.74 (13.84)	3.63 (12.90)	2.23 (4.48)	1.97 (3.41)	2.10 (3.95)	2.47 (5.59)	2.52 (5.89)	2.49 (5.74)	4.74 (22.04)	4.84 (23.15)	4.79 (22.59)
Hand weeding (20 and 40 DAS)	2.76 (7.19)	2.63 (6.50)	2.69 (6.84)	2.07 (3.78)	1.79 (2.72)	1.93 (3.25)	2.02 (3.58)	1.85 (2.96)	1.93 (3.27)	3.87 (14.54)	3.56 (12.19)	3.72 (13.37)
Weedy check	7.28 (52.48)	7.46 (55.60)	7.37 (54.04)	4.67 (21.31)	4.68 (21.50)	4.68 (21.41)	3.75 (13.60)	4.08 (16.42)	3.91 (15.01)	9.37 (87.40)	9.68 (93.53)	9.52 (90.46)
S.Em. ±	0.05	0.05	0.04	0.03	0.02	0.02	0.03	0.03	0.02	0.04	0.05	0.03
C.D. (P = 0.05)	0.16	0.15	0.11	0.09	0.06	0.05	0.08	0.07	0.05	0.12	0.13	0.09

Values are $\sqrt{(X + 0.5)}$ transformed and original values are in parenthesis



T₁ - Conventional tillage – Conventional tillage
T₂ - Conventional tillage – Zero tillage
T₃ - Zero tillage – Zero tillage
T₄ - Zero tillage – Conventional tillage

W₁ - Atrazine @ 1.0 kg a.i./ha
W₂ - 2,4-D @ 0.75 kg a.i./ha
W₃ - Hand weeding (20 and 40 DAS)
W₄ - Weedy check

Fig. 4.2 Effect of tillage practices and weed control measures on mean total weed dry weight in maize at 30, 60 DAS and at harvest

4.1.2 Crop Studies

4.1.2.1 Growth and development parameters

4.1.2.1.1 Plant height (cm)

The data on plant height of maize in Maize - Berseem cropping sequence recorded at 30 and 60 DAS and at harvest are presented in Table 4.9 and graphically depicted in Figure 4.3. From the data, it could be noticed that the mean plant height of maize increased with the advancement of crop age during both the years of investigation and reached maximum at harvest.

Conventional tillage recorded the highest maize plant height compared to zero tillage. Both the conventional tillage and zero tillage were at par during first year. However, during second year lowest maize plant height was recorded in zero tillage - zero tillage. Based on two years pooled data, the highest maize plant height (49.43, 174.53 and 214.01 cm) was recorded in conventional tillage - conventional tillage treatment at 30 and 60 DAS and at harvest, respectively which was significantly higher compared to other tillage practices.

Across the years, all the weed control treatments significantly increased plant height of maize over weedy check at 30, 60 DAS and at harvest. The maximum plant height was recorded in hand weeding twice at 20 and 40 DAS followed by atrazine @ 1.0 kg a.i./ha, 2,4-D @ 0.75 kg a.i./ha. On pooled basis, minimum plant height (38.65, 156.67 and 188.44 cm) at 30 and 60 DAS and at harvest was recorded in weedy check.

4.1.2.1.2 Dry matter accumulation (g/plant)

Periodically dry matter accumulation/plant of maize as influenced by different tillage practices and weed control measures under study is presented in Table 4.10.

During first year, maximum dry matter of maize was recorded in conventional tillage compared to zero tillage; both the conventional tillage and zero tillage treatment were on par. However, during second year the lowest dry matter of maize was recorded in zero tillage - zero tillage, which was significantly lower over conventional tillage - conventional tillage,

Table 4.8 Effect of tillage practices and weed control measures on weed control efficiency and weed index in maize

Treatments	Weed control efficiency (%)						Weed index (%)	
	30 DAS		60 DAS		At harvest			
	2015	2016	2015	2016	2015	2016	2015	2016
Tillage practices								
CT (Maize) - CT (Berseem)	-	-	-	-	-	-	-	-
CT (Maize) - ZT (Berseem)	-	-	-	-	-	-	-	-
ZT (Maize) - ZT (Berseem)	-	-	-	-	-	-	-	-
ZT (Maize) - CT (Berseem)	-	-	-	-	-	-	-	-
Weed control measures								
Atrazine @ 1.0 kg a.i./ha	89.49	92.33	85.74	89.77	78.64	82.96	13.26	12.92
2,4-D @ 0.75 kg a.i./ha	85.73	86.00	82.27	82.76	74.79	75.25	25.06	28.27
Hand weeding (20 and 40 DAS)	93.83	95.47	90.62	93.91	83.36	86.96	-	-
Weedy check	-	-	-	-	-	-	37.27	41.92

conventional tillage - zero tillage and zero tillage - conventional tillage. In pooled data, the highest dry matter of maize (30.66, 78.05 and 140.25 g/plant) was recorded in conventional tillage - conventional tillage treatment at 30 and 60 DAS and at harvest.

A critical analysis of data clearly indicates that, dry matter of maize was significantly influenced by weed control treatments. Among all the weed control treatments the highest dry matter of maize was recorded in hand weeding twice at 20 and 40 DAS followed by atrazine @ 1.0 kg a.i./ha and 2,4-D @ 0.75 kg a.i./ha. As per pooled value, the lowest dry matter of maize (21.35, 66.54 and 126.51 g/plant) was recorded from weedy check treatment at 30 and 60 DAS and at harvest.

4.1.2.1.3 Days to 50% silking

The data recorded on days to 50% silking of maize are presented in Table 4.11.

Both the tillage and weed control treatments exerted non-significant influence on days to 50 percent silking in maize. During both the years and as per the pooled data, the less number of days (65.50, 65.58 and 65.54 days) taken by the crop to reach 50 percent silking stage was registered with conventional tillage - conventional tillage adopted treatment.

In case of weed control measures, hand weeding twice at 20 and 40 DAS took less number of days (65.50 and 65.83 days) to 50 percent silking compared to other weed control treatments during both the years.

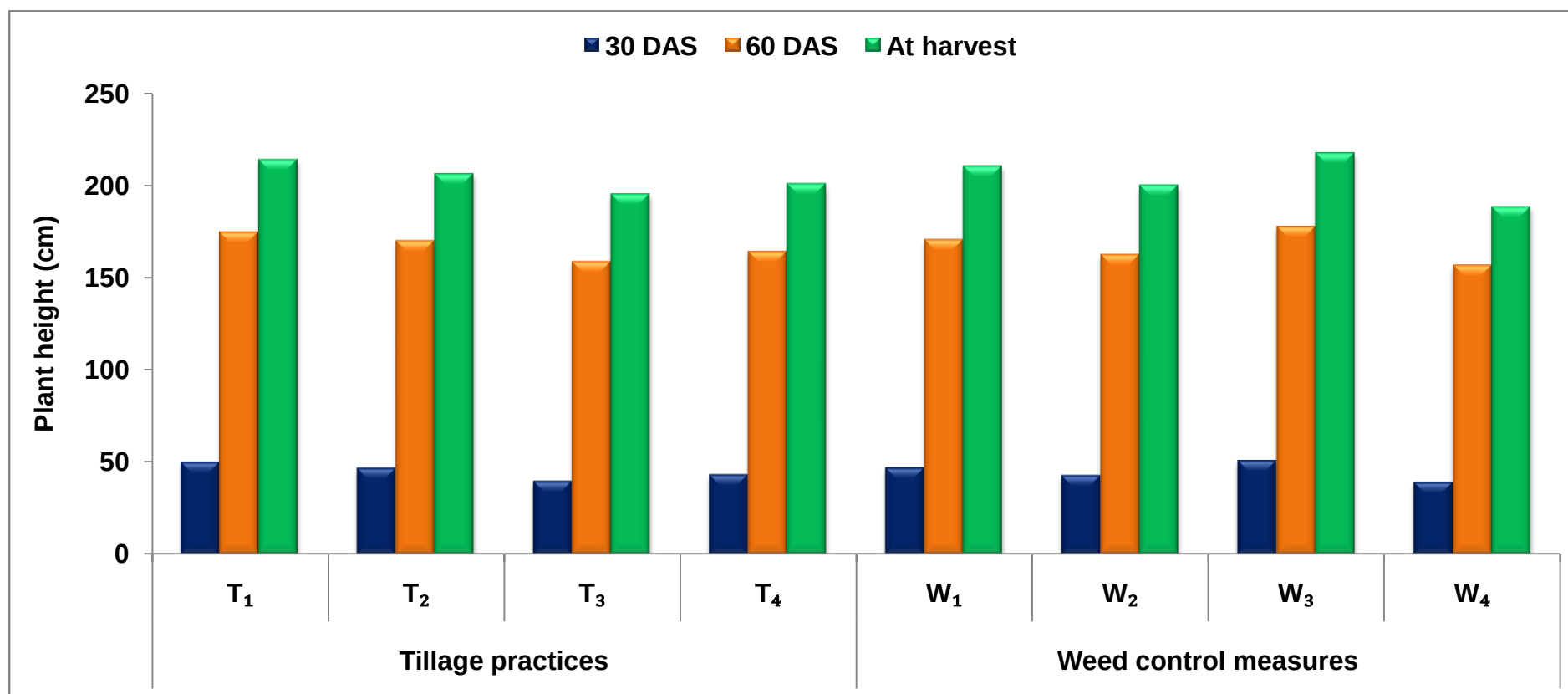
4.1.2.1.4 Days to maturity

The number of days required to reach physiological maturity stage was found non-significant due to different tillage practices and weed control measures (Table 4.11).

Alike days to 50% Silking, days to maturity in 2015 and 2016 was also reduced with adoption of conventional tillage - conventional tillage over conventional tillage - zero tillage, zero tillage - zero tillage and zero tillage - conventional tillage.

Table 4.9 Effect of tillage practices and weed control measures on plant height of maize

Treatments	Plant height (cm)								
	30 DAS			60 DAS			At harvest		
	2015	2016	Pooled	2015	2016	Pooled	2015	2016	Pooled
Tillage practices									
CT (Maize) - CT (Berseem)	47.31	51.55	49.43	171.92	177.14	174.53	208.58	219.43	214.01
CT (Maize) - ZT (Berseem)	44.94	47.64	46.29	167.58	172.22	169.90	203.22	209.56	206.39
ZT (Maize) - ZT (Berseem)	38.75	39.79	39.27	157.03	159.86	158.44	193.50	197.42	195.46
ZT (Maize) - CT (Berseem)	41.64	43.72	42.68	162.15	166.03	164.09	198.42	203.58	201.00
S.Em. $\pm$	1.02	0.87	0.67	1.53	0.74	0.85	1.89	1.21	1.12
C.D. (P = 0.05)	3.53	3.01	2.06	5.30	2.57	2.62	6.54	4.17	3.45
Weed control measures									
Atrazine @ 1.0 kg a.i./ha	44.78	48.04	46.41	167.92	172.92	170.42	206.97	214.03	210.50
2,4-D @ 0.75 kg a.i./ha	41.44	43.09	42.27	160.24	164.56	162.40	197.44	202.89	200.17
Hand weeding (20 and 40 DAS)	48.22	52.47	50.34	175.25	179.72	177.49	213.39	222.11	217.75
Weedy check	38.19	39.10	38.65	155.28	158.06	156.67	185.92	190.96	188.44
S.Em. $\pm$	0.94	0.72	0.59	1.64	0.99	0.96	1.89	0.97	1.06
C.D. (P = 0.05)	2.73	2.11	1.68	4.80	2.88	2.72	5.51	2.84	3.02



T₁ - Conventional tillage – Conventional tillage
 T₂ - Conventional tillage – Zero tillage
 T₃ - Zero tillage – Zero tillage
 T₄ - Zero tillage – Conventional tillage

W₁ - Atrazine @ 1.0 kg a.i./ha
 W₂ - 2,4-D @ 0.75 kg a.i./ha
 W₃ - Hand weeding (20 and 40 DAS)
 W₄ - Weedy check

Fig. 4.3 Effect of tillage practices and weed control measures on mean plant height of maize at 30, 60 DAS and at harvest

Among all weed control measures during both the years less number of days to maturity was recorded in weed control treatment hand weeding twice at 20 and 40 DAS.

4.1.2.2 Yield attributes and yield

4.1.2.2.1 Grains/cob

Grains per cob data of maize recorded under different tillage practices and weed control measures are presented in Table 4.12.

The analyzed data indicated that during first year zero tillage recorded the lowest grains per cob compared to conventional tillage; both the conventional tillage and zero tillage were at par. However, during second year the highest grains per cob was recorded in conventional tillage - conventional tillage. On pooled basis, compared to other tillage practices, the highest grains per cob (337.92) was also observed under conventional tillage - conventional tillage treatment.

Irrespective of the years, the weed control treatments imposed in maize had a significant influence on grains per cob in maize. Among weed control treatments, the highest grains per cob were recorded in hand weeding twice at 20 and 40 DAS followed by application of atrazine @ 1.0 kg a.i./ha and 2,4-D @ 0.75 kg a.i./ha. Based on pooled value, the lowest grains per cob (293.43) were noted in weedy check.

4.1.2.2.2 100 grain weight (g)

The perusal both the years of experimentation and mean data as influenced by tillage practices and weed control measures are presented in Table 4.12.

A critical analysis of data clearly indicates that during first year conventional tillage recorded the highest 100 grain weight compared to zero tillage; both the conventional tillage and zero tillage were at par. Whereas, during second year the lowest 100 grain weight was recorded in zero tillage - zero tillage, which was significantly lower over conventional tillage - conventional tillage, conventional tillage - zero tillage and zero tillage - conventional tillage. The pooled data indicates that the highest 100 grain

Table 4.10 Effect of tillage practices and weed control measures on dry matter accumulation of maize

Treatments	Dry matter accumulation (g/plant)								
	30 DAS			60 DAS			At harvest		
	2015	2016	Pooled	2015	2016	Pooled	2015	2016	Pooled
Tillage practices									
CT (Maize) - CT (Berseem)	29.75	31.58	30.66	75.83	80.27	78.05	136.33	144.17	140.25
CT (Maize) - ZT (Berseem)	28.00	29.34	28.67	73.00	75.42	74.21	134.50	139.08	136.79
ZT (Maize) - ZT (Berseem)	22.92	23.26	23.09	68.42	69.17	68.79	128.13	129.00	128.56
ZT (Maize) - CT (Berseem)	24.13	25.94	25.03	70.88	72.71	71.79	129.96	132.48	131.22
S.Em. $\pm$	1.13	0.27	0.58	0.93	0.46	0.52	0.53	0.39	0.33
C.D. (P = 0.05)	3.89	0.92	1.78	3.21	1.59	1.59	1.83	1.34	1.01
Weed control measures									
Atrazine @ 1.0 kg a.i./ha	27.75	29.65	28.70	74.50	77.42	75.96	133.46	138.42	135.94
2,4-D @ 0.75 kg a.i./ha	24.38	25.08	24.73	68.67	69.71	69.19	129.38	131.79	130.58
Hand weeding (20 and 40 DAS)	31.46	33.89	32.68	78.96	83.35	81.16	139.96	147.63	143.79
Weedy check	21.21	21.49	21.35	66.00	67.08	66.54	126.13	126.90	126.51
S.Em. $\pm$	1.04	0.31	0.54	0.76	0.31	0.41	1.03	0.88	0.68
C.D. (P = 0.05)	3.03	0.89	1.54	2.23	0.90	1.17	3.00	2.57	1.92



Plate 4.1 CT - CT with atrazine @ 1.0 kg a.i./ha



Plate 4.2 CT - ZT with 2,4-D @ 0.75 kg a.i./ha

weight (26.40 g) was observed under conventional tillage - conventional tillage treatment.

During both the years, among all weed control treatments maximum 100 grain weight were recorded in hand weeding twice at 20 and 40 DAS (26.13 and 27.34 g) followed by application of atrazine @ 1.0 kg a.i./ha (24.44 and 25.19 g), 2,4-D @ 0.75 kg a.i./ha (23.15 and 23.37 g) and in weedy check treatment (22.38 and 22.45 g).

4.1.2.2.3 Shelling (%)

The maize shelling percentage data as influenced by tillage practices and weed control measures are presented in Table 4.12.

Conventional tillage recorded highest maize shelling percentage compared to zero tillage; both the conventional tillage and zero tillage were on par during first year. However, during second year, the lowest maize shelling percentage was recorded in zero tillage - zero tillage (73.41%). Based on two years pooled data, the highest maize shelling percentage (77.79 %) was recorded in conventional tillage - conventional tillage which was significantly higher over other tillage practices.

Across the years, all the weed control treatments registered significantly higher shelling percentage over weedy check. The maximum shelling percentage was recorded in hand weeding twice at 20 and 40 DAS followed by atrazine @ 1.0 kg a.i./ha and 2,4-D @ 0.75 kg a.i./ha. On pooled basis, minimum shelling percentage (71.35 %) was recorded in weedy check.

4.1.2.2.4 Grain yield (q/ha)

During both the years of investigation and the pooled data presented in Table 4.13 and depicted in Figure 4.4, grain yield was significantly influenced by tillage and weed management practices.

The highest grain yield (28.53, 31.54 and 30.03 q/ha) of maize was obtained during individual year of study and in pooled data when maize was grown under conventional tillage - conventional tillage and it was significantly higher than the yield of maize obtained under conventional tillage - zero tillage (27.25, 29.43 and 28.34 q/ha), zero tillage - zero tillage (21.25, 22.13 and

Table 4.11 Effect of tillage practices and weed control measures on days to 50% silking and maturity of maize

Treatments	Days to 50% silking			Days to maturity		
	2015	2016	Pooled	2015	2016	Pooled
Tillage practices						
CT (Maize) - CT (Berseem)	65.50	65.58	65.54	102.67	102.92	102.79
CT (Maize) - ZT (Berseem)	65.83	66.03	65.93	103.08	103.50	103.29
ZT (Maize) - ZT (Berseem)	66.67	67.71	67.19	104.67	105.79	105.23
ZT (Maize) - CT (Berseem)	66.42	67.08	66.75	103.50	105.25	104.38
S.Em. $\pm$	0.71	0.51	0.44	0.58	0.92	0.54
C.D. (P = 0.05)	NS	NS	NS	NS	NS	1.67
Weed control measures						
Atrazine @ 1.0 kg a.i./ha	66.08	66.42	66.25	103.00	103.63	103.31
2,4-D @ 0.75 kg a.i./ha	66.25	67.00	66.63	103.67	104.42	104.04
Hand weeding (20 and 40 DAS)	65.50	65.83	65.67	102.17	103.25	102.71
Weedy check	66.58	67.16	66.87	105.08	106.17	105.63
S.Em. $\pm$	0.87	0.89	0.62	1.09	1.61	0.97
C.D. (P = 0.05)	NS	NS	NS	NS	NS	NS



Plate 4.3 ZT - ZT with atrazine @ 1.0 kg a.i./ha



Plate 4.4 CT - CT with hand weeding at 20 and 40 DAS

21.69 q/ha) and zero tillage - conventional tillage (22.17, 24.28 and 23.23 q/ha). On pooled basis, grain yield recorded under conventional tillage - conventional tillage was 5.96, 38.45 and 29.27 percent higher over conventional tillage - zero tillage, zero tillage - zero tillage and zero tillage - conventional tillage.

In case of weed control measures, the highest grain yield of maize (30.58 and 33.88 q/ha) during 2015 and 2016 was recorded with hand weeding twice at 20 and 40 DAS and it was significantly higher over the yield of maize recorded under atrazine @ 1.0 kg a.i./ha (26.53 and 29.50 q/ha), 2,4-D @ 0.75 kg a.i./ha (22.92 and 24.30 q/ha) and weed check (19.18 and 19.68 q/ha). The pooled data revealed that grain yield recorded from hand weeding twice at 20 and 40 DAS was 15.02, 36.50 and 65.87 percent significantly higher over the grain yield of maize recorded under atrazine @ 1.0 kg a.i./ha, 2,4-D @ 0.75 kg a.i./ha and weed check.

4.1.2.2.5 Stover yield (q/ha)

Different tillage and weed control techniques in maize significantly influenced the stover yield of maize during both the years (Table 4.13 and Figure 4.4).

Irrespective of the years, significantly higher stover yield (63.64 and 66.77 q/ha) of maize was produced with conventional tillage - conventional tillage. As per pooled value, stover yield recorded under conventional tillage - conventional tillage was 6.71, 17.37 and 12.84 percent higher over conventional tillage - zero tillage, zero tillage - zero tillage and zero tillage - conventional tillage.

Different weed control measures imposed to maize influenced the stover yield of maize. During both the years hand weeding twice at 20 and 40 DAS recorded significantly higher stover yield (67.99 and 71.60 q/ha) than atrazine @ 1.0 kg a.i./ha (61.74 and 64.05 q/ha), 2,4-D @ 0.75 kg a.i./ha (56.30 and 57.77 q/ha) and weedy check (49.41 and 50.41 q/ha). On pooled basis, hand weeding twice at 20 and 40 DAS recorded 10.97, 22.35 and 39.83 percent significantly higher stover yield of maize over atrazine @ 1.0 kg a.i./ha, 2,4-D @ 0.75 kg a.i./ha and weedy check.

Table 4.12 Effect of tillage practices and weed control measures on grains per cob, 100 grain weight and shelling percentage of maize

Treatments	Grains/cob			100 grain weight (g)			Shelling (%)		
	2015	2016	Pooled	2015	2016	Pooled	2015	2016	Pooled
Tillage practices									
CT (Maize) - CT (Berseem)	335.72	340.11	337.92	25.86	26.94	26.40	76.75	78.82	77.79
CT (Maize) - ZT (Berseem)	327.66	331.14	329.40	24.45	25.02	24.73	75.97	77.22	76.59
ZT (Maize) - ZT (Berseem)	309.08	311.10	310.09	22.54	22.67	22.61	73.23	73.41	73.32
ZT (Maize) - CT (Berseem)	317.25	320.22	318.74	23.24	23.72	23.48	74.31	75.10	74.71
S.Em. $\pm$	2.46	1.55	1.45	0.42	0.28	0.25	0.40	0.41	0.29
C.D. (P = 0.05)	8.52	5.35	4.48	1.45	0.99	0.78	1.40	1.40	0.88
Weed control measures									
Atrazine @ 1.0 kg a.i./ha	335.69	340.26	337.98	24.44	25.19	24.82	76.53	77.91	77.22
2,4-D @ 0.75 kg a.i./ha	316.42	317.86	317.14	23.15	23.37	23.26	73.61	74.25	73.93
Hand weeding (20 and 40 DAS)	344.72	350.47	347.60	26.13	27.34	26.73	78.83	81.00	79.91
Weedy check	292.89	293.97	293.43	22.38	22.45	22.41	71.30	71.39	71.35
S.Em. $\pm$	2.44	1.39	1.40	0.59	0.32	0.33	0.62	0.48	0.39
C.D. (P = 0.05)	7.12	4.05	3.99	1.72	0.92	0.95	1.81	1.39	1.11



Plate 4.5 ZT - CT with weedy check



Plate 4.6 ZT - CT with hand weeding at 20 and 40 DAS

4.1.2.3 Quality parameters

4.1.2.3.1 Protein content (%)

The protein content percentage of maize grain was not significantly influenced due to different tillage practices and weed control measures are presented in Table 4.13.

The findings showed that among all tillage practices, conventional tillage - conventional tillage treatment recorded the highest protein content percentage compared to other tillage treatments. But the differences between tillage treatments were non- significant.

Similarly like tillage practices, hand weeding twice at 20 and 40 DAS recorded highest protein content percentage compared to other weed control treatments. However, the differences among the weed control treatments were non-significant.

4.1.2.4 Economics

The data on cost of cultivation, gross returns, net returns and benefit: cost ratio as influenced by various tillage practices and weed control measures are presented in Table 4.14.

