

**INTEGRATED EFFECT OF TILLAGE AND WEED
CONTROL METHODS ON WEED DYNAMICS AND
WEED MANAGEMENT IN MAIZE (*Zea mays* L.)**

THESIS

By

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Submitted to



**CHAUDHARY SARWAN KUMAR
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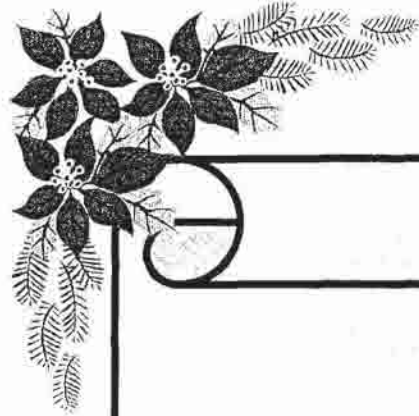
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Partial fulfilment of the requirements for the degree

OF

**DOCTOR OF PHILOSOPHY IN AGRICULTURE
(AGRONOMY)**

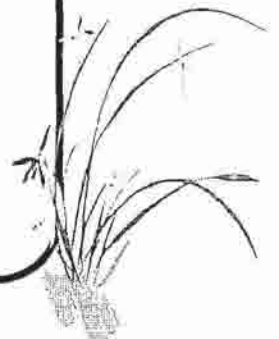
(2006)



**“Dedicated to the
memory of
my father**

Late Sh. Onkar Chopra

**whose silent
presence has
guided my efforts”**



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CERTIFICATE – I

This is to certify that the thesis entitled "**Integrated effect of tillage and weed control methods on weed dynamics and weed management in maize (*Zea mays L.*)**" submitted in partial fulfilment of the requirements for the award of the degree of **Doctor of Philosophy (Agriculture)** in the subject of **Agronomy** of Chaudhary Sarwan Kumar Himachal Pradesh Krishi Vishvavidyalaya, Palampur, is a bonafide research work carried out by **Mr. Pankaj Chopra (Admission No. A-2001-40-04)**, son of **Late Shri Onkar Chopra** under my supervision and that no part of this thesis has been submitted for any other degree or diploma.

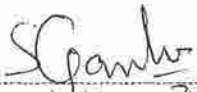
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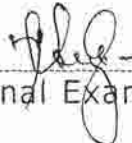

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CERTIFICATE – II

This is to certify that the thesis entitled "**Integrated effect of tillage and weed control methods on weed dynamics and weed management in maize (*Zea mays* L.)**" submitted by **Mr. Pankaj Chopra (Admission No. A-2001-40-04)** son of **Late Shri Onkar Chopra** to the Chaudhary Sarwan Kumar Himachal Pradesh Krishi Vishvavidyalaya, Palampur, in partial fulfilment of the requirements for the degree of **Doctor of Philosophy (Agriculture)** in the subject of **Agronomy**, has been approved by the Advisory Committee after an oral examination of the student in collaboration with an External Examiner.




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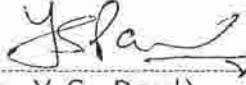
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Place: Palampur

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(PANKAJ CHOPRA)

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***I*ntroduction**

INTRODUCTION

Maize is one of the most important *Kharif* crop grown in India and occupies an area of 0.7 million hectares with annual production of 1.48 million tonnes (Anonymous, 2004)^a. In Himachal Pradesh, out of 420.22 thousand hectare area under *Kharif* cereals, maize occupies highest area (301.28 thousand hectares) and is next to wheat (366.52 thousand hectares) among *Rabi* and *Kharif* cereals (Anonymous, 2004)^b. Because of C₄ physiological mechanism and congenial climatic conditions available for its growth and development, it has highest production (768.20 thousand tonnes) amongst all the cereals in H.P. with an average productivity of 2550 kg/ha which is higher than the national average of 2114 kg/ha (Anonymous, 2004). However, this productivity is much lower than the realisable potential leaving much scope for improvement.

Among different factors, severe competition by wide range of weeds with this crop is considered to be the major factor for not realising the realisable potential in mid-hills sub humid zone of Himachal Pradesh (Singh *et al.*, 1992), where weather conditions are most conducive for the growth of weeds. Under these conditions weeds pose a serious problem because planting of maize commences with the onset of monsoon and farmers hardly get chance to remove weeds manually because of wet conditions of soil due to continuous rains. In addition, maize being a wide spaced crop, provide enough opportunity for the weeds to invade and offer competition. The benefits obtainable from different agricultural inputs are mitigated by a single factor weeds, if left uncontrolled.

Weeds compete with the crop for nutrients, light, moisture and space right from its emergence. The severe competition by weeds result in considerable yield reduction, if weeds are not managed effectively and at right time. Singh *et al.* (1996) and Pandey *et al.* (2001) reported that on an average weeds caused 50-60 and 30-95 per cent reduction in grain yield of maize in Palampur and Uttranchal, respectively.

Weed management has been of primary importance to the hill farmers whose efforts for combating the weed menace in maize mostly involve handweeding and hoeing operations. But these manual methods are laborious, time consuming and involve high costs of labour. Therefore the best alternative to mitigate the competition by weeds right from early stages is application of pre-emergence herbicides. At present, atrazine a pre-emergence herbicide has been recommended to control weeds in this crop. But, because of narrow spectrum of weed control and chances of development of herbicide resistance with wide spread and continuous use of atrazine (Holt and LeBaron, 1990), there is urgent need to find out the alternative herbicide with different mechanism of action for effective control of weeds. Acetachlor [2 chloro 2' methyl-6'ethyl-N (ethoxy methyl) acetanilide] belonging to acetanilide group has been suggested to be the more effective alternative (Tomordi, 1987) and therefore was evaluated in the present study. But at present the prohibitive costs, unavailability of herbicides, pesticide residue, their environmental hazards and establishment of resistant species and biotypes are major constraints in the adoption of herbicides alone as a regular practice. These facts necessitate the use of herbicides in conjunction with other weed control practices. Integrated weed management involves the deliberate selection, integration and implementation of

effective weed control measures with due consideration of economics, ecological and sociological consequences (Buchanan, 1976). Production practices like tillage methods *viz.* zero tillage and seed bed preparation *viz.* raised seed bed selectively stimulate the crop to provide maximum competition to weeds. So, there is a need to integrate tillage and weed control methods (Burnside, 1979 and Lal, 1991).

Tillage influences the vertical distribution of weed seeds in soil layer affecting weed seed germination rates, survival of weeds and efficacy of weed control tactics, thus affecting weed population dynamics through alteration of environment by different tillage systems which favours life cycle of certain weeds over others (Buhler, 1995). Therefore, the study of weed dynamics in different tillage systems constitute an important aspect of the experiment.

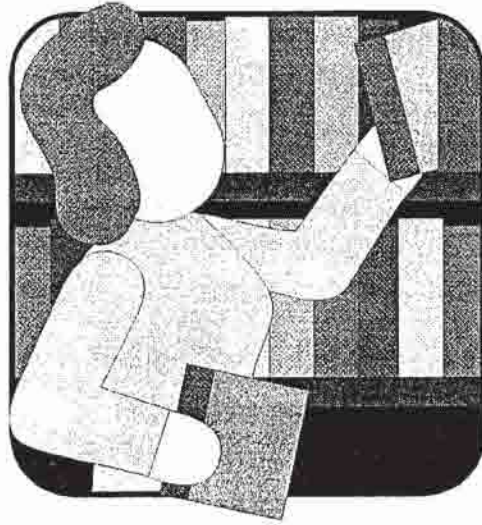
Tillage involves stirring soil with implements to provide good tilth and to destroy weeds. On an average around 30 per cent of the total expenditure of crop production is incurred on the tillage operation (Singh *et al.*, 2002). With the dramatic improvement made in tillage cum seeding equipments and herbicide technology, it has been made possible to grow successful crops without manipulation of soil. But the success of zero tillage is largely dependent on solving the key issue of weed management (Gebhardt *et al.*, 1985). Under such conditions application of non-selective herbicides before sowing and selective herbicide after sowing proved to be effective and helpful in gaining various direct and indirect benefits of zero tillage like low cultivation cost, more stability of soil aggregates, reduced soil erosion, increased infiltration rate, increase in organic matter content in surface soil, and improvement in soil trafficability etc. (Blevins and Frye, 1993). Moreover, the high rainfall pattern of the state during *Kharif*

permit less time for preparation of seed beds for sowing maize. Therefore, it is imperative to study the benefit of zero-tillage with appropriate weed control methods in maize under such situations.

Raised seed bed option with precise herbicide treatment can also provide a favourable soil environment for crop emergence, early growth, and higher productivity by better water relation and weed control in both poorly drained and moderately well drained soils (Hatfield *et al.*, 1998), apart from its beneficial effects of reducing leaching of nutrients and minimizing lodging under high rainfall situations. Therefore, working out the technique of integration of raised seed bed with effective weed control practice is important for such situations.

Keeping all these aspects in mind, the present study entitled, "Integrated effect of tillage and weed control methods on weed dynamics and weed management in maize (*Zea mays* L.)" was undertaken with the following objectives:

1. To study the integrated effect of tillage and weed control methods on dynamics of weed flora and its management,
2. to study the integrated effect of these treatments on growth, development and productivity of maize, and
3. to find out the comparative economics of different treatments.



***R*eview of *L*iterature**

REVIEW OF LITERATURE

The use of herbicides in field crops for the control of weeds has gathered momentum in recent years. It has been established that weed control through herbicides is paying preposition and can be successfully employed for controlling weeds in crops. But the regular and constant use of single herbicide for long years in a single crop and similar type of weeds has resulted in the development of resistance towards the particular herbicides. Under such conditions integration of herbicide weed control method with other cultural methods *viz.* tillage plays imperative role for achieving accepted level of weed management and enable farmers to obtain moderate to high crop yield on sustainable basis, protecting the crop from pests and use land intensively and economically without soil degradation.

The pertinent literature available on the integrated weed management in maize has been reviewed in this chapter under the following heads:

1. Crop-weed competition
 - i) Weed flora associated
 - ii) Critical period of competition
 - iii) Losses caused by weeds

2. Effect of tillage methods on
 - i) Weed seed bank and its distribution
 - ii) Species-wise weed density and dry matter
 - iii) Soil properties
 - iv) Root growth
 - v) Crop growth and development
 - vi) Yield and yield contributing characters
 - vii) Economics of tillage methods
3. Effect of weed control methods on
 - i) Species-wise weed density and dry matter
 - ii) Crop growth and development
 - iii) Yield and yield contributing characters
 - iv) Economics of weed control methods
4. Effect of integrated weed management on
 - i) Weed seed bank and its distribution
 - ii) Species-wise weed count and dry matter
 - iii) Crop growth and development
 - iv) Yield and yield attributes
 - v) Economics of integrated weed management methods

2.1 CROP-WEED COMPETITION

Competition between crop plants and weeds is a critical factor in the growing of useful plants. Competition is the action of endeavoring to gain what another endeavors to gain at the same time; the striving of two or

more for the same object. Competition is usually evident in cultivated fields. The keenest competition between weeds and crop plant usually occurs when the individuals competing are most alike in their vegetative habits, method of reproduction and demand upon the environment. The chief environmental factors in plant competition are water, light and mineral nutrients. A principle of plant competition is that the first plants to occupy any area of soil, small or large, tend to exclude others. This principle finds application in practical weed control. Practices should be such that crop plants occupy the soil before weeds. Thus seed bed preparation, tillage, depth of seeding and date of seeding play important parts in making it possible for crop plants to evade competition with weeds. Weeds that appear in a crop after it is well established usually have negligible competing ability (Crafts and Robbins, 1962).

Weeds are successful because of their genetic diversity and ability to adapt to and take advantage of conditions created by crop production systems. Therefore, modifying crop management input will result in a altered competitive environment in which the morphological and physiological traits that confer success will be altered.

2.1.1 Weed flora associated

Angiras and Singh (1988) reported that maize being a rainy season crop is invaded by a wide range of weed flora in Palampur (H.P.) conditions. *Echinochloa* sp., *Cyperus* sp., *Commelina benghalensis* and *Panicum*

dichotomiflorum dominate during early stages of crop and *Ageratum conyzoides* towards the tasseling and maturity of the crop. In an another study carried out by Singh *et al.* (1992) at experimental farm of Department of Agronomy, Palampur (H.P.) the dominant weed species observed were *Echinochloa crus-galli* (L.) Beauv., *Setaria glauca* (L.) Beauv., *Gallinsoga parviflora* L., *Cyperus esculentus* L., *Commelina benghalensis* L., *Cynodon dactylon* (L.), Pers., *Panicum dichotomiflorum* Michx., *Digitaria sanguinalis* (L.) Scop., *Polygonum alatum* L. and *Ageratum conyzoides* L. At similar mid-hill conditions of H.P. *Echinochloa colona*, *E. crus-galli*, *Cyperus iria*, *C. esculentus*, *Commelina benghalensis* and *Ageratum conyzoides* were the dominant weeds associated with maize crop. *Ageratum conyzoides* consisted more than 90% of total weed flora (Saini and Angiras, 1998).

Frank and Thomas (1992) from their survey conducted in 593 maize and soybean fields in SW Ontario found that the most abundant weeds were *Setaria viridis*, *Chenopodium album*, *Agropyron repens*, *Amaranthus retroflexus*, *Ambrosia artemisiifolia* and *Teraxacum officinale*. In experimental farms of university of Wisconsin at Arlington and Hancock the species present included common lambs quarters, pig weed species (mostly *Amaranthus retroflexus*), fall Panicum (*Panicum dichotomiflorum*), proso millet (*Panicum miliaceum*), foxtail species (mostly *Setaria glauca*) (Yenish *et al.*, 1992).

Kalia and Singh (1993) from Dhaulakuan, Himachal Pradesh on sandy loam soils reported that the most problematic weeds were *Echinochloa crus-galli*, *E. colonum*, *Setaria glauca*, *Panicum dichotomiflorum*, *Ageratum conyzoides*, *Polygonum alatum*, *Cyperus rotundus*, *Commelina benghalensis*, *Cynodon dactylon*, *Sorghum halepense*, *Euphorbia heterophylla* and *Digitaria sanguinalis*. From another research station of CSK HPKV Palampur at Bajaura, Kullu (H.P.), Thakur and Sharma (1996) found that weed flora associated with the maize crop were *Cyperus rotundus*, *Dactyloctenium aegyptium*, *Sorghum halepense*, *Eleusine indica* and *Brachiaria platyphylla*, *Gallinsoga parviflora*, *Commelina benghalensis* and *Convolvulus arvensis*.

In sandy loam soils of Umer Kote, Orissa grasses viz. *Cynodon dactylon* (L.) Pers., *Digitaria setigera*, *Digitaria ciliaris*, *Leptochloa chinensis* Nees (Retz.) Koeler, *Dactyloctenium aegyptium* (L.) and *Eleusine indica* Gaertn., sedges, viz. *Cyperus rotundus* L. and *Cyperus iria* L., and broad-leaf weeds, viz. *Celosia argentea* L., *Commelina benghalensis* L., *Sida acuta* Burm.f. and *Aeschynomene indica* and *Acanthospermum hispidum* DC were reported to be the dominating weeds in maize (Rout and Satapathy, 1996). In Peshawar (Pakistan) *Echinochloa crus-galli*, *Leptochloa* sp., *Cyperus rotundus*, *Trianthema portulacartrum*, *Digitaria sanguinalis*, *Convolvulus arvensis*, *Sorghum halepense* and *Digera* sp. were identified as weeds infesting maize (Khan *et al.*, 1998).

In a study carried out by Konstantinovic *et al.* (1999) in Yugoslavia, a number of weed species observed included *Amaranthus retroflexus*, *Chenopodium album*, *Datura stramonium*, *Echinochloa crus-galli*, *Hibiscus trionum*, *Polygonum lapathifolium* and *Setaria viridis*. Sandhu *et al.* (1999) surveyed maize fields in Punjab and revealed the presence of 75 weed species. The predominant weeds associated with the crop were *Eleusine aegyptiacum*, *Eragrostis tenella*, *Leptochloa panicea*, *Trianthema portulacastrum*, *Digera arvensis*. Besides these some other serious weeds like *Panicum colonum*, *Digitaria ciliaris*, *Commelina benghalensis* and new weeds like *Brachiaria reptans* were also observed.

Sharma *et al.* (2000) reported that the predominant weed species in a field trial on maize in Ballawal Saunkhri (Punjab) were mainly grasses (85.0-90.4%), such as *Echinochloa crus-galli*, *Eleusine indica*, *Digitaria sanguinalis* and *Cynodon dactylon*. In another maize trial at Pantnagar, the dominant weed species associated with the maize crop were *Cynodon dactylon*, *Echinochloa colonum*, *Euphorbia hirta*, *Paspalum scrobiculatum*, *Eleusine indica*, *Cyperus rotundus* and *Panicum repens* (Khajanji *et al.*, 2002). Pandey *et al.* (2002) from VPKAS Almora, Uttaranchal on loamy clay soil found that the maize crop was infested with *Echinochloa colona*, *Brachiaria ramosa* and *Panicum repens* among grassy weeds, *Ageratum conyzoides*, *Gallinsoga parviflora*, *Euphorbia geniculata* and *Oxalis latifolia* among non-grassy weeds and *Cyperus rotundus* among sedges. Grassy, non-grassy and sedges constituted 90.0, 7.5, 2.5 and 48.5, 37.0, 14.5 per cent in 1997 and 1998, respectively.

2.1.2 Critical period of crop-weed competition

The critical period can be defined as “the shortest span of time in the ontogeny of crop growth when weeding will result in higher economic returns”. A fundamental principle of plant competition is that early occupants on a soil tend to exclude the later ones. This principle finds application in practical weed control. Weeds are capable of accumulating dry matter faster than the crop plants. Thus, the duration of weed infestation and time of weed removal have a significant influence on crop growth and economic yield (Mishra, 1997).

The yield loss of a crop is dependent on the length of crop-weed competition and the stage at which such competition occurs. It is generally agreed that maize is most sensitive to weed competition during the first month after sowing. Weed growth before 10 days or after 30-40 days have little effect. Experiments carried out in PAU, Ludhiana on loamy soil by Sandhu and Gill (1973), have reported that critical stage of crop-weed competition is first 2-6 weeks of sowing. Nayital *et al.* (1989) also recorded similar duration as critical period for competition in the same crop at Bajaura (H.P.).

It was well established by Krishnamurthy *et al.* (1981) that 30 days after sowing is critical period of weed competition in maize, which warrants the use of herbicides because mechanical weeding at early stages is not possible sometimes due to frequent rains. Studies carried out on crop weed competition have shown that weeds pose serious threat to maize between 20-60 days after sowing (Parker, 1983).

From their trial in Taiwan with no-till maize Yang *et al.* (1993) concluded that an acceptable yield of no-till maize can be obtained when weed competition occurs for less than 6 weeks after sowing. In a study conducted by Hatam and Khattak (1995) in Pakistan found that plots kept free of weeds for the whole season and first four weeks after seedling emergence produced the highest grain yield and grain per cob. Usman *et al.* (1999) in the northern Guinea savannah ecological zone of Nigeria reported that weed free for just the initial 3 weeks after sowing (WAS) did not decrease the grain yield. Weed infestation for 9 WAS and above and the weed removal for just 3 WAS caused severe reduction in total yield of maize crop.

Thus the critical period of weed control is the period during the life cycle of a crop when it must be kept weed free in order to prevent a specific level of yield loss (Van Acker *et al.*, 1993; Weaver and Tan, 1987) and this period vary from 2-6 weeks as reported by most of the workers.

2.1.3 Losses caused by weeds

The weeds interfere and reduce the efficiency, add to the cost of agricultural operations, bring down the yields and markedly lower down the land value. The losses due to weeds depend upon type of weed flora, their density, agroclimatic conditions, fertility and moisture status, soil type and type of growth of the crop etc.

Angiras and Singh (1989) reported that season long infestation of composite weed flora in maize reduced grain yield by 28-100% under mid hill conditions of Palampur. Under similar conditions, Singh *et al.* (1996) reported yield reduction to the tune of 50-60% due to weeds. Saini and Angiras (1998) in experiments conducted under silty clay loam soils of Palampur (HP) reported reduction in grain yield of maize by 67 per cent due to weeds in unweeded control over effective treatment of atrazine at 1.5 kg/ha.

In an experiment conducted at Bajaura (H.P.) weed infestation resulted in reduction in yield to the extent of 33-72 per cent (Thakur and Sharma, 1996). Pandey *et al.* (1998) conducted experiment under mid-hill conditions of North-Western Himalayas and revealed that wide row spacing in maize coupled with favourable environment, allow luxuriant weed growth which may reduce maize yield by 30-100%. In another study Pandey *et al.* (2001) reported that season long weed infestation caused yield losses ranging from 30-95% in maize. From Ludhiana Sandhu *et al.* (1999) reported that a wide variety of weeds in maize caused losses ranging from 30 to 50% in grain yield and sometimes even more. Sharma *et al.* (2000) reported loss in grain yield of maize due to uncontrolled weed growth upto 42.3% in first year and 32.4% in second year of experimentation at Ballawal Saunkhri in Punjab.

According to Pandey *et al.* (2002) among different categories of weeds grass weeds offered maximum competition to the crop and reduced grain yield by 77.4% followed by non-grass weeds (44.2%) and sedges (38.4%).

Depending on type of weed flora, their density, locations and soil type the losses due to uncontrolled growth of weeds can extend upto 100 per cent.

2.2 EFFECT OF TILLAGE METHODS

2.2.2 Effect on species-wise weed density and dry matter

Tillage system influenced species-wise weed density and their dry matter. Blackshaw *et al.* (1994) observed that weed densities were greater in zero-tillage plots than in either minimum tillage or conventional tilled plots and weed species such as *Taraxacum officinale* and *Sonchus arvensis* L. increased in the minimum and zero-tillage treatments. Similarly, Felix and Owen (1999) reported more weeds under no-till regime compared to conventional tillage.