4.1.2.4.1 Cost of cultivation

During 2015 and 2016 zero tillage - zero tillage recorded the lowest cost of cultivation (30,674 and 30,790 ₹/ha) than zero tillage - conventional tillage (30,796 and 31,076 ₹/ha), conventional tillage - zero tillage (34,472 and 34,761 ₹/ha) and conventional tillage - conventional tillage (34,641 and 35,042 ₹/ha).

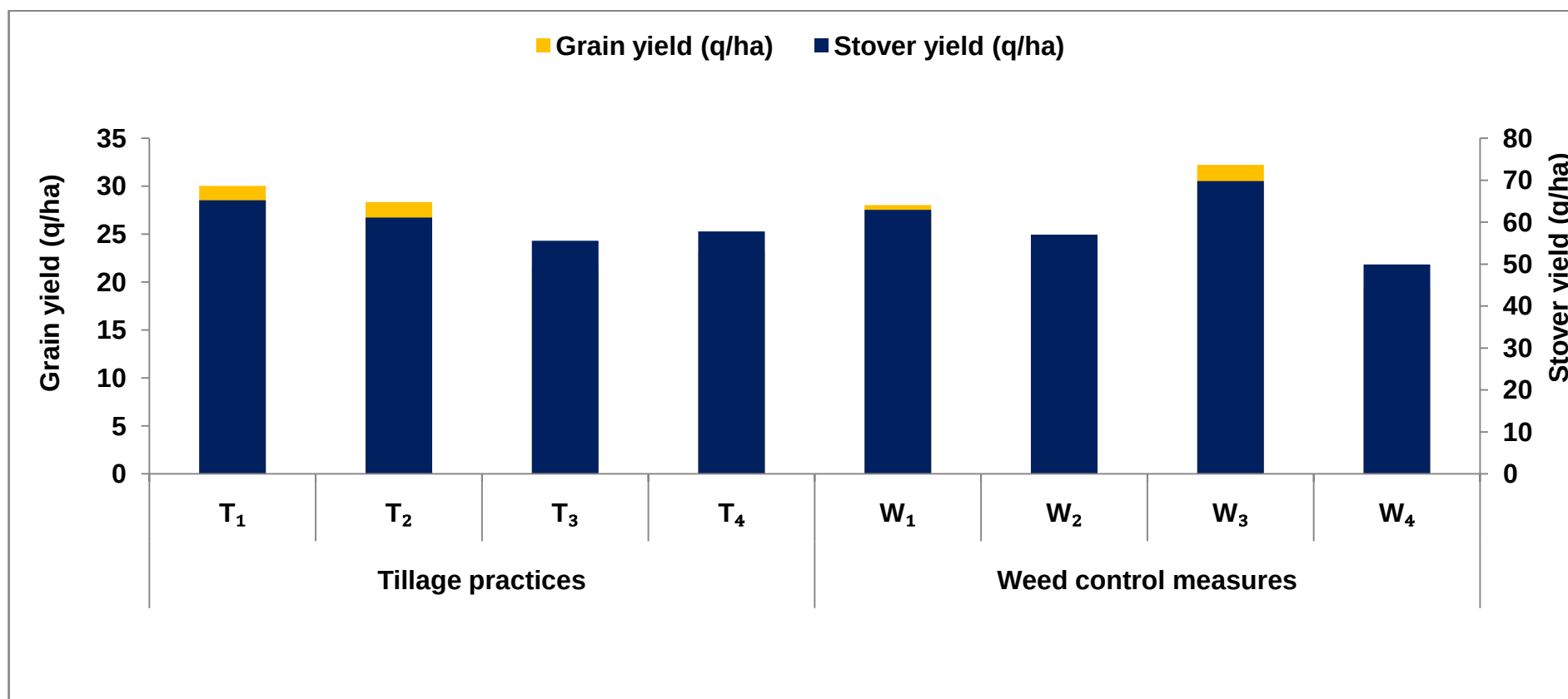
Among weed control measures, during both the years of investigation hand weeding twice at 20 and 40 DAS recorded the highest cost of cultivation (39,036 and 39,475 ₹/ha) followed by atrazine @ 1.0 kg a.i./ha (31,337 and 31,733 ₹/ha), 2,4-D @ 0.75 kg a.i./ha (30,690 and 30,874 ₹/ha) and weedy check (29,520 and 29,586 ₹/ha).

4.1.2.4.2 Gross returns

Conventional tillage - conventional tillage recorded the highest gross

Table 4.13 Effect of tillage practices and weed control measures on grain and stover yield and protein content of maize

Treatments	Yield (q/ha)						Protein content (%)		
	Grain			Stover					
	2015	2016	Pooled	2015	2016	Pooled	2015	2016	Pooled
Tillage practices									
CT (Maize) - CT (Berseem)	28.53	31.54	30.03	63.64	66.77	65.20	9.85	10.01	9.93
CT (Maize) - ZT (Berseem)	27.25	29.43	28.34	60.02	62.17	61.10	9.74	9.84	9.79
ZT (Maize) - ZT (Berseem)	21.25	22.13	21.69	54.85	56.25	55.55	9.52	9.57	9.54
ZT (Maize) - CT (Berseem)	22.17	24.28	23.23	56.92	58.65	57.78	9.64	9.72	9.68
S.Em. $\pm$	0.15	0.17	0.11	0.52	0.41	0.33	0.12	0.17	0.10
C.D. (P = 0.05)	0.53	0.57	0.35	1.81	1.44	1.03	NS	NS	NS
Weed control measures									
Atrazine @ 1.0 kg a.i./ha	26.53	29.50	28.02	61.74	64.05	62.89	9.76	9.88	9.82
2,4-D @ 0.75 kg a.i./ha	22.92	24.30	23.61	56.30	57.77	57.04	9.60	9.68	9.64
Hand weeding (20 and 40 DAS)	30.58	33.88	32.23	67.99	71.60	69.79	9.87	10.02	9.94
Weedy check	19.18	19.68	19.43	49.41	50.41	49.91	9.52	9.56	9.54
S.Em. $\pm$	0.14	0.17	0.11	0.33	0.46	0.29	0.25	0.13	0.14
C.D. (P = 0.05)	0.40	0.49	0.31	0.96	1.36	0.81	NS	NS	NS



T₁ - Conventional tillage – Conventional tillage
 T₂ - Conventional tillage – Zero tillage
 T₃ - Zero tillage – Zero tillage
 T₄ - Zero tillage – Conventional tillage

W₁ - Atrazine @ 1.0 kg a.i./ha
 W₂ - 2,4-D @ 0.75 kg a.i./ha
 W₃ - Hand weeding (20 and 40 DAS)
 W₄ - Weedy check

Fig. 4.4 Effect of tillage practices and weed control measures on mean grain and stover yield of maize

returns (61,880 and 67,343 ₹/ha) during both the years of study due to higher grain and stover yield and this was followed by conventional tillage - zero tillage (58,888 and 62,795 ₹/ha), zero tillage - conventional tillage (50,333 and 54,006 ₹/ha), and lower being with zero tillage - zero tillage (48,338 and 50,061 ₹/ha).

The highest gross returns (66,265 and 72,305 ₹/ha respectively during both the years) were registered with hand weeding twice at 20 and 40 DAS. This was followed by atrazine @ 1.0 kg a.i./ha (58,309 and 63,471 ₹/ha) and 2,4-D @ 0.75 kg a.i./ha (51,266 and 53,786 ₹/ha). The weedy check treatment recorded the lowest gross returns (43,598 and 44,643 ₹/ha) compared to other weed control treatments.

4.1.2.4.3 Net returns

The net returns followed similar trend as that of gross returns. Higher net returns were observed with conventional tillage - conventional tillage (27,239 and 32,300 ₹/ha) followed by conventional tillage - zero tillage (24,415 and 28,034 ₹/ha), zero tillage - conventional tillage (19,537 and 22,930 ₹/ha), and zero tillage - zero tillage (17,663 and 19,271 ₹/ha).

In case of weed control treatments, hand weeding twice at 20 and 40 DAS recorded the highest net returns (27,229 and 32,830 ₹/ha) followed by application of atrazine @ 1.0 kg a.i./ha (26,972 and 31,738 ₹/ha), 2,4-D @ 0.75 kg a.i./ha (20,576 and 22,912 ₹/ha) and weedy check (14,077 and 15,056 ₹/ha).

4.1.2.4.4 Benefit: cost ratio

During both the years of study due to higher gross and net returns conventional tillage - conventional tillage recorded the highest benefit: cost ratio (1.79 and 1.92), followed by conventional tillage - zero tillage (1.71 and 1.81), zero tillage - conventional tillage (1.63 and 1.74), and the lowest being with zero tillage - zero tillage (1.58 and 1.63).

In contrast to the above results, during 2015 and 2016 application of atrazine @ 1.0 kg a.i./ha recorded the highest benefit: cost ratio (1.86 and 2.00)

Table 4.14 Effect of tillage practices and weed control measures on cost of cultivation, gross return, net return and B:C ratio of maize

Treatments	Cost of cultivation (₹/ha)		Gross returns (₹/ha)		Net returns (₹/ha)		Benefit: cost ratio	
	2015	2016	2015	2016	2015	2016	2015	2016
Tillage practices								
CT (Maize) - CT (Berseem)	34641	35042	61880	67343	27239	32300	1.79	1.92
CT (Maize) - ZT (Berseem)	34472	34761	58888	62795	24415	28034	1.71	1.81
ZT (Maize) - ZT (Berseem)	30674	30790	48338	50061	17663	19271	1.58	1.63
ZT (Maize) - CT (Berseem)	30796	31076	50333	54006	19537	22930	1.63	1.74
Weed control measures								
Atrazine @ 1.0 kg a.i./ha	31337	31733	58309	63471	26972	31738	1.86	2.00
2,4-D @ 0.75 kg a.i./ha	30690	30874	51266	53786	20576	22912	1.67	1.74
Hand weeding (20 and 40 DAS)	39036	39475	66265	72305	27229	32830	1.70	1.83
Weedy check	29520	29586	43598	44643	14077	15056	1.48	1.51

Price of: Grain - ₹ 15.00/kg; Stover - ₹ 3.00/kg

followed by hand weeding twice at 20 and 40 DAS (1.70 and 1.83), 2,4-D @ 0.75 kg a.i./ha (1.67 and 1.74) and weedy check (1.48 and 1.51).

4.2 Berseem

4.2.1 Weed studies

4.2.1.1 Weed flora

Weed flora identified in the experimental field during the study were classified into grassy, broad leaf and sedges and are presented in Table 4.15.

Among the grasses, *Poa annua* was predominant. The only sedge observed was *Cyperus rotundus* while, *Rumex dentatus*, *Chenopodium album*, *Cichorium intybus*, *Melilotus alba*, *Melilotus indica* and *Trifolium resupinatum* were the major broad leaf weeds. *Rumex dentatus*, *Coronopus didymus* and *Chenopodium album* were seen throughout the crop period. However, 50 DAS onwards *Melilotus alba*, *Melilotus indica*, *Eclipta alba*, *Sonchus oleraceus*, *Sonchus asper*, *Medicago denticulate*, *Medicago auxalis* and *Trifolium resupinatum* were found to be dominant.

4.2.1.2 Weed density (No. /m²)

The total weed density recorded at different stages 25, 45, 65 and 85 DAS were statistically analyzed and presented in Table 4.16 and illustrated in Figure 4.5.

4.2.1.2.1 Total weed density

Tillage practices significantly influenced the total weed density at all stages of observation during both the years. At 25, 45, 65 and 85 DAS conventional tillage - conventional tillage recorded significantly lower total weed density compared to zero tillage - conventional tillage, conventional tillage - zero tillage and zero tillage - zero tillage. On pooled basis, the highest total weed population (7.87, 7.90, 7.45 and 6.83 /m²) was recorded in zero tillage - zero tillage treatment at 25, 45, 65 and 85 DAS.

During 2015-16 and 2016-17 at all stages of observation weed control measures significantly influenced the total weed population over weedy check. Among all weed control treatments significantly lower total weed density were registered with four hand weeding at 20, 40, 60 and 80 DAS

Table 4.15 Weed flora of the berseem experimental field

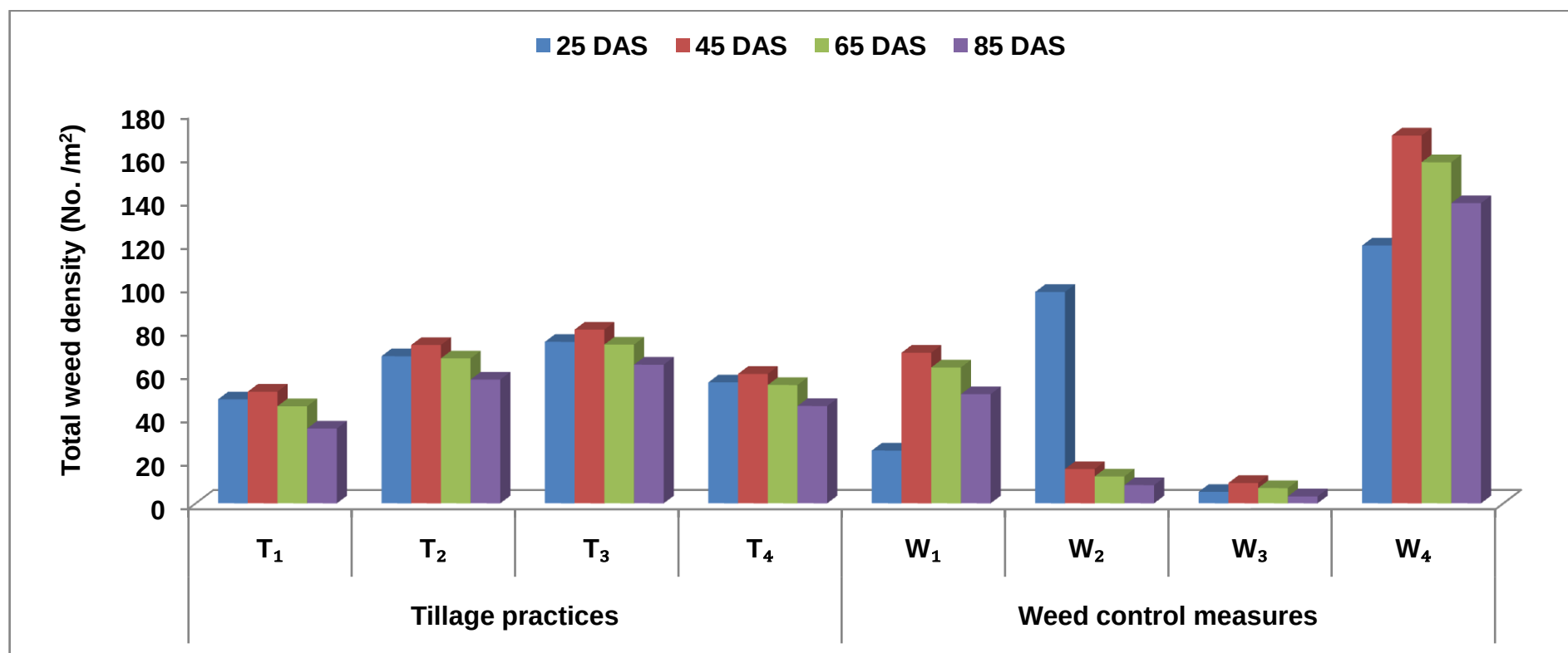
S. No.	Botanical Name	Common Name	Family	Life Cycle
A.Grassy weeds				
1.	<i>Dactyloctenium aegyptium</i> (L.) Beauv	Crow foot grass	Poaceae	Annual
2.	<i>Digitaria sanguinalis</i> (L.) Scop	Crab grass	Poaceae	Annual
3.	<i>Phalaris minor</i> Retz.	Little seed canary grass	Poaceae	Annual
4.	<i>Poa annua</i> L.	Annual bluegrass	Poaceae	Annual
B. Broad leaf weeds				
1.	<i>Anagalis arvensis</i> L.	Scarlet pimpernel	Primulaceae	Annual
2.	<i>Chenopodium album</i> L.	Common lambsquarter	Chenopodiaceae	Annual
3.	<i>Cichorium intybus</i> L.	Chicory	Asteraceae	Annual
4.	<i>Coronopus didymus</i> L.	Swinecress	Brassicaceae	Annual
5.	<i>Eclipta alba</i> (L.) Hassk	False daisy	Asteraceae	Annual
6.	<i>Medicago denticulate</i> Willd.	Rough medik	Fabaceae	Annual
7.	<i>Melilotus alba</i> Medikus.	White sweetclover	Fabaceae	Annual
8.	<i>Melilotus indica</i> L.	Annual yellow sweetclover	Fabaceae	Annual

9.	<i>Physalis minima</i> L.	Native gooseberry	Solanaceae	Annual
10.	<i>Rumex dentatus</i> L.	Toothed dock	Polygonaceae	Annual
11.	<i>Sonchus asper</i> (L.) Hill	Perennial sowthistle	Asteraceae	Annual
12.	<i>Spergula arvensis</i> L.	Corn spurry	Caryophyllaceae	Annual
13.	<i>Trifolium resupinatum</i> L.	Shaftal	Fabaceae	Annual
C. Sedges				
1.	<i>Cyperus rotundus</i> L.	Purple nut sedge	Cyperaceae	Perennial

Table 4.16 Effect of tillage practices and weed control measures on total weed density in berseem

Treatments	Total weed density (No. /m ²)											
	25 DAS			45 DAS			65 DAS			85 DAS		
	2015-16	2016-17	Pooled	2015-16	2016-17	Pooled	2015-16	2016-17	Pooled	2015-16	2016-17	Pooled
Tillage practices												
CT (Maize) - CT (Berseem)	6.21 (49.82)	5.88 (45.96)	6.05 (47.89)	6.48 (54.08)	5.97 (48.77)	6.23 (51.43)	5.98 (46.75)	5.46 (42.67)	5.72 (44.71)	5.07 (35.92)	4.61 (33.00)	4.84 (34.46)
CT (Maize) - ZT (Berseem)	7.37 (66.09)	7.43 (69.42)	7.40 (67.75)	7.49 (71.00)	7.54 (74.83)	7.51 (72.92)	7.01 (64.17)	7.09 (69.33)	7.05 (66.75)	6.25 (53.58)	6.44 (60.42)	6.34 (57.00)
ZT (Maize) - ZT (Berseem)	7.82 (72.17)	7.92 (76.58)	7.87 (74.38)	7.84 (77.33)	7.96 (82.71)	7.90 (80.02)	7.36 (70.33)	7.54 (75.92)	7.45 (73.13)	6.70 (60.50)	6.96 (67.25)	6.83 (63.88)
ZT (Maize) - CT (Berseem)	6.81 (57.42)	6.55 (54.00)	6.68 (55.71)	6.97 (61.79)	6.62 (57.46)	6.79 (59.63)	6.68 (56.63)	6.18 (52.38)	6.43 (54.50)	5.75 (46.25)	5.34 (43.42)	5.54 (44.83)
S.Em. ±	0.02	0.05	0.03	0.03	0.07	0.04	0.05	0.06	0.04	0.06	0.04	0.04
C.D. (P = 0.05)	0.08	0.16	0.08	0.11	0.23	0.11	0.17	0.20	0.12	0.22	0.15	0.12
Weed control measures												
Pendimethalin + Imazethapyr @ 0.75 kg a.i./ha	5.08 (25.82)	4.75 (22.78)	4.91 (24.30)	8.51 (72.38)	8.12 (66.38)	8.11 (69.38)	8.03 (64.25)	7.79 (60.92)	7.91 (62.58)	7.23 (52.17)	6.89 (48.42)	7.06 (50.29)
Imazethapyr @ 0.1 kg a.i./ha	9.99 (99.67)	9.75 (95.08)	9.87 (97.38)	4.18 (17.17)	3.82 (14.42)	4.00 (15.79)	3.79 (14.00)	3.30 (10.75)	3.54 (12.38)	3.15 (9.75)	2.65 (7.00)	2.90 (8.38)
Hand weeding (20, 40, 60 and 80 DAS)	2.46 (5.88)	2.22 (4.70)	2.34 (5.29)	3.27 (10.25)	2.97 (8.50)	3.12 (9.38)	2.93 (8.17)	2.47 (5.83)	2.70 (7.00)	1.98 (3.50)	1.80 (2.92)	1.89 (3.21)
Weedy check	10.69 (114.13)	11.07 (123.41)	10.88 (118.77)	12.82 (164.42)	13.17 (174.47)	12.99 (169.44)	12.29 (151.46)	12.71 (162.79)	12.50 (157.13)	11.41 (130.83)	12.01 (145.75)	11.71 (138.29)
S.Em. ±	0.05	0.03	0.03	0.04	0.04	0.03	0.04	0.04	0.03	0.05	0.05	0.03
C.D. (P = 0.05)	0.13	0.10	0.08	0.12	0.11	0.08	0.12	0.12	0.08	0.13	0.13	0.09

Values are $\sqrt{(X + 0.5)}$ transformed and original values are in parenthesis



T₁ - Conventional tillage – Conventional tillage
T₂ - Conventional tillage – Zero tillage
T₃ - Zero tillage – Zero tillage
T₄ - Zero tillage – Conventional tillage

W₁ - Pendimethalin + Imazethapyr @ 0.75 kg a.i./ha
W₂ - Imazethapyr @ 0.1 kg a.i./ha
W₃ - Hand weeding (20, 40, 60 and 80 DAS)
W₄ - Weedy check

Fig. 4.5 Effect of tillage practices and weed control measures on mean total weed density in berseem at 25, 45, 65 and 85 days after sowing

followed by pendimethalin + imazethapyr @ 0.75 kg a.i./ha only at 25 DAS and at 45, 65 and 85 DAS imazethapyr @ 0.1 kg a.i./ha. Based on two years pooled data, the highest total weed density (10.88, 12.99, 12.50 and 11.71 /m²) at 25, 45, 65 and 85 DAS was recorded from weedy check.

4.2.1.3. Weed dry weight (g/m²)

A perusal of data on weed dry weight recorded at 25, 45, 65 and 85 DAS are presented in Table 4.17 and illustrated in Figure 4.6.

4.2.1.3.1 Total weed dry weight

Data on total weed dry weight exhibited significant variation due to different tillage practices. Conventional tillage - conventional tillage recorded the lowest total weed dry weight. As per pooled data, the lowest total weed dry weight (1.72, 3.70, 2.89 and 2.33 g/m²) was recorded in conventional tillage -conventional tillage treatment at 25, 45, 65 and 85 DAS, respectively which was significantly lower over zero tillage followed by conventional tillage (1.85, 4.20, 3.37 and 2.60 g/m²), conventional tillage followed by zero tillage (2.00, 4.79, 3.81 and 3.02 g/m²) and continuous zero tillage (2.10, 5.22, 4.10 and 3.35 g/m²).

Across the years, in berseem all the weed control measures significantly reduced the total weed dry weight over weedy check. During both the years, among all weed control treatments the lowest total weed dry weight was registered with four hand weeding at 20, 40, 60 and 80 DAS followed by pendimethalin + imazethapyr @ 0.75 kg a.i./ha only at 25 DAS and at 45, 65 and 85 DAS imazethapyr @ 0.1 kg a.i./ha. Pooled data indicated that, at 25, 45, 65 and 85 DAS the highest total weed dry weight (3.35, 8.07, 6.18 and 4.84 g/m²) was recorded from weedy check.

4.2.1.4 Weed control efficiency (%)

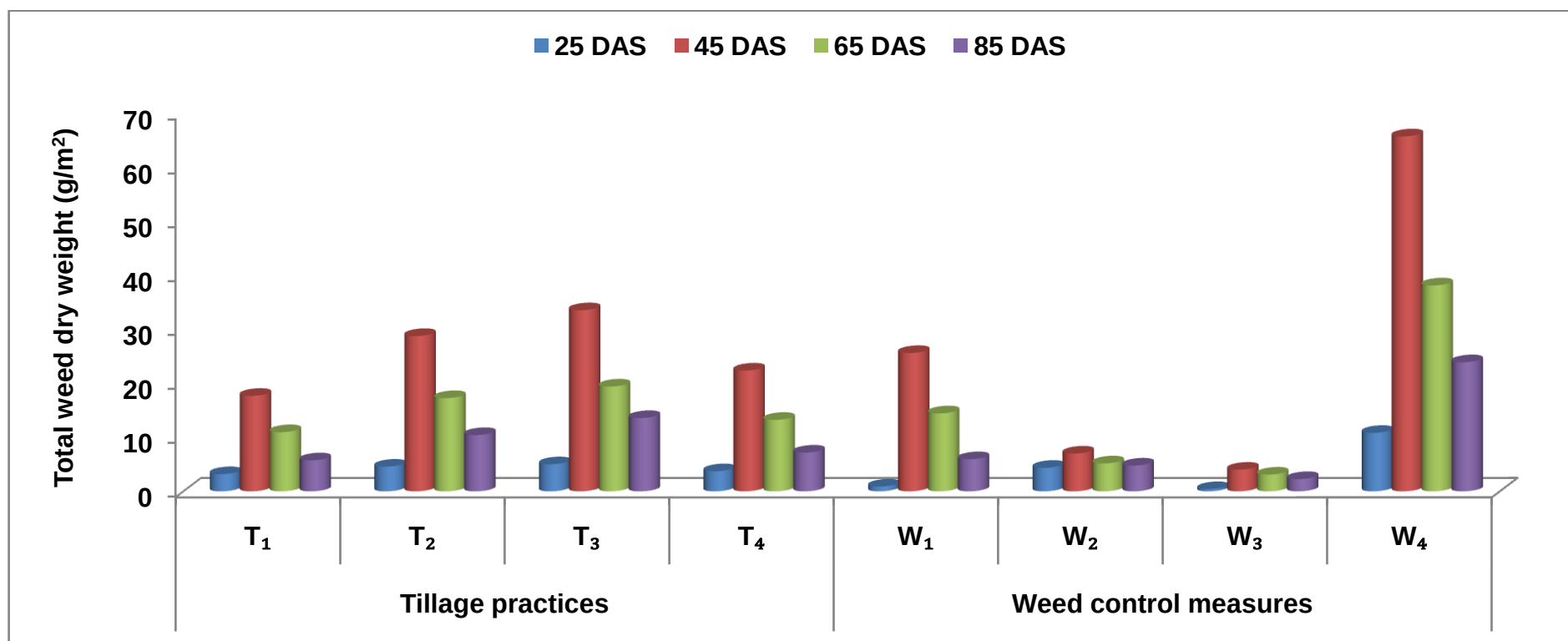
The data on weed control efficiency calculated based on weed dry weight at 25, 45, 65 and 85 DAS was significantly influenced by different weed control measures are presented in Table 4.18.

Study of the data revealed that highest weed control efficiency at 25, 45, 65 and 85 DAS was registered with four hand weeding at 20, 40, 60 and

Table 4.17 Effect of tillage practices and weed control measures on total weed dry weight in berseem

Treatments	Total weed dry weight (g/m ²)											
	25 DAS			45 DAS			65 DAS			85 DAS		
	2015-16	2016-17	Pooled	2015-16	2016-17	Pooled	2015-16	2016-17	Pooled	2015-16	2016-17	Pooled
Tillage practices												
CT (Maize) - CT (Berseem)	1.78 (3.38)	1.66 (2.99)	1.72 (3.19)	4.07 (20.94)	3.34 (14.43)	3.70 (17.68)	3.04 (12.40)	2.75 (9.52)	2.89 (10.96)	2.45 (6.32)	2.21 (5.15)	2.33 (5.74)
CT (Maize) - ZT (Berseem)	2.02 (4.43)	1.99 (4.72)	2.00 (4.57)	4.68 (26.96)	4.89 (30.55)	4.79 (28.75)	3.63 (15.55)	3.99 (18.96)	3.81 (17.26)	2.92 (9.17)	3.12 (11.66)	3.02 (10.42)
ZT (Maize) - ZT (Berseem)	2.09 (4.69)	2.11 (5.33)	2.10 (5.01)	5.02 (30.00)	5.42 (37.05)	5.22 (33.52)	3.90 (16.91)	4.29 (21.88)	4.10 (19.40)	3.27 (12.31)	3.44 (14.82)	3.35 (13.57)
ZT (Maize) - CT (Berseem)	1.90 (3.90)	1.80 (3.56)	1.85 (3.73)	4.45 (24.45)	3.95 (20.27)	4.20 (22.36)	3.54 (14.02)	3.20 (12.45)	3.37 (13.23)	2.71 (7.86)	2.49 (6.51)	2.60 (7.18)
S.Em. ±	0.004	0.01	0.01	0.04	0.03	0.02	0.02	0.02	0.02	0.01	0.04	0.02
C.D. (P = 0.05)	0.014	0.04	0.02	0.13	0.10	0.07	0.07	0.08	0.05	0.03	0.13	0.06
Weed control measures												
Pendimethalin + Imazethapyr @ 0.75 kg a.i./ha	1.28 (1.14)	1.07 (0.65)	1.17 (0.89)	5.27 (27.48)	4.86 (23.75)	5.07 (25.61)	3.92 (14.95)	3.75 (13.93)	3.83 (14.44)	2.58 (6.20)	2.47 (5.69)	2.53 (5.95)
Imazethapyr @ 0.1 kg a.i./ha	2.26 (4.64)	2.14 (4.08)	2.20 (4.36)	2.84 (7.67)	2.52 (6.33)	2.68 (7.00)	2.31 (5.26)	2.30 (5.09)	2.30 (5.17)	2.36 (5.16)	2.20 (4.41)	2.28 (4.78)
Hand weeding (20, 40, 60 and 80 DAS)	0.98 (0.48)	0.93 (0.36)	0.95 (0.42)	2.15 (4.24)	2.03 (3.78)	2.09 (4.01)	1.89 (3.22)	1.82 (3.01)	1.86 (3.11)	1.72 (2.48)	1.59 (2.08)	1.66 (2.28)
Weedy check	3.26 (10.14)	3.43 (11.50)	3.35 (10.82)	7.96 (62.96)	8.18 (68.44)	8.07 (65.70)	5.99 (35.45)	6.36 (40.79)	6.18 (38.12)	4.68 (21.82)	4.99 (25.97)	4.84 (23.90)
S.Em. ±	0.01	0.01	0.01	0.04	0.04	0.03	0.02	0.02	0.01	0.02	0.02	0.01
C.D. (P = 0.05)	0.03	0.02	0.02	0.11	0.11	0.07	0.05	0.06	0.04	0.05	0.05	0.04

Values are $\sqrt{(X + 0.5)}$ transformed and original values are in parenthesis



T₁ - Conventional tillage – Conventional tillage
T₂ - Conventional tillage – Zero tillage
T₃ - Zero tillage – Zero tillage
T₄ - Zero tillage – Conventional tillage

W₁ - Pendimethalin + Imazethapyr @ 0.75 kg a.i./ha
W₂ - Imazethapyr @ 0.1 kg a.i./ha
W₃ - Hand weeding (20, 40, 60 and 80 DAS)
W₄ - Weedy check

Fig. 4.6 Effect of tillage practices and weed control measures on mean total weed dry weight in berseem at 25, 45, 65 and 85 days after sowing

80 DAS over other treatments. Among herbicidal treatment only at 25 DAS pre-emergence application of pendimethalin + imazethapyr @ 0.75 kg a.i./ha, and at 45, 65 and 85 DAS post-emergence application of imazethapyr @ 0.1 kg a.i./ha registered highest weed control efficiency.

4.2.1.5 Weed index (%)

The weed index data varied greatly due to various weed management treatments are presented in Table 4.19.

The weed index calculated in respect of different treatments in comparison to the highest yield producing treatment *i.e.* four hand weeding at 20, 40, 60 and 80 DAS revealed that the reduction in yield was maximum under weedy check plot (52.68 and 53.86 %) showing the greater competition stress, while lower weed index was observed under application of imazethapyr @ 0.1 kg a.i./ha (4.91 and 4.69 %) during 2015-16 and 2016-17).

4.2.2 Crop Studies

4.2.2.1 Growth and development parameters

4.2.2.1.1 Berseem dry weight (g)

The berseem dry weight recorded at 1st, 2nd and 3rd cut as influenced by different tillage practices and weed control measures during both the years are presented in Table 4.19 and graphically depicted in Figure 4.7.

The different tillage practices showed significant variation in respect of berseem dry weight at 1st, 2nd and 3rd cut. At 1st, 2nd and 3rd cut conventional tillage - conventional tillage treatment recorded significantly higher dry weight. The dry weight recorded at 1st, 2nd and 3rd cut was comparable with zero tillage - conventional tillage, conventional tillage - zero tillage and zero tillage - zero tillage. Two years of pooled data noted that, the highest dry weight of berseem (41.79, 45.10 and 50.63 g) was recorded in conventional tillage - conventional tillage treatment at 1st, 2nd and 3rd cut. While, the lowest dry weight was recorded in zero tillage - zero tillage (34.31, 36.48 and 40.10 g).

Table 4.18 Effect of tillage practices and weed control measures on weed control efficiency in berseem

Treatments	Weed control efficiency (%)							
	25 DAS		45 DAS		65 DAS		85 DAS	
	2015-16	2016-17	2015-16	2016-17	2015-16	2016-17	2015-16	2016-17
Tillage practices								
CT (Maize) - CT (Berseem)	-	-	-	-	-	-	-	-
CT (Maize) - ZT (Berseem)	-	-	-	-	-	-	-	-
ZT (Maize) - ZT (Berseem)	-	-	-	-	-	-	-	-
ZT (Maize) - CT (Berseem)	-	-	-	-	-	-	-	-
Weed control measures								
Pendimethalin + Imazethapyr @ 0.75 kg a.i./ha	88.79	94.35	56.36	65.30	57.81	65.85	71.58	78.09
Imazethapyr @ 0.1 kg a.i./ha	54.20	64.49	87.82	90.75	85.17	87.52	76.35	83.04
Hand weeding (20, 40, 60 and 80 DAS)	95.29	96.83	93.26	94.47	90.93	92.62	88.65	91.99
Weedy check	-	-	-	-	-	-	-	-

Among all the weed control treatments, highest dry weight of berseem were recorded in four hand weeding at 20, 40, 60 and 80 DAS followed by post-emergence application of imazethapyr @ 0.1 kg a.i./ha and pre-emergence application of pendimethalin + imazethapyr @ 0.75 kg a.i./ha. Based on pooled value, lowest dry weight of berseem (32.52, 33.77 and 35.83 g) was recorded from weedy check treatment at 1st, 2nd and 3rd cut.

4.2.2.1.2 Plant height at harvest (cm)

The plant height recorded at harvest was analyzed statistically and presented in Table 4.20.

Conventional tillage - conventional tillage were found best with significantly taller plants (61.25 and 63.38 cm) over zero tillage - conventional tillage, conventional tillage - zero tillage and zero tillage - zero tillage during both the years. Relatively shorter plant height (56.58 and 58.78 cm) of berseem at harvest was observed with zero tillage - zero tillage treatment.

In case of weed control measures, irrespective of the years the highest plant height (62.94 and 65.96 cm) of berseem at harvest were registered with four hand weeding at 20, 40, 60 and 80 DAS followed by post-emergence application of imazethapyr @ 0.1 kg a.i./ha (59.81 and 62.75 cm) and pre-emergence application of pendimethalin + imazethapyr @ 0.75 kg a.i./ha (57.31 and 59.03 cm) over weedy check (55.14 and 56.21 cm).

4.2.2.2 Yield attributes and yield

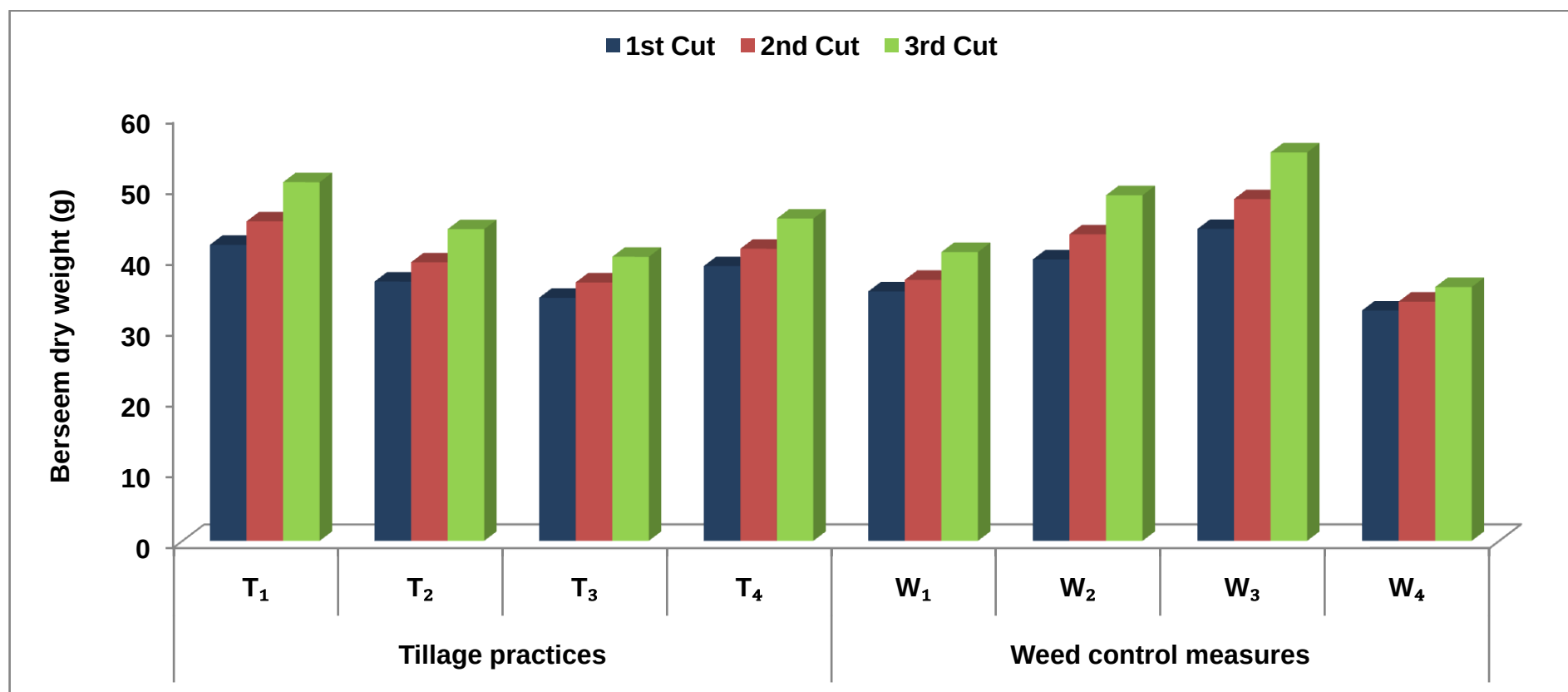
4.2.2.2.1 No. of effective tillers/m²

The data pertaining to number of effective tillers/m² are presented in Table 4.20.

Numbers of effective tillers/m² were significantly influenced by different tillage practices. Among all the tillage treatments, across the years maximum number of effective tillers/m² (262.97 and 269.83 /m²) were recorded with conventional tillage - conventional tillage, followed by zero tillage - conventional tillage and conventional tillage - zero tillage. The minimum number of effective tillers (245.70 and 247.96 /m²) was noticed under zero tillage - zero tillage.

Table 4.19 Effect of tillage practices and weed control measures on weed index and dry weight of berseem

Treatments	Weed index (%)		Berseem dry weight (g)								
			1st Cut			2nd Cut			3rd Cut		
	2015-16	2016-17	2015-16	2016-17	Pooled	2015-16	2016-17	Pooled	2015-16	2016-17	Pooled
Tillage practices											
CT (Maize) - CT (Berseem)	-	-	40.79	42.79	41.79	43.79	46.42	45.10	49.17	52.08	50.63
CT (Maize) - ZT (Berseem)	-	-	36.08	37.12	36.60	38.54	40.08	39.33	42.83	44.67	43.75
ZT (Maize) - ZT (Berseem)	-	-	33.88	34.75	34.31	36.08	36.88	36.48	39.21	41.00	40.10
ZT (Maize) - CT (Berseem)	-	-	37.94	39.63	38.78	40.13	42.38	41.23	44.42	47.08	45.75
S.Em. ±	-	-	0.29	0.22	0.18	0.15	0.45	0.24	0.20	0.16	0.13
C.D. (P = 0.05)	-	-	1.00	0.74	0.56	0.51	1.55	0.73	0.68	0.55	0.39
Weed control measures											
Pendimethalin + Imazethapyr @ 0.75 kg a.i./ha	35.21	34.72	34.79	35.62	35.21	36.38	37.33	36.85	40.08	41.46	40.77
Imazethapyr @ 0.1 kg a.i./ha	11.01	10.77	38.83	40.63	39.73	42.13	44.42	43.27	47.21	50.38	48.79
Hand weeding (20, 40, 60 and 80 DAS)	-	-	42.73	45.33	44.03	46.58	49.92	48.25	52.92	56.75	54.83
Weedy check	52.68	53.86	32.33	32.71	32.52	33.46	34.08	33.77	35.42	36.25	35.83
S.Em. ±	-	-	0.33	0.29	0.22	0.31	0.28	0.21	0.42	0.42	0.30
C.D. (P = 0.05)	-	-	0.95	0.84	0.62	0.89	0.83	0.59	1.21	1.22	0.84



T₁ - Conventional tillage – Conventional tillage
T₂ - Conventional tillage – Zero tillage
T₃ - Zero tillage – Zero tillage
T₄ - Zero tillage – Conventional tillage

W₁ - Pendimethalin + Imazethapyr @ 0.75 kg a.i./ha
W₂ - Imazethapyr @ 0.1 kg a.i./ha
W₃ - Hand weeding (20, 40, 60 and 80 DAS)
W₄ - Weedy check

Fig. 4.7 Effect of tillage practices and weed control measures on mean dry weight of berseem

All the weed control approaches significantly increased the number of effective tillers/m² over weedy check. During 2015-16 and 2016-17 four hand weeding at 20, 40, 60 and 80 DAS resulted in significantly higher number of effective tillers/m². The next best treatment was post-emergence application of imazethapyr @ 0.1 kg a.i./ha, which was significantly superior to pre-emergence application of pendimethalin + imazethapyr @ 0.75 kg a.i./ha. Weedy check registered the lowest number of effective tillers/m².

4.2.2.2.2 Test weight (g)

The perusal of data presented in Table 4.20 revealed that during both the years the test weight was significantly influenced by different tillage practices and weed control measures.

Alike, number of effective tillers/m², berseem seed test weight was also significantly influenced by different tillage practices. During both the years the highest test weight were recorded under conventional tillage - conventional tillage (3.30 and 3.52 g), followed by zero tillage - conventional tillage (3.07 and 3.23 g), conventional tillage - zero tillage (2.93 and 3.07 g) and zero tillage - zero tillage (2.82 and 2.89 g).

Among all weed control measures during both the years of study, significantly higher test weight (3.29 and 3.61 g) were observed with four hand weeding at 20, 40, 60 and 80 DAS followed by post-emergence application of imazethapyr @ 0.1 kg a.i./ha (3.09 and 3.24 g) and pre-emergence application pendimethalin + imazethapyr @ 0.75 kg a.i./ha (2.94 and 3.03 g). While, the lowest test weight (2.81 and 2.84 g) was registered in weedy check treatment.

4.2.2.2.3 Green fodder yield (q/ha)

The data on green fodder yield of berseem as influenced by tillage and weed management practices are presented in Table 4.21 and depicted in Figure 4.8.

Green fodder yield of berseem varied significantly due to various tillage practices. The significantly higher green fodder yield (414.27, 427.59 and 420.93 q/ha) during individual year of study and in pooled mean of berseem were obtained when berseem was grown under conventional tillage -

Table 4.20 Effect of tillage practices and weed control measures on plant height, effective tillers and test weight of berseem

Treatments	Plant height at harvest (cm)			No. of effective tillers/m ²			Test weight (g)		
	2015-16	2016-17	Pooled	2015-16	2016-17	Pooled	2015-16	2016-17	Pooled
Tillage practices									
CT (Maize) - CT (Berseem)	61.25	63.38	62.31	262.97	269.83	266.40	3.30	3.52	3.41
CT (Maize) - ZT (Berseem)	58.17	60.24	59.20	254.67	258.25	256.46	2.93	3.07	3.00
ZT (Maize) - ZT (Berseem)	56.58	58.78	57.68	245.70	247.96	246.83	2.81	2.89	2.85
ZT (Maize) - CT (Berseem)	59.19	61.56	60.38	258.75	263.00	260.88	3.07	3.23	3.15
S.Em. $\pm$	0.52	0.37	0.32	1.00	1.23	0.79	0.03	0.03	0.02
C.D. (P = 0.05)	1.79	1.28	0.98	3.45	4.26	2.44	0.09	0.09	0.06
Weed control measures									
Pendimethalin + Imazethapyr @ 0.75 kg a.i./ha	57.31	59.03	58.17	252.19	255.21	253.70	2.94	3.02	2.98
Imazethapyr @ 0.1 kg a.i./ha	59.81	62.75	61.28	262.44	267.42	264.93	3.09	3.24	3.16
Hand weeding (20, 40, 60 and 80 DAS)	62.94	65.96	64.45	268.45	275.50	271.98	3.29	3.61	3.45
Weedy check	55.14	56.21	55.67	239.00	240.92	239.96	2.81	2.84	2.83
S.Em. $\pm$	0.52	0.26	0.29	0.67	0.60	0.45	0.06	0.05	0.04
C.D. (P = 0.05)	1.51	0.76	0.82	1.96	1.74	1.28	0.17	0.15	0.11



Plate 4.7 CT - CT with imazethapyr @ 0.1 kg a.i./ha



Plate 4.8 CT - ZT with imazethapyr @ 0.1 kg a.i./ha

conventional tillage. On pooled basis, green fodder yield recorded under conventional tillage - conventional tillage was 3.16, 7.33 and 12.11 percent higher over zero tillage - conventional tillage, conventional tillage - zero tillage and zero tillage - zero tillage.

Whereas, in weed control measures, during 2015-16 and 2016-17 the highest green fodder yield of berseem (432.17 and 447.13 q/ha) was recorded with four hand weeding at 20, 40, 60 and 80 DAS and it was significantly higher over the yield of berseem recorded under post-emergence application of imazethapyr @ 0.1 kg a.i./ha (405.39 and 427.85 q/ha), pre-emergence application pendimethalin + imazethapyr @ 0.75 kg a.i./ha (378.08 and 381.88 q/ha) and weedy check (359.16 and 361.56 q/ha). The pooled data indicated that, the green fodder yield recorded from four hand weeding at 20, 40, 60 and 80 DAS were 5.52, 15.70 and 22.00 percent higher over the green fodder yield of berseem recorded under application of imazethapyr @ 0.1 kg a.i./ha, pendimethalin + imazethapyr @ 0.75 kg a.i./ha and weedy check.