Composition and density of weeds differ among tillage systems. No-tillage system typically have higher population of small-seeded annual weeds *viz.*, *Setaria* sp., common lambs quarter (*Chenopodium* sp.), pig weed (*Amaranthus* sp.), while tillage systems have more large seeded annual weeds like common cocklebur (*Xanthium strumarium*) and velvetleaf (Wrucke and Arnold, 1985). Similarly, in an another study by Koskinen and

McWhorter (1986) reported that small seeded species such as common lambs quarters, pig weed and fall Panicum tend to predominate as tillage is reduced. However, velvetleaf (*Abutilon theophrasti*) a relatively large seeded weed has been decreased in no-tillage. In this regard some observations were recorded by Buhler and Daniel (1988) and reported that *Setaria faberi* density in maize was greater (i.e. 1400 shoots/m²) under no-tillage than conventional tillage (170 shoots/m²), while velvet leaf (*Abutilon theophrasti*) density was greater (120 plants/m²) under conventional tillage compared to 20 plants/m² in no-tillage. Buhler (1992) conducted field trial at Hancock, Wisconsin and revealed that density of *Setaria viridis* was greater in no-tillage than in conventional tillage system, while ridge tillage had densities lower than all other tillage systems.

Contrary, to these Johnson *et al.* (1989) found no difference in foxtail (*Setaria sp.*) or common lambs quarters populations between no-tillage and conventional tillage corn production.

Maksymowicz *et al.* (1986) reported that tillage had no effect on broad leaved weed components of the population but a significant increase in biomass of *Digitaria sanguinalis*, *Cynodon dactylon* and *Sorghum halepense* was found on no-tillage as opposed to conventionally tilled plots. Similarly, Wrucke and Arnold (1985) revealed that there was increased annual grass density in no-till compared to conventional till in a corn-soybean rotation, but no change in annual broad leaf species. In an another

experiment conducted by Teasdale *et al.* (1991) on loamy sand soils at Salisbury, reported that total weed density increased after 1 and 2 years of no-tillage and conventional tillage, respectively in a 4-year experiment. Population of *Digitaria sauguinalis*, *Eleusine indica* and *Mollugo verticillata* (29-76, 52-92 and 65-288 plants/m², respectively) were higher in the no-tillage compared to the conventional tillage treatment (3-14, 8-65 and 19-149 plants/m², respectively) in at least 2 years.

Owen (1992) observed greater grass and small seeded annual broadleaf weed population under no-tillage compared with tilled systems. Wicks *et al.* (1994) concluded that in no-tillage there will be a marked drop in the variety of annual species, however concomitantly there will be an increase in winter annual, biennial and all types of perennial weed seeds.

Perennial weeds *viz.* dandelion, field bind weed (*Convolvulus arvensis*) and quack grass (*Elytrigia repens* L.) became more prevalent in no-tillage compared to systems that included pre plant tillage (Pollard and Cussans, 1976). Williams *et al.* (1983) suggested that perennial grass and broadleaf weed populations increased when tillage is reduced. They concluded that perennial monocots might be the greatest threat to adoption of reduced-tillage systems. Reduced tillage would favour rhizome and stolon bearing perennials over annuals. Similarly, Coffman and Frank (1991) demonstrated that conservation tillage (i.e. zero tillage) caused a decrease in annual weed populations, while perennial weeds became more dominant.

Contrary to these, Buhler *et al.* (1994) reported that perennial weed population did not change dramatically in response to tillage.

Results on this aspect, varied among experiments, Buhler (1995) proposed some general trend, as tillage is reduced increased population of perennial, summer annual grass, biennial and winter annual species occurs, while densities of large seeded dicot species often decrease.

According to Wilson (1993) ridge tillage enhanced the development of Kochia (*Kochia scoparia*) and reduced the density of wild proso millet (*Panicum miliaceum*) and common lambs quarter (*Chenopodium album*) on fine sandy loam soil at Scottsbluff, NE.

2.2.1 Effect on weed seed bank and its distribution

Reduced tillage concentrated most of the seeds in top 0 to 5 cm of soil. Pareja and Staniforth (1985) reported from green house study on silty clay loam soil that 85 per cent of seed in zero tillage were in the 0 to 5 cm soil depth compared to only 25% in conventional systems. Mester and Buhler (1986) also reported that maximum weed seeds accumulate at or near the firm soil surface in systems with little or no-tillage.

Production systems with intensive tillage distribute weed seeds throughout the plough depth, whereas, in reduced tillage, new weed seeds remain near the soil surface (Pareja *et al.*, 1985 and Hoffman *et al.*, 1998). Reduced tillage left 50 per cent of the weed seed in the upper 7 cm of the soil, compared with more intensive tillage systems where weed seeds were distributed evenly throughout the upper 30 cm (Wilson, 1988). Cardina *et al.*

(1991) also reported that number of weed seed decreased with depth in continuous no-till after 25 years of experimentation as compared to minimum and conventional tillage. In this context Yenish *et al.* (1992) carried out experiments at Arlington and Hancock and found that after 5 years of experiment 60 per cent of the weed seeds in the soil seed bank were located in the top 1 cm of soil in no-tillage, whereas seeds were distributed uniformly in the top 19 cm of soil in conventional tilled mould board ploughed plots.

Contrary to these findings Clements *et al.* (1996) from their study reported that there were fewer seeds in the weed seed bank in Chisel ploughed and no-tillage plots compared with those in mould board-ploughed plots.

Buhler and Mester (1991) reported that over 40 per cent of giant foxtail plants in no-tillage originated in the upper 1 cm of soil compared to 15 per cent in conventional tillage. Similarly, Schreiber (1992) reported from Purdue University that reducing tillage from conventional ploughing to Chiseling to no-tilling increased giant foxtail seed in the top 0 to 2.5 cm of silty clay loam soil. No tillage increased giant foxtail seed over conventional tillage in each year collected data.

Clement *et al.* (1996) from southwest Ontario, Canada reported that vertical distribution of seeds in the silty loam soil varied with tillage systems. The top 5 cm of soil contained 33 per cent of the seed bank in ridge till system and 74 per cent in no-till system. In ridge till systems, the

highest concentration of seeds (45%) was in the 5 to 10 cm layer. The 5 to 10 cm layer contained the highest concentration of seeds on both the ridge and in the furrow. The top 5 cm contained 33 per cent of the seed bank on the ridge, 27 per cent of the seed bank was in furrow.

Thus, it is evident that most of seeds in minimum, little or zero tillage were concentrated in the upper layer of the soil, while in conventional tillage the seeds were distributed uniformly in different soil depths.

2.2.3 Effect on soil properties

Infiltration is one of the most important process in the soil phase of the hydrological cycle because its rate often determines the amount of run off over the soil surface during rainstorm. Tillage can modify soil surface conditions to retain water for longer time to promote greater infiltration in soils that are slowly permeable. However, Blevins and Frye (1993); Zhai *et al.* (1990) observed that soil moisture is higher in reduced tillage soils because of increased pore space and residue cover that results in higher infiltration rates especially during droughts.

Bulk density is widely used soil parameters to know the structure status of the soils. The magnitude of change in bulk density of soil depends upon its antecedent properties, time of measurement, depth and intensity of tillage operations. Soil loosening decreases and compaction increases the bulk density. No-tillage generally increases the bulk density of soil in surface layer. No tillage always results in a higher soil bulk density and, as a

consequence, greater soil strength (Cannell, 1985; Martino and Shaykewich, 1994). According to Ball-Coelho *et al.* (1998) the bulk density was greater under no-till (1.5 mg m^{-3}) than under conventional till (1.4 mg m^{-3}) in corn field in the top 0-15 cm soil.

2.2.4 Effect on root growth

No tillage may induce changes in the conditions of the topsoil (lower soil temperature, higher soil moisture contents, and higher soil bulk density (BD) and, accordingly, greater soil strength). These soil traits limit root growth and the shoot development of thermophilic crops such as maize. Only few studies have been carried out on the spatial distribution of roots as influenced by tillage and the results are contradictory.

According to Schumran (1965) increased soil bulk density in no-till reduced root growth. Logsdon *et al.* (1987) and Hill (1990) reported that a high soil bulk density can result in short roots. A negative correlation was found between root growth and soil bulk density or soil strength (Huang and Liu, 1989). The greater the soil strength, the more it mechanically impedes root growth, which may slow root elongation (Castillo *et al.*, 1982; Lachno *et al.*, 1982) and increase the root diameters (Lachno *et al.*, 1982; Chassot and Richner, 2002). Thereby, nutrient uptake and plant growth are affected indirectly (Peterson *et al.*, 1984). Similarly, Chassot and Richner (2002) reported that an increase in top bulk density caused a linear decrease in root length, root mass and root/shoot ratio.

Goss (1977), Cannell (1985) and Goss and Russell (1980) reported that a higher soil BD (soil strength) may stimulate root branching and induce the formation of lateral roots but block the growth of the main axes. Similarly, Ball-Coelho *et al.* (1998) reported that there was more horizontal root development under no-tillage, particularly in the upper half of the A-horizon, while under conventional tillage roots were more vertically oriented. There were few roots below the A-horizon (0.25 m) under either system.

Barber (1971) studied corn root distribution in a Raub silt loam soil and reported that when soil was ploughed annually corn roots developed more extensively to a greater depth than where soil was not tilled or tilled to a 5 cm depth only. Roots were finer and longer/g in tilled soil than in untilled soil. Also, Maurya and Lal (1980) found that there were more maize roots in the surface layer (0-10 cm) with no-tillage than in conventionally ploughed plots and also at 10-40 cm maize roots were more abundant in the no-tillage plots.

2.2.5 Effect on crop growth and development

In Ontario, Vyn *et al.* (1980) reported that plant density and emergence were normally not affected by tillage. The effect was expressed only after seedlings emergence. Chassot *et al.* (2001) reported slower growth and development of shoot in no-tillage systems in contrast with conventional tillage systems. From other field trial conducted at Ontario, by Barry and Miller (1986) concluded that slower growth with zero-tillage

usually begins at the four or five leaf stage and continues until 10 to 12 leaf stage and also it was hypothesized that restriction of nodal root development occurs with zero-tillage and causes reduction in shoot growth.

Sawhney *et al.* (1989) conducted experiment at Ludhiana on Loamy sand soil and found that planting the crop on ridges resulted in early emergence and vigorous growth.

Dwyer *et al.* (1995) from Ottawa, Canada reported that over three years, the ranking of maize dry weight at 6 leaf, 12 leaf and silking stages was more in ridge till than no-till. Tillage effects were only significant at early vegetative stages.

In drained conditions of Aurora, New York, maize growth under ridge tillage was slower than conventional tillage while, in undrained condition with some flooding ridge tillage shortened flood duration resulting in increased plant survival, faster growth and development (Cox *et al.*, 1990).

2.2.6 Effect on yield and yield contributing characters

According to Sharma *et al.* (1988) tillage increased grain yield of maize by 242 per cent in clay loam soil. Kaul *et al.* (1970) conducted experiment at Ludhiana on sandy loam soil and found that deep tillage proved significantly better over no cultivation and showed increase in yield over other cultivation treatments. The increase in yield in favour of deep tillage was 14.5 q/ha as compared to no-cultivation. Similarly, Masand *et al.* (1993) in Himachal Pradesh conditions evaluated the effect of three tillage

methods *viz.* minimum, conventional and deep and found that maximum yield of maize was obtained with deep tillage and minimum with minimum tillage treatments. Conventional tillage was the next best treatment after deep tillage.

In results of 20 years of trials in S. Ontario, maize sown without tillage yielded 10-20 per cent less than maize sown with conventional tillage except on very coarse-textured soils or where maize followed a sod crop (Vyn *et al.*, 1980).

In another study carried out by Barry and Miller (1986) revealed that yields with zero tillage was 10-15% lower than those with conventional tillage. According to Acharya and Sharma (1994) who, carried out their study on silty clay loam soil of Palampur (H.P.) found that the grain yield of no-tillage was comparable to conventional tillage for the first three years in case of maize. The yield decreased significantly in no-tillage compared with conventional-tillage for the subsequent three years due to development of impedance.

Cox *et al.* (1990) from Aurora, New York reported that under drained conditions, maize grain yield was 10 per cent less under zero tillage than conventional tillage (8.68 and 9.60 t/ha, respectively) and 5 per cent lower under ridge tillage (RT) (9.05 t/ha). While, under undrained conditions with some flooding, grain yields were significantly higher under ridge tillage than conventional tillage and zero tillage (7.92, 7.09 and 7.19 t/ha, respectively).

Brar and Cheema (1988) studied the effect of different agronomic practices for managing excess water in maize and they found that among different management practices, sowing maize on ridges was one of the way to produce significantly higher grain yield. The thousand grain weight were also significantly higher when the crop was sown on ridges/raised bed. Similarly, Lal *et al.* (1988) from Pantnagar, reported that planting of maize on the ridge (29.29 t/ha), on raised bed (28.25 t/ha) gave significantly higher grain yield than planting on flat beds (24.27 t/ha). Also, from other experiment it was concluded that planting the crop (winter maize) on ridges resulted in significantly higher yield (51.9 q/ha) over the crop raised on flat beds (41.5 q/ha) and higher shelling percentage (Sawhney *et al.*, 1989).

Contrary to these, in New Delhi, Sawat and Dayanand (1994) tested furrow and ridge methods of sowing along with three moisture conservation practices and found that methods of sowing did not produce any significant effect on either yield or yield contributing characters.

Fausey (1990) observed that corn and soybean yields were improved under ridge-tillage on a Clermont silt loam soil due to improved drainage.

Thus it can be concluded that in most of the studies on different tillage methods, zero tillage resulted in significantly lower yield over other *viz.* conventional, raised seed bed and deep tillage while in another tillage practice raised/ridge tillage was significantly superior or equally good to conventional tillage.

2.2.7 Economics of tillage methods

Zero tillage significantly reduces cost of production. Farmers quote a figure of about Rs. 2000-2500/ha less cost because of saving in diesel and labour. No-till allows farmer to make a profit and is a necessity these days (Mishra, 2004). Chauhan *et al.* (2001) reported that zero tillage reduce diesel consumption by 40-70 litres per hectare depending upon soil conditions. However, Stefanic and Stefanic (1996) conducted field research in northeastern Croatia to evaluate the effects of 7 tillage systems and weed infestation on the economic results of maize (cv. OSSK 407) production. They reported that no-tillage led to significant losses of gross margin compared to other treatments. The other treatments (6 tillage) showed no significant differences in terms of profitability. Similarly, Phillips *et al.* (1997) initiated a tillage project at the University of Illinois, Dixon to evaluate conservation tillage systems for land being removed from the Conservation Reserve Program (CRP). No-till (NT), chisel plough (CP), and mouldboard plough (MP) tillage systems on a silt loam (Typic Fragjudalf) soil were studied. No-tillage led to significant losses of gross margin compared to other treatments. The other treatments (6 tillage) showed no significant differences in terms of profitability.

Dogra *et al.* (2002) revealed from their study that deep tillage was most beneficial to the farmer in terms of maize yield and net returns despite its higher cost of cultivation and soil loss. Zero tillage, though had the lowest cost of cultivation and soil loss, was not economical because of poor net returns.

Vannini *et al.*, (1994) carried out field trials at Carpi and indicated that gross margins with ridge tillage closely reflected crop yield, being significantly higher in the first year and decreasing in advantage thereafter. However, ridge tillage resulted in a 15-24% reduction in tillage costs and 10-12% reduction in total variable costs as compared to conventional tillage.

2.3 EFFECT OF WEED CONTROL METHODS

2.3.1 Effect on weed count and dry matter

(i) Atrazine

Roberts and Neilson (1981) found that herbicides influence seed number and species composition of the seed bank. Certain species decrease in the seed bank and other increase depending on herbicide use and when triazines were applied consecutively to corn fields for 16 years in England, the seed bank decreased 96 per cent and number of species was reduced by half. Similarly in an another study by Schweizer and Zimdahl (1984) reported that the seed bank was reduced 98 per cent, after atrazine was applied to corn field for 6 years at Fort Collins, Colorado on clay loam soil.

Long term use of atrazine in North Carolina was associated with replacement of large crab grass (*Digitaria sanguinalis*) by fall Panicum (Johnson and Coble, 1986).

Sangwan *et al.* (1989) conducted trial at HAU, Hissar in winter maize and reported that 2,4-D 0.5 kg/ha applied post-emergence and atrazine 0.75 kg/ha pre-emergence provided greater reduction in dry matter

and N-uptake by weeds than 0.25-0.75 kg/ha cytrazine, 1-2 kg/ha, alachlor 0.25-0.50 kg/ha atrazine \pm 1 kg alachlor or hand weeding at 30, 60 and 90 days after sowing.

In loamy sand soil of Ludhiana, atrazine 1.0 kg/ha (pre.) was as effective as atrazine 1.0 kg/ha applied 5 DAS, band application of atrazine 0.35 kg/ha or a directed spray of paraquat 0.25 kg/ha mixed with surfactant (Brar *et al.*, 1991). In an another experiment at same location, atrazine and simazine 1.0 kg/ha and hand weeding significantly reduced the density and dry matter of weeds over rest of the treatments (Walia *et al.*, 1995).

From Egypt, Risk and El-Bially (1996) reported that atrazine 0.6 kg/0.42 ha reduced the incidence of weeds and gave 97.6 per cent control of weeds even after 70 DAS compared to the unweeded control and consequently had the lowest weed coverage i.e. 29.2 per cent at harvest. Similarly, Rout and Satapathy (1996) reported that atrazine 1.25 kg/ha (pre-emergence) was more than 90% efficient in reducing dry matter of weeds. Saini and Angiras (1998) revealed that atrazine 1.5 kg/ha (pre-emergence) followed by atrazine 0.75 kg/ha (post-emergence) being at par with metolachlor 1.5 kg/ha (pre-emergence) followed by atrazine 0.75 kg/ha (2-3 leaf stage of *Ageratum*) and alachlor 1.5 kg/ha (pre-emergence) followed by atrazine 0.75 kg/ha (2-3 leaf stage of *Ageratum*) resulted in significantly higher maize grain yield by reducing population and dry matter of weeds in silty clay loam soils of Palampur (H.P.).

In an another study carried out by Singh *et al.* (1998) at Birsa found that pre-emergence application of atrazine at 0.5 kg/ha, atrazine + alachlor both at 0.5 kg/ha, and atrazine at 0.5 kg/ha combined with hand weeding at 45 DAS were effective to reduce density and dry matter of weeds. Sharma *et al.* (2000) obtained 74.8-83.6 per cent reduction in total weed count with atrazine 1.0 kg/ha over control in sandy loam soils of Saunkhri, Nawan Shahar, Punjab.

Saini (2000) reported from Himachal Pradesh that atrazine at 2.0 and 2.5 kg/ha provided the lowest weed dry weight, whereas, atrazine 1.0 kg/ha did not provide adequate control.

Under Almora conditions of Uttaranchal Pandey *et al.* (2001) found that atrazine 1.25 kg/ha pre-emergence significantly reduced the population and dry weight of weeds. Atrazine was more effective than pendimethalin 1.5 kg/ha or alachlor 2.0 kg/ha (Pre.) against *Ageratum conyzoides*.

Post-emergence application of atrazine at 0.75 kg/ha at tasseling stage of maize have been recommended to control an obnoxious weed *Ageratum conyzoides* in maize in Hirnachel Pradesh (Anonymous, 1995).

But the continuous use of these triazine herbicides resulted in development of resistance in certain weed species. Vencill and Foy (1988) found from Virginea that smooth pig weed (*Amaranthus hybridus*) has been found resistant to triazine herbicides such as atrazine. Similarly Cavers and Benoit (1989) reported that continued use of triazine herbicides in corn fields in Ontario altered weed species composition and resulted in large increase in triazine resistant weeds.

Ritter *et al.* (1989) carried field studies near Delta, PA on slaty silt loam soil and revealed that pre-emergence application of atrazine with cyanazine or simazine provided poor season long control of *Setaria faberi* in no-tillage corn. The same author with his associates also done green house studies and reported that triazine resistant giant foxtail tolerated pre-emergence application of atrazine or simazine at dosages to 9.0 kg/ha.

(ii) Acetachlor

Lynn (1980) reported that in maize, acetachlor 2 lb/acre pre-emergence was very effective to control *Setaria* sp., *Panicum dichotomiflorum*, *Amaranthus retroflexus* and *Cyperus esculentus*. In another study Miklos (1981) obtained good control of monocotyledonous weeds in maize with both acetachlor and metolachlor at 1 or 2 kg/ha. Acetachlor 1 or 2 kg/ha controlled *Chenopodium album* and *Polygonum lapathifolium* well in rotations and moderately in monocultures. In dry spells acetachlor at rates of 3 and 4 kg/ha performed the better of two.

Nelson and Bryant (1981) worked for the control of wooly cupgrass in maize and found that good control was achieved with 2.5 or 3.5 lb/ha acetachlor whether incorporated before sowing or applied pre-emergence. Control of Shatter cane (*Sorghum bicolor*) was inadequate with acetachlor. In another study on silty clay loam soil at Stratford, Iowa, Owen *et al.* (1993) evaluated wooly cupgrass control in corn with pre-sowing incorporated and pre-emergence application of acetachlor (1.7-6.7 kg/ha),

alachlor (2.2-9.0 kg/ha) and metolachlor (1.7-6.7 kg/ha). Averaged over both application rates acetachlor at 3.4 kg/ha controlled > 85 per cent of woolly cupgrass in 5 of the 6 years.

Pre-emergence application of 3.36 kg/ha of acetachlor, 2.4 kg acetachlor + 1.08 kg 2,4-D amine/ha, 1.6 kg atrazine + 2.4 kg acetachlor/ha and 1.92 kg alachlor + 2.4 kg butachlor/ha all gave good control of *Acanthospermum australe* (Ruckheim and Batistela, 1982). In experiment carried out by Da Silva *et al.* (1982) found that pre-emergence application of acetachlor 2.4-3.6 kg/ha controlled *Ageratum conyzoides* more effectively than alachlor.

In studies conducted at Martonvasar Hungary, the effects of three chloroacetanilides on weed control were compared by Tomordi (1987). Among these herbicides acetachlor was more effective in reducing weed density than propachlor or metolachlor and showed greater spectrum of activity. Geriev (1996) reported that acetachlor began to be widely used in maize in North Osetiya, Russia and when it was applied at 3 litres/ha before sowing or pre-emergence, 90-95 per cent effective control against annual gramineous and dichotyledonous weed was achieved.

Krausz *et al.* (2000) evaluated grass control in no-till maize with herbicides applied at different times and found that the herbicides applied pre-emergence provided more consistent giant foxtail (*Setaria faberi*) and barn yard grass (*Echinochloa crus-galli*) control (90 to 98%) than the same

herbicides applied early post emergence. Similarly, Nikolova and Baeva (2004) revealed that acetachlor significantly decreased the number of *Setaria glauca* and *Echinochloa crus-galli* plants.

Thus the inference which can be drawn from the above cited literature on acetachlor that as pre-emergence application, this herbicide provided good control of weeds especially monocotyledonous and proved better over the other herbicides of the same group.

2.3.2 Effect on crop growth

A study was conducted in Maharashtra, India, to assess the efficacy of different herbicides and their effect on the growth of maize. Weed free control had the highest plant height, number of leaves per plant, dry matter per plant and harvest and was at par with handweeding and pre-emergence application of atrazine 1.0 kg/ha (Shinde *et al.*, 2001).

Da-Silva *et al.* (1982) reported that when acetachlor was applied at various rates (i.e. 2.4-3.6 kg/ha), slight reduction in maize plant height was noticed at highest rate. However, Lynn (1980) reported crop injury when application rate was increased. Crop injury increased from 5 per cent at 1.5 lb to 11 per cent at 2 lb/acre.

Nikolova and Baeva (2004) reported that acetachlor had significant effects on maize growth and development when applied at 1.35-2.25 kg/ha.

2.3.3 Effect on yield and yield attributes

Under conditions of Himachal Pradesh Chakor and Awasthi (1983) reported that pre-emergence application of simazine or atrazine 1-2.5 kg/ha to maize gave effective weed control and increased the grain yields from 2.56 to 5.47-6.62 t/ha in first year and from 2.8 to 6.8-7.28 t/ha in second year compared with 5.81 and 6.78 t/ha, respective yield with two hand weedings. From their trials carried out for two consecutive years at Ludhiana on loamy sand soil Gill *et al.* (1987) recorded that maximum grain yield of 3.87 and 2.8 t ha⁻¹ during first and second years, respectively was in the pre-emergence application of atrazine 1.0 kg/ha, which was closely followed by the pre-emergence application of sugrazine (50 and 80 WP). Similarly, Madhu and Nanjappa (1993) reported significant increase by atrazine 0.75 or 1.00 kg/ha over unweeded check at Bangalore, Karnataka. Significant increase in grain yield and all the yield attributes with atrazine over weedy check was also reported by Paradkar and Sharma (1993) at Chhindwara on clay loam soil.

Dixit *et al.* (1996) reported from New Delhi that highest grain yield was given by 0.75 kg atrazine/ha applied pre-emergence plus 0.25 kg/ha atrazine applied at the knee high and tasseling growth stages. Mishra *et al.* (1996) conducted field trial in Bihar for two years and found that pre-emergence application of atrazine 1.0 kg/ha was the most effective to control weeds and produced the highest grain yield of 3.35 and 2.47 t/ha, respectively.

From Bajaura, Himachal Pradesh Thakur and Sharma (1996) found that atrazine 1.25 kg/ha as pre-emergence and two hand weedings remained at par with each other resulted in significantly higher grain yield, test weight and grain weight/cob. Under similar location Sharma *et al.* (1998) reported that atrazine 1.25 kg/ha (pre) significantly increased grain yield compared to unweeded check.

Significantly higher grain yield was achieved with application of 3.36 kg acetachlor/ha, 2.4 kg acetachlor + 1.08 kg 2,4-D amine/ha, 1.6 kg atrazine + 2.4 kg acetachlor/ha and 1.92 kg alachlor + 2.4 kg butachlor/ha (Ruckheim and Batistela, 1982). Tomordi (1987) carried out his study at Hungary and found that at low or recommended application rates yields of maize were greater with acetachlor and above a rate of above 3 kg/ha metolachlor gave the highest yield. Similarly, at 3 kg/ha acetachlor application rate significantly higher grain and green mass yield was reported by Geriev (1996).

2.3.4 Effect on economics

Shah and Koul (1990) reported that atrazine 1 kg/ha resulted in highest economic returns over all weed control treatments (Rs. 10.16-12.73/Rs. invested). Similarly, in an another study carried out by Khajanji *et al.* (2002) from Pantnagar, Uttranchal reported that application of atrazine was better than the weedy control in respect of benefit:cost and energy output:input ratios.

2.3.5 Effect on biochemical properties

Randhawa *et al.* (1988) reported from PAU, Ludhiana that atrazine at 0.25, 0.5 and 0.75 kg/ha (pre-emergence) increased the protein content of the grain compared to two handweedings. Risk and El-Bially (1996) analysed that atrazine 0.6 kg a.i./0.42/ha recorded 73.0% increase in protein yield compared to unweeded control.

2.4 INTEGRATED EFFECT OF TILLAGE AND WEED CONTROL METHODS

Some of herbicide combinations that provided weed control in corn with tilled soil were not adequate in a no-till system. Because of this higher rates of herbicides may be necessary under reduced-tilled conditions. From Indiana, Griffith *et al.* (1973) revealed that increasing the herbicide rate used in tilled soil by 20 per cent did not always gave adequate control under no-till conditions. Similarly, Johnson *et al.* (1989) reported that plant residue on the soil surface may alter the behaviour of herbicides applied to the soil surface in no-tilled soil. Depending on percentage surface cover and residue type, upto 60 per cent of the herbicide applied may be intercepted by residue. Interaction of soil-applied herbicide with surface residue may be partially responsible for the effect of tillage system on weed control. In other study carried out by Koskinen and McWhorter (1986) revealed that weed management in conservation tillage cropping systems, especially no-till, depends heavily on herbicides. As a consequence, the amount of herbicide used is often greater in conservation tillage systems than in conventional tillage systems.

Kells *et al.* (1980) reported from Lexington, Kentucky that if herbicides rates were reduced, less weed control was observed when residue was present. Greater weed control was maintained under conventional tillage than no-tillage when equal level of atrazine were present in the soil which is silt loam in texture.

In Brazil, Ferri and Vidal (2004) tested acetachlor 1680, 3360 and 5040 g/ha applied on tillage and no-tillage systems with and without straw mulch and found that weed control with acetachlor was more efficient on tillage than on no-tillage system.

2.4.1 Effect on species wise weed count and dry matter

Triplett and Lytle (1972) found that fall Panicum (*Panicum dichotomiflorum* Mech X.) density increased rapidly when triazine herbicides were used for several years under no-tillage as compared to conventional tillage with moldboard plough system and annual weed composition of a community changed rapidly in no-till cultures, depending on weed species present and the herbicide selected. However, all species of annual weeds were not uniformly controlled by zero-tillage due to increased weed population resistant to a herbicide at Wooster, Ohio on Canfield silt loam soil.

From a five year study using conservation tillage methods in the Maryland Piedmont on silty loam soil Coffman and Frank (1991) reported that weed flora dominance shifted from giant foxtail in the first year to smooth pigweed the following year. Smooth pigweed then dominated the

flora for the duration of study. Canada thistle occurred in measurable densities in all treatments that had not received atrazine applied pre-emergence. According to Buhler (1992) *Setaria viridis*, *Amaranthus retroflexus* were more difficult to control in no-tillage than in the conventional and ridge tillage systems with several herbicides treatments including atrazine 2.2 kg/ha at Hancock, WI on loamy sand soil.

Mueller and Hayes (1997) conducted trial on a fine loamy soil in Tennessee, USA using pre-emergence herbicides alachlor 2.8 kg/ha, metolachlor 2.2 kg/ha, dimethenamid 1.3 kg/ha, pendimethalin 1.1 kg/ha and acetachlor-Z and acetachlor-M (2.0 kg/ha). Control of *Brachiaria platyphylla* with pre-emergence herbicides was usually lower in no-tillage plots than in plots with tillage. In second year of experimentation, the best weed control was in tilled plots treated with acetachlor. Acetachlor provided control for about 4-weeks under no-tillage and about 8-weeks after tillage. Acetachlor provided consistent control regardless of the rainfall pattern after the application. There were no differences in acetachlor formulations.

2.4.2 Effect on weed seed distribution

Integration of herbicides with tillage and cultivation practices has altered the size and nature of seed bank (Roberts, 1981). From Indiana, Bauman and Ross (1983) revealed that reducing or eliminating tillage may also influence the behaviour of soil applied herbicides. Plant residue on the soil surface intercepts some of the herbicide applied, reducing the amount reaching the soil and altering distribution.

On ridge tillage aspect Forcella and Lindstrom (1988) conducted their research in clay loam soil of Morris, WN and suggested that cultivation improved weed control following herbicides treatments and reduced weed seed production in maize crop. Hoffman *et al.* (1998) reported from Boone Country in silty clay loam soils that tillage affected vertical distribution of seeds, while the quantity of weed seeds in the top 5 cm of soil was regulated by weed control practices.

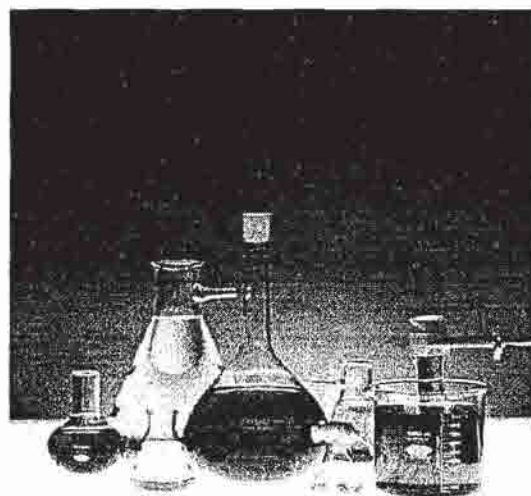
2.4.3 Effect on crop development

Rungnapa (1985) from Thailand showed that flowering date was not affected by tillage system, methods of weed control and methods of fertilizer application.

2.4.4 Effect on yield and yield contributing characters

Buhler and Daniel (1988) reported that several herbicides including atrazine 3.4 kg/ha resulted in corn yield similar to the weed free under conventional tillage but no herbicide treatment produced corn yield similar to the weed free control under no-till conditions.

An experiment was conducted at University of Minnesota, Morris, MN on clay loam soil and found that withholding herbicides for one year reduced yield of continuous corn by 10-27 per cent in ridge tillage and only 2-4 per cent in conventional tillage (Forcella and Lindstrom, 1988).



Materials and Methods

MATERIALS AND METHODS

A field experiment entitled, "Integrated effect of tillage and weed control methods on weed dynamics and weed management in maize (*Zea mays* L.)" was conducted at the research farm of Department of Agronomy, CSK Himachal Pradesh Krishi Vishvavidyalaya, Palampur (H.P.) during the *Kharif* seasons of 2002 and 2003. The materials used in the experiments and methods employed for evaluating the treatments are described in detail in this chapter.

3.1 EXPERIMENTAL SITE

3.1.1 Location

Experimental farm of Department of Agronomy representing mid-hills of Kangra Valley is located at 32°6' N latitude and 76°3' E longitude having an elevation of 1290.8 metres above mean sea level.

3.1.2 Climate and weather conditions

Agroclimatically, Palampur represents the mid-hill sub-temperate humid zone of Himachal Pradesh and endowed with mild summers and cool winters alongwith high rainfall of about 1250 mm per annum. A major part (75 per cent) of total rainfall is received during monsoon period (June to September) while, rest is received in winter months. The weekly averages of

meteorological data collected from the Meteorological observatory of the Department of Agronomy during the course of investigation are presented in Appendices I(a) & I(b) and depicted graphically in Fig. 3.1.

A cursory glance at Fig. 3.1 and meteorological data presented in Appendices I(a) & I(b) reveals that the mean weekly maximum temperature of 24.6°C to 31.6°C and 25.9°C to 33.1°C and mean weekly minimum temperature of 14.9°C to 20.4°C and 14.6°C to 20.7°C were recorded during the life cycles of maize crop in 2002 and 2003, respectively. The average weekly mean temperature ranged between 20.8°C to 25.3°C and 20.2°C to 26.5°C during crop season of 2002 and 2003, respectively. The total rainfall received during the crop season of 2002 and 2003 amounted to 914.2 mm and 1820.0 mm, respectively. Out of the total rainfall during the cropping period 492.3 mm (53.85 per cent) and 1289.1 mm (70.83 per cent) was received during the period between emergence to silking and only 421.9 mm (46.15 per cent) and 530.9 mm (27.42 per cent) from silking to maturity during the years 2002 and 2003, respectively. The mean relative humidity of 53.5 to 91.0 per cent and 52.0 to 89.5 per cent were recorded during the crop seasons of first and second year, respectively. The mean sunshine hours varied from 1.2 to 8.8 hours and 2.1 to 7.1 hours during whole crop season in 2002 and 2003, respectively.

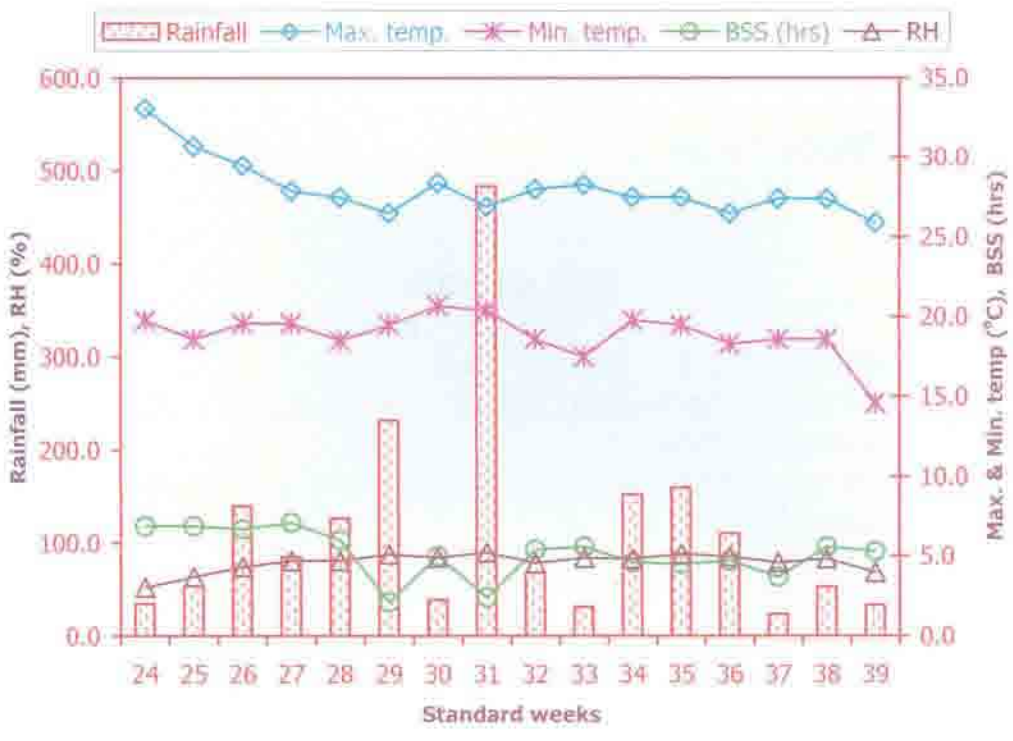
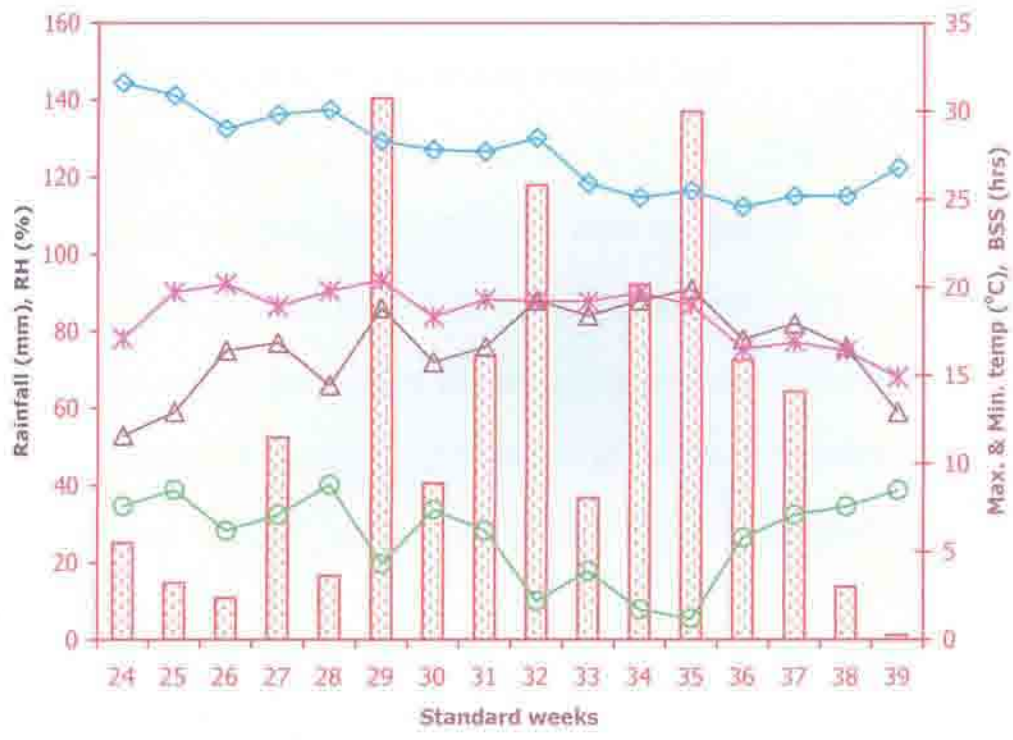


Fig. 3.1 Mean weekly weather data recorded at Palampur during *kharif* 2002 and 2003

3.1.3 Physico-chemical properties of soil

Prior to the start of experiment (*Kharif* 2002 and 2003) three composite soil samples (0-15 cm) from each replication were collected and were air dried, ground, passed through 2 mm sieve and analyzed for their physico-chemical properties by the standard methods as mentioned in Table 3.1. It is evident from the data that soil of the experimental field was silty clay loam in texture, acidic in reaction, medium in available nitrogen, available phosphorus and available potassium.

Table 3.1 Physico-chemical characteristics of soil prior to experimentation

Particulars	Content in soil		Analytical method employed
	2002	2003	
A. Mechanical characteristics			
Sand	20.4	19.8	International pipette method (Piper, 1966)
Silt	43.4	46.3	
Clay	35.8	33.9	
Texture	Silty clay loam		
B. Chemical characteristics			
pH	5.6	5.5	1:2.5 soil water suspension using glass electrode pH meter (Jackson, 1967)
Available N (kg/ha)	302.8	296.6	Alkaline permanganate method (Subbiah and Asija, 1956)
Available P (kg/ha)	17.8	18.6	Olsen's method (Olsen's <i>et al.</i> , 1954)
Available K (kg/ha)	316.7	321.9	Extraction with normal neutral ammonium acetate and determined by flame photometer method (Black, 1965)

3.1.4 Cropping history

The experimental site was under general crop of maize and wheat in the system for the last 2 years continuously before the present experiment in which recommended package of practices for fertilizers and other inputs were used.

3.2 EXPERIMENTAL DETAILS

3.2.1 Treatments

Twelve treatment combinations under test included three tillage methods in main plots and four weed control methods in sub-plots. The layout plan is given in Fig. 3.2. The treatment details are given below:

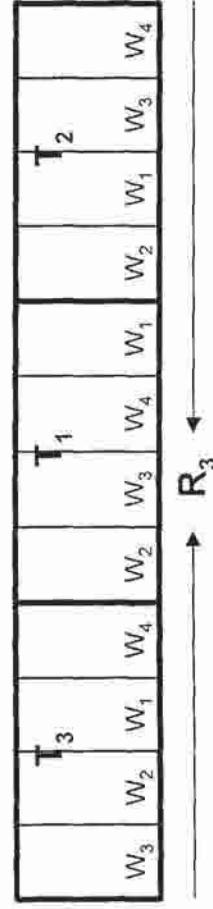
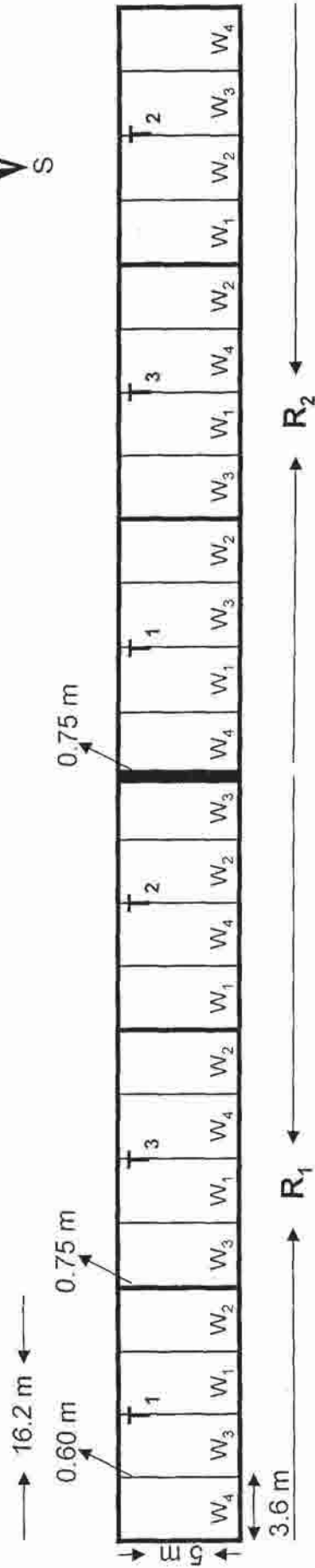
(A) Main plots – Tillage methods

- (i) Conventional tillage
- (ii) Zero tillage
- (iii) Raised seed bed

(B) Sub-plots – Weed control methods

- (i) Unweeded
- (ii) Acetachlor 0.75 kg/ha (pre-emergence)
- (iii) Acetachlor 1.25 kg/ha (pre-emergence)
- (iv) Atrazine 1.50 kg/ha (pre-emergence)

Atrazine 0.75 kg/ha was applied at 2-3 leaf stage of *Ageratum conyzoides*.