4.2.2.2.4 Seed yield (q/ha)

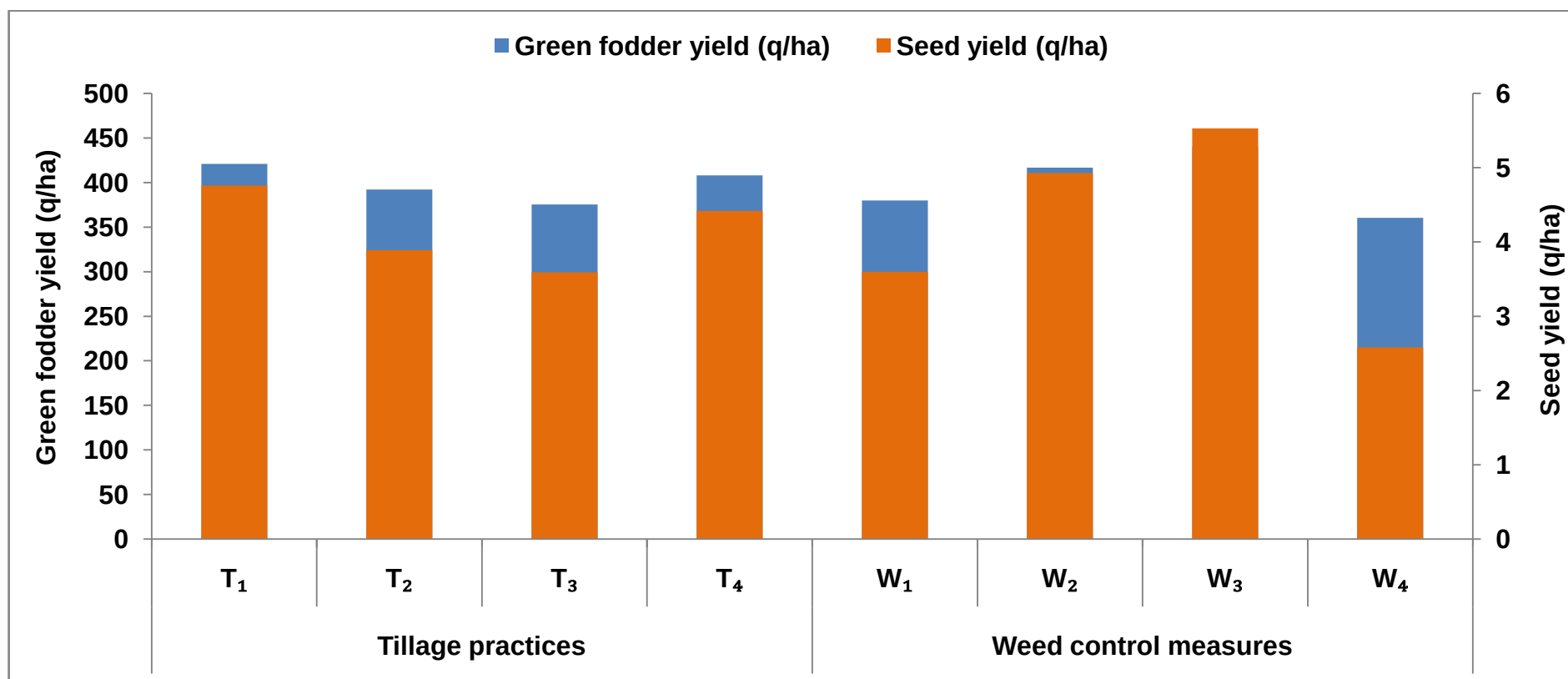
During both the years different tillage and weed control techniques in berseem significantly influenced the seed yield of berseem (Table 4.21 and Figure 4.8).

Across the years, the highest seed yield (4.52 and 4.99 q/ha) of berseem was produced with conventional tillage - conventional tillage, this was significantly higher over the seed yield of berseem produced with zero tillage - conventional tillage (4.27 and 4.56 q/ha), conventional tillage - zero tillage (3.77 and 4.00 q/ha), and zero tillage - zero tillage (3.51 and 3.65 q/ha). Based on pooled data, seed yield recorded under conventional tillage - conventional tillage was 7.46, 22.10 and 32.68 percent higher over zero tillage - conventional tillage, conventional tillage - zero tillage and zero tillage - zero tillage.

Different weed control approaches imposed to berseem influenced the seed yield of berseem. Among all the weed control treatments, during both the years four hand weeding at 20, 40, 60 and 80 DAS recorded the highest

Table 4.21 Effect of tillage practices and weed control measures on green fodder, seed and straw yield of berseem

Treatments	Yield (q/ha)								
	Green fodder			Seed			Straw		
	2015-16	2016-17	Pooled	2015-16	2016-17	Pooled	2015-16	2016-17	Pooled
Tillage practices									
CT (Maize) - CT (Berseem)	414.27	427.59	420.93	4.52	4.99	4.75	20.53	23.07	21.80
CT (Maize) - ZT (Berseem)	385.97	398.39	392.18	3.77	4.00	3.89	14.41	15.82	15.11
ZT (Maize) - ZT (Berseem)	372.01	378.88	375.45	3.51	3.65	3.58	13.07	14.13	13.60
ZT (Maize) - CT (Berseem)	402.54	413.57	408.05	4.27	4.56	4.42	16.86	19.04	17.95
S.Em. $\pm$	2.46	2.04	1.60	0.05	0.08	0.05	0.24	0.31	0.19
C.D. (P = 0.05)	8.51	7.05	4.92	0.19	0.26	0.14	0.83	1.06	0.60
Weed control measures									
Pendimethalin + Imazethapyr @ 0.75 kg a.i./ha	378.08	381.88	379.98	3.46	3.74	3.60	15.10	16.64	15.87
Imazethapyr @ 0.1 kg a.i./ha	405.39	427.85	416.62	4.75	5.11	4.93	17.64	19.90	18.77
Hand weeding (20, 40, 60 and 80 DAS)	432.17	447.13	439.65	5.34	5.73	5.53	21.27	23.74	22.50
Weedy check	359.16	361.56	360.36	2.53	2.64	2.58	10.86	11.77	11.32
S.Em. $\pm$	1.61	2.06	1.31	0.09	0.07	0.05	0.31	0.32	0.22
C.D. (P = 0.05)	4.69	6.02	3.72	0.25	0.19	0.15	0.90	0.94	0.64



T₁ - Conventional tillage – Conventional tillage
 T₂ - Conventional tillage – Zero tillage
 T₃ - Zero tillage – Zero tillage
 T₄ - Zero tillage – Conventional tillage

W₁ - Pendimethalin + Imazethapyr @ 0.75 kg a.i./ha
 W₂ - Imazethapyr @ 0.1 kg a.i./ha
 W₃ - Hand weeding (20, 40, 60 and 80 DAS)
 W₄ - Weedy check

Fig. 4.8 Effect of tillage practices and weed control measures on mean green fodder and seed yield of berseem



Plate 4.9 ZT - ZT with pendimethalin + imazethapyr @ 0.75 kg a.i./ha



Plate 4.10 ZT - CT with hand weeding at 20, 40, 60 and 80 DAS

seed yield (5.34 and 5.73 q/ha) than application of imazethapyr @ 0.1 kg a.i./ha (4.75 and 5.11 q/ha), pendimethalin + imazethapyr @ 0.75 kg a.i./ha (3.46 and 3.74 q/ha) and weed check (2.53 and 2.64 q/ha). On pooled basis, four hand weeding at 20, 40, 60 and 80 DAS recorded 12.17, 53.61 and 114.34 percent significantly higher seed yield of berseem than imazethapyr @ 0.1 kg a.i./ha, pendimethalin + imazethapyr @ 0.75 kg a.i./ha and weedy check.

4.2.2.2.5 Straw yield (q/ha)

The result presented in Table 4.21 regarding the straw yield was significantly influenced by tillage and weed control techniques.

Various tillage treatments had influence on straw yield during 2015-16 and 2016 -17. Conventional tillage - conventional tillage registered the highest straw yield (20.53 and 23.07 q/ha) of berseem over zero tillage - conventional tillage (16.86 and 19.04 q/ha), conventional tillage - zero tillage (14.41 and 15.82 q/ha) and zero tillage - zero tillage (13.07 and 14.13 q/ha) during both the years. The two years pooled data also followed the similar trend.

Similarly like green fodder, straw yield (21.27 and 23.74 q/ha) of berseem were also significantly increased with four hand weeding at 20, 40, 60 and 80 DAS compared to straw yield of berseem recorded under post-emergence application of imazethapyr @ 0.1 kg a.i./ha (17.64 and 19.90 q/ha) and pre-emergence application of pendimethalin + imazethapyr @ 0.75 kg a.i./ha (15.10 and 16.64 q/ha). The lowest straw yield was noticed with weedy check (10.86 and 11.77 q/ha). The pooled data also indicated similar trend to two years investigation data.

4.2.2.2.6 Dry matter yield (q/ha)

The data pertaining to dry matter yield as influenced by tillage practices and weed control measures are presented in Table 4.22.

Dry matter yield of berseem was significantly influenced by different tillage practices. Among all the tillage practices, during both the years the highest dry matter yield (37.25 and 40.71 q/ha) of berseem were recorded with conventional tillage - conventional tillage, followed by zero tillage - conventional tillage and conventional tillage - zero tillage. The lowest dry

Table 4.22 Effect of tillage practices and weed control measures on dry matter and crude protein yield and crude protein content of berseem

Treatments	Yield (q/ha)						Crude protein (%)		
	Dry matter			Crude protein					
	2015-16	2016-17	Pooled	2015-16	2016-17	Pooled	2015-16	2016-17	Pooled
Tillage practices									
CT (Maize) - CT (Berseem)	37.25	40.71	38.99	8.14	8.92	8.53	21.78	21.85	21.82
CT (Maize) - ZT (Berseem)	30.56	32.97	31.76	6.63	7.20	6.92	21.63	21.72	21.68
ZT (Maize) - ZT (Berseem)	27.34	28.81	28.07	5.89	6.24	6.06	21.44	21.52	21.48
ZT (Maize) - CT (Berseem)	33.11	35.91	34.51	7.20	7.85	7.52	21.68	21.76	21.72
S.Em. $\pm$	0.25	0.14	0.14	0.06	0.05	0.04	0.08	0.16	0.09
C.D. (P = 0.05)	0.88	0.47	0.44	0.21	0.18	0.12	NS	NS	NS
Weed control measures									
Pendimethalin + Imazethapyr @ 0.75 kg a.i./ha	28.13	29.26	28.69	6.04	6.30	6.17	21.47	21.52	21.49
Imazethapyr @ 0.1 kg a.i./ha	34.75	38.76	36.76	7.59	8.50	8.05	21.84	21.92	21.88
Hand weeding (20, 40, 60 and 80 DAS)	41.07	45.44	43.26	9.09	10.13	9.61	22.13	22.29	22.21
Weedy check	24.31	24.95	24.63	5.13	5.28	5.21	21.10	21.12	21.11
S.Em. $\pm$	0.19	0.24	0.15	0.08	0.07	0.05	0.20	0.17	0.13
C.D. (P = 0.05)	0.56	0.70	0.44	0.23	0.20	0.15	0.57	0.48	0.37



Plate 4.11 ZT - ZT with weedy check



Plate 4.12 ZT - CT with weedy check

matter yield (27.34 and 28.81 q/ha) was noticed under zero tillage - zero tillage.

A critical analysis of data clearly indicated that weed control measures has significantly increased the dry matter yield of berseem over weedy check. During 2015-16 and 2016-17 highest dry matter yield (41.07 and 45.44 q/ha) was observed with four hand weeding at 20, 40, 60 and 80 DAS followed by post-emergence application of imazethapyr @ 0.1 kg a.i./ha (34.75 and 38.76 q/ha), pre-emergence application pendimethalin + imazethapyr @ 0.75 kg a.i./h (28.13 and 29.26 q/ha) and weedy check (24.31 and 24.94 q/ha).

4.2.2.2.7 Crude protein yield (q/ha)

The data on crude protein yield was significantly influenced by tillage practices and weed control measures are presented in Table 4.22.

The crude protein yield of the berseem increased with conventional tillage - conventional tillage and it was comparable to zero tillage - conventional tillage, conventional tillage - zero tillage and zero tillage - zero tillage. According to two years pooled data, the highest crude protein yield (8.53 q/ha) of berseem was recorded in conventional tillage - conventional tillage treatment. However, the lowest crude protein yield (6.06 q/ha) was recorded in zero tillage - zero tillage treatment.

Among weed control measures, highest crude protein yield was recorded in four hand weeding at 20, 40, 60 and 80 DAS followed by post-emergence application of imazethapyr @ 0.1 kg a.i./ha, pre-emergence application of pendimethalin + imazethapyr @ 0.75 kg a.i./h and weedy check. On pooled basis, maximum crude protein yield (9.61 q/ha) was recorded in four hand weeding at 20, 40, 60 and 80 DAS and lowest with weedy check (5.21 q/ha).

4.2.2.3 Quality parameters

4.2.2.3.1 Crude protein (%)

The crude protein percentage of berseem was not significantly influenced by tillage practices and significantly influenced by weed control measures are presented in Table 4.22.

The experimental findings revealed that across the years, among all tillage practices conventional tillage - conventional tillage recorded the highest crude protein percentage compared to zero tillage - conventional tillage, conventional tillage - zero tillage and zero tillage - zero tillage. However, the differences among various tillage treatments were non-significant.

During both the years, the highest crude protein percentage was recorded with four hand weeding at 20, 40, 60 and 80 DAS, which was however, on par with application of imazethapyr @ 0.1 kg a.i./ha as post-emergence and significantly higher over with pre-emergence application of pendimethalin + imazethapyr @ 0.75 kg a.i./ha and weedy check.

4.2.2.4 Economics

The data on cost of cultivation, gross returns, net returns and benefit: cost ratio as influenced by different tillage practices and weed control measures are presented in Table 4.23.

4.2.2.4.1 Cost of cultivation

During both the years of experimentation, zero tillage - zero tillage recorded the lowest cost of cultivation (55,959 and 56,512 ₹/ha) compared to zero tillage - conventional tillage (59,483 and 59,865 ₹/ha), conventional tillage - zero tillage (56,184 and 56,571 ₹/ha) and conventional tillage - conventional tillage (59,650 and 60,012 ₹/ha).

Among weed control measures four hand weeding at 20, 40, 60 and 80 DAS recorded the highest cost of cultivation (69,872 and 70,271 ₹/ha) followed by imazethapyr @ 0.1 kg a.i./ha (54,815 and 55,143 ₹/ha), pendimethalin + imazethapyr @ 0.75 kg a.i./ha (54,317 and 54,612 ₹/ha) and weedy check (52,273 and 52,934 ₹/ha).

4.2.2.4.2 Gross returns

Conventional tillage - conventional tillage recorded the highest gross returns (1,18,950 and 1,28,547 ₹/ha) during both the years of study due to higher green fodder, seed and straw yield and this was followed by zero tillage - conventional tillage (1,12,804 and 1,19,156 ₹/ha), conventional tillage

- zero tillage (1,02,498 and 1,07,850 ₹/ha), and lower being with zero tillage - zero tillage (96,620 and 99,864 ₹/ha).

The highest gross returns (1,33,930 and 1,42,289 ₹/ha respectively during both the years) were registered with four hand weeding at 20, 40, 60 and 80 DAS. This was followed by imazethapyr @ 0.1 kg a.i./ha (1,20,881 and 1,29,468 ₹/ha) and pendimethalin + imazethapyr @ 0.75 kg a.i./ha (96,978 and 1,02,233 ₹/ha). The lowest gross returns (79,083 and 81,425 ₹/ha) were obtained with weedy check.

4.2.2.4.3 Net returns

The net returns also followed similar trend as that of gross returns. Higher net returns were observed with conventional tillage - conventional tillage (59,300 and 68,535 ₹/ha) followed by zero tillage - conventional tillage (53,321 and 59,291 ₹/ha), conventional tillage - zero tillage, (46,314 and 51,278 ₹/ha), and zero tillage - zero tillage (40,661 and 43,352 ₹/ha).

While, among various weed control measures application of imazethapyr @ 0.1 kg a.i./ha recorded the highest net returns (66,066 and 74,325 ₹/ha) followed by four hand weeding at 20, 40, 60 and 80 DAS (64,059 and 72,018 ₹/ha), pendimethalin + imazethapyr @ 0.75 kg a.i./ha (42,661 and 47,621 ₹/ha) and weedy check (26,810 and 28,492 ₹/ha).

4.2.2.4.4 Benefit: cost ratio

During 2015-16 and 2016-17 due to higher gross and net returns conventional tillage - conventional tillage recorded highest benefit: cost ratio (1.99 and 2.14), followed by zero tillage - conventional tillage (1.90 and 1.99), conventional tillage - zero tillage (1.82 and 1.91), and lower being with zero tillage - zero tillage (1.73 and 1.77).

In contrast to the above results, during both the years application of imazethapyr @ 0.1 kg a.i./ha recorded the highest benefit: cost ratio (2.21 and 2.35) followed by four hand weeding at 20, 40, 60 and 80 DAS (1.92 and 2.02), pendimethalin + imazethapyr @ 0.75 kg a.i./ha (1.79 and 1.87) and weedy check (1.51 and 1.54).

Table 4.23 Effect of tillage practices and weed control measures on cost of cultivation, gross return, net return and B:C ratio of berseem

Treatments	Cost of cultivation (₹/ha)		Gross returns (₹/ha)		Net returns (₹/ha)		Benefit: cost ratio	
	2015-16	2016-17	2015-16	2016-17	2015-16	2016-17	2015-16	2016-17
Tillage practices								
CT (Maize) - CT (Berseem)	59650	60012	118950	128547	59300	68535	1.99	2.14
CT (Maize) - ZT (Berseem)	56184	56571	102498	107850	46314	51278	1.82	1.91
ZT (Maize) - ZT (Berseem)	55959	56512	96620	99864	40661	43352	1.73	1.77
ZT (Maize) - CT (Berseem)	59483	59865	112804	119156	53321	59291	1.90	1.99
Weed control measures								
Pendimethalin + Imazethapyr @ 0.75 kg a.i./ha	54317	54612	96978	102233	42661	47621	1.79	1.87
Imazethapyr @ 0.1 kg a.i./ha	54815	55143	120881	129468	66066	74325	2.21	2.35
Hand weeding (20, 40, 60 and 80 DAS)	69872	70271	133930	142289	64059	72018	1.92	2.02
Weedy check	52273	52934	79083	81425	26810	28492	1.51	1.54

Price of: Green fodder - ₹ 1.00/kg; Seed - ₹ 158.00/kg; Straw - ₹ 3.00/kg

4.2.2.5 System productivity and economics of maize – berseem cropping system

Data pertaining to economics of Maize - Berseem cropping system as influenced by various tillage practices and weed control measures are presented in Table 4.24 and illustrated in Figure 4.9.

During both the years, in Maize - Berseem cropping system, the highest maize equivalent yield (103.72 and 112.63 q/ha), gross returns (1,80,830 and 1,95,890 ₹/ha) , net returns (86,539 and 1,00,836 ₹/ha) and benefit: cost ratio (1.92 and 2.06) were recorded with conventional tillage - conventional tillage treatment. Whereas, the lowest maize equivalent yield (83.05 and 85.87q/ha), gross returns (1,44,958 and 1,49,925 ₹/ha) , net returns (58,325 and 62,623 ₹/ha) and benefit: cost ratio (1.67 and 1.72) were registered in zero tillage - zero tillage treatment.

Among all the weed control measures, two hand weeding at 20 and 40 DAS in maize and four hand weeding at 20, 40, 60 and 80 DAS in berseem resulted in higher maize equivalent yield (115.61 and 124.00 q/ha), gross returns (2,00,195 and 2,14,594 ₹/ha) and net returns (91,288 and 1,04,848 ₹/ha). However, higher benefit: cost ratio (2.01 and 2.13) was obtained with application of 2, 4-D @ 0.75 kg a.i./ha in maize and application of imazethapyr @ 0.1 kg a.i./ha in berseem.

4.2.2.6 Soil properties

The data on soil chemical and physical properties influenced by tillage practices and weed control measures are furnished in Table 4.25 and depicted in Figure 4.10.

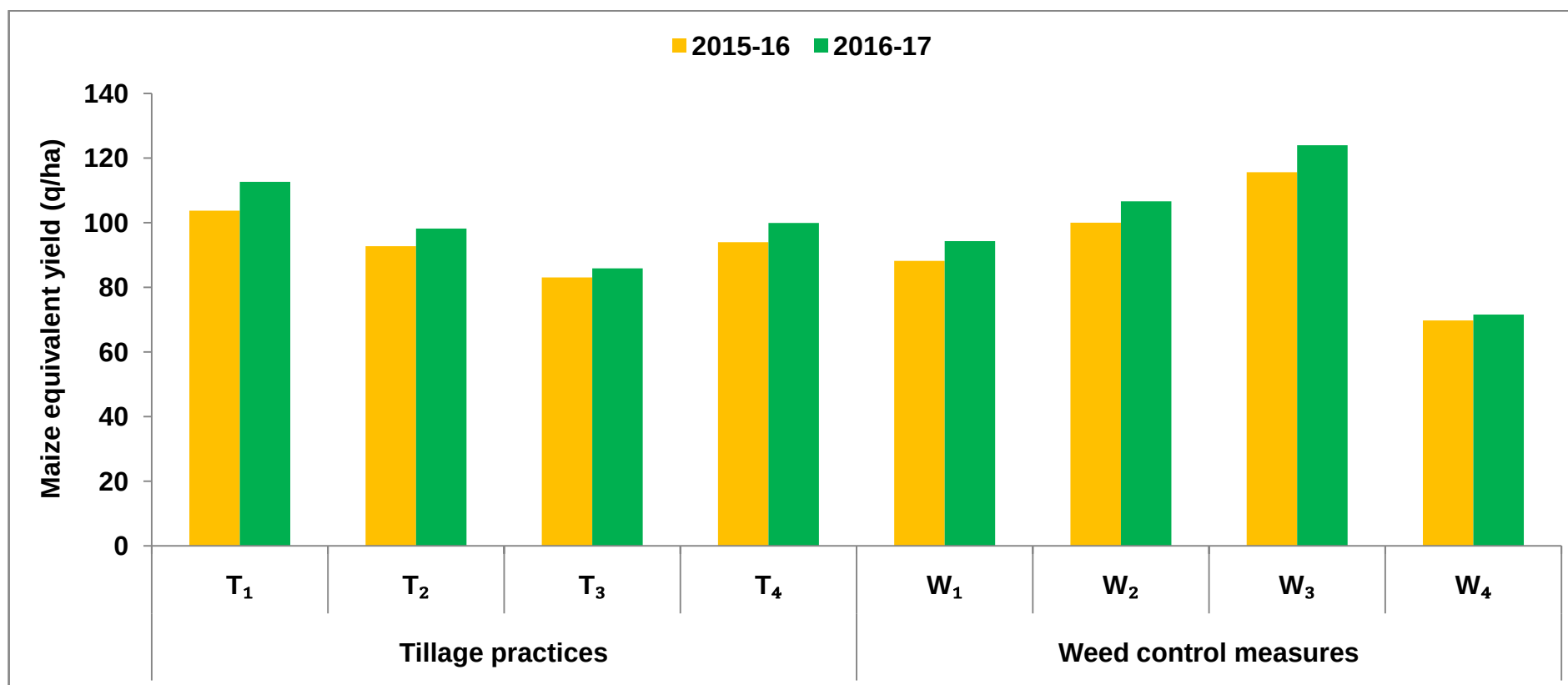
4.2.2.6.1 Organic carbon (%)

At the end of first cropping sequence different tillage practices did not record any significant increase in soil organic carbon. However, during second year significant increase in soil organic carbon (0.65 %) was recorded highest being with zero tillage - zero tillage.