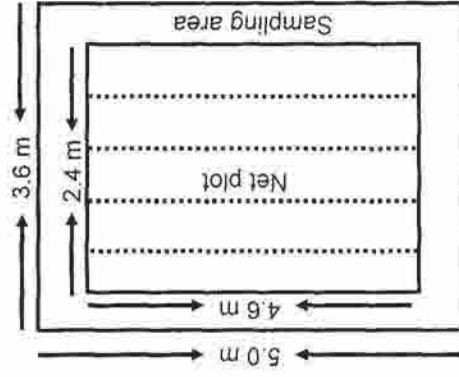


Main plot

- T₁ = Conventional tillage
- T₂ = Zero tillage
- T₃ = Raised seed bed

Sub plot

- W₁ = Unweeded
- W₂ = Acetachlor 0.75 kg ha⁻¹ (pre.)
- W₃ = Acetachlor 1.25 kg ha⁻¹ (pre.)
- W₄ = Atrazine 1.50 kg ha⁻¹ (pre.)



Gross and net plot

Gross plot size = 5.0 m x 3.6 m
 Net plot size = 4.6 m x 2.4 m

Fig. 3.2 Layout Plan

Design	:	Split plot
Replications	:	Three
Treatments	:	Main-plots : 3
		Sub-plots : 4
Total number of plots	:	36
Plot size	:	Gross : 5.0 m x 3.6 m
		Net : 4.6 x 2.4 m

3.3 FIELD OPERATIONS

3.3.1 Field preparation and layout

The experimental area was divided into three equal parts to adjust three replications and each replication was divided into three main plots. The treatments in the main plots were randomized first in each replication. Tillage treatments *viz.*, zero, conventional and raised seed bed were then imposed. Each main plot was further sub divided into four equal sub-plots to assign different weed control treatments after randomization. Zero tillage included no soil disturbance except opening a small furrow for seed placement with the help of Power tiller operated zero till drill and leaving about 5-10% of residue of previous wheat crop. For conventionally tilled plots the land was first ploughed with disc plough (primary tillage) followed by 2-3 times harrowing and planking (secondary tillage) while, raised seed bed was prepared with the help of raised seed bed planted after performing primary tillage operations as in conventional tillage.

3.3.2 Sowing

The certified seeds of maize hybrid variety PSCL-3438 of Pioneer company were sown on 11th June during both the years in rows 60 cm apart at plant to plant distance of 20 cm with the seed rate of 20 kg/ha. Zero tillage and raised seed bed sowing was done with power tiller drawn zero till maize planter and raised seed bed planter, respectively (Plate I).

3.3.3 Fertilizer application

All the plots received uniform application of 120 kg nitrogen, 60 kg phosphorus and 40 kg potassium through urea (46% N), single super phosphate (16% P₂O₅) and muriate of potash (60% K₂O), respectively. One third nitrogen and full dose of phosphorus and potassium was applied as basal dose and remaining two third of nitrogen was applied in two equal splits at knee-high and pre-tasseling stages. The basal dose of fertilizer in zero tillage plots and in raised seed bed plots was drilled with zero tillage maize planter drill and raised seed bed planter, respectively, while in conventional tillage plots basal dose was placed below the seed in the open furrows made by hand operated plough. The two splits of nitrogen were given by placing fertilizer by the sides of maize rows avoiding direct contact with plants.

3.3.4 Detail of herbicides used and their application

Sr. No.	Common name	Trade name	a.i.	Chemical name
1.	Acetachlor	MON-8485 (Code No.)	90 EC	2-chloro 2'methyl 6;ethyl N(ethoxymethyl) astenalide
2.	Atrazine	Him taf	50 WP	2-chloro 4-isopropyl amino 6-ethyl amino S-triazine



Sowing with conventional tillage methods



Sowing with power tiller operated zero tillage maize planter



Raised seed bed planter

Plate I

Methods used for sowing under various tillage methods

All herbicides were applied as pre-emergence within 48 hours of sowing with the help of Maruyama power sprayer fitted with flat fan nozzle using 600 litre of water per hectare. The plots in which *Ageratum conyzoides* appeared were sprayed with atrazine 0.75 kg/ha at 2-3 leaf stage of *Ageratum*.

Zero tilled plots were sprayed with paraquat 0.6 kg/ha before sowing to kill the existing weeds and stubbles of wheat crop.

3.3.5 Harvesting

The maize crop was harvested when cob sheath turned brown and the grains were hard. The harvesting was done manually by picking the cobs from the plants of each net plot (4.6 m x 2.4 m) separately by leaving one row on borders and 20 cm from each side of the plot. The harvesting was done on 27th September, 2002 during first year and on 24th September, 2003 during second year.

3.4 OBSERVATIONS RECORDED

3.4.1 Soil studies

3.4.1.1 Soil moisture content

Soil samples were taken from two soil depths (0-15 cm and 15-30 cm) before the crop sowing with the help of tube auger in each crop season. The moisture was determined by drying the soil samples in an electric hot air oven at 105°C till the weight was constant and moisture content was calculated on oven dry basis.

3.4.1.2 Bulk density

After the harvest of each crop, bulk density of the soil from 0-15 cm and 15-30 cm soil depths was determined by using standard core method (Black, 1965). For this purpose, metal cores of known volume were used for collecting undisturbed soil samples from two spots of each plot at both the depths. The mean values of bulk density for each plot at two depths was calculated.

3.4.1.3 Infiltration rate

Infiltration behaviour of the soil under different treatments was studied at maize harvest using double infiltrometer. The infiltrometers were pushed into the soil to a depth of 0.10 m. A pointed nail was fixed inside the inner infiltrometer at about 0.10 m height from the surface of soil. Same water level was maintained in both the inner and outer infiltrometers. The volume of water infiltrated into soil as a function of time was measured by replacing the amount of water reduced in inner infiltrometer ring with the help of measuring cylinder. The depth of the water infiltrated was computed by dividing the volume with the cross-section area of the inner infiltrometer. Regular determinations were made at periodical intervals until the steady state condition of water flux was reached. The data were plotted as infiltration rate vs. time for computing the infiltration rate.

3.4.2 Crop studies

3.4.2.1 Growth studies

The following observations pertaining to emergence, growth, yield contributing characters and yield of maize crop were recorded from each plot.

3.4.2.1.1 Emergence count

Two samples each of one metre row length were fixed at random in each plot before the emergence of crop. Emergence count was recorded from two samples daily from the date of emergence start till it was constant. The mean of two samples at final observation was recorded as the emergence count per metre.

3.4.2.1.2 Plant height

Five plants of maize were selected at random from the central four rows of each plot and tagged. The height was measured at 30 days interval from the date of sowing. Before tasseling stage, the height was recorded from soil surface to the base of the fully opened top leaf whereas, after tasseling the height was measured upto the base of the tassel. The mean plant height (cm) was obtained by dividing the plant height by five.

3.4.2.1.3 Number of functional leaves per plant

The photosynthetically active (green) leaves of five tagged plants were counted at the same time when the height was measured. The fully opened and completely green leaves were considered as photosynthetically active leaves. The total number of leaves were divided by five to get the mean number of leaves per plant.

3.4.2.1.4 Dry matter accumulation

In order to study the pattern of dry matter accumulation, three plants from each plot were randomly sampled at 30 days interval from the sample rows of each plot from either side of net plot rows. The dry matter accumulation per plant was worked out after drying the chopped samples in sun for one day and at 70°C in oven till constant weight and then dividing total weight by three.

3.4.2.1.5 Stalk diameter at harvest

Stalk diameter of five selected maize plants from each plot was measured at the base with the help of Vernier Caliper. The mean stalk diameter was calculated in milli-meter by dividing total diameter by five.

3.4.2.1.6 Lateral and vertical spread of roots

The root samples were taken by rectangular core method (Bohm, 1979) Rectangular core of varying dimension and depth was used for each month. The root samples were initially washed with tubewell water and then with distilled water to make them free from soil particles. The lateral and vertical spread was determined by placing the roots over the graph paper. The widest lateral spread of the root from each side of the root shoot joint point and longest vertical length of the root from the same point was determined by recording the counts for intersection of roots (N) with vertical and horizontal lines of 1 cm grid from the graph paper.

3.4.2.1.7 Lodging percentage

The lodging percentage in each net plot was determined by utilizing the data on number of maize plants lodged and total plant population at harvest using formula:

$$\text{Lodging percentage} = \frac{\text{Number of plants lodged in each net plot}}{\text{Total plant population in each net plot}} \times 100$$

3.4.2.2 Developmental studies

The data pertaining to the development studies of maize crop as affected by different treatments were recorded at respective times.

3.4.2.2.1 Days taken to emergence

The emergence count was recorded from the sampling area daily from the date of first emergence till it was constant and number of days taken to emergence was calculated from the date of sowing.

3.4.2.2.2 Days taken to 50% tasseling and 50% silking

The plots were visited every alternate day from the date of first appearance of tassel and silk till complete tasseling and silking. The dates on which 50 per cent plants in net plot showed tasseling or silking were recorded and used for calculating number of days taken for 50% tasseling and silking, respectively from the date of sowing.

3.4.2.2.3 Days taken to maturity

When the cob sheaths of almost all the maize plants turned brownish yellow and started drying, and the grains hardened, the date was noted and number of days taken from the date of sowing to maturity were calculated.

3.4.2.3 Yield and yield contributing characters

3.4.2.3.1 Effective plant population

The total number of cob bearing maize plants present in each net plot were counted before harvesting. The number of effective plants per hectare was obtained by multiplying with the factor 905.80.

3.4.2.3.2 Length of cobs

The length of cobs was measured from the butt edge to the last grain at the other end. The total length of five cobs was divided by 5 to get the mean cob length.

3.4.2.3.3 Number of grains per cob

Total number of grains were shelled manually from each randomly selected 5 cobs and counted. The total number of grains of five cobs were then averaged by dividing with 5 to workout the number of grains per cob.

3.4.2.3.4 Test weight

Fully dried 1000-grains were taken out randomly from five fully dried cobs taken for sampling from each net plot and their weight was recorded.

3.4.2.3.5 Shelling percentage

The shelling percentage was determined by taking representative sample of 5 cobs from each net plot. The weight of these cobs was recorded before the grains were separated. The weight of separated grains was recorded. The shelling percentage was then calculated with following formulae:

$$\text{Shelling percentage} = \frac{\text{Grain weight of 5 cobs}}{\text{Total weight of 5 cobs}} \times 100$$

3.4.2.3.6 Grain yield

All the picked and stripped cobs from each net plot were weighed. Grain samples were taken immediately after shelling and per cent moisture was determined by taking the fresh weight of grains and their dry weight after drying in oven. The grain yield was calculated by multiplying the total weight of all stripped cobs from each net plot with shelling percentage. The yield was adjusted at 15 per cent moisture by multiplying with the factor. The plot yield (kg) was converted into kg per hectare by multiplying with factor 905.80.

3.4.2.3.7 Stover yield

The decobbed maize plants were harvested close to the ground and were dried in Sun. The weight (kg) of stover of each net plot was recorded and converted into kilogram per hectare by multiplying with factor 905.80.

3.4.2.3.8 Biological yield

Biological yield was calculated by adding dry weight of cob and stover of net plot and converted to per hectare basis by multiplying with 905.80 factor.

3.4.2.3.9 Harvest index

Harvest index was calculated by using the following formula:

$$\text{Harvest index} = \frac{\text{Grain yield (kg/ha)}}{\text{Biological yield (kg/ha)}} \times 100$$

3.4.3 Weed studies

The following observations on weeds associated with the crop were recorded.

3.4.3.1 Weed seed bank studies

Soil samples were taken after seed bed preparation but prior to seeding and herbicide application. Rectangular cores of 25 cm x 25 cm were sampled in triplicate from each of the main plots. The samples were collected from the area between two crop rows in zero and conventionally tilled plots. While, in raised seed bed the sample was taken from the bed. The soil samples were taken at 0-10 cm, 10-20 cm and 20-30 cm depths. The composite samples of respective main plots were made and each sampled depth was placed separately in 5 cm deep plastic tray. The trays were placed in open and watered daily. Seedling emergence was counted over a period of three months and the soil was stirred once per month. Seedlings were identified by species. Cumulative seedling numbers were considered to represent the pool of viable non-dormant seed bank in different depths of the soil of the sampled plots.

3.4.3.2 Depth of emergence of different weed species

Weed seedlings were carefully taken out of the soil with the help of spade, soon after the emergence of weeds. For determining the depth of emergence of different weed species the achlorophyllous portion from the seed to the ground level was measured with the help of meter scale.

3.4.3.3 Species-wise and total weed count

Before the emergence of crop and weeds an area of 0.0625 m² was earmarked at two places by fixing 25 cm x 25 cm quadrates randomly in each net plot. Species-wise and total weed count was recorded at monthly interval from these fixed quadrates. The data obtained from two quadrates were averaged and multiplied by 16 to get species-wise and total weed count per square metre.

3.4.3.4 Species-wise and total dry matter of weeds

Species-wise weed samples were collected at monthly interval from 50 cm x 50 cm quadrate placed randomly outside the net plot area. These samples were first air dried and then oven dried at a temperature of 70°C till constant weight. Species-wise and total dry matter accumulation of weeds per square metre was calculated by multiplying the recorded values by 4.

3.4.3.5 Weed control efficiency (WCE)

Species-wise and total weed control efficiency of different treatments was worked out at maximum weed dry matter as per the formula outlined by Lal (1990).

$$\text{WCE (\%)} = \frac{W_c - W_t}{W_c} \times 100$$

where, W_c - Weed dry weight in unweeded conventional tillage plots

W_t - Weed dry weight in treated plot

3.4.3.6 Days taken to emergence of grasses, sedges and broad leaved weed species

In each plot an area of 50 cm x 50 cm was demarcated and visited at every alternate day after sowing of the crop till tasseling. The date on which grasses, broad leaved and sedges emerged in maximum proportion were recorded and number of days taken to emergence of different categories of weeds was recorded.

3.4.3.7 Days taken to flowering and senescence

In each plot weed plants were tagged in an earmarked area of 50 cm x 50 cm and visited at every alternate day after the appearance of the first flower and initiation of senescence. The dates on which maximum tagged weed species have attained maximum flowering and senescence was recorded and used for calculating number of days taken to flowering and senescence of various weeds.

3.4.4 Biochemical studies

Representative samples of maize grain and stover at harvest and weeds at maximum dry matter stage from each plot were collected, dried in an oven till constant weight, processed and analyzed for total nitrogen, phosphorus and potassium uptake (Jackson, 1967).

3.4.4.1 Nutrient uptake by weeds and crop

The uptake of nitrogen, phosphorus and potassium by grain and straw at harvest and by weeds at maximum dry matter stage was calculated by multiplying the content of each nutrient with respective weight of grains, straw yields and weed dry matter at respective stages separately. The respective nutrient uptake from grain and straw yield was added to determine the nutrient wise total uptake by crops and weeds.

3.4.4.2 Protein content in maize grains

The oven dried samples of maize grain were analyzed for total nitrogen following Kjeldahl's method (A.O.A.C., 1970). Nitrogen content determined as per above procedure was multiplied by 6.25 to get the protein content in maize grains.

3.4.4.3 Starch content in maize grains

Random grain samples (15% moisture) were collected from each net plot produce and starch content was estimated according to the method given by Dubois *et al.* (1956).

3.4.5 Economic studies

With the objectives of working out the economic profitability of different treatments, cost of cultivation, gross returns, net returns and benefit:cost ratio of each treatment were calculated taking prevailing local market prices of inputs and the output. These values were worked out as under.

3.4.5.1 Cost of cultivation

Cost of cultivation was worked out for each treatment and appended in Appendix 3. The requirements of mechanical power for various field operations such as ploughing, harrowing, planking, sowing, ridging and labourers for spraying, top dressing of nitrogen (urea), watch and ward, thinning, harvesting, threshing and cleaning were calculated for respective treatment on hectare basis as per the approved norms/rates of the university.

3.4.5.2 Gross returns

Gross returns were obtained by multiplying the quantity of produce per hectare with the prevailing prices of produce as per the approved rates of the university.

3.4.5.3 Net returns

Net returns were worked out by subtracting the cost of cultivation per hectare from the gross returns per hectare.

3.4.5.4 Benefit:cost ratio

The benefit:cost ratio was calculated as per following formulae:

$$\text{Benefit:cost ratio} = \frac{\text{Net returns (Rs./ha)}}{\text{Cost of cultivation (Rs./ha)}}$$

3.5 STATISTICAL ANALYSIS

The data obtained were subjected to statistical analysis as outlined by Gomez and Gomez (1984) and were tested at 5 per cent level of significance to interpret the treatment differences. The weed count data, weed dry matter data and weed seed bank data were analyzed after subjecting the original data to $\sqrt{x+1}$ transformation and the treatment effects were compared by using transformed means. The ANOVA table has been appended in Appendix III.



Results

EXPERIMENTAL RESULTS

The results emanating from the present investigation entitled, "Integrated effect of tillage and weed control methods on weed dynamics and management in maize (*Zea mays* L.)" have been presented in this chapter. The sole and integrated effect of different treatments have been described under the following headings:

4.1 Weed dynamics studies

4.2 Crop studies

4.3 Economic studies

4.1 WEED DYNAMICS STUDIES

4.1.1 Distribution of weed species

Based on the species wise and total weed count at maximum weed population stage (60 DAS) in the unweeded check plots of the experimental area, the percentage invasion by different weed species was calculated and have been presented in Table 4.1.

A perusal of the data revealed that *Digitaria sanguinalis* (L.) Scop., *Echinochloa colona* (L.) Link and *Panicum dichotomiflorum* Michx. were the dominant grass weeds and constituted 45.30, 26.67 and 15.10 per cent of the total weed flora, during 2002, respectively and 30.86, 24.56 and 12.56

per cent of the total weed flora during 2003, respectively. Among broad leaved weeds *Commelina benghalensis* L. was dominant and constituted 5.37 and 17.71 per cent of total weed flora during first and second year, respectively. *Cyperus iria* was the only sedge present in the experimental area and constituted 3.35 and 6.57 per cent of the total weed flora during 2002 and 2003, respectively. The other weed species include *Oxalis latifolia* L., *Polygonum alatum* L., *Ageratum conyzoides* L., *Cynodon dactylon* L. and *Ipomoea purpurea* (L.) Roth together constituted only 3.69 and 7.71 per cent of the total weed flora during first and second year, respectively.

Table 4.1 Species-wise distribution of weeds in experimental area at 60 days after sowing

Weed species	Population (No./m ²)		Percentage of total	
	2002	2003	2002	2003
<i>Digitaria sanguinalis</i> (L.) Scop.	180.00	144.00	45.30	30.86
<i>Echinochloa colona</i> (L.) Link	104.00	114.67	26.17	24.57
<i>Panicum dichotomiflorum</i> Michx.	60.00	58.67	15.10	12.57
<i>Commelina benghalensis</i> L.	21.33	82.67	5.37	17.71
<i>Cyperus iria</i> L.	13.33	30.67	3.35	6.57
<i>Brachiaria romosa</i> L.	14.67	16.00	3.69	3.43
Other weeds*	14.67	36.00	3.69	7.71
Total	397.33	466.67	100	100

*(*Oxalis latifolia* L., *Ageratum conyzoides* L., *Cynodon dactylon* L., *Ipomoea purpurea* (L.) Roth, *Polygonum alatum* L.)

4.1.2 Weed seed bank studies

The data on distribution of weed seeds in different depths of soil as affected by tillage and weed control methods has been presented in Table 4.2 and 4.3.

4.1.2.1 *Digitaria sanguinalis*

The data presented in Table 4.2 revealed that while significantly lowest number of seeds of *Digitaria* were recorded in raised seed beds at depths of 0-10 cm, zero tillage resulted in significantly lowest population of its seeds in 10-20 cm and 20-30 cm depths during both the year. The remaining tillage methods in each of the soil depths being statistically at par were next best in influencing its seed bank. However, conventional tillage was statistically at par with zero tillage in 0-10 cm soil depth during first year and with raised seed bed during second year.

4.1.2.2 *Echinochloa colona*

It is evident from the data in Table 4.2 that while significantly lowest number of seeds of *Echinochloa colona* were recorded in raised seed bed at 0-10 cm soil depth, zero tillage resulted in significantly lowest seeds in 10-20 cm and 20-30 cm soil layer during both the years. However, raised seed was at par with conventional tillage during second year with respect to seed bank in 0-10 cm soil layer and zero tillage was at par with conventional tillage in influencing the seed bank of *Echinochloa* in 20-30 cm soil layer during first year. The raised seed being statistically at par with conventional tillage was next best in reducing the seed bank of *Echinochloa* at 10-20 cm during both the years and at 20-30 cm soil depth during first year.