During 2015-16 soil organic carbon was not significantly influenced by weed control measures. Whereas, during 2016-17 at the end of second

Table 4.24 System productivity and economics of maize - berseem cropping system as influenced by tillage practices and weed control measures

Treatments	Maize equivalent yield (q/ha)		Gross returns (₹/ha)		Net returns (₹/ha)		Benefit: cost ratio	
	2015-16	2016-17	2015-16	2016-17	2015-16	2016-17	2015-16	2016-17
Tillage practices								
CT (Maize) - CT (Berseem)	103.72	112.63	180830	195890	86539	100836	1.92	2.06
CT (Maize) - ZT (Berseem)	92.70	98.17	161386	170645	70730	79312	1.78	1.87
ZT (Maize) - ZT (Berseem)	83.05	85.87	144958	149925	58325	62623	1.67	1.72
ZT (Maize) - CT (Berseem)	94.00	99.90	163136	173162	72857	82221	1.81	1.90
Weed control measures								
Recommended herbicides for both the crop	88.16	94.33	155287	165705	69633	79359	1.81	1.92
Recommended herbicides for both the crop	99.98	106.64	172148	183255	86643	97237	2.01	2.13
Recommended hand weedings for both the crop	115.61	124.00	200195	214594	91288	104848	1.84	1.96
Weedy check	69.73	71.61	122680	126068	40887	43548	1.50	1.53



T₁ - Conventional tillage – Conventional tillage
 T₂ - Conventional tillage – Zero tillage
 T₃ - Zero tillage – Zero tillage
 T₄ - Zero tillage – Conventional tillage

W₁ - Recommended herbicides for both the crop
 W₂ - Recommended herbicides for both the crop
 W₃ - Recommended hand weeding for both the crop
 W₄ - Weedy check

Fig. 4.9 Effect of tillage practices and weed control measures on maize equivalent yield during 2015-16 and 2016-17

cropping sequence among all the weed control measures weedy check recorded the highest soil organic carbon followed by application of atrazine @ 1 kg a.i./ha in maize and application pendimethalin + imazethapyr @ 0.75 kg a.i./ha in berseem.

4.2.2.6.2 pH

Different tillage system failed to record variation in soil pH during first year at the end of first cropping sequence. During second year the lowest soil pH (6.78) was registered under zero tillage - zero tillage adoption.

Alike soil organic carbon, during first year at the end of first cropping sequence various tillage systems failed to record variation in soil pH. Among all the weed control treatments the lowest soil pH (6.74) was observed from weedy check during second year.

4.2.2.6.3 EC (dS/ m)

The data indicated that similar to pH, electrical conductivity of soil was also not significantly influenced by different tillage practices during first year. But, during second year the lowest electrical conductivity was noted in zero tillage - zero tillage which was significantly lower over rest of the tillage practices.

During first year, weed control approaches failed to record perceptible variation in electrical conductivity of soil. While, end of second cropping sequence weedy check treatment gained significantly lower soil electrical conductivity (0.18 dS/ m) over recommended herbicides (0.23 and 0.25 dS/ m) and recommended hand weeding for both the crop (0.27 dS/ m).

4.2.2.6.4 Bulk density (Mg/m³)

The findings showed that different tillage treatments did not found any significant variation in bulk density during first year. During second year, at the end of second cropping sequence conventional tillage - conventional tillage adopted treatment recorded the lowest bulk density (1.23 mg/m³) which was statically at par with zero tillage - conventional tillage (1.24 mg/m³).

Across the years, after completion of cropping sequence the bulk density of soil was not significantly influenced by various weed control

Table 4.25 Final soil properties in maize - berseem cropping system as influenced by tillage practices and weed control measures

Treatments	Soil properties									
	Organic carbon (%)		pH		EC (dS/ m)		Bulk density (Mg/m ³)		Particle density (Mg/m ³)	
	2015-16	2016-17	2015-16	2016-17	2015-16	2016-17	2015-16	2016-17	2015-16	2016-17
Tillage practices										
CT (Maize) - CT (Berseem)	0.54	0.56	7.05	6.94	0.30	0.27	1.25	1.23	2.35	2.34
CT (Maize) - ZT (Berseem)	0.58	0.60	7.00	6.90	0.26	0.23	1.27	1.30	2.39	2.41
ZT (Maize) - ZT (Berseem)	0.59	0.65	6.93	6.78	0.22	0.18	1.30	1.34	2.42	2.46
ZT (Maize) - CT (Berseem)	0.56	0.58	7.03	6.92	0.29	0.25	1.25	1.24	2.36	2.35
S.Em. ±	0.01	0.01	0.03	0.01	0.02	0.01	0.02	0.01	0.02	0.02
C.D. (P = 0.05)	NS	0.03	NS	0.04	NS	0.04	NS	0.05	NS	0.05
Weed control measures										
Recommended herbicides for both the crop	0.57	0.60	6.99	6.88	0.26	0.23	1.26	1.27	2.37	2.39
Recommended herbicides for both the crop	0.57	0.59	7.02	6.93	0.28	0.25	1.27	1.28	2.38	2.40
Recommended hand weedings for both the crop	0.55	0.57	7.04	6.99	0.29	0.27	1.28	1.30	2.40	2.42
Weedy check	0.58	0.63	6.97	6.74	0.24	0.18	1.25	1.25	2.35	2.35
S.Em. ±	0.02	0.01	0.04	0.02	0.02	0.01	0.02	0.01	0.03	0.02
C.D. (P = 0.05)	NS	0.03	NS	0.06	NS	0.03	NS	NS	NS	NS

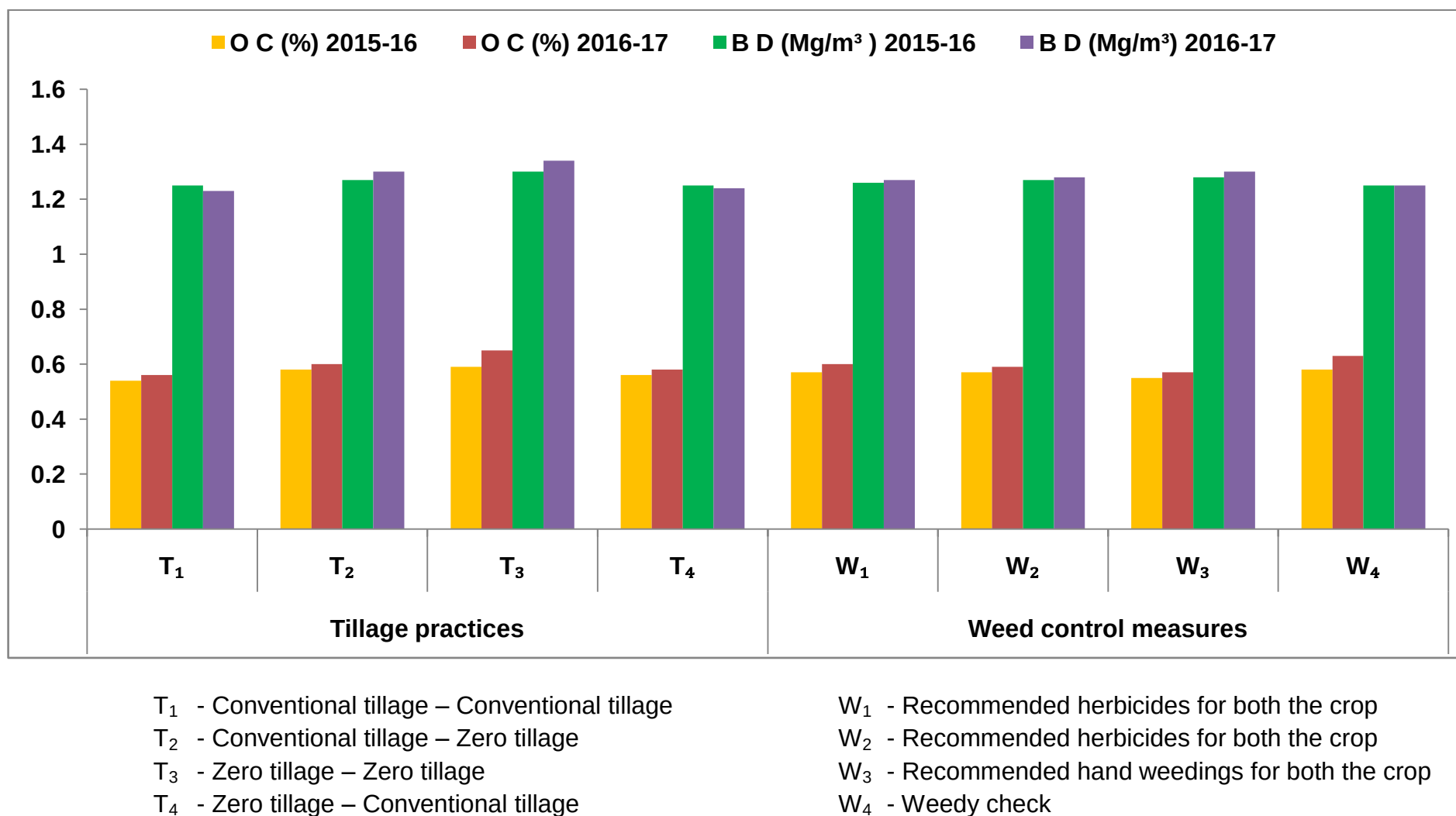


Fig. 4.10 Effect of tillage practices and weed control measures on soil organic carbon and bulk density during 2015-16 and 2016-17

treatments.

4.2.2.6.5 Particle density (Mg/m^3)

A critical analysis of data revealed that during first year different tillage system failed to record significant variation in particle density of soil at the end of cropping sequence. Though, during second year the lowest particle density (2.34 mg/m^3) of soil was recorded under zero tillage - zero tillage adopted treatment.

During both the years, like bulk density all the weed management practices had no influence on particle density of soil.

Chapter - V

DISCUSSION

The results of the experiment entitled “**Weed management in Maize - Berseem cropping system under different tillage practices**” presented in the preceding chapter are discussed in this chapter. Attempts have been made to explain and confirm the experimental findings by establishing cause and effect relationship in the light of available literature on the subject.

5.1 Maize

5.1.1 Weed flora

The weed flora of experimental site were five species of grasses, fourteen species of broad leaved weeds and one species of sedge. Among the grasses, *Echinochloa colona* and *Echinochloa crusgalli* were predominant. The *Celosia argentea*, *Commelina diffusa*, *Digera arvensis*, *Corchorus olitorius* and *Trianthema portulacastrum* were the major broad leaved weeds while sedge only *Cyperus rotundus* was observed. Similar weed flora in maize was also reported by Owla *et al.* (2015).

5.1.2 Effect of tillage practices

5.1.2.1 Weed indices

The experimental results showed that conventionally tilled plots had less number of grassy weeds competing with crops as compared to zero tilled plots. The possible reason might be that due to the repeated tillage operation i.e. ploughing, harrowing and cross cultivator followed by planking of soil has killed the newly germinated weeds. However, under zero tillage condition the highest density of grassy weeds might be due to non disturbance of the top soil and deposition of grassy weeds seeds like *Echinochloa sp* on the top layer of soil (0-10 cm). Apart from this, the zero tillage condition has also favoured the nut development of *Cyperus rotundus*. In the present results increased population of grassy and sedges weeds under zero tillage in *kharif* maize crop are in close agreement with the findings of Sarma and Gautam (2010) and Shekhar *et al.* (2014).

The density of broad leaf weeds was decreased under zero tillage condition compared to conventional tillage at each stage of crop growth (30 and 60 DAS and at harvest). This may be mainly due to that non disturbance of top layer soil has given favourable condition to weeds *Echinochloa sp* (grassy) and *Cyperus rotundus* (Sedge) for early emergence and better growth. Further increased population of grassy and sedges weeds having smothering effect on broad leaf weeds may be the promising reason for reduction in density of broad leaf weeds. Similar findings were also reported by Sarma and Gautam (2010) and Shekhar *et al.* (2014).

Similarly like weed density, in conventionally tilled plots the decreased dry weight of grassy and sedges weeds and increased dry weight of broad leaf weeds at 30 and 60 DAS and at harvest during both the years could be the direct effect of increased/decreased weed population of respective weeds at each state of crop growth.

5.1.2.2 Growth and development

The results of the experiment indicated that the plant height and dry matter accumulation of maize at each successive growth stages were higher under adoption of conventional tillage - conventional tillage which was significantly superior to zero tillage. The present study revealed that higher plant height and dry matter accumulation under conventional tillage - conventional tillage may be due to the good soil physical properties (less bulk and particle density), lower weed infestation and less crop weed competition and better initial growth. The results confirm the finding of Shekhar *et al.* (2014).

Different tillage practices have exerted non significant variation in days to 50 percent silking and days to maturity. This clearly indicates that observed differences in various growth and development parameters are only due to the differences in tillage practices.

5.1.2.3 Yield attributes and yield

During both the years of study different tillage practices brought significant effect on yield attributes and yield of maize. As compared to conventional tillage - zero tillage, zero tillage - zero tillage and zero tillage -

conventional tillage significantly higher values of yield attributes viz. grains per cob and 100 grain weight and grain and stover yield was recorded with conventional tillage - conventional tillage. The probable reason could be that the favourable soil physical condition promoted the root growth for better uptake of water and nutrients. This was attributed to efficient partitioning of metabolites and adequate accumulation and translocation of photosynthates, resulted in increased yield attributes and yield. The results are in close conformity with the findings of Sarma and Gautam (2010), Singh *et al.* (2011) and Shekhar *et al.* (2014).

5.1.2.4 Protein content (%)

Protein content is genetically governed one of the very important traits of maize grain. Various tillage practices found non-significant improvement on the quality parameters of maize viz. protein content.

5.1.2.5 Economics

The highest gross returns, net returns and benefit: cost ratio of *kharif* maize was observed under conventional tillage - conventional tillage, while lowest gross returns, net return and benefit: cost ratio were observed under zero tillage - zero tillage. The returns to investment was much higher in conventional tillage due to enhancement in grain and stover yields, which lead to increase in net returns and benefit: cost ratio over zero tillage (Sarma and Gautam, 2010).

5.1.3 Effect of weed control measures

5.1.3.1 Weed indices

The weed density, dry weight and weed control efficiency recorded at 30 and 60 DAS and at harvest were significantly influenced by the various weed control measures. Significantly lower weed density, dry weight and higher weed control efficiency was obtained with hand weeding twice at 20 and 40 DAS over atrazine @ 1.0 kg a.i./ha, 2,4-D @ 0.75 kg a.i./ha and weedy check. The reduced weed density, dry weight and enhanced weed control efficiency is due to removal of weeds manually through hand weeding in whole plot prevent the germination, regeneration and multiplication of weeds and enhance the crop growth by pulverization of soil and whatever

weeds emerged later on were effectively removal by subsequent hand weeding at 40 DAS. Effective control of weeds through hand weeding was also reported by Parameswari (2013).

The minimum weed index (13.26 and 12.92 %) during 2015 and 2016 was observed with pre-emergence application of atrazine @ 1.0 kg a.i./ha followed by 2,4-D @ 0.75 kg a.i./ha. This was mainly due to efficient weed control and increased yield. Whereas, the highest weed index was reported in weedy check treatment due to severe yield loss. These results are in agreement with the results reported by Parameswari (2013).

5.1.3.2 Growth and development

The plant height and dry matter accumulation recorded at 30 and 60 DAS and at harvest were higher under hand weeding twice at 20 and 40 DAS over rest of the weed control measures. This might be due to reduction in weed density and dry weight, better aeration of soil and robust growth of roots has increased the water and nutrient uptake which might had resulted more cell division and cell elongation in meristematic tissue of plant which led to significant increase in growth attributes. Incremental increase in plant height and dry matter accumulation of maize by twice hand weeding were also noticed by Rao *et al.* (2009), Parameswari (2013) and Shekhar *et al.* (2014).

The days to 50 percent silking and days to maturity was not significantly influenced by various weed control measures.

5.1.3.3 Yield attributes and yield

The maximum grains per cob, 100 grain weight and grain and stover yield recorded in hand weeding twice at 20 and 40 DAS was significantly superior to application of atrazine @ 1.0 kg a.i./ha , 2,4-D @ 0.75 kg a.i./ha and weedy check. Maximum grain and stover yield might be due to less crop-weed competition resulted in vigorous growth and greater dry matter accumulation by crop. Parameswari (2013) and Swetha *et al.* (2015) also found higher grain yield of maize with two hand weeding at 20 and 40 DAS. The minimum grain yield was recorded under weedy check which was attributed to more weed growth, limited uptake of water and nutrients by crop

and poor yield attributing characters. These results are in the line with Barla *et al.* (2016).

5.1.3.4 Protein content (%)

Different weed control measures could not bring significant impact on protein content of maize grain. Among all the weed control approaches two hand weeding at 20 and 40 DAS recorded the highest protein content in maize grain. Choudhary *et al.* (2013) also made similar observations.

5.1.3.5 Economics

Application of atrazine @ 1.0 kg a.i./ha resulted in higher benefit: cost ratio (1.86 and 2.00) during both the years, and this was followed by 2,4-D @ 0.75 kg a.i./ha (1.67 and 1.74) compared to hand weeding twice at 20 and 40 DAS (1.70 and 1.83). The lower benefit: cost ratio was due to higher cost of cultivation as many labour was engaged in hand weeding. Higher benefit: cost ratio due to application of atrazine + alachlor was also observed by Choudhary *et al.* (2013).

5.2 Berseem

5.2.1 Weed flora

The weed species found in the experimental field was one species of sedge *Cyperus rotundus*, four species of grassy weeds *Poa annua*, *Phalaris minor*, *Dactyloctenium aegyptium* and *Digitaria sanguinalis* and thirteen broad leaved weeds namely *Anagalis arvensis*, *Chenopodium album*, *Coronopus didymus*, *Melilotus alba*, *Melilotus indica*, *Cichorium intybus*, *Eclipta alba*, *Sonchus asper*, *Medicago denticulate*, *Trifolium resupinatum*, *Rumex dentatus*, *Physalis minima* and *Spergula arvensis*. Pathan *et al.* (2013) also reported *Cynodon dactylon*, *Chloris barbata*, *Digitaria longiflora*, *Dactyloctenium aegyptium*, *Cyperus rotundus*, *Amaranthus viridis*, *Euphorbia geniculata*, *Celosia argentea*, *Trianthema portulacastrum*, *Commelina benghalensis*, *Corchorus aestuans*, *Parthenium hysterophorus*, *Tridax procumbens*, *Portulaca oleracea* and *Cichorium intybus* weed flora in berseem during rabi season.

5.2.2 Effect of tillage practices

5.2.2.1 Weed indices

The density of weeds was maximum at 45 DAS and there after it decreased at successive stage of crop growth during the crop period. This was due to the cutting of weeds with harvesting of berseem green fodder. It could be seen from the data that there was significant impact of tillage practices on weed density. In conventional tillage - conventional tillage significantly lower weed density had been found than the zero tillage - conventional tillage, conventional tillage - zero tillage and zero tillage - zero tillage. In the preceding crop it was well explained that lower weed density obtained under conventional tillage - conventional tillage might be due to the destroying of newly emerged weeds by the repeated tillage operation.

Alike weed density, at 25, 45, 65 and 85 DAS significantly lower weed dry weight was observed with conventional tillage - conventional tillage over rest of the tillage practices. This could be due to reduction in weed population by preparatory tillage.

5.2.2.2 Growth and development

The growth parameters plant height and dry matter accumulation of berseem were influenced significantly due to different tillage practices. Higher growth parameters of both the crops were recorded under conventional tillage - conventional tillage. It reflects that growing of maize and berseem under conventional tillage - conventional tillage showed better performance of both the crops than sowing of both crops under zero tillage – conventional tillage, zero tillage – zero tillage and conventional tillage – zero tillage. This can be due to deep ploughing under conventional tillage, loosened soil, decreased soil physical properties, permitted deeper root penetration and prolific growth. The lower growth parameters of berseem under zero tillage was might be due to more infestation of weeds *i.e.* *Coronopus didymus*, *Cichorium intybus*, *Sonchus asper*, *Rumex dentatus*, and *Spergula arvensis* had more competition for water, nutrients and light and thus reduced the growth of berseem.

5.2.2.3 Yield attributes and yield

Number of effective tillers and test weight of berseem seed were significantly higher in conventional tillage over zero tillage. Conventional tillage also produced higher green fodder, seed, straw, dry matter and crude protein yield than zero tillage. The decrease in yield attributes and yield of berseem under zero tillage might be as a result of poor seed bed condition for lower germination of seeds, heavy crop-weed competition and shallow root growth of plants which did not extract the nutrients and moisture from the deeper layers of soil.

5.2.2.4 Crude protein (%)

Continuous conventional tillage adoption recorded higher crude protein percentage compared to other tillage practices. However, the improvement was non-significant.

5.2.2.5 Economics

Significant impact on gross returns, net returns and benefit: cost ratio were found by various tillage practices. In Maize - Berseem cropping sequence the highest gross returns, net returns and benefit: cost ratio of berseem were observed when berseem was sown under conventional tillage after the maize. Whereas, lowest gross returns, net returns and benefit: cost ratio were observed when berseem was sown under zero tillage after the maize. The benefit was mainly due to substantial gain in berseem productivity through green fodder, seed and straw yield.

5.2.3 Effect of weed control measures

5.2.3.1 Weed indices

Execution of weed control treatments to berseem significantly influenced the total weed density and dry weight. Among all the weed control treatments imposed to berseem, four hand weeding at 20, 40, 60 and 80 DAS recorded significantly lowest total weed density, dry weight and higher weed control efficiency over rest of the treatments. Next in the order of reduced total weed density, dry weight and increased weed control efficiency was with post-emergence application of imazethapyr @ 0.1 kg a.i./ha due to suppression of grassy, broad leaf and sedges weeds. Jha *et al.* (2014) also reported reduced weed density, dry weight and higher weed control

efficiency by pre-emergence application of oxyfluorfen @ 0.100 kg a.i./ha+ imazethapyr @ 0.150 kg a.i./ha (Immediate after harvest of 1st cut).

During both the years, minimum weed index (11.01 and 10.77 %) was observed with post-emergence application of imazethapyr @ 0.1 kg a.i./ha followed by pre-emergence application of pendimethalin + imazethapyr @ 0.75 kg a.i./ha (35.21 and 34.72 %). This could be due to achievement of higher weed control efficiency by suppression of broad spectrum weeds through highly selective herbicides.

5.2.3.2 Growth and development

Berseem dry weight at 1st, 2nd and 3rd cut and plant height at harvest was observed to be the highest with four hand weeding at 20, 40, 60 and 80 DAS, which was comparable to application of imazethapyr @ 0.1 kg a.i./ha as post-emergence and with application of pendimethalin + imazethapyr @ 0.75 kg a.i./ha as pre-emergence. The lowest dry weight and plant height was observed with weedy check this might be due to higher weed competition would have checked the efficient utilization of resources by crop, which in turn would have retarded the crop growth.

5.2.3.3 Yield attributes and yield

Influence of various weed control measures was significant on yield attributes and yield of berseem. Hand weeding carried out at 20, 40, 60 and 80 DAS recorded higher green fodder, seed, straw, dry matter and crude protein yield of berseem. This might have weed free condition during crop growth period helped in increased uptake of moisture and nutrients. These results are in the line with Pathan *et al.* (2013) and Jha *et al.* (2014).

5.2.3.4 Crude protein (%)

Crude protein percentage of berseem was higher with four hand weeding at 20, 40, 60 and 80 DAS followed by post-emergence application of imazethapyr @ 0.1 kg a.i./ha which was on par with pre-emergence application of pendimethalin + imazethapyr @ 0.75 kg a.i./ha.

5.2.3.5 Economics

Higher net returns and benefit: cost ratio was found with post-emergence application of imazethapyr @ 0.1 kg a.i./ha. This was mainly due to lower costs incurred on herbicide for weed control. The present findings are in accordance with Kumar and Dhar (2008).

5.3 System productivity and economics

Conventionally tilled both maize and berseem produced the highest maize equivalent yield, gross returns, net returns and benefit: cost ratio compared to zero tillage - conventional tillage, conventional tillage - zero tillage, and zero tillage - zero tillage during both the years. Similar results were also reported by Surin *et al.* (2013) in rice - wheat and Shekhar *et al.* (2014) in wheat – maize cropping system.

Two hand weeding at 20 and 40 DAS in maize and four hand weeding at 20, 40, 60 and 80 DAS in berseem resulted in higher maize equivalent yield, gross returns and net returns. However, higher benefit: cost ratio was obtained with application of 2, 4-D @ 0.75 kg a.i./ha in maize and application of imazethapyr @ 0.1 kg a.i./ha in berseem due to low cost of cultivation.

5.4 Soil properties

Soil organic carbon, pH, electrical conductivity, bulk density and particle density were not significantly influence by different tillage practices during first year after the completion of first cropping sequence. However, during second year, soil organic carbon, bulk density and particle density exhibited increase, while pH and electrical conductivity exhibited decrease under continuous zero tillage adoption. No disturbance of soil under zero tillage caused compaction and decreased in volume of soil. Increase in soil bulk density with decreasing tillage intensity has been reported by Chopra and Angiras (2008) and Ram *et al.* (2010).

Similarly, like tillage practices during first year after the completion of first cropping sequence soil organic carbon, pH, electrical conductivity, bulk density and particle density were not significantly influenced by various weed control measures. During second year increase in soil organic carbon and decrease in pH, electrical conductivity was observed with weedy check.

Whereas, the difference among different weed control measures for bulk density and particle density were non-significant.

Chapter - VI

SUMMARY, CONCLUSION AND SUGGESTIONS FOR FURTHER WORK

The field experiment entitled “**Weed management in Maize – Berseem cropping system under different tillage practices**” was conducted for two consecutive years during *kharif* and *rabi* seasons of 2015-16 and 2016-17 to study the effect of weed control measures and tillage practices on growth and productivity of maize and berseem in maize - berseem cropping system. The experiment was conducted at Central Research Farm, Indian Grassland and Fodder Research Institute, Jhansi on clay loam soil. The experiment was laid out in a split-plot design consisting of four tillage practices viz. (i) conventional tillage maize and conventional tillage berseem (ii) conventional tillage maize and zero tillage berseem (iii) zero tillage maize and zero tillage berseem and (iv) zero tillage maize and conventional tillage berseem in main plots and four weed control measures viz. (i) atrazine @ 1.0 kg a.i./ha for maize and pendimethalin + imazethapyr @ 0.75 kg a.i./ha for berseem (ii) 2,4-D @ 0.75 kg a.i./ha for maize and imazethapyr @ 0.1 kg a.i./ha for berseem (iii) two hand weeding at 20 and 40 DAS for maize and four hand weeding at 20, 40, 60 and 80 DAS for berseem and (iv) weedy check for maize and berseem in sub plots and replicated three times. The salient findings presented and discussed in the preceding chapters are summarized here below.

6.1 Maize

6.1.1 Weed flora

- During both the years, the maize field was mainly infested with twenty weed species, out of which *Echinochloa colona* and *Echinochloa crusgalli* among grasses, *Celosia argentea*, *Commelina diffusa*, *Digera arvensis*, *Corchorus olitorius* and *Trianthema portulacastrum* among broad leaf and *Cyperus rotundus* among sedges were the most predominant weed species present in the experimental field.

6.1.2 Effect of tillage practices

6.1.2.1 Weed indices

- Weed density and dry matter was significantly influenced by the tillage practices. Conventional tillage - conventional tillage recorded the lowest weed density and dry weight during both the years at 30 and 60 DAS and at harvest over rest of tillage practices.

6.1.2.2 Growth and development

- Plant height and dry matter accumulation of maize increased with advancement of crop age during both the years of investigation and reached maximum at harvest. In comparison to other tillage practices, during both the years and on pooled basis conventional tillage - conventional tillage registered significantly higher plant height and dry weight of maize at 30 and 60 DAS and at harvest compared to conventional tillage - zero tillage, zero tillage - zero tillage and zero tillage - conventional tillage.
- Less number of days for days to 50% silking and days to maturity was observed in conventional tillage - conventional tillage over rest of the tillage treatments. However, the difference among all the tillage treatments was non-significant.

6.1.2.3 Yield attributes and yield

- During both the years of experimentation conventional tillage - conventional tillage recorded the highest maize yield attributes such as grains/cob (335.72 and 340.11), 100 grain weight (25.86 and 26.94 g) and shelling percentage (76.75 and 78.82%).
- Significant variation on maize seed and stover yield was observed under different tillage practices. On pooled basis, conventional tillage - conventional tillage produced 5.99, 27.79 and 22.66 percent higher grain yield over conventional tillage - zero tillage, zero tillage - zero tillage and zero tillage - conventional tillage.

6.1.2.4 Quality parameters

- Across the years the protein content percentage of maize grain was not significantly influenced by various tillage treatments.

6.1.2.5 Economics

- Economics of various tillage treatments indicated that compared to other tillage treatments conventional tillage - conventional tillage recorded the highest gross returns, net returns and benefit: cost ratio.

6.1.3 Weed control measures

6.1.3.1 Weed indices

- Hand weeding twice at 20 and 40 DAS provided the lowest weed density and dry weight in maize over weedy check during both the years at 30 and 60 DAS and at harvest.
- Pre-emergence application of atrazine @ 1.0 kg a.i./ha recorded the lower weed index . While, higher weed control efficiency at 30 and 60 DAS and at harvest was reported with hand weeding twice at 20 and 40 DAS.

6.1.3.2 Growth and development

- In comparison to other weed control approaches at 30 and 60 DAS and at harvest the highest plant height and dry weight of maize was registered with hand weeding twice at 20 and 40 DAS.
- Days to 50% silking and days to maturity was not significantly influenced by various weed control measures. The Less number of days for days to 50% silking and days to maturity was noticed with hand weeding twice at 20 and 40 DAS.

6.1.3.3 Yield attributes and yield

- Among the weed management practices, across the years, hand weeding twice at 20 and 40 DAS gave the highest maize grains/cob, 100 grain weight and shelling percentage followed by application of atrazine @ 1.0 kg a.i./ha.
- In comparison to atrazine @ 1.0 kg a.i./ha, 2,4-D @ 0.75 kg a.i./ha and weedy check, hand weeding twice at 20 and 40 DAS produced the highest maize grain (30.58 and 33.88 q/ha) and stover (67.99 and 71.60 q/ha) yield during both the years.

6.1.2.4 Quality parameters

- Protein content percentage of maize grain was not significantly influenced by different weed control measures.

6.1.2.4 Economics

- Irrespective of the years hand weeding twice at 20 and 40 DAS recorded the highest gross returns (66,265 and 72,305 ₹/ha) and net returns (27,229 and 32,830 ₹/ha). However, highest benefit: cost ratio (1.86 and 2.00) was observed with application of atrazine @ 1.0 kg a.i./ha.

6.2 Berseem

6.2.1 Weed flora

- The dominant weed flora of the experimental plot consisted of *Rumex dentatus*, *Chenopodium album*, *Cichorium intybus*, *Melilotus alba*, *Melilotus indica*, *Trifolium resupinatum*, *Rumex dentatus*, *Coronopus didymus*, *Chenopodium album*, *Poa annua* and *Cyperus rotundus* in berseem.

6.2.2 Effect of tillage practices

6.2.2.1 Weed indices

- At 25, 45, 65 and 85 DAS significantly lower weed density and dry weight was recorded with conventional tillage - conventional tillage over rest of the tillage practices.

6.2.2.2 Growth and development

- Conventional tillage - conventional tillage in first and second year recorded the highest berseem dry weight (at 1st, 2nd and 3rd Cut) and plant height (at harvest) compared to zero tillage - conventional tillage, conventional tillage - zero tillage and zero tillage - zero tillage.

6.2.2.3 Yield attributes and yield

- Highest number of effective tillers/m² (262.97 and 269.83 /m²) and test weight (3.30 and 3.52 g) of berseem were obtained with conventional tillage - conventional tillage.

- The response of tillage practices to green fodder, seed, straw, dry matter and crude protein yield of berseem was quadratic in nature. During individual year in compared to other tillage practices conventional tillage - conventional tillage produced the highest green fodder (414.27 and 427.59 q/ha), seed (4.52 and 4.99 q/ha), straw (20.53 and 23.07 q/ha), dry matter (37.25 and 40.71 q/ha) and crude protein (8.10 and 8.92 q/ha) yield.

6.2.2.4 Quality parameters

- Different tillage practices had no significant impact on crude protein content of berseem.

6.2.2.5 Economics

- Across the years of investigation, treatment combinations conventional tillage - conventional tillage recorded the highest gross returns (1,18,950 and 1,28,547 ₹/ha), net returns (59,300 and 68,535 ₹/ha) and benefit: cost ratio (1.99 and 2.14) over other tillage practices.

6.2.3 Weed control measures

6.2.3.1 Weed indices

- Four hand weeding at 20, 40, 60 and 80 DAS recorded significantly lower weed density and dry weight in berseem compared to application of imazethapyr @ 0.1 kg a.i./ha, pendimethalin + imazethapyr @ 0.75 kg a.i./ha and weedy check.
- Irrespective of the years, four hand weeding at 20, 40, 60 and 80 DAS recorded higher weed control efficiency at 25, 45, 65 and 85 DAS. Whereas, the lower weed index was observed with post-emergence application of imazethapyr @ 0.1 kg a.i./ha.

6.2.3.2 Growth and development

- Different weed control measures have shown significant variation on dry weight and plant height of berseem. After four hand weeding treatment, post-emergence application of imazethapyr @ 0.1 kg a.i./ha

recorded the highest berseem dry weight (at 1st , 2nd and 3rd Cut) and plant height (at harvest).

6.2.3.3 Yield attributes and yield

- Four hand weeding at 20, 40, 60 and 80 DAS and application of imazethapyr @ 0.1 kg a.i./ha significantly improved yield attributing parameters compared to weedy check. Highest number of effective tillers/m² (268.45 and 275.50 /m²) and test weight (3.29 and 3.61 g) of berseem were noted with four hand weeding.
- Marked variation by weed control measures was observed on green fodder, seed, straw, dry matter and crude protein yield of berseem. During both the years in compared to rest of the weed control approaches four hand weeding at 20, 40, 60 and 80 DAS produced the highest green fodder (432.17 and 447.13 q/ha), seed (5.34 and 5.73 q/ha), straw (21.27 and 23.74 q/ha), dry matter (41.07 and 45.44 q/ha) and crude protein (9.04 and 10.08 q/ha) yield.

6.2.2.4 Quality parameters

- Crude protein content of berseem was higher with four hand weeding at 20, 40, 60 and 80 DAS and was found at par with application of imazethapyr @ 0.1 kg a.i./ha.

6.2.2.5 Economics

- Application of imazethapyr @ 0.1 kg a.i./ha fetched maximum net returns (66,066 and 74,325 ₹/ha) and benefit: cost ratio (2.21 and 2.35) during both the years. While, the highest gross returns (1,33,930 and 1,42,289 ₹/ha) was observed with four hand weeding at 20, 40, 60 and 80 DAS.

6.3 Maize - Berseem Cropping System

- Conventionally tilled both maize and berseem produced highest maize equivalent yield (103.72 and 112.63 q/ha), gross returns (1,80,830 and 1,95,890 ₹/ha), net returns (86,539 and 1,00,836 ₹/ha) and benefit: cost ratio (1.92 and 2.06) which was comparatively higher than the rest of the tillage practices.

- Among all the weed control measures, two hand weeding at 20 and 40 DAS in maize and four hand weeding at 20, 40, 60 and 80 DAS in berseem resulted in higher maize equivalent yield (115.61 and 124.00 q/ha), gross returns (2,00,195 and 2,14,594 ₹/ha) and net returns (91,288 and 1,04,848 ₹/ha). However, higher benefit: cost ratio (2.01 and 2.13) was obtained with application of 2, 4-D @ 0.75 kg a.i./ha in maize and application of imazethapyr @ 0.1 kg a.i./ha in berseem.
- During first year after the end of first cropping sequence organic carbon, bulk density and partical density of soil did not vary significantly under different tillage practices. However, during second year the value of aforesaid soil parameters were highest under zero tillage - zero tillage.
- Various weed control approaches failed to record perceptible variation in organic carbon, bulk density and partical density of soil during first year. While, end of second cropping sequence weedy check treatment recorded the highest organic carbon.

6.4 Conclusion

On the basis of result obtained from the experiment conducted for two successive years (2015-16 and 2016-17) in Maize - Berseem cropping system. The following conclusions are drawn-

- It is inferred that among various tillage practices adoption of conventional tillage in maize and berseem has produced highest maize equivalent yield, gross returns, net returns and benefit: cost ratio compared to conventional tillage - zero tillage, zero tillage - zero tillage and zero tillage - conventional tillage.
- Two hand weeding at 20 and 40 DAS in maize and four hand weeding at 20, 40, 60 and 80 DAS in berseem recorded higher maize equivalent yield, gross returns and net returns. Nevertheless, higher benefit: cost ratio was registered with application of 2,4-D @ 0.75 kg a.i./ha in maize and application of imazethapyr @ 0.1 kg a.i./ha in berseem.

- The impact of tillage practices on soil properties was reflected in second year. Practicing zero tillage in maize and berseem has increased the soil organic carbon, bulk and partical density and decreased the pH and electrical conductivity.

6.5 Suggestions for further work

Future research could be proposed on the following lines for strengthening the recommendation in respect of tillage practices and weed control measures for Maize - Berseem cropping system.

1. This investigation should be continued at least for five years for getting a firm recommendation.
2. Effect of herbicide usage on microbial population and soil quality.
3. Weed seed bank studies in Maize - Berseem cropping system.
4. Herbicide residue analysis of berseem harvested green fodder.

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APPENDIX - I

Maize cost of cultivation during 2015 (₹/ha)

Operations	Treatments															
	T ₁ W ₁	T ₁ W ₂	T ₁ W ₃	T ₁ W ₄	T ₂ W ₁	T ₂ W ₂	T ₂ W ₃	T ₂ W ₄	T ₃ W ₁	T ₃ W ₂	T ₃ W ₃	T ₃ W ₄	T ₄ W ₁	T ₄ W ₂	T ₄ W ₃	T ₄ W ₄
Land preparation	3000	3000	3000	3000	3000	3000	3000	3000	0	0	0	0	0	0	0	0
Seed	2200	2200	2200	2200	2200	2200	2200	2200	2200	2200	2200	2200	2200	2200	2200	2200
Sowing	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500
Fertilizer cost	5769	5769	5769	5769	5769	5769	5769	5769	5769	5769	5769	5769	5769	5769	5769	5769
Fertilizer application	600	600	600	600	600	600	600	600	600	600	600	600	600	600	600	600
Irrigation	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000
Hand weeding	0	0	8000	0	0	0	8000	0	0	0	8000	0	0	0	8000	0
Herbicide cost	640	473	0	0	640	473	0	0	640	473	0	0	640	473	0	0
Herbicide application	200	200	0	0	200	200	0	0	200	200	0	0	200	200	0	0
Bird scaring	6000	6000	6000	6000	6000	6000	6000	6000	6000	6000	6000	6000	6000	6000	6000	6000
Harvesting	2400	2400	2400	2400	2400	2400	2400	2400	2400	2400	2400	2400	2400	2400	2400	2400
Dehusking	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000
Shelling and Grading	4303	3380	4755	2738	3919	3356	4648	2576	3037	2860	3050	2361	2853	2596	3815	2531
Total	33612	32522	41224	31207	33228	32498	41117	31045	29346	29002	36519	27830	29162	28738	37284	28000

APPENDIX - II

Maize cost of cultivation during 2016 (₹/ha)

Operations	Treatments															
	T ₁ W ₁	T ₁ W ₂	T ₁ W ₃	T ₁ W ₄	T ₂ W ₁	T ₂ W ₂	T ₂ W ₃	T ₂ W ₄	T ₃ W ₁	T ₃ W ₂	T ₃ W ₃	T ₃ W ₄	T ₄ W ₁	T ₄ W ₂	T ₄ W ₃	T ₄ W ₄
Land preparation	3000	3000	3000	3000	3000	3000	3000	3000	0	0	0	0	0	0	0	0
Seed	2200	2200	2200	2200	2200	2200	2200	2200	2200	2200	2200	2200	2200	2200	2200	2200
Sowing	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500
Fertilizer cost	5769	5769	5769	5769	5769	5769	5769	5769	5769	5769	5769	5769	5769	5769	5769	5769
Fertilizer application	600	600	600	600	600	600	600	600	600	600	600	600	600	600	600	600
Irrigation	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000
Hand weeding	0	0	8000	0	0	0	8000	0	0	0	8000	0	0	0	8000	0
Herbicide cost	640	473	0	0	640	473	0	0	640	473	0	0	640	473	0	0
Herbicide application	200	200	0	0	200	200	0	0	200	200	0	0	200	200	0	0
Bird scaring	6000	6000	6000	6000	6000	6000	6000	6000	6000	6000	6000	6000	6000	6000	6000	6000
Harvesting	2400	2400	2400	2400	2400	2400	2400	2400	2400	2400	2400	2400	2400	2400	2400	2400
Dehusking	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000
Shelling and Grading	4892	3757	5353	2777	4431	3562	5076	2587	3101	2793	3449	2427	3272	2817	4147	2678
Total	34201	32899	41822	31246	33740	32704	41545	31056	29410	28935	36918	27896	29581	28959	37616	28147

APPENDIX - III

Input cost in maize

S. No.	Particulars	Input/unit	Rate (₹/unit)	Cost (₹/ha)
1.	Land preparation			
	(a) Ploughing	Once	700	700
	(b) Harrowing	Thrice	700	2100
	(c) Planking	Once	200	200
2.	Seed	20 kg	110	2200
3.	Sowing	Seed drill	700	1400
		(2 hours)		
		0.5 man-day	200	100
4.	Fertilizer			
	(a) N through urea	326 kg	5.60	1826
	(b) P through SSP	375 kg	8.56	3210
	(c) K through MOP	66.66 kg	11	733
	(d) Application cost	Thrice	200	600
		(3 man-days)		
5.	Irrigation	Twice	2500	5000
6.	Hand weeding	Twice	200	8000
		(40 man-days)		
7.	Herbicide			
	(a) Atrazine	2 kg	320	640
	(b) 2,4-D	1.97 litre	240	473
	(c) Application cost	1 man-day	200	200
8.	Bird scaring	30 man-days	200	6000
9.	Harvesting	12 man-days	200	2400
10.	Dehusking	10 man-days	200	2000
11.	Shelling and Grading	Once	133	133
	(₹/q)			

APPENDIX - IV

Berseem cost of cultivation during 2015-16 (₹/ha)

Operations	Treatments															
	T ₁ W ₁	T ₁ W ₂	T ₁ W ₃	T ₁ W ₄	T ₂ W ₁	T ₂ W ₂	T ₂ W ₃	T ₂ W ₄	T ₃ W ₁	T ₃ W ₂	T ₃ W ₃	T ₃ W ₄	T ₄ W ₁	T ₄ W ₂	T ₄ W ₃	T ₄ W ₄
land preparation	3000	3000	3000	3000	0	0	0	0	0	0	0	0	3000	3000	3000	3000
seed	3160	3160	3160	3160	3160	3160	3160	3160	3160	3160	3160	3160	3160	3160	3160	3160
sowing	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500
Fertilizer cost	4186	4186	4186	4186	4186	4186	4186	4186	4186	4186	4186	4186	4186	4186	4186	4186
Fertilizer application	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200
Irrigation	25000	25000	25000	25000	25000	25000	25000	25000	25000	25000	25000	25000	25000	25000	25000	25000
Hand weeding	0	0	16000	0	0	0	16000	0	0	0	16000	0	0	0	16000	0
Herbicide cost	1163	1100	0	0	1163	1100	0	0	1163	1100	0	0	1163	1100	0	0
Herbicide application	200	200	0	0	200	200	0	0	200	200	0	0	200	200	0	0
GFY	11000	11000	11000	11000	11000	11000	11000	11000	11000	11000	11000	11000	11000	11000	11000	11000
Harvesting																
Seed	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000
Harvesting																
Threshing	1759	2138	2218	1460	1317	1815	2105	1136	1357	1726	2023	687	1773	1975	2227	1168
Grading	971	1180	1224	805	727	1001	1161	627	749	952	1116	379	978	1090	1229	644
Total	56139	56664	71487	54311	52453	53162	68312	50809	52515	53024	68185	50112	56160	56411	71502	53859

APPENDIX - V

Berseem cost of cultivation during 2016-17 (₹/ha)

Operations	Treatments															
	T ₁ W ₁	T ₁ W ₂	T ₁ W ₃	T ₁ W ₄	T ₂ W ₁	T ₂ W ₂	T ₂ W ₃	T ₂ W ₄	T ₃ W ₁	T ₃ W ₂	T ₃ W ₃	T ₃ W ₄	T ₄ W ₁	T ₄ W ₂	T ₄ W ₃	T ₄ W ₄
land preparation	3000	3000	3000	3000	0	0	0	0	0	0	0	0	3000	3000	3000	3000
seed	3160	3160	3160	3160	3160	3160	3160	3160	3160	3160	3160	3160	3160	3160	3160	3160
sowing	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500
Fertilizer cost	4186	4186	4186	4186	4186	4186	4186	4186	4186	4186	4186	4186	4186	4186	4186	4186
Fertilizer application	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200
Irrigation (10)	25000	25000	25000	25000	25000	25000	25000	25000	25000	25000	25000	25000	25000	25000	25000	25000
Hand weeding	0	0	16000	0	0	0	16000	0	0	0	16000	0	0	0	16000	0
Herbicide cost	1163	1100	0	0	1163	1100	0	0	1163	1100	0	0	1163	1100	0	0
Herbicide application	200	200	0	0	200	200	0	0	200	200	0	0	200	200	0	0
GFY	11000	11000	11000	11000	11000	11000	11000	11000	11000	11000	11000	11000	11000	11000	11000	11000
Harvesting																
Seed	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000
Harvesting																
Threshing	1974	2167	2538	1829	1523	2320	2320	1208	1506	1901	2336	1474	1966	2111	2409	1643
Grading	1089	1196	1400	1009	840	1280	1280	667	831	1049	1289	813	1084	1164	1329	907
Total	56472	56709	71984	54884	52772	53946	68646	50921	52747	53296	68671	51334	56459	56621	71784	54596

APPENDIX - VI

Input cost in berseem

S. No.	Particulars	Input/unit	Rate (₹/unit)	Cost (₹/ha)
1.	Land preparation			
	(a) Ploughing	Once	700	700
	(b) Harrowing	Thrice	700	2100
	(c) Planking	Once	200	200
2.	Seed	20 kg	158	3160
3.	Sowing	Seed drill	700	1500
		(2 hours)		
		0.5 man-day	200	100
4.	Fertilizer			
	(a) N through urea	43.47	5.60	243
	(b) P through SSP	375 kg	8.56	3210
	(c) K through MOP	66.66 kg	11	733
	(d) Application cost	Once	200	200
		(1 man-day)		
5.	Irrigation	10 times	2500	25000
6.	Hand weeding	4 times	200	16000
		(80 man-days)		
7.	Herbicide			
	(a) Pendimethalin	2.3 litre	505	1163
	+			
	Imazethapyr			
	(b) Imazethapyr	1 litre	1100	1100
	(c) Application cost	1 man-day	200	200
8.	GFY Harvesting	(30 man-days)	200	6000
9.	Seed Harvesting	(20 man-days)	200	4000
10.	Threshing (₹/q)	Once	483	483
11.	Grading (₹/q)	Once	267	267

APPENDIX - VII

Interaction effect of tillage practices and weed control measures on grain yield (q/ha) of maize