Table 4.2 Effect of tillage methods on distribution of weed seeds (No./m²) of *Digitaria sanguinalis*, *Echinochloa colona* and *Panicum dichotomiflorum* in different soil depths

Treatments	0-10 cm		10-20 cm		20-30 cm	
	2002	2003	2002	2003	2002	2003
<i>Digitaria sanguinalis</i>						
Zero tillage	60.8 (212.8)	64.0 (244.8)	27.2 (32.0)	33.6 (59.2)	16.0 (0.0)	16.0 (0.0)
Conventional tillage	56.0 (187.2)	52.8 (160.0)	44.8 (107.2)	52.8 (160.0)	32.0 (48.0)	28.8 (36.8)
Raised seed bed	32.0 (48.0)	44.8 (107.2)	41.6 (91.2)	46.4 (123.2)	35.2 (59.2)	35.2 (59.2)
SEm ±	4.8	4.8	4.8	4.8	1.6	3.2
CD (P=0.05)	12.8	14.4	12.8	12.8	6.4	9.6
<i>Echinochloa colona</i>						
Zero tillage	57.6 (196.8)	59.2 (0.0)	28.8 (36.8)	28.8 (36.8)	17.6 (4.8)	16.0 (0.0)
Conventional tillage	54.4 (171.2)	49.6 (139.2)	46.4 (116.8)	43.2 (100.8)	27.2 (32.0)	24.0 (20.8)
Raised seed bed	38.4 (80.0)	43.2 (100.8)	41.6 (91.2)	40.0 (84.8)	33.6 (52.8)	32.0 (48.0)
SEm ±	4.8	3.2	4.8	1.6	3.2	1.6
CD (P=0.05)	11.2	9.6	11.2	6.4	9.6	6.4
<i>Panicum dichotomiflorum</i>						
Zero	53.0 (160.0)	46.4 (116.8)	20.8 (11.2)	25.6 (27.2)	16.0 (0.0)	16.0 (0.0)
Conventional	46.4 (116.8)	40.0 (84.8)	35.2 (64.0)	38.4 (75.2)	24.0 (20.8)	27.2 (32.0)
Raised seed bed	28.8 (36.8)	35.2 (59.2)	33.6 (52.8)	35.2 (59.2)	28.8 (36.8)	27.2 (32.0)
SEm ±	1.6	1.6	3.2	1.6	1.6	1.6
CD (P=0.05)	6.4	6.4	8.0	4.8	6.4	6.4

Values in parentheses are means of original values

4.1.2.3 *Panicum dichotomiflorum*

The data on weed seed bank in Table 4.2 indicate that number of seeds of *Panicum* were found to be significantly lowest in raised seed bed plots at 0-10 cm and in zero tilled plots at 10-20 and 20-30 cm soil depths during both the years. However, raised seed bed was at par with conventional tillage and zero tillage at par with conventional tillage during second year in influencing the seed bank of *Panicum* at 0-10 cm and 20-30 cm soil depth, respectively. The raised seed bed being statistically at par with conventional tillage was next best in reducing the seed bank of *Panicum dichotomiflorum* at 10-20 cm soil depth during both the years and at 20-30 cm soil depth during first year.

4.1.2.4 *Commelina benghalensis*

None of the tillage methods had significant influence on distribution of *Commelina benghalensis* weed seeds at various soil depths during second year and 0-10 cm soil depth during first year (Table 4.3). At 10-20 cm and 20-30 cm soil depths significantly lowest number of seeds of *Commelina* were recorded in zero tilled plots. The remaining tillage methods being statistically at par were next best in influencing its seed bank.

4.1.2.5 *Ageratum conyzoides*

The data in Table 4.3 revealed that raised seed bed being statistically at par with conventional tillage resulted in significantly lower number of seeds of *Ageratum conyzoides* in 0-10 cm soil depth during

second year. At remaining soil depths significantly lowest number of seeds of *Ageratum* were found in zero tilled plots. The rest of the tillage methods being statistically alike were next best in reducing its seed bank at 10-20 cm during second year and 20-30 cm soil depths during both the years. However, during first year conventional tillage was the next best in reducing its seed bank in 10-20 cm soil depth.

Table 4.3 Effect of tillage methods on distribution of weed seeds (No./m²) of *Commelina benghalensis* and *Ageratum conyzoides* in different soil depths

Treatments	0-10 cm		10-20 cm		20-30 cm	
	2002	2003	2002	2003	2002	2003
<i>Commelina benghalensis</i>						
Zero tillage	44.8 (112.0)	46.4 (116.8)	22.4 (16.0)	22.4 (16.0)	16.0 (0.0)	16.0 (0.0)
Conventional tillage	52.8 (155.2)	44.8 (107.2)	38.4 (75.2)	30.4 (43.2)	28.8 (36.8)	22.4 (16.0)
Raised seed bed	52.8 (155.2)	46.4 (116.8)	38.4 (75.2)	35.2 (59.2)	24.0 (20.8)	24.0 (20.8)
SEm ±	6.4	8.0	4.8	4.8	1.6	8.0
CD (P=0.05)	NS	NS	14.4	NS	6.4	NS
<i>Ageratum conyzoides</i>						
Zero tillage	104.0 (656.0)	121.6 (923.2)	54.4 (171.2)	52.8 (164.8)	22.4 (16.0)	16.0 (0.0)
Conventional tillage	89.6 (484.8)	97.6 (580.8)	65.6 (251.2)	76.8 (352.0)	51.2 (148.8)	44.8 (112.0)
Raised seed bed	80.0 (384.0)	84.8 (443.2)	78.4 (368.0)	72.0 (304.0)	59.2 (203.2)	49.6 (144.0)
SEm ±	11.2	8.0	4.8	4.8	8.0	4.8
CD (P=0.05)	NS	24.0	11.2	14.4	20.8	11.2

Values in parentheses are means of original values

4.1.4 Progressive weed count

The data on species-wise and total progressive weed density have been presented in Table 4.5 to 4.15. In general the population of all the weed species and their total increased upto 60 DAS and decreased thereafter with exception of *Brachiaria ramosa* which appeared late in the growing season, during both the years of investigation.

4.1.4.1 *Digitaria sanguinalis*

It is evident from the data in Table 4.5 that the population of *Digitaria sanguinalis* was significantly influenced by different tillage and weed control methods at all the times of observation during both the years of study.

Raised seed bed resulted in significantly lowest population of *Digitaria sanguinalis* at all the stages of observation during both the years. However, it was statistically at par with conventional tillage at 90 DAS during second year. Conventional tillage being the next best was significantly superior to zero tillage at 60 DAS during both the years and 30 DAS and harvest of the crop during second year.

All the weed control treatments reduced the population of *Digitaria sanguinalis* significantly as compared to unweeded check at all the times of observation during both the years (Table 4.5). Among these treatments, atrazine 1.5 kg/ha and acetachlor 1.25 kg/ha being statistically at par were significantly superior in reducing its population during both the years except at 90 DAS during 2003, where acetachlor 1.25 kg/ha was the next best.

Table 4.5 Effect of tillage and weed control methods on progressive weed count of *Digitaria sanguinalis* (No./m²)

Treatments	30 DAS		60 DAS		90 DAS		At harvest	
	2002	2003	2002	2003	2002	2003	2002	2003
Tillage methods								
Zero	4.7 (21.3)	5.9 (35.7)	8.6 (89.3)	9.6 (96.7)	6.8 (46.7)	7.6 (60.7)	5.8 (33.7)	6.4 (42.3)
Conventional	4.4 (18.3)	5.2 (28.0)	7.4 (74.3)	8.4 (74.0)	6.2 (39.3)	6.6 (46.0)	5.3 (28.3)	5.6 (32.7)
Raised seed bed	3.3 (10.0)	4.4 (19.7)	6.2 (51.3)	7.4 (55.3)	4.8 (24.5)	5.9 (35.0)	4.1 (17.0)	4.9 (24.3)
SEm ±	0.4	0.2	0.4	0.3	0.5	0.4	0.3	0.2
CD (P=0.05)	1.0	0.5	1.1	0.9	1.3	1.2	0.8	0.5
Weed control methods								
Unweeded	5.7 (31.6)	7.4 (53.8)	11.0 (165.3)	11.7 (137.8)	8.6 (73.1)	9.7 (92.9)	7.3 (52.0)	8.2 (65.8)
Acetachlor 0.75 kg/ha	4.1 (15.6)	5.5 (29.3)	7.4 (56.4)	8.4 (70.7)	5.8 (32.4)	7.0 (48.0)	5.0 (23.6)	5.7 (32.0)
Acetachlor 1.25 kg/ha	3.3 (9.8)	4.2 (16.0)	6.0 (32.0)	7.2 (51.1)	4.7 (22.0)	5.3 (26.7)	4.1 (16.0)	4.6 (19.6)
Atrazine 1.5 kg/ha	3.3 (9.3)	3.7 (12.0)	5.2 (32.9)	6.6 (41.8)	4.6 (19.8)	4.8 (21.3)	3.9 (13.8)	4.1 (15.1)
SEm ±	0.3	0.3	0.4	0.3	0.2	0.2	0.2	0.4
CD (P=0.05)	0.6	0.7	0.8	0.7	0.5	0.5	0.5	0.8

Table 4.6 Integrated effect of tillage and weed control methods on population of *Digitaria sanguinalis* (No./m²) at 60 DAS

Tillage methods	Weed control methods			
	Unweeded	Acetachlor 0.75 kg/ha	Acetachlor 1.25 kg/ha	Atrazine 1.5 kg/ha
2002				
Zero	14.01 (194.67)	9.24 (84.00)	6.26 (37.33)	6.55 (41.33)
Conventional	13.49 (180.00)	7.05 (48.00)	6.03 (34.67)	6.04 (34.67)
Raised seed bed	11.09 (121.33)	6.24 (37.33)	5.07 (24.00)	5.96 (22.67)
2003				
Zero	13.30 (176.00)	10.09 (100.00)	8.43 (69.33)	6.54 (41.33)
Conventional	12.08 (144.00)	7.87 (60.00)	6.95 (46.67)	6.87 (45.33)
Raised seed bed	9.71 (93.33)	7.33 (52.00)	6.24 (37.33)	6.38 (38.67)
	2002		2003	
	SE(m)±	CD (P=0.05)	SE(m)±	CD (P=0.05)
To compare two weed control methods at same level of tillage methods	0.46	0.96	0.59	1.23
To compare two tillage methods at same or different level of weed control methods	0.85	1.45	0.77	1.40

Values in parentheses are means of original values

The tillage and weed control methods interacted significantly in influencing the population of *Digitaria sanguinalis* at its maximum population stage (60 DAS) during both the years. The interaction data presented in Table 4.6 and Fig. 4.1 revealed that irrespective of weed control methods, raised seed bed resulted in significantly lower population of *Digitaria sanguinalis* during both the years. However, it was statistically at par with conventional tillage in all the weed control treatments except unweeded check during both the years. Zero tillage in combination with acetachlor 1.25 kg/ha or atrazine 1.5 kg/ha during the first year and in combination with atrazine 1.5 kg/ha during the second year were also behaved statistically similar to conventional and raised seed bed in reducing the population of this weed.

In each of the methods of tillage except zero tillage during second year, atrazine 1.5 kg/ha being statistically at par with acetachlor 1.25 kg/ha reduced the population of *Digitaria sanguinalis* significantly over rest of the weed control methods during both the years. However, in conventional tillage and raised seed bed acetachlor 0.75 kg/ha was statistically at par with acetachlor 1.25 kg/ha and atrazine 1.5 kg/ha during the second year. In zero tillage plots, atrazine 1.5 kg/ha was significantly superior over the remaining weed control treatments during second year.

Integration of raised seed bed with each of the chemical methods of weed control resulted in significantly lower population of *Digitaria sanguinalis* during both the years. However, it was statistically at par with

conventional tillage in integration with acetachlor 1.25 kg/ha or atrazine 1.5 kg/ha and raised seed bed with acetachlor 0.75 kg/ha during both the years and combination of zero tillage with acetachlor 1.25 kg/ha during first year and with atrazine 1.5 kg/ha during the second year.

4.1.4.2 *Echinochloa colona*

A perusal of the data in Table 4.7 indicate that tillage and weed control methods have significant influence on the population of *Echinochloa colona* at all the stages of observation during both the years of study except at 90 DAS during first year and at harvest during both the year where tillage method did not have any significant influence.

Table 4.7 Effect of tillage and weed control methods on progressive weed count of *Echinochloa colona* (No./m²)

Treatments	30 DAS		60 DAS		90 DAS		At harvest	
	2002	2003	2002	2003	2002	2003	2002	2003
Tillage methods								
Zero	3.6 (12.0)	4.7 (22.7)	6.7 (48.2)	7.9 (64.7)	4.9 (25.3)	6.6 (45.0)	4.2 (18.3)	5.2 (27.3)
Conventional	3.6 (12.7)	4.7 (21.7)	6.2 (42.0)	7.8 (61.7)	4.7 (23.0)	6.2 (38.7)	4.3 (18.3)	4.9 (23.7)
Raised seed bed	3.1 (8.7)	4.1 (16.0)	5.4 (30.0)	6.9 (48.3)	4.1 (16.0)	5.6 (31.0)	3.6 (12.0)	4.3 (18.7)
SEm ±	0.1	0.2	0.1	0.2	0.2	0.2	0.3	0.3
CD (P=0.05)	0.2	0.5	0.2	0.5	NS	0.5	NS	NS
Weed control methods								
Unweeded	5.0 (23.6)	6.5 (41.8)	9.6 (90.9)	10.5 (109.3)	7.0 (48.0)	8.6 (72.44)	6.1 (36.0)	7.0 (48.0)
Acetachlor 0.75 kg/ha	3.5 (10.2)	4.4 (17.8)	5.5 (29.3)	7.2 (50.2)	4.2 (16.4)	6.0 (34.2)	3.9 (13.3)	4.6 (19.6)
Acetachlor 1.25 kg/ha	2.8 (6.2)	3.6 (11.1)	4.8 (21.3)	6.3 (37.8)	3.6 (11.1)	5.1 (24.4)	3.2 (8.4)	3.9 (13.3)
Atrazine 1.5 kg/ha	2.4 (4.4)	3.4 (9.8)	4.5 (18.7)	6.1 (35.6)	3.4 (10.2)	4.9 (21.8)	23.0 (7.1)	3.7 (12.0)
SEm ±	0.3	0.4	0.3	0.3	0.3	0.4	0.2	0.3
CD (P=0.05)	0.7	0.9	0.7	0.6	0.7	0.8	0.5	0.6

Values in parentheses are means of original values

Raised seed bed resulted in significantly lowest population of *Echinochloa colona* at all the stages of observations during both the years. Conventional and zero tillage being statistically at par at all the observation stages except 60 DAS during first year were the next best.

All the weed control treatments were significantly superior over unweeded check in reducing the population of *Echinochloa colona* at all the stages of observation during both the years. Atrazine 1.5 kg/ha being statistically at par with acetachlor 1.25 kg/ha reduced its population significantly over remaining weed control treatments at all the stage of observation during both the years. However, acetachlor 0.75 kg/ha was statistically alike to its higher dose at 30 DAS during second year and at 90 DAS during first year of experimentation.

4.1.4.3 *Panicum dichotomiflorum*

A critical perusal at the data (Table 4.8) revealed that the tillage methods did not cause significant effect on the population of *Panicum dichotomiflorum* at all the stages of observation during both the years except at 60 and 90 DAS during 2003, when raised seed bed resulted in significantly lowest population of *Panicum dichotomiflorum*.

All the weed control treatments were significantly superior to unweeded check in reducing the population of *Panicum dichotomiflorum* at all the stages of observation during both the years except at 30 DAS during first year and at harvest during 2003, where, acetachlor 0.75 kg/ha was

statistically alike to unweeded check. Atrazine 1.5 kg/ha being statistically at par with acetachlor 1.25 kg/ha resulted in significantly lower population of this weed at all the stages of observation during both the years. However, acetachlor 1.25 kg/ha was also statistically at par with acetachlor 0.75 kg/ha at 30 DAS during 2002.

Table 4.8 Effect of tillage and weed control methods on progressive weed count of *Panicum dichotomiflorum* (No./m²)

Treatments	30 DAS		60 DAS		90 DAS		At harvest	
	2002	2003	2002	2003	2002	2003	2002	2003
Tillage methods								
Zero	2.8 (6.0)	3.1 (8.3)	4.1 (16.0)	6.1 (36.3)	3.7 (12.7)	4.9 (23.3)	3.0 (8.0)	3.7 (12.3)
Conventional	2.6 (5.0)	3.0 (8.0)	3.9 (13.7)	6.0 (35.3)	3.4 (10.0)	4.8 (22.3)	3.0 (7.3)	3.7 (12.3)
Raised seed bed	2.1 (2.7)	2.5 (5.0)	3.5 (11.0)	5.4 (27.7)	3.0 (7.7)	4.3 (17.0)	2.7 (5.7)	2.9 (7.3)
SEm ±	0.3	0.3	0.1	0.1	0.3	0.2	0.1	0.3
CD (P=0.05)	NS	NS	NS	0.3	NS	0.4	NS	NS
Weed control methods								
Unweeded	3.1 (7.6)	3.9 (13.8)	4.8 (21.3)	7.4 (53.3)	4.3 (17.3)	5.8 (32.4)	3.7 (12.0)	4.4 (17.8)
Acetachlor 0.75 kg/ha	2.7 (5.3)	3.2 (8.4)	4.1 (14.7)	6.1 (35.6)	3.7 (11.6)	5.1 (24.0)	3.2 (8.4)	3.9 (13.3)
Acetachlor 1.25 kg/ha	2.2 (3.1)	2.3 (3.6)	3.5 (10.2)	4.9 (21.8)	2.9 (6.7)	4.0 (14.2)	2.6 (4.9)	2.9 (6.7)
Atrazine 1.5 kg/ha	2.0 (2.2)	2.1 (2.7)	3.1 (8.0)	4.9 (21.8)	2.6 (4.9)	3.9 (12.9)	2.4 (4.0)	2.5 (4.9)
SEm ±	0.3	0.3	0.2	0.3	0.3	0.3	0.2	0.3
CD (P=0.05)	0.6	0.6	0.4	0.5	0.5	0.5	0.4	0.6

Values in parentheses are means of original values

4.1.4.4 *Brachiaria ramosa*

It is evident from the data in Table 4.9 that *Brachiaria* appeared after 30 DAS. Its population was significantly influenced by tillage and weed control methods at all the observation stages during both the years except at 90 DAS during 2003 where the tillage methods did not influence the population of *Brachiaria* significantly.

Table 4.9 Effect of tillage and weed control methods on progressive weed count of *Brachiaria ramosa* (No./m²)

Treatments	60 DAS		90 DAS		At harvest	
	2002	2003	2002	2003	2002	2003
Tillage methods						
Zero	3.1 (8.7)	3.8 (12.8)	3.5 (11.7)	3.7 (13.3)	3.4 (10.7)	3.6 (13.0)
Conventional	3.0 (7.7)	3.5 (10.7)	3.4 (9.7)	3.5 (11.7)	3.2 (9.0)	3.4 (11.0)
Raised seed bed	2.6 (5.3)	3.2 (8.2)	3.0 (7.7)	3.2 (9.3)	2.9 (7.0)	3.2 (9.3)
SEm ±	0.1	0.2	0.1	0.2	0.1	0.1
CD (P=0.05)	0.3	0.5	0.3	NS	0.2	0.2
Weed control methods						
Unweeded	3.6 (11.6)	4.0 (14.0)	4.1 (14.7)	4.3 (16.9)	4.1 (14.7)	4.3 (16.4)
Acetachlor 0.75 kg/ha	3.2 (8.4)	3.2 (8.7)	3.7 (11.6)	4.0 (14.2)	3.4 (9.8)	3.8 (12.9)
Acetachlor 1.25 kg/ha	1.4 (0.0)	1.4 (0.0)	1.4 (0.0)	1.4 (0.0)	1.4 (0.0)	1.4 (0.0)
Atrazine 1.5 kg/ha	3.3 (8.9)	3.7 (11.56)	3.8 (12.4)	4.1 (14.7)	3.6 (11.1)	4.1 (15.1)
SEm ±	0.2	0.2	0.1	0.2	0.1	0.2
CD (P=0.05)	0.4	0.4	0.3	0.3	0.3	0.4

Values in parentheses are means of original values

Raised seed bed resulted in significantly lower population of *Brachiaria ramosa* at all the stages of observation during both the years. However, it was statistically at par with conventional tillage at 60 DAS and harvest of the crop during 2003. Conventional tillage was significantly superior to zero tillage at harvest of the crop during 2002. However, it did not reduce the population of *Brachiaria ramosa* over zero tillage at 60 and 90 DAS during 2002.

All the weed control methods were found significantly superior over unweeded check in reducing the population of *Brachiaria ramosa* at all the stages of observation during both the years. Acetachlor 1.25 kg/ha resulted in 100 per cent control of *Brachiaria ramosa* at all the stages of observation

during both the years. Acetachlor 0.75 kg/ha was the next best treatment in reducing the density of this weed during both the years. However, it was statistically alike to atrazine at all the stages of observation during first year.

4.1.4.5 *Commelina benghalensis*

The data presented in Table 4.10 indicates that population of *Commelina benghalensis* was influenced significantly by tillage and weed control methods at all the stages of observation during both the years.

It is evident from the Table 4.10 that zero tillage resulted in significantly lowest population of *Commelina benghalensis* at all the stages of observation during both the years. Conventional tillage being statistically similar to zero tillage was significantly superior to raised seed bed to reduce its population at all the times of observation during 2002.

All the weed control methods were significantly superior to unweeded check in reducing the population of *Commelina* at all the stages during both the years. Among the weed control methods atrazine 1.5 kg/ha being statistically at par with acetachlor 1.25 kg/ha resulted in significant reduction in population in *Commelina* at all the stages of observation during both the years. However, at 60 DAS during 2002, acetachlor 1.25 kg/ha was next best to atrazine 1.5 kg/ha in reducing its population.

The tillage and weed control methods interacted significantly in influencing the population of *Commelina benghalensis* at its maximum population stage. The interaction data presented in Table 4.11 and Fig. 4.1

Table 4.10 Effect of tillage and weed control methods on progressive weed count of *Commelina benghalensis* (No./m²)

Treatments	30 DAS		60 DAS		90 DAS		At harvest	
	2002	2003	2002	2003	2002	2003	2002	2003
Tillage methods								
Zero	3.3 (9.3)	3.0 (7.7)	4.9 (23.2)	6.5 (40.7)	3.9 (14.3)	4.2 (16.7)	3.7 (12.3)	3.3 (10.0)
Conventional	3.4 (10.7)	3.7 (13.0)	5.4 (30.0)	7.1 (51.0)	4.2 (17.3)	5.2 (27.0)	3.8 (14.0)	4.1 (16.3)
Raised seed bed	4.2 (17.3)	4.5 (21.0)	6.8 (49.0)	8.3 (71.0)	5.3 (28.0)	6.0 (37.7)	4.8 (22.3)	5.0 (25.7)
SEm ±	0.2	0.2	0.3	0.2	0.4	0.3	0.1	0.1
CD (P=0.05)	0.7	0.6	0.9	0.6	1.0	0.8	0.4	0.4
Weed control methods								
Unweeded	4.8 (21.8)	5.5 (30.2)	8.1 (65.1)	9.3 (87.1)	6.0 (34.7)	7.1 (50.2)	5.4 (28.0)	5.9 (35.1)
Acetachlor 0.75 kg/ha	4.3 (17.3)	4.0 (14.7)	6.3 (39.1)	7.8 (59.6)	5.0 (24.0)	5.4 (28.4)	4.7 (20.4)	4.6 (20.0)
Acetachlor 1.25 kg/ha	2.7 (5.8)	2.8 (6.2)	4.4 (18.2)	6.0 (34.4)	3.5 (11.1)	4.0 (14.2)	3.3 (9.3)	3.1 (8.0)
Atrazine 1.5 kg/ha	2.6 (4.9)	2.5 (4.4)	3.9 (13.8)	6.1 (35.6)	3.4 (9.8)	4.2 (15.6)	3.0 (7.1)	2.8 (6.2)
SEm ±	0.2	0.3	0.2	0.2	0.3	0.2	0.3	0.2
CD (P=0.05)	0.5	0.6	0.5	0.4	0.7	0.5	0.6	0.5

Table 4.11 Integrated effect of tillage and weed control methods on population of *Commelina benghalensis* (No./m²) at 60 DAS

Tillage methods	Weed control methods				
	Unweeded	Acetachlor 0.75 kg/ha	Acetachlor 1.25 kg/ha	Atrazine 1.5 kg/ha	
2002					
Zero	6.62 (42.00)	5.18 (25.33)	4.03 (14.67)	3.55 (10.67)	
Conventional	7.86 (60.00)	5.94 (33.33)	4.18 (16.00)	3.52 (10.67)	
Raised seed bed	9.75 (93.33)	7.7 (58.67)	5.07 (24.00)	4.68 (20.00)	
2003					
Zero	7.61 (56.00)	6.87 (45.33)	5.81 (32.00)	5.60 (29.33)	
Conventional	9.20 (82.67)	7.51 (54.67)	6.05 (34.67)	5.82 (32.00)	
Raised seed bed	11.16 (122.67)	8.97 (78.67)	6.26 (37.33)	6.86 (45.33)	
		2002	2003		
		SE(m)±	CD (P=0.05)	SE(m)±	CD (P=0.05)
To compare two weed control methods at same level of tillage methods		0.42	0.88	0.34	0.72
To compare two tillage methods at same or different level of weed control methods		0.66	1.16	0.47	0.85

Values in parentheses are means of original values

revealed that under unweeded check conditions, while, zero tillage resulted in significantly lowest population of *Commelina*, the raised seed bed resulted in its highest population during both the years. Even at the lower dose of acetachlor also raised seed bed resulted in significantly highest population of *Commelina* during both the years. However, zero tillage and conventional tillage were statistically at par in reducing its population. At higher dose of acetachlor 1.25 kg/ha and atrazine 1.5 kg/ha, tillage methods behaved statistically at par in influencing its population during both the years. However, during second year raised seed bed was inferior to remaining tillage methods in reducing the population of *Commelina* in atrazine treated plots.

The data further revealed that in each of the methods of tillage, atrazine 1.5 kg/ha being statistically at par with acetachlor 1.25 kg/ha reduced the *Commelina benghalensis* population significantly over rest of the weed control treatments during both the years.

Integration of zero tillage and conventional tillage with either atrazine 1.5 kg/ha or acetachlor 1.25 kg/ha resulted in significantly lower population of *Commelina benghalensis* during both the years. However acetachlor 1.25 kg/ha in combination with raised seed bed was also statistically at par with these combinations during the second year.

4.1.4.6 *Cyperus iria*

It is evident from the data in Table 4.12 that tillage methods did not influence the population of *Cyperus iria* significantly during both the years. The data further revealed that among weed control treatments

atrazine 1.5 kg/ha being statistically at par with acetachlor 1.25 kg/ha reduced the population of *Cyperus iria* significantly at all the stages of observation during both the years. However, acetachlor 1.25 kg/ha behaved statistically at par with its lower dose in its poor performance to control *Cyperus* at 30 and 90 DAS during 2002.

Table 4.12 Effect of tillage and weed control methods on progressive weed count of *Cyperus iria* (No./m²)

Treatments	30 DAS		60 DAS		90 DAS		At harvest	
	2002	2003	2002	2003	2002	2003	2002	2003
Tillage methods								
Zero	2.7 (5.3)	3.0 (7.3)	3.6 (11.7)	4.6 (19.3)	3.0 (7.3)	3.3 (9.3)	4.0 (7.0)	2.7 (5.7)
Conventional	2.8 (6.0)	3.4 (9.7)	3.5 (10.3)	4.7 (20.7)	3.2 (8.3)	3.9 (13.7)	2.7 (5.7)	3.1 (8.0)
Raised seed bed	2.4 (4.0)	3.1 (7.7)	3.3 (9.0)	4.0 (14.7)	2.6 (5.0)	3.3 (9.3)	2.6 (5.0)	2.7 (6.0)
SEm \pm	0.3	0.1	0.2	0.3	0.2	0.3	0.1	0.2
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS
Weed control methods								
Unweeded	3.0 (7.6)	3.8 (12.4)	4.0 (14.7)	5.4 (27.1)	3.4 (9.8)	4.3 (16.9)	3.2 (8.4)	3.6 (10.7)
Acetachlor 0.75 kg/ha	2.8 (5.8)	3.4 (9.8)	3.7 (11.6)	4.5 (18.7)	3.1 (7.6)	3.8 (12.4)	2.8 (5.8)	3.2 (8.4)
Acetachlor 1.25 kg/ha	2.2 (3.1)	2.5 (4.4)	3.1 (7.6)	3.8 (12.9)	2.5 (4.4)	2.8 (5.8)	2.5 (4.4)	2.3 (3.6)
Atrazine 1.5 kg/ha	2.4 (4.0)	2.9 (6.2)	3.1 (7.6)	4.0 (14.2)	2.8 (5.8)	3.1 (8.0)	2.6 (4.9)	2.6 (5.3)
SEm \pm	0.2	0.2	0.3	0.2	0.2	0.2	0.2	0.2
CD (P=0.05)	0.5	0.5	0.6	0.3	0.4	0.4	0.5	0.5

Values in parentheses are means of original values

4.1.4.7 Other weeds

The weed species such as *Oxalis latifolia*, *Polygonum alatum*, *Ageratum conyzoides* and *Ipomoea* sp. were present in very small number therefore, they were taken together under the category of other weeds. The data on effect of tillage and weed control methods on count of these weeds so obtained have been embodied in Table 4.13.

Table 4.13 Effect of tillage and weed control methods on progressive count of other weeds (No./m²)

Treatments	30 DAS		60 DAS		90 DAS		At harvest	
	2002	2003	2002	2003	2002	2003	2002	2003
Tillage methods								
Zero	3.6 (11.7)	4.0 (15.0)	3.9 (13.7)	5.2 (25.7)	3.7 (13.0)	5.0 (23.3)	3.6 (11.7)	4.4 (18.0)
Conventional	3.3 (9.3)	3.4 (10.0)	3.7 (11.7)	5.4 (27.3)	3.2 (9.0)	4.9 (22.0)	3.4 (10.0)	3.8 (13.3)
Raised seed bed	3.1 (8.3)	2.9 (7.3)	3.4 (10.0)	5.1 (24.0)	3.4 (10.0)	4.3 (16.7)	3.2 (8.7)	3.6 (11.7)
SEm ±	0.4	0.5	0.3	0.3	0.2	0.1	0.3	0.5
CD (P=0.05)	NS	NS	NS	NS	NS	0.4	NS	NS
Weed control methods								
Unweeded	3.7 (12.9)	4.2 (16.4)	4.2 (16.0)	5.8 (32.4)	4.2 (16.0)	5.6 (29.3)	4.0 (14.2)	4.8 (22.2)
Acetachlor 0.75 kg/ha	3.3 (9.8)	3.2 (9.8)	3.5 (10.7)	5.2 (25.3)	3.4 (10.7)	4.7 (20.4)	3.6 (11.1)	3.7 (12.9)
Acetachlor 1.25 kg/ha	3.3 (8.9)	3.2 (8.4)	3.7 (11.6)	5.0 (23.6)	3.2 (8.4)	4.4 (17.8)	3.1 (8.0)	3.8 (12.4)
Atrazine 1.5 kg/ha	3.1 (7.6)	3.2 (8.4)	3.3 (8.9)	4.8 (21.3)	3.0 (7.6)	4.1 (15.1)	3.0 (7.1)	3.4 (9.8)
SEm ±	0.4	0.4	0.3	0.3	0.4	0.3	0.2	0.4
CD (P=0.05)	NS	0.8	0.5	0.4	NS	0.6	NS	0.8

Values in parentheses are means of original values

A perusal of the data revealed that the tillage methods did not influence the population of other weeds significantly at all the stages of observation during both the years except at 90 DAS during 2003, where raised seed bed was significantly superior over other tillage methods to reduce its population.

The data further revealed that during first year the weed control methods did not influence the population of other weeds at all the stages of observation except 60 DAS, when three herbicide treatments being statistically at par were significantly superior to unweeded check to reduce population of other weeds. During second year, atrazine 1.5 kg/ha being statistically at par with acetachlor 1.25 kg/ha resulted in significant reduction

in the population of other weeds. Acetachlor 0.75 kg/ha behaved statistically alike to atrazine 1.5 kg/ha and acetachlor 1.25 kg/ha at 30 DAS and harvest during 2003. However, the lower dose of acetachlor was at par with acetachlor 1.25 kg/ha in reducing the population of other weeds at 60 and 90 DAS during 2003.

4.1.4.8 Total weed count

A perusal of the data in Table 4.14 indicate that tillage and weed control methods have significant effect on total weed count at all the stages of observation during both the years except at harvest of the crop during 2002 where, tillage effects were non-significant.

Raised seed bed resulted in significantly lowest population of total weed at all the stages of observation during both the years. Conventional and zero tillage being significantly at par were next best in significantly reducing the total weed count at all the observation stages except at 60 DAS during first year and at harvest during second year.

All the weed control methods were significantly superior over unweeded check in reducing the total weed count at all the stages of observation during both the years. The data further revealed that among all the weed control methods, atrazine 1.5 kg/ha and acetachlor 1.25 kg/ha being statistically at par with each other resulted in significant reduction of total weed count at all the stages of observation during both the years.

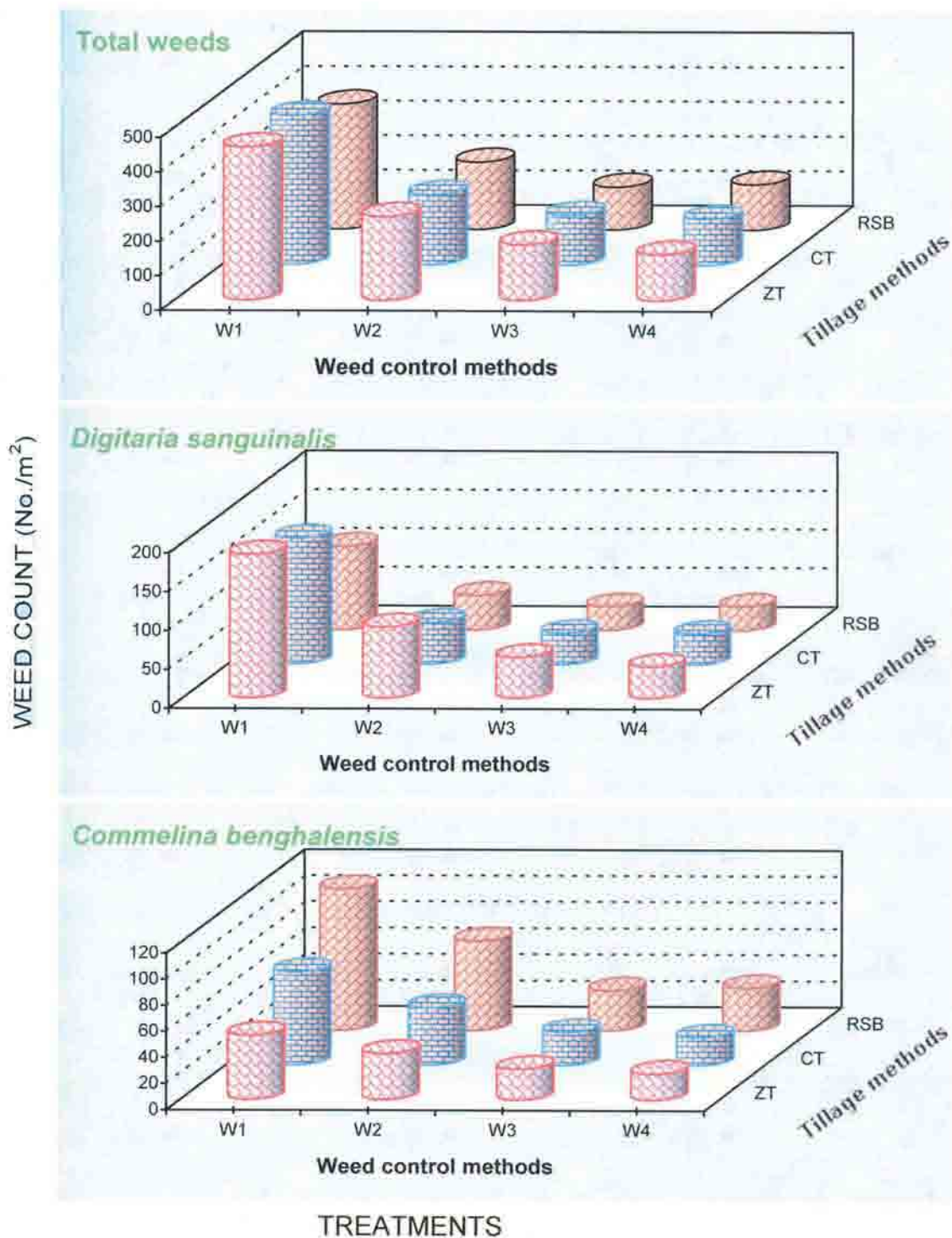
Table 4.14 Effect of tillage and weed control methods on progressive count of total weeds (No./m²)

Treatments	30 DAS		60 DAS		90 DAS		At harvest	
	2002	2003	2002	2003	2002	2003	2002	2003
Tillage methods								
Zero	8.5 (74.3)	10.3 (109.5)	13.8 (206.0)	16.5 (283.3)	11.2 (131.0)	13.6 (191.7)	9.9 (102.7)	11.1 (128.7)
Conventional	8.3 (69.7)	9.81 (101.0)	13.1 (186.0)	16.1 (270.0)	10.6 (116.7)	13.2 (181.3)	9.4 (92.7)	10.6 (117.3)
Raised seed bed	7.4 (56.3)	9.0 (84.8)	12.4 (164.3)	15.3 (241.0)	9.7 (98.8)	12.2 (156.0)	8.6 (77.7)	9.9 (103.0)
SEm ±	0.2	0.2	0.2	0.2	0.3	0.4	0.4	0.1
CD (P=0.05)	0.7	0.6	0.7	0.5	0.9	1.0	NS	0.4
Weed control methods								
Unweeded	10.9 (116.4)	13.6 (182.4)	19.4 (377.3)	21.2 (447.1)	14.7 (213.6)	17.7 (311.1)	12.9 (165.3)	14.8 (216.0)
Acetachlor 0.75 kg/ha	8.6 (72.4)	10.0 (98.4)	12.9 (165.8)	16.2 (260.0)	10.8 (114.2)	13.5 (181.8)	9.7 (92.4)	11.0 (119.1)
Acetachlor 1.25 kg/ha	6.3 (37.8)	7.8 (59.6)	10.3 (104.9)	13.5 (180.9)	8.2 (65.1)	10.3 (105.3)	7.3 (51.6)	8.1 (63.6)
Atrazine 1.5 kg/ha	6.5 (40.4)	7.4 (53.3)	9.8 (93.8)	13.2 (171.1)	8.4 (69.1)	10.4 (107.1)	7.5 (54.7)	8.3 (66.7)
SEm ±	0.3	0.3	0.3	0.3	0.3	0.3	0.2	0.3
CD (P=0.05)	0.6	0.7	0.6	0.6	0.6	0.6	0.5	0.7

Table 4.15 Integrated effect of tillage and weed control methods on total population of weeds (No./m²) at 60 DAS

Tillage methods	Weed control methods			
	Unweeded	Acetachlor 0.75 kg/ha	Acetachlor 1.25 kg/ha	Atrazine 1.5 kg/ha
2002				
Zero	20.3 (409.33)	14.2 (200.00)	10.7 (113.33)	10.2 (101.33)
Conventional	20.0 (397.33)	12.1 (144.00)	10.5 (108.00)	9.8 (94.67)
Raised seed bed	18.1 (325.33)	12.5 (153.33)	9.8 (93.33)	9.3 (85.33)
2003				
Zero	21.9 (476.00)	16.9 (282.67)	14.5 (209.33)	12.9 (165.33)
Conventional	21.6 (466.67)	16.2 (261.33)	13.5 (180.00)	13.2 (172.00)
Raised seed bed	20.0 (398.67)	15.4 (236.00)	12.5 (153.33)	13.3 (176.00)
	2002		2003	
	SE(m)±	CD (P=0.05)	SE(m)±	CD (P=0.05)
To compare two weed control methods at same level of tillage methods	0.49	1.03	0.50	1.06
To compare two tillage methods at same or different level of weed control methods	0.59	1.10	0.52	1.02

Values in parentheses are means of original values



CT - Conventional tillage
 ZT - Zero tillage
 RSB - Raised seed bed

W1 - Unweeded
 W2 - Acetachlor 0.75 kg/ha
 W3 - Acetachlor 1.25 kg/ha
 W4 - Atrazine 1.5 kg/ha

Fig. 4.1 Integrated effect of tillage and weed control methods on total and species-wise weed count (No./m²) at 60 DAS (averaged over two years)

The tillage and weed control methods interacted significantly to influence the total weed count at 60 DAS during both the years. The interaction data presented in Table 4.15 and Fig. 4.1 revealed that in each of the methods of weed control except unweeded check, raised seed bed being statistically at par with conventional tillage resulted in significantly lower total weed count during both the years. However, in atrazine 1.5 kg/ha treated plots all the tillage methods were statistically at par during both the years and in acetachlor 1.25 kg/ha treated plots during first year of experimentation.

In each of the methods of tillage, atrazine 1.5 kg/ha being statistically at par with acetachlor 1.25 kg/ha reduced the total weed count significantly over rest of the weed control treatments during both the years. However, in zero tillage method acetachlor 1.25 kg/ha was the next best in reducing the total weed count during the second year.

Atrazine 1.5 kg/ha in integration with any of the tillage methods resulted in significant reduction in total weed count during both the years. However, it was statistically at par with combination of raised seed bed and acetachlor 1.25 kg/ha during both the years (Plates II to IV).

4.1.5 Dry matter accumulation

Main and interaction effects of tillage and weed control methods on total and species-wise dry matter accumulation of weeds have been presented in Tables 4.16 to 4.28 and described in this section. However, the interaction effects on species-wise and total weeds have been explained only at maximum dry matter accumulation stage (60 DAS).



Unweeded plots in zero tillage



Unweeded plots in conventional tillage



Unweeded plots in raised seed bed

Plate II. Presence of weeds in unweeded plots of various tillage methods



Atrazine 1.5 kg/ha treated plot in zero tillage



Atrazine 1.5 kg/ha treated plot in conventional tillage



Atrazine 1.5 kg/ha treated plot in raised seed bed

Plate III. Effect of atrazine 1.5 kg/ha application in different tillage methods



Acetachlor 1.25 kg/ha treated plot in zero tillage



Acetachlor 1.25 kg/ha treated plot in conventional tillage



Acetachlor 1.25 kg/ha treated plot in raised seed bed

Plate IV. Effect of acetachlor 1.25 kg/ha application in different tillage methods

4.1.5.1 *Digitaria sanguinalis*

Dry matter accumulation by *Digitaria sanguinalis* was influenced significantly by tillage and weed control methods at all the stages of observation during both the years.

A perusal of the data in Table 4.16 and Fig. 4.2 revealed that raised seed bed resulted in significantly lowest dry matter accumulation of *Digitaria sanguinalis* at all the stages of observation during both the years. However, it was statistically at par with conventional tillage at 90 DAS during second year and harvest during first year. At other stages of observations, conventional tillage was the next best in reducing dry matter accumulation of *Digitaria sanguinalis* during both the years.

All the weed control methods were significantly superior to unweeded check in reducing the dry matter accumulation of *Digitaria sanguinalis* at all the stages of observation during both the years (Fig. 4.3). Atrazine 1.5 kg/ha being statistically at par with acetachlor 1.25 kg/ha was significantly superior over rest of the weed control treatments in decreasing the dry matter accumulation of *Digitaria sanguinalis* at all the stages of observation during both the years. Acetachlor 0.75 kg/ha was next best in significantly reducing dry matter accumulation of *Digitaria sanguinalis*.

The tillage and weed control methods interacted significantly in influencing the dry matter of *Digitaria sanguinalis* at its maximum dry matter stage (60 DAS) during both the years.