Weed control measures	Tillage practices									
	2015					2016				
	CT- CT	CT- ZT	ZT- ZT	ZT- CT	Mean	CT- CT	CT- ZT	ZT- ZT	ZT- CT	Mean
Atrazine @ 1 kg a.i./ha	32.35	29.47	22.83	21.45	26.53	36.78	33.32	23.32	24.60	29.50
2,4-D @ 0.75 kg a.i./ha	25.42	25.23	21.50	19.52	22.92	28.25	26.78	21.00	21.18	24.30
Hand weeding (20 and 40 DAS)	35.75	34.95	22.93	28.68	30.58	40.25	38.17	25.93	31.18	33.88
Weedy check	20.58	19.37	17.75	19.03	19.18	20.88	19.45	18.25	20.13	19.68
Mean	28.53	27.25	21.25	22.17		31.54	29.43	22.13	24.28	
	S.Em. ±		C.D. (P = 0.05)			S.Em. ±		C.D. (P = 0.05)		
Main treatment means	0.15		0.53			0.17		0.57		
Sub treatment means	0.14		0.40			0.17		0.49		
Sub treatment means at same level of main treatment	0.31		0.85			0.33		1.03		
Main treatment means at same level or different levels of sub treatments	0.28		0.88			0.34		1.03		

APPENDIX - VIII

Interaction effect of tillage practices and weed control measures on grain yield (q/ha) of maize

Weed control measures	Tillage practices				
	Pooled				
	CT- CT	CT- ZT	ZT- ZT	ZT- CT	Mean
Atrazine @ 1 kg a.i./ha	34.57	31.39	23.08	23.03	28.01
2,4-D @ 0.75 kg a.i./ha	26.83	26.01	21.25	20.35	23.61
Hand weeding (20 and 40 DAS)	38.00	36.56	24.43	29.93	32.23
Weedy check	20.73	19.41	18.00	19.58	19.43
Mean	30.03	28.34	21.69	23.22	
	S.Em. $\pm$		C.D. (P = 0.05)		
Main treatment means	0.11		0.35		
Sub treatment means	0.11		0.31		
Sub treatment means at same level of main treatment	0.22		0.63		
Main treatment means at same level or different levels of sub treatments	0.22		0.64		

APPENDIX - IX

Interaction effect of tillage practices and weed control measures on stover yield (q/ha) of maize

Weed control measures	Tillage practices									
	2015					2016				
	CT- CT	CT- ZT	ZT- ZT	ZT- CT	Mean	CT- CT	CT- ZT	ZT- ZT	ZT- CT	Mean
Atrazine @ 1 kg a.i./ha	66.02	62.95	59.80	58.18	61.74	71.02	65.13	58.93	61.12	64.05
2,4-D @ 0.75 kg a.i./ha	58.35	55.63	54.42	56.82	56.30	60.35	57.97	55.30	57.45	57.77
Hand weeding (20 and 40 DAS)	77.55	75.37	54.67	64.37	67.99	82.55	78.70	59.88	65.27	71.60
Weedy check	52.65	46.13	50.53	48.32	49.41	53.15	46.88	50.87	50.75	50.41
Mean	63.64	60.02	54.85	56.92		66.77	62.17	56.25	58.65	
	S.Em. $\pm$		C.D. (P = 0.05)			S.Em. $\pm$		C.D. (P = 0.05)		
Main treatment means	0.52		1.81			0.41		1.44		
Sub treatment means	0.33		0.96			0.46		1.36		
Sub treatment means at same level of main treatment	1.05		2.12			0.83		2.84		
Main treatment means at same level or different levels of sub treatments	0.78		2.48			0.91		2.77		

APPENDIX - X

Interaction effect of tillage practices and weed control measures on stover yield (q/ha) of maize

Weed control measures	Tillage practices				
	Pooled				
	CT- CT	CT- ZT	ZT- ZT	ZT- CT	Mean
Atrazine @ 1 kg a.i./ha	68.52	64.04	59.37	59.65	62.89
2,4-D @ 0.75 kg a.i./ha	59.35	56.80	54.86	57.13	57.04
Hand weeding (20 and 40 DAS)	80.05	77.03	57.28	64.82	69.79
Weedy check	52.90	46.51	50.70	49.53	49.91
Mean	65.20	61.10	55.55	57.78	
	S.Em. $\pm$		C.D. (P = 0.05)		
Main treatment means	0.33		1.03		
Sub treatment means	0.29		0.81		
Sub treatment means at same level of main treatment	0.57		1.62		
Main treatment means at same level or different levels of sub treatments	0.60		1.75		

APPENDIX - XI

Interaction effect of tillage practices and weed control measures on green fodder yield (q/ha) of berseem

Weed control measures	Tillage practices									
	2015-16					2016-17				
	CT- CT	CT- ZT	ZT- ZT	ZT- CT	Mean	CT- CT	CT- ZT	ZT- ZT	ZT- CT	Mean
Pendimethalin + Imazethapyr @ 0.75 kg a.i./ha	398.77	373.52	353.97	386.05	378.08	403.52	376.25	353.55	394.22	381.88
Imazethapyr @ 0.1 kg a.i./ha	424.12	399.48	382.33	415.62	405.39	452.37	420.58	402.92	435.55	427.85
Hand weeding (20, 40, 60 and 80 DAS)	454.78	416.28	410.97	446.63	432.17	471.27	443.03	418.63	455.58	447.13
Weedy check	379.42	354.58	340.78	361.85	359.16	383.20	353.68	340.42	368.93	361.56
Mean	414.27	385.97	372.01	402.54		427.59	398.39	378.88	413.57	
	S.Em. ±		C.D. (P = 0.05)			S.Em. ±		C.D. (P = 0.05)		
Main treatment means	2.46		8.51			2.04		7.05		
Sub treatment means	1.61		4.69			2.06		6.02		
Sub treatment means at same level of main treatment	4.92		NS			4.05		NS		
Main treatment means at same level or different levels of sub treatments	3.71		NS			4.11		NS		

APPENDIX - XII

Interaction effect of tillage practices and weed control measures on green fodder yield (q/ha) of berseem

Weed control measures	Tillage practices				
	Pooled				
	CT- CT	CT- ZT	ZT- ZT	ZT- CT	Mean
Pendimethalin + Imazethapyr @ 0.75 kg a.i./ha	401.14	374.88	353.76	390.13	379.98
Imazethapyr @ 0.1 kg a.i./ha	438.24	410.03	392.63	425.58	416.62
Hand weeding (20, 40, 60 and 80 DAS)	463.03	429.66	414.80	451.11	439.65
Weedy check	381.31	354.13	340.60	365.39	360.36
Mean	420.93	392.18	375.45	408.05	
	S.Em. $\pm$			C.D. (P = 0.05)	
Main treatment means	1.60			4.92	
Sub treatment means	1.31			3.72	
Sub treatment means at same level of main treatment	2.62			7.45	
Main treatment means at same level or different levels of sub treatments	2.77			8.11	

APPENDIX - XIII

Interaction effect of tillage practices and weed control measures on seed yield (q/ha) of berseem

Weed control measures	Tillage practices									
	2015-16					2016-17				
	CT- CT	CT- ZT	ZT- ZT	ZT- CT	Mean	CT- CT	CT- ZT	ZT- ZT	ZT- CT	Mean
Pendimethalin + Imazethapyr @ 0.75 kg a.i./ha	4.02	3.07	2.98	3.77	3.46	4.72	2.98	3.02	4.23	3.74
Imazethapyr @ 0.1 kg a.i./ha	5.17	4.50	4.42	4.92	4.75	5.67	4.77	4.67	5.33	5.11
Hand weeding (20, 40, 60 and 80 DAS)	5.62	5.07	5.02	5.65	5.34	5.97	5.83	5.53	5.57	5.73
Weedy check	3.27	2.45	1.63	2.75	2.53	3.62	2.43	1.40	3.10	2.64
Mean	4.52	3.77	3.51	4.27		4.99	4.00	3.65	4.56	
	S.Em. ±		C.D. (P = 0.05)			S.Em. ±		C.D. (P = 0.05)		
Main treatment means	0.05		0.19			0.08		0.26		
Sub treatment means	0.09		0.25			0.07		0.19		
Sub treatment means at same level of main treatment	0.11		NS			0.15		0.41		
Main treatment means at same level or different levels of sub treatments	0.16		NS			0.14		0.427		

APPENDIX - XIV

Interaction effect of tillage practices and weed control measures on seed yield (q/ha) of berseem

Weed control measures	Tillage practices				
	Pooled				
	CT- CT	CT- ZT	ZT- ZT	ZT- CT	Mean
Pendimethalin + Imazethapyr @ 0.75 kg a.i./ha	4.37	3.03	3.00	4.00	3.60
Imazethapyr @ 0.1 kg a.i./ha	5.42	4.63	4.54	5.13	4.93
Hand weeding (20, 40, 60 and 80 DAS)	5.79	5.45	5.28	5.61	5.53
Weedy check	3.44	2.44	1.52	2.93	2.58
Mean	4.75	3.89	3.58	4.42	
		S.Em. $\pm$		C.D. (P = 0.05)	
Main treatment means		0.05		0.14	
Sub treatment means		0.05		0.15	
Sub treatment means at same level of main treatment		0.11		0.31	
Main treatment means at same level or different levels of sub treatments		0.10		0.29	

APPENDIX - XV

Interaction effect of tillage practices and weed control measures on straw yield (q/ha) of berseem

Weed control measures	Tillage practices									
	2015-16					2016-17				
	CT- CT	CT- ZT	ZT- ZT	ZT- CT	Mean	CT- CT	CT- ZT	ZT- ZT	ZT- CT	Mean
Pendimethalin + Imazethapyr @ 0.75 kg a.i./ha	19.25	13.93	11.50	15.70	15.10	21.07	15.55	13.20	16.75	16.64
Imazethapyr @ 0.1 kg a.i./ha	19.52	16.88	15.98	18.18	17.64	24.37	18.23	16.57	20.45	19.90
Hand weeding (20, 40, 60 and 80 DAS)	25.92	19.67	17.98	21.52	21.27	28.33	22.05	20.87	23.70	23.74
Weedy check	17.45	7.15	6.82	12.03	10.86	18.50	7.43	5.90	15.25	11.77
Mean	20.53	14.41	13.07	16.86		23.07	15.82	14.13	19.04	
	S.Em. ±		C.D. (P = 0.05)			S.Em. ±		C.D. (P = 0.05)		
Main treatment means	0.24		0.83			0.31		1.06		
Sub treatment means	0.31		0.90			0.32		0.94		
Sub treatment means at same level of main treatment	0.48		1.88			0.61		1.99		
Main treatment means at same level or different levels of sub treatments	0.59		1.78			0.64		1.96		

APPENDIX - XVI

Interaction effect of tillage practices and weed control measures on straw yield (q/ha) of berseem

Weed control measures	Tillage practices				
	Pooled				
	CT- CT	CT- ZT	ZT- ZT	ZT- CT	Mean
Pendimethalin + Imazethapyr @ 0.75 kg a.i./ha	20.16	14.74	12.35	16.23	15.87
Imazethapyr @ 0.1 kg a.i./ha	21.94	17.56	16.28	19.32	18.77
Hand weeding (20, 40, 60 and 80 DAS)	27.13	20.86	19.43	22.61	22.50
Weedy check	17.98	7.29	6.36	13.64	11.32
Mean	21.80	15.11	13.60	17.95	
	S.Em. $\pm$		C.D. (P = 0.05)		
Main treatment means	0.19		0.60		
Sub treatment means	0.22		0.64		
Sub treatment means at same level of main treatment	0.45		1.28		
Main treatment means at same level or different levels of sub treatments	0.43		1.25		

APPENDIX – XVII

Mean sum of squares for grassy weed density (2015 and 2016)

Source of variation	d.f.	Grassy weed density (No. /m ²)					
		30 DAS		60 DAS		At harvest	
		2015	2016	2015	2016	2015	2016
Replication	2	0.301	0.222	0.205	0.089	0.205	0.124
Tillage practices (T)	3	1.849**	18.223**	1.416**	9.208**	1.262**	6.612**
Error (a)	6	0.027	0.022	0.094	0.056	0.025	0.026
Weed control (W)	3	147.934**	177.769**	136.269**	171.558**	137.632**	155.526**
T*W	9	0.110 ^{NS}	0.443**	0.048 ^{NS}	0.364**	0.082 ^{NS}	0.302**
Error (b)	24	0.082	0.044	0.056	0.022	0.041	0.069

NS – Non Significant, *– Significant at p = 0.05, **– Significant at p = 0.01

APPENDIX – XVIII

Mean sum of squares for grassy weed density (Pooled)

Source of variation	d.f.	Grassy weed density (No. /m ²)		
		30 DAS	60 DAS	At harvest
Year (Y)	1	0.292	0.115	0.082
Replication within year	4	0.261	0.147	0.164
Tillage practices (T)	3	15.837**	8.884**	6.811**
Y*T	3	4.235	1.741	1.062
Error (a)	12	0.024	0.075	0.025
Weed control (W)	3	324.670**	306.281**	292.480**
Y*W	3	1.034	1.547	0.678
T*W	9	0.458**	0.219**	0.160**
Y* T* W	9	0.095	0.193	0.224
Error (b)	48	0.063	0.039	0.055

NS – Non Significant, *– Significant at p = 0.05, **– Significant at p = 0.01

APPENDIX – XIX

Mean sum of squares for broad leaf weed density (2015 and 2016)

Source of variation	d.f.	Broad leaf weed density (No. /m ²)					
		30 DAS		60 DAS		At harvest	
		2015	2016	2015	2016	2015	2016
Replication	2	0.260	0.014	0.091	0.042	0.165	0.099
Tillage practices (T)	3	0.135 ^{NS}	0.421 ^{**}	0.198 ^{NS}	0.412 ^{**}	0.147 ^{NS}	0.602 ^{**}
Error (a)	6	0.036	0.017	0.043	0.037	0.076	0.050
Weed control (W)	3	64.262 ^{**}	81.322 ^{**}	65.008 ^{**}	79.314 ^{**}	61.607 ^{**}	72.722 ^{**}
T*W	9	0.070 ^{NS}	0.110 [*]	0.046 ^{NS}	0.070 ^{**}	0.053 ^{NS}	0.101 ^{NS}
Error (b)	24	0.032	0.036	0.085	0.019	0.070	0.047

NS – Non Significant, *– Significant at p = 0.05, **– Significant at p = 0.01

APPENDIX – XX

Mean sum of squares for broad leaf weed density (Pooled)

Source of variation	d.f.	Broad leaf weed density (No. /m ²)		
		30 DAS	60 DAS	At harvest
Year (Y)	1	4.062	2.368	1.747
Replication within year	4	0.137	0.066	0.132
Tillage practices (T)	3	0.487 ^{**}	0.546 ^{**}	0.578 ^{**}
Y*T	3	0.068	0.063	0.171
Error (a)	12	0.026	0.040	0.063
Weed control (W)	3	145.083 ^{**}	143.964 ^{**}	134.097 ^{**}
Y*W	3	0.502	0.358	0.232
T*W	9	0.159 ^{**}	0.051 ^{NS}	0.094 ^{NS}
Y* T* W	9	0.021	0.065	0.060
Error (b)	48	0.034	0.052	0.059

NS – Non Significant, *– Significant at p = 0.05, **– Significant at p = 0.01

APPENDIX – XXI

Mean sum of squares for sedges weed density (2015 and 2016)

Source of variation	d.f.	Sedges weed density (No. /m ²)					
		30 DAS		60 DAS		At harvest	
		2015	2016	2015	2016	2015	2016
Replication	2	0.283	0.308	0.266	0.288	0.053	0.011
Tillage practices (T)	3	0.475**	1.349**	0.747*	3.078**	0.606**	2.798**
Error (a)	6	0.047	0.030	0.108	0.013	0.060	0.037
Weed control (W)	3	36.276**	45.381**	35.460**	50.648**	32.815**	49.113**
T*W	9	0.098 ^{NS}	0.549**	0.046 ^{NS}	0.594**	0.209*	0.759**
Error (b)	24	0.052	0.064	0.050	0.038	0.082	0.081

NS – Non Significant, *– Significant at p = 0.05, **– Significant at p = 0.01

APPENDIX – XXII

Mean sum of squares for sedges weed density (Pooled)

Source of variation	d.f.	Sedges weed density (No. /m ²)		
		30 DAS	60 DAS	At harvest
Year (Y)	1	0.035	0.001	0.054
Replication within year	4	0.296	0.277	0.032
Tillage practices (T)	3	1.700**	3.416**	2.990**
Y*T	3	0.125	0.409	0.414
Error (a)	12	0.038	0.061	0.048
Weed control (W)	3	81.279**	85.311**	81.013**
Y*W	3	0.378	0.796	0.915
T*W	9	0.440**	0.402**	0.656**
Y* T* W	9	0.207	0.239	0.312
Error (b)	48	0.058	0.044	0.081

NS – Non Significant, *– Significant at p = 0.05, **– Significant at p = 0.01

APPENDIX – XXIII

Mean sum of squares for total weed density (2015 and 2016)

Source of variation	d.f.	Total weed density (No. /m ²)					
		30 DAS		60 DAS		At harvest	
		2015	2016	2015	2016	2015	2016
Replication	2	0.672	0.205	0.061	0.026	0.014	0.091
Tillage practices (T)	3	1.227**	11.432**	1.161**	7.750**	1.124**	5.675**
Error (a)	6	0.032	0.037	0.034	0.075	0.010	0.010
Weed control (W)	3	250.314**	300.996**	237.663**	299.632**	232.129**	274.580**
T*W	9	0.065 ^{NS}	0.326**	0.090**	0.539**	0.083 ^{NS}	0.709**
Error (b)	24	0.056	0.028	0.013	0.023	0.036	0.062

NS – Non Significant, *– Significant at p = 0.05, **– Significant at p = 0.01

APPENDIX – XXIV

Mean sum of squares for total weed density (Pooled)

Source of variation	d.f.	Total weed density (No. /m ²)		
		30 DAS	60 DAS	At harvest
Year (Y)	1	1.392	0.810	0.145
Replication within year	4	0.439	0.044	0.052
Tillage practices (T)	3	10.022**	7.450**	5.862**
Y*T	3	2.637	1.461	0.937
Error (a)	12	0.034	0.054	0.010
Weed control (W)	3	549.731**	534.946**	505.350**
Y*W	3	1.579	2.349	1.359
T*W	9	0.315**	0.344**	0.428**
Y* T* W	9	0.077	0.285	0.365
Error (b)	48	0.042	0.018	0.049

NS – Non Significant, *– Significant at p = 0.05, **– Significant at p = 0.01

APPENDIX – XXV

Mean sum of squares for grassy weed dry weight (2015 and 2016)

Source of variation	d.f.	Grassy weed dry weight (g/m ²)					
		30 DAS		60 DAS		At harvest	
		2015	2016	2015	2016	2015	2016
Replication	2	0.015	0.055	0.103	0.019	0.102	0.062
Tillage practices (T)	3	0.497**	4.448**	0.758**	2.899**	0.520**	2.843**
Error (a)	6	0.012	0.007	0.013	0.011	0.010	0.007
Weed control (W)	3	39.315**	47.484**	49.493**	60.263**	53.443**	60.429**
T*W	9	0.025 ^{NS}	0.076**	0.025 ^{NS}	0.100**	0.026 ^{NS}	0.205**
Error (b)	24	0.024	0.012	0.036	0.011	0.035	0.033

NS – Non Significant, *– Significant at p = 0.05, **– Significant at p = 0.01

APPENDIX – XXVI

Mean sum of squares for grassy weed dry weight (Pooled)

Source of variation	d.f.	Grassy weed dry weight (g/m ²)		
		30 DAS	60 DAS	At harvest
Year (Y)	1	0.006	0.057	0.018
Replication within year	4	0.035	0.061	0.082
Tillage practices (T)	3	3.955**	3.276**	2.891**
Y*T	3	0.990	0.380	0.471
Error (a)	12	0.009	0.012	0.009
Weed control (W)	3	86.532**	109.308**	113.615**
Y*W	3	0.267	0.449	0.257
T*W	9	0.085**	0.079**	0.111**
Y* T* W	9	0.016	0.047	0.120
Error (b)	48	0.018	0.023	0.034

NS – Non Significant, *– Significant at p = 0.05, **– Significant at p = 0.01

APPENDIX – XXVII

Mean sum of squares for broad leaf weed dry weight (2015 and 2016)

Source of variation	d.f.	Broad leaf weed dry weight (g/m ²)					
		30 DAS		60 DAS		At harvest	
		2015	2016	2015	2016	2015	2016
Replication	2	0.040	0.014	0.056	0.011	0.018	0.009
Tillage practices (T)	3	0.033 ^{NS}	0.104**	0.051 ^{NS}	0.113**	0.043 ^{NS}	0.336**
Error (a)	6	0.009	0.008	0.012	0.011	0.021	0.018
Weed control (W)	3	16.789**	19.920**	20.979**	25.379**	17.682**	21.821**
T*W	9	0.004 ^{NS}	0.044*	0.011 ^{NS}	0.020**	0.009 ^{NS}	0.034**
Error (b)	24	0.030	0.019	0.023	0.005	0.011	0.005

NS – Non Significant, *– Significant at p = 0.05, **– Significant at p = 0.01

APPENDIX – XVIII

Mean sum of squares for broad leaf weed dry weight (Pooled)

Source of variation	d.f.	Broad leaf weed dry weight (g/m ²)		
		30 DAS	60 DAS	At harvest
Year (Y)	1	0.497	0.574	0.784
Replication within year	4	0.027	0.033	0.013
Tillage practices (T)	3	0.086**	0.139**	0.295**
Y*T	3	0.051	0.026	0.083
Error (a)	12	0.008	0.011	0.020
Weed control (W)	3	36.642**	46.253**	39.393**
Y*W	3	0.067	0.106	0.109
T*W	9	0.029 ^{NS}	0.012 ^{NS}	0.035**
Y* T* W	9	0.019	0.018	0.008
Error (b)	48	0.025	0.014	0.008

NS – Non Significant, *– Significant at p = 0.05, **– Significant at p = 0.01

APPENDIX – XXIX

Mean sum of squares for sedges weed dry weight (2015 and 2016)

Source of variation	d.f.	Sedges weed dry weight (g/m ²)					
		30 DAS		60 DAS		At harvest	
		2015	2016	2015	2016	2015	2016
Replication	2	0.0000	0.0004	0.068	0.066	0.014	0.035
Tillage practices (T)	3	0.0021**	0.0087**	0.158*	0.494**	0.084**	0.881**
Error (a)	6	0.0001	0.0000	0.025	0.003	0.005	0.023
Weed control (W)	3	0.0704**	0.0986**	9.233**	13.285**	7.517**	12.567**
T*W	9	0.0003**	0.0034**	0.013 ^{NS}	0.126**	0.004 ^{NS}	0.198**
Error (b)	24	0.0001	0.0000	0.011	0.009	0.010	0.008

NS – Non Significant, *– Significant at p = 0.05, **– Significant at p = 0.01

APPENDIX – XXX

Mean sum of squares for sedges weed dry weight (Pooled)

Source of variation	d.f.	Sedges weed dry weight (g/m ²)		
		30 DAS	60 DAS	At harvest
Year (Y)	1	0.0004	0.000	0.000
Replication within year	4	0.0002	0.067	0.024
Tillage practices (T)	3	0.0097**	0.594**	0.752**
Y*T	3	0.0011	0.059	0.213
Error (a)	12	0.0001	0.014	0.014
Weed control (W)	3	0.1677**	22.311**	19.740**
Y*W	3	0.0013	0.207	0.344
T*W	9	0.0027**	0.082**	0.122**
Y* T* W	9	0.0010	0.056	0.080
Error (b)	48	0.0001	0.010	0.009

NS – Non Significant, *– Significant at p = 0.05, **– Significant at p = 0.01

APPENDIX – XXXI

Mean sum of squares for total weed dry weight (2015 and 2016)