Table 4.16 Effect of tillage and weed control methods on progressive dry matter accumulation of *Digitaria sanguinalis* (g/m²)

Treatments	30 DAS		60 DAS		90 DAS		At harvest	
	2002	2003	2002	2003	2002	2003	2002	2003
Tillage methods								
Zero	4.0 (15.0)	4.4 (19.9)	7.3 (58.9)	7.7 (65.1)	5.6 (32.6)	6.1 (38.7)	5.1 (26.3)	5.7 (33.4)
Conventional	3.4 (10.0)	3.8 (14.9)	6.2 (41.9)	6.7 (47.4)	4.6 (22.3)	5.2 (28.7)	4.2 (17.6)	5.3 (28.0)
Raised seed bed	2.8 (6.2)	2.9 (8.9)	5.1 (29.1)	6.1 (41.3)	3.9 (15.9)	5.0 (26.6)	3.6 (13.4)	4.5 (20.7)
SEm ±	0.1	0.1	0.2	0.1	0.2	0.2	0.3	0.1
CD (P=0.05)	0.3	0.4	0.5	0.3	0.6	0.4	0.9	0.4
Weed control methods								
Unweeded	4.5 (18.4)	6.1 (36.3)	10.3 (106.5)	10.9 (116.9)	7.5 (55.5)	8.4 (71.4)	6.8 (44.5)	7.5 (58.6)
Acetachlor 0.75 kg/ha	3.5 (10.9)	3.7 (13.1)	5.7 (32.5)	6.6 (42.1)	4.4 (18.4)	5.2 (25.4)	4.0 (14.8)	5.0 (23.7)
Acetachlor 1.25 kg/ha	2.8 (6.2)	2.5 (4.6)	4.3 (17.5)	5.1 (24.1)	3.4 (10.3)	4.1 (15.1)	3.3 (9.2)	4.00 (14.1)
Atrazine 1.5 kg/ha	2.8 (6.2)	2.5 (4.2)	4.3 (16.6)	4.9 (21.8)	3.5 (10.3)	3.9 (13.5)	3.09 (8.00)	3.9 (13.1)
SEm ±	0.3	0.3	0.2	0.2	0.2	0.1	0.2	0.2
CD (P=0.05)	0.6	0.6	0.5	0.4	0.4	0.3	0.5	0.4

Table 4.17 Integrated effect of tillage and weed control methods on dry matter accumulation of *Digitaria sanguinalis* (g/m²) at 60 DAS

Tillage methods	Weed control methods			
	Unweeded	Acetachlor 0.75 kg/ha	Acetachlor 1.25 kg/ha	Atrazine 1.5 kg/ha
2002				
Zero	11.81 (138.13)	7.40 (57.93)	5.11 (24.27)	4.72 (20.40)
Conventional	10.30 (104.27)	5.24 (25.47)	4.63 (19.47)	4.49 (18.27)
Raised seed bed	8.89 (77.13)	4.58 (19.00)	3.29 (8.87)	3.62 (11.20)
2003				
Zero	12.02 (142.53)	7.95 (61.33)	5.62 (29.73)	5.36 (26.80)
Conventional	10.45 (107.13)	6.15 (35.87)	5.14 (24.47)	4.89 (22.00)
Raised seed bed	10.15 (101.13)	5.57 (29.07)	4.50 (18.23)	4.29 (16.60)
	2002		2003	
	SE(m)±	CD (P=0.05)	SE(m)±	CD (P=0.05)
To compare two weed control methods at same level of tillage methods	0.42	0.87	0.32	0.67
To compare two tillage methods at same or different level of weed control methods	0.51	0.95	0.31	0.63

Values in parentheses are means of original values

The interaction data presented in Table 4.17 and Fig. 4.4 revealed that in each of the methods of weed control, raised seed bed decreased the dry matter of *Digitaria sanguinalis* significantly during both the years. However, it was statistically at par with conventional tillage in acetachlor 0.75 kg/ha and atrazine 1.5 kg/ha treated plots during both the years and in unweeded check during second year.

While comparing two weed control methods at same level of tillage, it is clear from the data that in each of the tillage methods, atrazine 1.5 kg/ha being statistically at par with acetachlor 1.25 kg/ha reduced the dry matter of *Digitaria sanguinalis* significantly during both the years. The lower dose of acetachlor was also statistically at par with its higher dose and atrazine 1.5 kg/ha in conventional tillage during first year.

The integration of atrazine 1.5 kg/ha or acetachlor 1.25 kg/ha with raised seed bed resulted in significantly lower dry matter of *Digitaria sanguinalis* during both the years. However, integration of atrazine 1.5 kg/ha with conventional tillage was also equally effective during 2003.

4.1.5.2 *Echinochloa colona*

The data presented in Table 4.18 and Fig. 4.2 and 4.3 revealed that the tillage and weed control methods affected the dry matter accumulation of *Echinochloa colona* significantly at all the stages of observation during both the years except at 30 DAS, during 2002, where tillage methods failed to influence the dry matter accumulation of *Echinochloa colona*.

Table 4.18 Effect of tillage and weed control methods on progressive dry matter accumulation of *Echinochloa colona* (g/m²)

Treatments	30 DAS		60 DAS		90 DAS		At harvest	
	2002	2003	2002	2003	2002	2003	2002	2003
Tillage methods								
Zero	3.7 (13.0)	4.2 (17.9)	5.2 (29.2)	5.8 (34.8)	4.0 (16.4)	4.9 (24.1)	3.6 (11.8)	4.7 (21.6)
Conventional	3.6 (13.2)	4.0 (16.6)	4.8 (25.9)	5.6 (33.0)	3.8 (14.7)	4.7 (22.6)	3.2 (9.3)	4.3 (18.6)
Raised seed bed	3.3 (10.1)	3.4 (12.2)	4.1 (17.6)	5.0 (25.8)	3.2 (9.7)	4.23 (17.7)	2.76 (6.4)	3.8 (13.7)
SEm ±	0.2	0.1	0.2	0.1	0.1	0.1	0.2	0.2
CD (P=0.05)	NS	0.4	0.5	0.4	0.3	0.3	0.5	0.5
Weed control methods								
Unweeded	5.4 (27.5)	6.3 (38.4)	8.0 (62.7)	8.5 (70.6)	6.1 (35.1)	7.0 (46.6)	4.7 (20.1)	6.2 (37.4)
Acetachlor 0.75 kg/ha	3.4 (10.2)	3.8 (12.8)	4.2 (16.0)	5.3 (26.6)	3.2 (8.6)	4.6 (18.9)	3.1 (7.8)	4.2 (15.7)
Acetachlor 1.25 kg/ha	2.7 (5.2)	2.8 (6.2)	3.5 (10.8)	4.1 (15.0)	2.9 (6.4)	3.6 (10.9)	2.6 (5.0)	3.4 (10.0)
Atrazine 1.5 kg/ha	2.7 (5.6)	2.5 (4.7)	3.1 (7.5)	3.8 (12.6)	2.5 (4.3)	3.4 (9.5)	2.3 (3.6)	3.2 (8.6)
SEm ±	0.2	0.2	0.1	0.1	0.1	0.1	0.1	0.2
CD (P=0.05)	0.4	0.5	0.3	0.2	0.2	0.2	0.3	0.4

Table 4.19 Integrated effect of tillage and weed control methods on dry matter accumulation of *Echinochloa colona* (g/m²) at 60 DAS

Tillage methods	Weed control methods				
	Unweeded	Acetachlor 0.75 kg/ha	Acetachlor 1.25 kg/ha	Atrazine 1.5 kg/ha	
2002					
Zero	8.45 (69.47)	5.02 (23.33)	4.14 (15.20)	3.28 (8.80)	
Conventional	8.58 (71.60)	4.06 (14.53)	3.42 (9.73)	3.09 (7.60)	
Raised seed bed	6.98 (46.93)	3.48 (10.13)	3.06 (7.40)	2.82 (6.07)	
2003					
Zero	8.85 (76.33)	5.69 (30.40)	4.55 (18.73)	3.97 (13.87)	
Conventional	8.73 (74.20)	5.70 (30.53)	4.03 (14.27)	3.87 (13.07)	
Raised seed bed	7.96 (61.37)	4.57 (19.00)	3.72 (11.93)	3.56 (10.73)	
		2002	2003		
		SE(m)±	CD (P=0.05)	SE(m)±	CD (P=0.05)
To compare two weed control methods at same level of tillage methods		0.21	0.44	0.18	0.38
To compare two tillage methods at same or different level of weed control methods		0.33	0.59	0.27	0.48

Values in parentheses are means of original values

The data further revealed that all weed control methods were found significantly superior over unweeded check in reducing the dry matter accumulation of *Echinochloa colona* at all the stages of observation during both the years. Among weed control methods, atrazine 1.5 kg/ha resulted in significantly lowest dry matter accumulation of *Echinochloa colona* at all the stages of observation during both the years. However, it was statistically similar to acetachlor 1.25 kg/ha at 30 DAS during both the years and harvest during second year.

The interaction data presented in Table 4.19 and Fig. 4.4 revealed that irrespective of weed control methods, raised seed bed resulted in significantly lowest dry matter of *Echinochloa colona* during both the years at 60 DAS. However, it was statistically at par with conventional and zero tillage methods in plots treated with atrazine 1.5 kg/ha and with conventional method in acetachlor 1.25 kg/ha treated plots during both the years and in acetachlor 0.75 kg/ha treated plots during first year of experimentation.

While comparing two weed control methods at same level of tillage methods, it is clear from the data that in zero tillage method, atrazine 1.5 kg/ha resulted in significantly lowest dry matter of *Echinochloa* during both the years. Whereas, in conventional and raised seed bed method, acetachlor 1.25 kg/ha and atrazine 1.5 kg/ha were equally effective to reduce the dry matter of *Echinochloa colona* during both the years. While in zero tillage,

acetachlor 1.25 kg/ha was the next best and its lower dose was next best in remaining two tillage methods to reduce dry matter of *Echinochloa colona* during both the years.

The interaction of atrazine 1.5 kg/ha with any of the tillage method and integration of acetachlor 1.25 kg/ha with raised seed bed being statistically alike resulted in significantly lower dry matter of *Echinochloa colona* during both the years. However, combination of acetachlor 1.25 kg/ha with conventional tillage was also statistically at par with all these combinations during second year of experimentation.

4.1.5.3 *Panicum dichotomiflorum*

Tillage and weed control methods have significant influence on dry matter accumulation by *Panicum dichotomiflorum* at all the stages of observation during both the years (Table 4.20 and Figs 4.2 and 4.3).

Raised seed bed resulted in significantly lowest dry matter accumulation by *Panicum dichotomiflorum* at all the stages of observation during both the years. Conventional tillage was the next best in reducing dry matter accumulation by *Panicum dichotomiflorum* at rest of the stages of observation except 30 DAS and at harvest of the crop during first year and 60 and 90 DAS during second year, where, it was significantly at par with zero tillage.

All the weed control methods were significantly superior to unweeded check in decreasing the dry matter accumulation by *Panicum dichotomiflorum* at all the stages during both the years. The data further

revealed that atrazine 1.5 kg/ha being statistically at par with acetachlor 1.25 kg/ha was significantly superior to all weed control treatments in decreasing its dry matter accumulation at all the stages of observation during both the years except at 90 DAS during 2003, where, acetachlor 1.25 kg/ha was the next best to reduce the dry matter accumulation of *Panicum dichotomiflorum*.

The tillage and weed control methods interacted significantly in influencing the dry matter accumulation of *Panicum dichotomiflorum* at 90 DAS during both the years (Table 4.21 and Fig. 4.4). The data revealed that in each of the methods of weed control, raised seed bed resulted in significantly lowest dry of *Panicum dichotomiflorum* during both the years. However, in atrazine 1.5 kg/ha treated plots conventional tillage was statistically at par with raised seed bed during both the years. While, during first year zero tillage and conventional tillage being statistically at par were next best in unweeded check and acetachlor 1.25 kg/ha and 0.75 kg/ha treated plots, both tillage methods were statistically at par only in acetachlor 1.25 kg/ha treated plots during second year.

In each of the methods of tillage, atrazine 1.5 kg/ha being statistically at par with acetachlor 1.25 kg/ha resulted in significantly lower dry matter accumulation of *Panicum dichotomiflorum* during both the years. However, in raised seed bed, acetachlor 0.75 kg/ha was equally effective to these weed control methods in significantly reducing the dry matter of *Panicum dichotomiflorum* during first year.

Table 4.20 Effect of tillage and weed control methods on progressive dry matter accumulation of *Panicum dichotomiflorum* (g/m²)

Treatments	30 DAS		60 DAS		90 DAS		At harvest	
	2002	2003	2002	2003	2002	2003	2002	2003
Tillage methods								
Zero	2.3 (3.7)	2.4 (3.9)	2.8 (6.4)	3.6 (11.7)	2.5 (4.7)	3.1 (7.7)	2.2 (3.3)	2.7 (5.2)
Conventional	2.2 (2.9)	2.2 (3.0)	2.5 (5.0)	3.8 (13.2)	2.3 (3.8)	3.2 (9.2)	2.1 (2.5)	2.8 (6.07)
Raised seed bed	1.8 (1.1)	1.8 (1.1)	1.8 (1.3)	2.8 (6.2)	1.7 (1.00)	2.5 (4.2)	1.6 (0.7)	2.3 (3.3)
SEm ±	0.1	0.1	0.1	0.1	0.0	0.1	0.1	0.1
CD (P=0.05)	0.2	0.2	0.2	0.3	0.1	0.2	0.2	0.1
Weed control methods								
Unweeded	2.6 (4.8)	2.7 (5.3)	3.3 (9.0)	4.5 (18.5)	2.9 (6.8)	3.8 (12.3)	2.6 (4.8)	3.2 (8.4)
Acetachlor 0.75 kg/ha	2.1 (2.5)	2.1 (2.5)	2.5 (4.6)	3.7 (12.4)	2.3 (3.5)	3.2 (8.2)	2.1 (2.4)	2.7 (5.4)
Acetachlor 1.25 kg/ha	1.7 (1.5)	1.9 (1.5)	1.9 (1.6)	2.7 (5.6)	1.8 (1.2)	2.5 (4.1)	1.7 (0.8)	2.2 (3.0)
Atrazine 1.5 kg/ha	1.8 (1.4)	1.8 (1.3)	1.9 (1.6)	2.6 (4.9)	1.8 (1.2)	2.3 (3.4)	1.7 (0.7)	2.2 (2.7)
SEm ±	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
CD (P=0.05)	0.2	0.2	0.3	0.2	0.2	0.2	0.2	0.2

Table 4.21 Integrated effect of tillage and weed control methods on dry matter accumulation of *Panicum dichotomiflorum* (g/m²) at 90 DAS

Tillage methods	Weed control methods			
	Unweeded	Acetachlor 0.75 kg/ha	Acetachlor 1.25 kg/ha	Atrazine 1.5 kg/ha
2002				
Zero	3.33 (9.10)	2.70 (5.33)	2.03 (2.13)	2.07 (2.33)
Conventional	3.23 (8.43)	2.51 (4.33)	1.82 (1.40)	1.69 (1.87)
Raised seed bed	2.17 (2.73)	1.64 (0.73)	1.43 (0.03)	1.51 (0.30)
2003				
Zero	3.82 (12.63)	3.27 (8.70)	2.65 (5.00)	2.51 (4.33)
Conventional	4.24 (16.03)	3.74 (12.00)	2.63 (4.93)	2.38 (3.67)
Raised seed bed	3.19 (8.23)	2.44 (3.97)	2.10 (2.40)	2.07 (2.30)
	2002		2003	
	SE(m)±	CD (P=0.05)	SE(m)±	CD (P=0.05)
To compare two weed control methods at same level of tillage methods	0.18	0.38	0.16	0.33
To compare two tillage methods at same or different level of weed control methods	0.17	0.35	0.18	0.34

Values in parentheses are means of original values

Integration of raised seed bed with atrazine 1.5 kg/ha or acetachlor 1.25 kg/ha being statistically at par with integration of conventional tillage with atrazine 1.5 kg/ha resulted in significantly lower dry matter accumulation of *Panicum* during both the years. However, combination of raised seed bed with acetachlor 0.75 kg/ha was also statistically equally effective during first year of experimentation.

4.1.5.4 *Brachiaria ramosa*

The data presented in Table 4.22 revealed that the *Brachiaria ramosa* emerged only after 30 days of sowing of the crop during both the years. It is evident from the data that tillage and weed control methods have significant influence in checking the dry matter accumulation of *Brachiaria ramosa* at all the stages of observation except at 90 DAS during second year and harvest of the crop during both years.

Among tillage methods raised seed bed resulted in significantly lowest dry matter accumulation of *Brachiaria ramosa* at 60 DAS during both the years and at 90 DAS during first year. Conventional tillage being statistically at par with zero tillage were next best at 60 DAS during second year and 90 DAS during first year in reducing its dry matter accumulation.

Acetachlor 1.25 kg/ha resulted in complete control of this weed. Acetachlor 0.75 kg/ha was the next best in reducing the dry matter accumulation of the *Brachiaria ramosa* at all the stages of observation during both the years. However, it was statistically at par with atrazine 1.5 kg/ha in being next best at harvest during first year.

Table 4.22 Effect of tillage and weed control methods on progressive dry matter accumulation of *Brachiaria ramosa* (g/m²)

Treatments	60 DAS		90 DAS		At harvest	
	2002	2003	2002	2003	2002	2003
Tillage methods						
Zero	2.3 (3.6)	2.1 (2.7)	2.4 (3.6)	2.4 (4.1)	1.8 (1.3)	2.1 (2.6)
Conventional	2.2 (3.3)	2.1 (2.5)	2.4 (3.3)	2.3 (3.8)	1.9 (1.7)	2.1 (2.8)
Raised seed bed	2.0 (2.1)	1.9 (1.8)	2.0 (2.1)	2.2 (2.9)	1.7 (1.0)	2.0 (2.0)
SEm \pm	0.1	0.1	0.1	0.1	0.1	0.1
CD (P=0.05)	0.1	0.1	0.1	NS	NS	NS
Weed control methods						
Unweeded	2.6 (4.8)	2.4 (3.8)	2.8 (4.8)	2.8 (5.7)	2.1 (2.4)	2.4 (3.8)
Acetachlor 0.75 kg/ha	2.2 (3.0)	2.1 (2.3)	2.3 (3.0)	2.4 (3.9)	1.8 (1.1)	2.1 (2.5)
Acetachlor 1.25 kg/ha	1.4 (0.0)	1.4 (0.0)	1.4 (0.0)	1.4 (0.0)	1.4 (0.0)	1.4 (0.0)
Atrazine 1.5 kg/ha	2.5 (4.2)	2.2 (3.1)	2.6 (4.2)	2.6 (4.7)	1.9 (1.8)	2.3 (3.5)
SEm \pm	0.1	0.1	0.1	0.1	0.1	0.1
CD (P=0.05)	0.2	0.1	0.2	0.1	0.2	0.1

Values in parentheses are means of original values

Tillage and weed control methods did not interacted significantly in influencing the dry matter of *Brachiaria ramosa*.

4.1.5.5 *Commelina benghalensis*

Dry matter accumulation by *Commelina benghalensis* was influenced significantly by tillage and weed control methods at all the stages of observation during both the years (Table 4.23 and Figs 4.2 and 4.3).

A perusal of the data in Table 4.23 revealed that zero tillage was significantly superior to other tillage methods in decreasing the dry matter accumulation of *Commelina benghalensis* at all the stages of observation during both the years. Conventional tillage was the next best in reducing the dry matter accumulation of the weed at all the observation stages during both the years. However, it was statistically at par with raised seed bed at 90 DAS during 2003.

All the weed control methods were significantly superior over unweeded check in decreasing the dry matter accumulation of *Commelina benghalensis* at all the stages of observation during both the years. Among weed control methods, atrazine 1.5 kg/ha resulted in significantly lowest dry matter accumulation of *Commelina benghalensis* at all the stages of observation during both the years. However, it was statistically at par with acetachlor 1.25 kg/ha at 60 DAS during 2002 and all the stages of observation except 60 DAS during 2003. At rest of the stages acetachlor 1.25 kg/ha was next best in significantly reducing dry matter accumulation of *C. benghalensis*.

The interaction data of tillage and weed control methods on dry matter of *Commelina benghalensis* at 60 DAS presented in Table 4.24 and Fig. 4.4 revealed that in each of the weed control treatment, zero tillage being statistically at par with conventional tillage resulted in significantly lower dry matter of *Commelina benghalensis* during both the years except in unweeded check and acetachlor 0.75 kg/ha treated plots during first year when zero tillage was significantly superior to conventional tillage. However, conventional tillage was statistically at par with raised seed bed in atrazine and acetachlor treated plots during second year.

While comparing two weed control methods at same level of tillage method, it is evident from the data that in each of the tillage methods, atrazine 1.5 kg/ha being statistically at par with acetachlor 1.25 kg/ha

Table 4.23 Effect of tillage and weed control methods on progressive dry matter accumulation of *Commelina benghalensis* (g/m²)

Treatments	30 DAS		60 DAS		90 DAS		At harvest	
	2002	2003	2002	2003	2002	2003	2002	2003
Tillage methods								
Zero	2.3 (3.8)	2.5 (4.7)	2.8 (6.3)	3.6 (11.8)	2.5 (4.7)	3.1 (7.7)	2.2 (3.2)	2.7 (5.6)
Conventional	2.8 (6.4)	3.2 (9.3)	3.5 (11.3)	4.4 (18.1)	3.2 (8.9)	4.3 (18.4)	2.8 (6.7)	3.6 (11.2)
Raised seed bed	3.2 (9.1)	3.6 (12.5)	4.5 (19.7)	5.0 (25.8)	3.8 (13.6)	4.5 (20.1)	3.5 (11.6)	4.4 (18.4)
SEm ±	0.1	0.1	0.1	0.1	0.2	0.3	0.2	0.1
CD (P=0.05)	0.3	0.3	0.3	0.4	0.5	0.8	0.4	0.2
Weed control methods								
Unweeded	3.8 (12.8)	4.3 (17.6)	5.1 (25.0)	6.1 (36.0)	4.5 (18.5)	5.0 (24.5)	4.0 (14.8)	4.6 (20.5)
Acetachlor 0.75 kg/ha	3.2 (8.2)	3.6 (10.8)	3.9 (13.7)	4.7 (20.6)	3.5 (10.7)	4.1 (15.0)	3.1 (8.2)	3.9 (13.4)
Acetachlor 1.25 kg/ha	2.2 (2.9)	2.3 (3.6)	2.8 (6.4)	3.4 (9.8)	2.5 (4.2)	3.5 (13.8)	2.2 (3.2)	2.9 (6.8)
Atrazine 1.5 kg/ha	1.9 (1.8)	2.3 (3.2)	2.5 (4.7)	3.1 (7.8)	2.2 (2.9)	3.1 (7.8)	2.0 (2.4)	2.8 (6.2)
SEm ±	0.1	0.1	0.1	0.1	0.1	0.5	0.2	0.1
CD (P=0.05)	0.2	0.3	0.3	0.2	0.3	1.0	0.3	0.3

Table 4.24 Integrated effect of tillage and weed control methods on dry matter accumulation of *Commelina benghalensis* (g/m²) at 60 DAS

Tillage methods	Weed control methods				
	Unweeded	Acetachlor 0.75 kg/ha	Acetachlor 1.25 kg/ha	Atrazine 1.5 kg/ha	
2002					
Zero	3.90 (13.33)	2.88 (6.33)	2.25 (3.20)	2.08 (2.33)	
Conventional	4.91 (22.13)	4.05 (14.40)	2.63 (4.93)	2.39 (3.80)	
Raised seed bed	6.42 (39.47)	4.71 (20.33)	3.58 (10.93)	3.14 (7.93)	
2003					
Zero	5.01 (23.13)	3.97 (13.80)	2.78 (5.73)	2.57 (4.67)	
Conventional	5.75 (31.20)	4.96 (22.60)	3.50 (10.33)	3.17 (8.07)	
Raised seed bed	7.46 (53.73)	5.24 (25.47)	3.92 (13.40)	3.54 (10.53)	
		2002	2003		
		SE(m)±	CD (P=0.05)	SE(m)±	CD (P=0.05)
To compare two weed control methods at same level of tillage methods		0.29	0.58	0.53	0.36
To compare two tillage methods at same or different level of weed control methods		0.31	0.59	0.51	1.02

Values in parentheses are means of original values

resulted in significantly lower dry matter of *Commelina benghalensis* during both the years except in raised seed bed during second year where atrazine was significantly superior to acetachlor 1.5 kg/ha.