Source of variation	d.f.	Total weed dry weight (g/m ²)					
		30 DAS		60 DAS		At harvest	
		2015	2016	2015	2016	2015	2016
Replication	2	0.009	0.043	0.029	0.002	0.044	0.015
Tillage practices (T)	3	0.280**	3.336**	0.534**	2.207**	0.335**	2.096**
Error (a)	6	0.003	0.007	0.011	0.015	0.004	0.009
Weed control (W)	3	58.094**	69.712**	81.633**	101.278**	77.841**	95.028**
T*W	9	0.022*	0.121**	0.027 ^{NS}	0.137**	0.011 ^{NS}	0.254**
Error (b)	24	0.008	0.021	0.013	0.009	0.020	0.024

NS – Non Significant, *– Significant at p = 0.05, **– Significant at p = 0.01

APPENDIX – XXXII

Mean sum of squares for total weed dry weight (Pooled)

Source of variation	d.f.	Total weed dry weight (g/m ²)		
		30 DAS	60 DAS	At harvest
Year (Y)	1	0.200	0.286	0.093
Replication within year	4	0.026	0.016	0.029
Tillage practices (T)	3	2.747**	2.451**	2.040**
Y*T	3	0.869	0.290	0.392
Error (a)	12	0.005	0.013	0.006
Weed control (W)	3	127.470**	182.203**	172.285**
Y*W	3	0.336	0.708	0.585
T*W	9	0.115**	0.104**	0.134**
Y* T* W	9	0.028	0.060	0.130
Error (b)	48	0.014	0.011	0.022

NS – Non Significant, *– Significant at p = 0.05, **– Significant at p = 0.01

APPENDIX – XXXIII

Mean sum of squares for plant height (2015 and 2016)

Source of variation	d.f.	Plant height (cm)					
		30 DAS		60 DAS		At harvest	
		2015	2016	2015	2016	2015	2016
Replication	2	23.836	21.485	8.216	26.521	102.676	73.803
Tillage practices (T)	3	168.527**	307.024**	502.955**	675.348**	501.398**	1054.309**
Error (a)	6	12.490	9.065	28.148	6.644	42.843	17.472
Weed control (W)	3	223.373**	406.231**	921.382**	1078.799**	1717.127**	2203.942**
T*W	9	5.260 ^{NS}	8.489 ^{NS}	55.882 ^{NS}	20.813 ^{NS}	35.478 ^{NS}	63.495**
Error (b)	24	10.515	6.293	32.440	11.647	42.816	11.333

NS – Non Significant, *– Significant at p = 0.05, **– Significant at p = 0.01

APPENDIX – XXXIV

Mean sum of squares for plant height (Pooled)

Source of variation	d.f.	Plant height (cm)		
		30 DAS	60 DAS	At harvest
Year (Y)	1	152.007	411.792	1034.688
Replication within year	4	22.661	17.368	88.239
Tillage practices (T)	3	464.815**	1171.907**	1500.987**
Y*T	3	10.735	6.396	54.720
Error (a)	12	10.777	17.396	30.158
Weed control (W)	3	615.851**	1994.706**	3904.128**
Y*W	3	13.753	5.475	16.941
T*W	9	9.522**	54.581 ^{NS}	54.124 ^{NS}
Y* T* W	9	4.227	22.114	44.850
Error (b)	48	8.404	22.043	27.075

NS – Non Significant, *– Significant at p = 0.05, **– Significant at p = 0.01

APPENDIX – XXXV

Mean sum of squares for dry matter accumulation (2015 and 2016)

Source of variation	d.f.	Dry matter accumulation (g/plant)					
		30 DAS		60 DAS		At harvest	
		2015	2016	2015	2016	2015	2016
Replication	2	0.474	0.428	24.391	1.277	20.271	9.185
Tillage practices (T)	3	123.714*	161.539**	119.186**	262.998**	176.007**	550.125**
Error (a)	6	15.203	0.854	10.300	2.534	3.340	1.793
Weed control (W)	3	233.200**	349.926**	407.102**	659.289**	426.632**	966.157**
T*W	9	6.792 ^{NS}	11.727**	4.778 ^{NS}	22.102**	2.007 ^{NS}	10.533 ^{NS}
Error (b)	24	12.972	1.129	7.010	1.133	12.684	9.308

NS – Non Significant, *– Significant at p = 0.05, **– Significant at p = 0.01

APPENDIX – XXXVI

Mean sum of squares for dry matter accumulation (Pooled)

Source of variation	d.f.	Dry matter accumulation (g/plant)		
		30 DAS	60 DAS	At harvest
Year (Y)	1	42.454	133.600	375.250
Replication within year	4	0.451	12.834	14.728
Tillage practices (T)	3	282.332**	367.806**	672.108**
Y*T	3	2.921	14.377	54.024
Error (a)	12	8.028	6.417	2.567
Weed control (W)	3	577.047**	1050.747**	1338.150**
Y*W	3	6.078	15.645	54.639
T*W	9	10.836 ^{NS}	17.759**	5.792 ^{NS}
Y* T* W	9	7.684	9.122	6.748
Error (b)	48	7.050	4.072	10.996

NS – Non Significant, *– Significant at p = 0.05, **– Significant at p = 0.01

APPENDIX – XXXVII

Mean sum of squares for growth attributing characters (2015 and 2016)

Source of variation	d.f.	Days to 50% silking		Days to maturity	
		2015	2016	2015	2016
Replication	2	10.333	9.531	14.771	5.036
Tillage practices (T)	3	3.410 ^{NS}	11.267 ^{NS}	8.910 ^{NS}	22.658 ^{NS}
Error (a)	6	6.056	3.073	4.076	10.106
Weed control (W)	3	2.465 ^{NS}	4.372 ^{NS}	18.243 ^{NS}	20.158 ^{NS}
T*W	9	0.243 ^{NS}	0.158 ^{NS}	1.021 ^{NS}	5.214 ^{NS}
Error (b)	24	9.153	9.407	14.139	31.200

NS – Non Significant, *– Significant at p = 0.05, **– Significant at p = 0.01

APPENDIX – XXXVIII

Mean sum of squares for growth attributing characters (Pooled)

Source of variation	d.f.	Days to 50% silking	Days to maturity
Year (Y)	1	5.950	18.815
Replication within year	4	9.932	9.904
Tillage practices (T)	3	13.507 ^{NS}	28.711*
Y*T	3	1.170	2.857
Error (a)	12	4.564	7.091
Weed control (W)	3	6.590 ^{NS}	38.072 ^{NS}
Y*W	3	0.247	0.329
T*W	9	0.304 ^{NS}	4.790 ^{NS}
Y* T* W	9	0.096	1.445
Error (b)	48	9.280	22.669

NS – Non Significant, *– Significant at p = 0.05, **– Significant at p = 0.01

APPENDIX – XXXIX

Mean sum of squares for yield attributing characters (2015 and 2016)

Source of variation	d.f.	Grains/cob		100 grain weight (g)		Shelling (%)	
		2015	2016	2015	2016	2015	2016
Replication	2	12.137	7.480	13.151	0.788	5.144	9.002
Tillage practices (T)	3	1636.319**	1921.969**	25.445**	40.706**	30.394**	67.533**
Error (a)	6	72.812	28.703	2.111	0.973	1.968	1.978
Weed control (W)	3	6326.958**	7575.487**	32.299**	55.926**	130.434**	211.241**
T*W	9	192.596*	182.310**	4.078 ^{NS}	7.333**	6.416 ^{NS}	4.325 ^{NS}
Error (b)	24	71.473	23.067	4.160	1.196	4.601	2.708

NS – Non Significant, *– Significant at p = 0.05, **– Significant at p = 0.01

APPENDIX – XL

Mean sum of squares for yield attributing characters (Pooled)

Source of variation	d.f.	Grains/cob	100 grain weight (g)	Shelling (%)
Year (Y)	1	247.609	7.656	27.606
Replication within year	4	9.808	6.969	7.073
Tillage practices (T)	3	3552.399**	65.214**	94.123**
Y*T	3	5.889	0.937	3.803
Error (a)	12	50.757	1.542	1.973
Weed control (W)	3	13870.568**	86.602**	336.800**
Y*W	3	31.877	1.623	4.874
T*W	9	374.150**	10.737**	2.667 ^{NS}
Y* T* W	9	0.756	0.674	8.073
Error (b)	48	47.270	2.678	3.655

NS – Non Significant, *– Significant at p = 0.05, **– Significant at p = 0.01

APPENDIX – XLI

Mean sum of squares for grain and stover yield and protein content (2015 and 2016)

Source of variation	d.f.	Grain yield (q/ha)		Stover yield (q/ha)		Protein content (%)	
		2015	2016	2015	2016	2015	2016
Replication	2	0.046	0.427	2.908	2.463	0.762	0.609
Tillage practices (T)	3	157.536**	230.479**	176.076**	251.049**	0.245 ^{NS}	0.423 ^{NS}
Error (a)	6	0.282	0.331	3.271	2.065	0.159	0.334
Weed control (W)	3	285.873**	457.657**	749.830**	976.819**	0.293 ^{NS}	0.501 ^{NS}
T*W	9	20.527**	24.959**	76.231**	71.438**	0.011 ^{NS}	0.015 ^{NS}
Error (b)	24	0.224	0.338	1.310	2.589	0.751	0.210

NS – Non Significant, *– Significant at p = 0.05, **– Significant at p = 0.01

APPENDIX – XLII

Mean sum of squares for grain and stover yield and protein content (Pooled)

Source of variation	d.f.	Grain yield (q/ha)	Stover yield (q/ha)	Protein content (%)
Year (Y)	1	100.042	105.630	0.224
Replication within year	4	0.236	2.685	0.686
Tillage practices (T)	3	383.329**	423.734**	0.655 ^{NS}
Y*T	3	4.686	3.391	0.013
Error (a)	12	0.306	2.668	0.247
Weed control (W)	3	732.950**	1718.769**	0.780 ^{NS}
Y*W	3	10.581	7.880	0.014
T*W	9	44.108**	143.042**	0.010 ^{NS}
Y* T* W	9	1.378	4.628	0.016
Error (b)	48	0.281	1.949	0.480

NS – Non Significant, *– Significant at p = 0.05, **– Significant at p = 0.01

APPENDIX – XLIII

Mean sum of squares for total weed density (2015-16 and 2016-17)

Source of variation	d.f.	Total weed density (No. /m ²)							
		25 DAS		45 DAS		65 DAS		85 DAS	
		2015-16	2016-17	2015-16	2016-17	2015-16	2016-17	2015-16	2016-17
Replication	2	0.009	0.033	0.016	0.003	0.059	0.005	0.002	0.005
Tillage practices (T)	3	5.815**	9.907**	4.250**	9.622**	4.138**	10.347**	5.889**	13.43**
Error (a)	6	0.006	0.026	0.011	0.054	0.028	0.039	0.049	0.021
Weed control (W)	3	187.46**	208.44**	231.51**	262.61**	222.68**	266.44**	220.27**	262.97**
T*W	9	0.121**	0.438**	0.273**	0.672**	0.555**	0.786**	0.492**	0.909**
Error (b)	24	0.025	0.015	0.021	0.016	0.020	0.022	0.025	0.025

NS – Non Significant, *– Significant at p = 0.05, **– Significant at p = 0.01

APPENDIX – XLIV

Mean sum of squares for total weed density (Pooled)

Source of variation	d.f.	Total weed density (No. /m ²)			
		25 DAS	45 DAS	65 DAS	85 DAS
Year (Y)	1	0.278	0.723	0.887	0.273
Replication within year	4	0.021	0.010	0.032	0.004
Tillage practices (T)	3	15.429**	13.313**	13.661**	18.464**
Y*T	3	0.293	0.559	0.824	0.858
Error (a)	12	0.016	0.033	0.033	0.035
Weed control (W)	3	395.245**	493.376**	488.045**	481.816**
Y*W	3	0.661	0.747	1.065	1.430
T*W	9	0.453**	0.877**	1.315**	1.293**
Y* T* W	9	0.106	0.069	0.026	0.108
Error (b)	48	0.020	0.019	0.021	0.025

NS – Non Significant, *– Significant at p = 0.05, **– Significant at p = 0.01

APPENDIX – XLV

Mean sum of squares for total weed dry weight (2015-16 and 2016-17)

Source of variation	d.f.	Total weed dry weight (g/m ²)							
		25 DAS		45 DAS		65 DAS		85 DAS	
		2015-16	2016-17	2015-16	2016-17	2015-16	2016-17	2015-16	2016-17
Replication	2	0.000	0.001	0.006	0.021	0.005	0.020	0.004	0.001
Tillage practices (T)	3	0.224**	0.467**	1.911**	10.354**	1.555**	6.067**	1.425**	3.791**
Error (a)	6	0.000	0.002	0.017	0.011	0.005	0.006	0.001	0.016
Weed control (W)	3	12.797**	16.202**	83.229**	94.722**	41.670**	50.002**	19.715**	26.950**
T*W	9	0.007**	0.164**	0.084**	0.803**	0.408**	0.162**	0.254**	1.018**
Error (b)	24	0.001	0.001	0.017	0.016	0.003	0.006	0.004	0.003

NS – Non Significant, *– Significant at p = 0.05, **– Significant at p = 0.01

APPENDIX – XLVI

Mean sum of squares for total weed density (Pooled)

Source of variation	d.f.	Total weed dry weight (g/m ²)			
		25 DAS	45 DAS	65 DAS	85 DAS
Year (Y)	1	0.070	0.581	0.024	0.012
Replication within year	4	0.001	0.013	0.012	0.002
Tillage practices (T)	3	0.667**	10.508**	6.659**	4.867**
Y*T	3	0.023	1.757	0.963	0.349
Error (a)	12	0.001	0.014	0.005	0.008
Weed control (W)	3	28.836**	177.477**	91.334**	46.358**
Y*W	3	0.163	0.473	0.338	0.307
T*W	9	0.105**	0.443**	0.230**	1.082**
Y* T* W	9	0.066	0.444	0.339	0.190
Error (b)	48	0.001	0.016	0.004	0.004

NS – Non Significant, *– Significant at p = 0.05, **– Significant at p = 0.01

APPENDIX – XLVII

Mean sum of squares for berseem dry weight (2015-16 and 2016-17)

Source of variation	d.f.	Berseem dry weight (g)					
		1st Cut		2nd Cut		3rd Cut	
		2015-16	2016-17	2015-16	2016-17	2015-16	2016-17
Replication	2	0.360	3.060	1.349	1.172	0.328	2.661
Tillage practices (T)	3	102.999**	142.512**	125.311**	193.285**	204.616**	259.139**
Error (a)	6	1.012	0.556	0.259	2.415	0.460	0.300
Weed control (W)	3	251.069**	372.090**	413.033**	606.799**	715.116**	1000.875**
T*W	9	5.358**	6.766**	2.945*	7.063**	4.996*	5.412*
Error (b)	24	1.268	0.989	1.128	0.965	2.073	2.106

NS – Non Significant, *– Significant at p = 0.05, **– Significant at p = 0.01

APPENDIX – XLVIII

Mean sum of squares for berseem dry weight (Pooled)

Source of variation	d.f.	Berseem dry weight (g)		
		1st Cut	2nd Cut	3rd Cut
Year (Y)	1	46.970	77.940	127.190
Replication within year	4	1.710	1.260	1.495
Tillage practices (T)	3	243.816**	314.662**	461.773**
Y*T	3	1.695	3.933	1.982
Error (a)	12	0.784	1.337	0.380
Weed control (W)	3	617.218**	1010.468**	1703.773**
Y*W	3	5.940	9.364	12.218
T*W	9	9.413**	3.058**	10.028**
Y* T* W	9	2.712	6.949	0.380
Error (b)	48	1.129	1.047	2.089

NS – Non Significant, *– Significant at p = 0.05, **– Significant at p = 0.01

APPENDIX – XLIX

Mean sum of squares for growth and yield attributing characters (2015-16 and 2016-17)

Source of variation	d.f.	Plant height at harvest (cm)		No. of effective tillers/m ²		Test weight (g)	
		2015-16	2016-17	2015-16	2016-17	2015-16	2016-17
Replication	2	22.919	0.919	2.069	2.755	0.011	0.096
Tillage practices (T)	3	45.891**	45.881**	652.007**	1014.116**	0.525**	0.879**
Error (a)	6	3.206	1.647	11.960	18.200	0.009	0.008
Weed control (W)	3	135.299**	217.986**	1996.831**	2728.644**	0.505**	1.297**
T*W	9	0.560 ^{NS}	1.193 ^{NS}	58.053**	34.709**	0.070 ^{NS}	0.119**
Error (b)	24	3.205	0.805	5.405	4.255	0.039	0.031

NS – Non Significant, *– Significant at p = 0.05, **– Significant at p = 0.01

APPENDIX – L

Mean sum of squares for growth and yield attributing characters (Pooled)

Source of variation	d.f.	Plant height at harvest (cm)	No. of effective tillers/m ²	Test weight (g)
Year (Y)	1	114.844	431.039	0.528
Replication within year	4	11.919	2.412	0.053
Tillage practices (T)	3	91.676**	1643.601**	1.380**
Y*T	3	0.096	22.522	0.024
Error (a)	12	2.427	15.080	0.008
Weed control (W)	3	347.840**	4694.862**	1.707**
Y*W	3	5.445	30.614	0.094
T*W	9	0.979 ^{NS}	88.167**	0.184**
Y* T* W	9	0.774	4.595	0.006
Error (b)	48	2.005	4.830	0.035

NS – Non Significant, *– Significant at p = 0.05, **– Significant at p = 0.01

APPENDIX – LI

Mean sum of squares for green fodder, seed and straw yield (2015-16 and 2016-17)

Source of variation	d.f.	Green fodder yield (q/ha)		Seed yield (q/ha)		Straw yield (q/ha)	
		2015-16	2016-17	2015-16	2016-17	2015-16	2016-17
Replication	2	70.960	1.292	0.132	0.049	0.401	2.618
Tillage practices (T)	3	4125.651**	5236.229**	2.519**	4.199**	128.847**	185.859**
Error (a)	6	72.666	49.789	0.036	0.070	0.683	1.117
Weed control (W)	3	12214.198**	18872.473**	19.267**	23.057**	229.994**	308.766**
T*W	9	62.864 ^{NS}	22.615 ^{NS}	0.132 ^{NS}	0.549**	6.711**	7.931**
Error (b)	24	30.932	51.142	0.087	0.052	1.149	1.253

NS – Non Significant, *– Significant at p = 0.05, **– Significant at p = 0.01

APPENDIX – LII

Mean sum of squares for growth and yield attributing characters (Pooled)

Source of variation	d.f.	Green fodder yield (q/ha)	Seed yield (q/ha)	Straw yield (q/ha)
Year (Y)	1	2856.347	1.938	77.400
Replication within year	4	36.126	0.091	1.510
Tillage practices (T)	3	9313.003**	6.599**	311.949**
Y*T	3	48.877	0.119	2.758
Error (a)	12	61.227	0.053	0.900
Weed control (W)	3	30541.004**	42.232**	535.725**
Y*W	3	545.666	0.092	3.036
T*W	9	42.239 ^{NS}	0.541**	12.223**
Y* T* W	9	43.240	0.140	2.419
Error (b)	48	41.037	0.069	1.201

NS – Non Significant, *– Significant at p = 0.05, **– Significant at p = 0.01

APPENDIX – LIII

Mean sum of squares for dry matter and crude protein yield and crude protein percentage (2015-16 and 2016-17)

Source of variation	d.f.	Dry matter yield (q/ha)		Crude protein yield (q/ha)		Crude protein (%)	
		2015-16	2016-17	2015-16	2016-17	2015-16	2016-17
Replication	2	0.533	0.157	0.019	0.007	0.016	0.034
Tillage practices (T)	3	210.511**	301.181**	10.775**	15.295**	0.245 ^{NS}	0.234 ^{NS}
Error (a)	6	0.772	0.221	0.045	0.034	0.084	0.297
Weed control (W)	3	656.041**	1026.242**	36.492**	57.202**	2.426**	3.080**
T*W	9	2.619**	4.386**	0.115 ^{NS}	0.210**	0.042 ^{NS}	0.040 ^{NS}
Error (b)	24	0.444	0.697	0.075	0.056	0.461	0.331

NS – Non Significant, *– Significant at p = 0.05, **– Significant at p = 0.01

APPENDIX – LIV

Mean sum of squares for dry matter and crude protein yield and crude protein percentage (Pooled)

Source of variation	d.f.	Dry matter yield (q/ha)	Crude protein yield (q/ha)	Crude protein (%)
Year (Y)	1	154.220	8.266	0.160
Replication within year	4	0.345	0.013	0.025
Tillage practices (T)	3	507.545**	25.866**	0.479 ^{NS}
Y*T	3	4.147	0.203	0.000
Error (a)	12	0.496	0.039	0.190
Weed control (W)	3	1660.074**	92.466**	5.485**
Y*W	3	22.209	1.228	0.021
T*W	9	6.114**	0.281**	0.080 ^{NS}
Y* T* W	9	0.891	0.044	0.002
Error (b)	48	0.570	0.065	0.396

NS – Non Significant, *– Significant at p = 0.05, **– Significant at p = 0.01

APPENDIX – LV

Mean sum of squares for final soil properties (2015-16 and 2016-17)

Source of variation	d.f.	Organic carbon (%)		Bulk density (Mg/m ³)		Particle density (Mg/m ³)	
		2015-16	2016-17	2015-16	2016-17	2015-16	2016-17
Replication	2	0.007	0.003	0.002	0.002	0.005	0.003
Tillage practices (T)	3	0.005 ^{NS}	0.018 ^{**}	0.009 ^{NS}	0.031 ^{**}	0.012 ^{NS}	0.038 ^{**}
Error (a)	6	0.003	0.001	0.004	0.003	0.005	0.003
Weed control (W)	3	0.002 ^{NS}	0.008 [*]	0.002 ^{NS}	0.005 ^{NS}	0.006 ^{NS}	0.009 ^{NS}
T*W	9	0.001 ^{NS}	0.001 ^{NS}	0.001 ^{NS}	0.001 ^{NS}	0.001 ^{NS}	0.001 ^{NS}
Error (b)	24	0.007	0.002	0.004	0.002	0.008	0.006

NS – Non Significant, *– Significant at p = 0.05, **– Significant at p = 0.01

APPENDIX – LVI

Mean sum of squares for final soil properties (Pooled)

Source of variation	d.f.	Organic carbon (%)	Bulk density (Mg/m ³)	Particle density (Mg/m ³)
Year (Y)	1	0.020	0.001	0.004
Replication within year	4	0.005	0.002	0.004
Tillage practices (T)	3	0.020 ^{**}	0.037 ^{**}	0.047 ^{**}
Y*T	3	0.003	0.003	0.004
Error (a)	12	0.002	0.003	0.004
Weed control (W)	3	0.009 ^{NS}	0.006 ^{NS}	0.014 ^{NS}
Y*W	3	0.001	0.000	0.001
T*W	9	0.002 ^{NS}	0.002 ^{NS}	0.001 ^{NS}
Y* T* W	9	0.000	0.000	0.001
Error (b)	48	0.004	0.003	0.007

NS – Non Significant, *– Significant at p = 0.05, **– Significant at p = 0.01

VITA

The author was born on 7th April 1984 at Village - Mowala, Post – Karali, Tehsil. - Baihar, District – Balaghat, Madhya Pradesh. He has completed his school education in 2002 from Vivekanand Higher Secondary School, Baihar. Thereafter, he joined Bhartiya College of Agriculture, Durg, Chhattisgarh and completed his Bachelor Degree (B.Sc. Ag.) in 2006-07. During the year 2007 he qualified ICAR, JRF exam and joined the Master Degree programme in Agronomy discipline in College of Agriculture, Rajendranagar, Hyderabad (A.P.) and successfully completed the post graduate degree M. Sc. (Ag.) during the year 2009. In the year 2011 he selected for Agricultural Research Service at the same time he also qualified ICAR, NET exam.

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Place: Gwalior

(Vinod Kumar Wasnik)

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