Integration of zero or conventional tillage with either atrazine 1.5 kg/ha or acetachlor 1.25 kg/ha being statistically at par resulted in significantly lower dry matter accumulation of *Commelina benghalensis* during both the years. However combination of raised seed bed with atrazine 1.5 kg/ha was also statistically at par with these superior combinations during second year.

4.1.5.6 *Cyperus iria*

It is evident from the data in Table 4.25 and Fig. 4.2 that dry matter accumulation by *Cyperus iria* was not influenced significantly by tillage methods at all the stages of observation during the first year and at harvest of crop during second year. During second year, raised seed bed resulted in significantly lowest dry matter accumulation of *Cyperus iria*. Zero tillage was next best in reducing its dry matter at all the stages of observation.

All the weed control methods were significantly superior to unweeded check in decreasing the dry matter accumulation by *Cyperus iria* at all the stages of observation during both the years (Fig. 4.3). Atrazine 1.5 kg/ha being statistically at par with acetachlor 1.25 kg/ha resulted in significantly lower dry matter of *Cyperus iria* at all the stages of observation

during both the years except at 30 DAS during second year and 60 DAS during first year where, acetachlor 1.25 kg/ha was significantly inferior to it. Acetachlor 0.75 kg/ha was also statistically at par with acetachlor 1.25 kg/ha at 60 DAS and harvest of the crop during the first year and 90 DAS during both the years.

Table 4.25 Effect of tillage and weed control methods on progressive dry matter accumulation of *Cyperus iria* (g/m²)

Treatments	30 DAS		60 DAS		90 DAS		At harvest	
	2002	2003	2002	2003	2002	2003	2002	2003
Tillage methods								
Zero	1.7 (0.9)	1.9 (1.7)	2.2 (3.1)	2.8 (5.7)	2.1 (2.3)	2.5 (4.6)	1.9 (1.7)	2.3 (3.4)
Conventional	1.8 (1.1)	2.2 (3.1)	2.3 (3.2)	3.1 (7.5)	2.1 (2.3)	2.7 (5.2)	1.8 (1.4)	2.3 (3.5)
Raised seed bed	1.6 (0.5)	1.8 (1.3)	2.0 (2.0)	2.3 (3.2)	1.9 (1.6)	2.1 (2.4)	1.8 (1.2)	2.0 (2.0)
SEm ±	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
CD (P=0.05)	NS	0.1	NS	0.2	NS	0.2	NS	NS
Weed control methods								
Unweeded	1.9 (1.4)	2.3 (3.2)	2.5 (4.4)	3.2 (8.3)	2.3 (3.5)	2.8 (6.2)	2.1 (2.3)	2.5 (4.4)
Acetachlor 0.75 kg/ha	1.7 (0.9)	2.0 (2.2)	2.1 (2.6)	2.7 (5.5)	2.0 (1.8)	2.4 (4.0)	1.8 (1.3)	2.3 (3.1)
Acetachlor 1.25 kg/ha	1.6 (0.5)	1.9 (1.5)	2.1 (2.2)	2.4 (4.1)	1.9 (1.6)	2.3 (3.1)	1.7 (0.8)	2.1 (2.4)
Atrazine 1.5 kg/ha	1.6 (0.5)	1.8 (1.3)	1.9 (1.7)	2.4 (4.0)	1.8 (1.4)	2.2 (2.9)	1.6 (0.7)	2.0 (2.1)
SEm ±	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
CD (P=0.05)	0.1	0.1	0.2	0.3	0.2	0.2	0.2	0.2

Values in parentheses are means of original values

4.1.5.7 Other weeds

The data in Table 4.26 revealed that tillage and weed control methods affected the dry matter accumulation of other weeds significantly at all the stages of observation during both the years except at 30 DAS during 2002 where weed control methods failed to have significant influence on dry matter accumulation by other weeds.

Table 4.26 Effect of tillage and weed control methods on progressive dry matter accumulation of other weeds (g/m²)

Treatments	30 DAS		60 DAS		90 DAS		At harvest	
	2002	2003	2002	2003	2002	2003	2002	2003
Tillage methods								
Zero	2.1 (2.5)	2.2 (3.0)	2.7 (5.8)	3.0 (7.5)	2.4 (3.9)	2.9 (6.8)	2.3 (3.3)	2.9 (6.4)
Conventional	2.1 (2.4)	2.4 (3.9)	2.6 (5.0)	3.4 (9.8)	2.4 (3.8)	3.1 (7.9)	2.3 (3.4)	2.7 (5.5)
Raised seed bed	1.9 (1.6)	2.0 (1.9)	2.1 (2.4)	2.3 (3.4)	1.8 (1.4)	2.2 (3.0)	1.8 (1.2)	2.0 (2.2)
SEm ±	0.1	0.1	0.2	0.2	0.2	0.1	0.1	0.2
CD (P=0.05)	0.1	0.1	0.4	0.5	0.4	0.3	0.3	0.4
Weed control methods								
Unweeded	2.2 (2.9)	2.6 (5.0)	2.9 (6.8)	3.6 (11.1)	2.5 (4.4)	3.4 (9.5)	2.4 (4.1)	3.1 (7.8)
Acetachlor 0.75 kg/ha	2.0 (2.1)	2.2 (2.8)	2.4 (4.0)	2.8 (6.3)	2.2 (3.0)	2.7 (5.5)	2.1 (2.6)	2.4 (4.1)
Acetachlor 1.25 kg/ha	2.1 (2.3)	2.1 (2.3)	2.4 (4.2)	2.6 (5.2)	2.2 (3.0)	2.5 (4.2)	2.1 (2.5)	2.3 (3.2)
Atrazine 1.5 kg/ha	1.8 (1.3)	1.9 (1.7)	2.1 (2.6)	2.5 (4.8)	1.9 (1.7)	2.5 (4.3)	1.8 (1.4)	2.3 (3.6)
SEm ±	0.1	0.1	0.2	0.3	0.1	0.1	0.2	0.1
CD (P=0.05)	NS	0.2	0.4	0.6	0.3	0.3	0.4	0.3

Values in parentheses are means of original values

Raised seed bed resulted in significantly lowest dry matter accumulation of other weeds at all the stages of observation during both the years. Zero tillage and conventional tillage being statistically at par with each other were next best at all the stages during both the years except at 30 DAS, during second year.

The data further revealed that atrazine 1.5 kg/ha resulted in significantly lower dry matter accumulation of other weeds at all the stages during both the years. However, acetachlor 1.25 and acetachlor 0.75 kg/ha at 60 DAS and harvest of the crop during both the years and acetachlor 1.25 kg/ha at 90 DAS during second year were also statistically at par with atrazine 1.5 kg/ha. At rest of the stages acetachlor 1.25 kg/ha being statistically alike to acetachlor 0.75 kg/ha was the next best in reducing the dry matter accumulation by other weeds.

4.1.5.8 Total weeds

Results pertaining to total dry matter accumulation by weeds at different stages have been given in Table 4.27 and 4.28.

A perusal of the data in Table 4.27 and Fig. 4.2 and 4.3 revealed that dry matter accumulation of total weeds was influenced significantly by tillage and weed control methods at all the stages of observation during both the years.

Raised seed bed resulted in significantly lowest total dry matter accumulation of weeds at all the stages of observation during both the years. Conventional tillage being the next best was significantly superior to zero tillage at all the stages of observation during both the years except at 30 DAS during both the years and at 90 DAS and harvest of the crop during second year where both were statistically at par.

All the weed control treatments were significantly superior to unweeded check in decreasing the dry matter accumulation of total weeds at all the stages of observation during both the years. The data further revealed that atrazine 1.5 kg/ha being statistically at par with acetachlor 1.25 kg/ha was significantly superior to remaining weed control methods in decreasing dry matter accumulation of total weeds at all the stages of observation during both the years.

Tillage and weed control methods interacted significantly in influencing the total weeds dry matter accumulation during both the years. The interaction data presented in Table 4.28 and Fig. 4.4 revealed that in

Table 4.27 Effect of tillage and weed control methods on progressive dry matter accumulation of total weeds (g/m²)

Treatments	30 DAS		60 DAS		90 DAS		At harvest	
	2002	2003	2002	2003	2002	2003	2002	2003
Tillage methods								
Zero	6.2 (38.9)	6.9 (51.0)	10.0 (112.6)	11.4 (139.4)	8.0 (68.5)	9.4 (93.6)	6.9 (50.9)	8.7 (78.2)
Conventional	5.9 (36.0)	6.8 (50.8)	9.2 (94.6)	11.1 (131.3)	7.5 (60.0)	9.6 (95.7)	6.4 (42.6)	8.5 (75.6)
Raised seed bed	5.3 (28.6)	5.8 (37.9)	8.1 (73.7)	9.8 (107.3)	6.5 (45.5)	8.5 (76.9)	5.7 (35.0)	7.7 (62.3)
SEm ±	0.2	0.1	0.2	0.1	0.1	0.3	0.2	0.2
CD (P=0.05)	0.4	0.3	0.4	0.3	0.3	0.8	0.4	0.4
Weed control methods								
Unweeded	8.3 (67.9)	10.4 (105.9)	14.8 (219.0)	16.3 (265.3)	11.4 (129.7)	13.3 (176.2)	9.7 (93.1)	11.9 (140.8)
Acetachlor 0.75 kg/ha	6.0 (34.8)	6.8 (44.2)	8.7 (75.5)	10.8 (115.8)	7.1 (49.2)	9.1 (81.3)	6.3 (38.1)	8.4 (68.2)
Acetachlor 1.25 kg/ha	4.5 (18.5)	4.6 (19.8)	6.7 (42.8)	8.1 (63.8)	5.3 (26.6)	6.9 (45.3)	4.8 (21.6)	6.4 (39.4)
Atrazine 1.5 kg/ha	4.3 (16.7)	4.2 (16.4)	6.2 (31.2)	7.8 (59.0)	5.3 (26.4)	7.3 (52.2)	4.5 (18.5)	6.4 (39.8)
SEm ±	0.2	0.3	0.2	0.1	0.2	0.3	0.2	0.1
CD (P=0.05)	0.4	0.6	0.5	0.3	0.4	0.6	0.5	0.4

Table 4.28 Integrated effect of tillage and weed control methods on total dry matter accumulation of weeds (g/m²) at 60 DAS

Tillage methods	Weed control methods			
	Unweeded	Acetachlor 0.75 kg/ha	Acetachlor 1.25 kg/ha	Atrazine 1.5 kg/ha
2002				
Zero	16.00 (253.93)	10.14 (101.47)	7.20 (50.07)	6.83 (44.73)
Conventional	15.10 (226.00)	3.42 (69.00)	6.97 (46.60)	6.21 (36.60)
Raised seed bed	13.38 (177.00)	7.61 (56.00)	5.79 (31.60)	5.67 (30.20)
2003				
Zero	16.95 (285.33)	11.71 (135.13)	8.57 (71.53)	8.21 (65.40)
Conventional	16.34 (264.93)	11.30 (125.67)	8.45 (69.47)	8.20 (65.20)
Raised seed bed	15.74 (245.70)	9.42 (86.67)	7.24 (50.43)	6.94 (46.27)
	2002		2003	
	SE(m)±	CD (P=0.05)	SE(m)±	CD (P=0.05)
To compare two weed control methods at same level of tillage methods	0.37	0.78	0.22	0.45
To compare two tillage methods at same or different level of weed control methods	0.42	0.80	0.25	0.47

Values in parentheses are means of original values

each of the weed control treatments, raised seed bed resulted in significantly lower total weed dry matter accumulation during both the years. However, it was statistically at par with conventional tillage in case of atrazine 1.5 kg/ha treated plots during 2002. Conventional tillage was significantly superior to zero tillage in acetachlor 0.75 kg/ha during the first year and unweeded check during both the years. However, in the remaining weed control treatments during both the years conventional tillage was statistically at par with zero tillage in reducing the total weed dry matter.

The data further revealed that in each of the methods of tillage, atrazine 1.5 kg/ha being statistically at par with acetachlor 1.25 kg/ha decreased the total weed dry matter accumulation during both the years. Acetachlor 0.75 kg/ha was the next best during both the years.

Integration of raised seed bed with either atrazine 1.5 kg/ha or acetachlor 1.25 kg/ha being statistically at par with each other resulted in significantly lower total dry matter accumulation of total weeds during both the years. However, combination of conventional tillage and atrazine 1.5 kg/ha was equally effective during the first year, while, during the second year it was the next best combination and was statistically alike to combinations of conventional tillage with acetachlor 1.25 kg/ha and zero tillage with either atrazine 1.5 kg/ha or acetachlor 1.25 kg/ha.

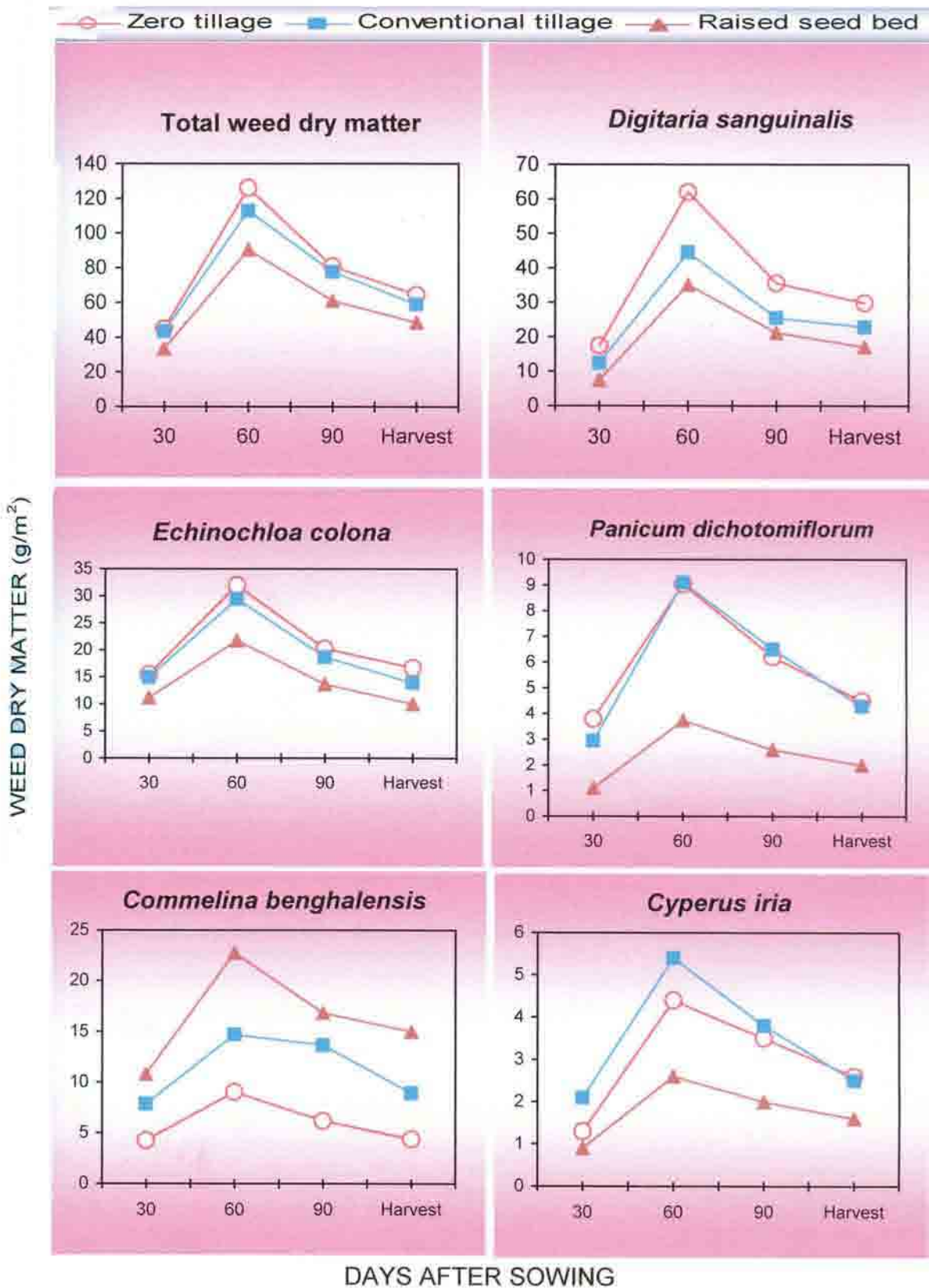


Fig. 4.2 Effect of tillage methods on total and species-wise progressive weed dry matter (g/m²) of weeds (averaged over two years)

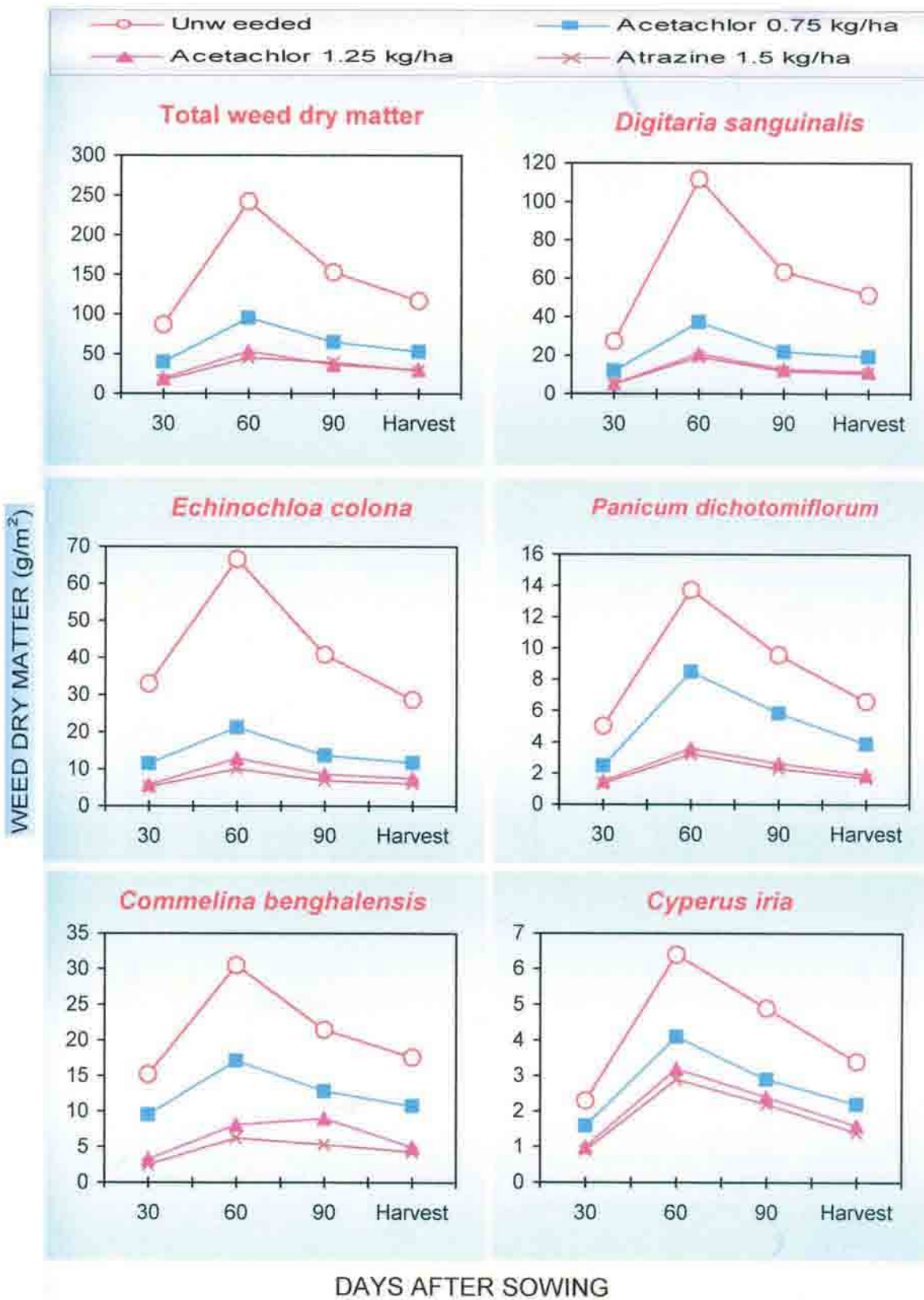
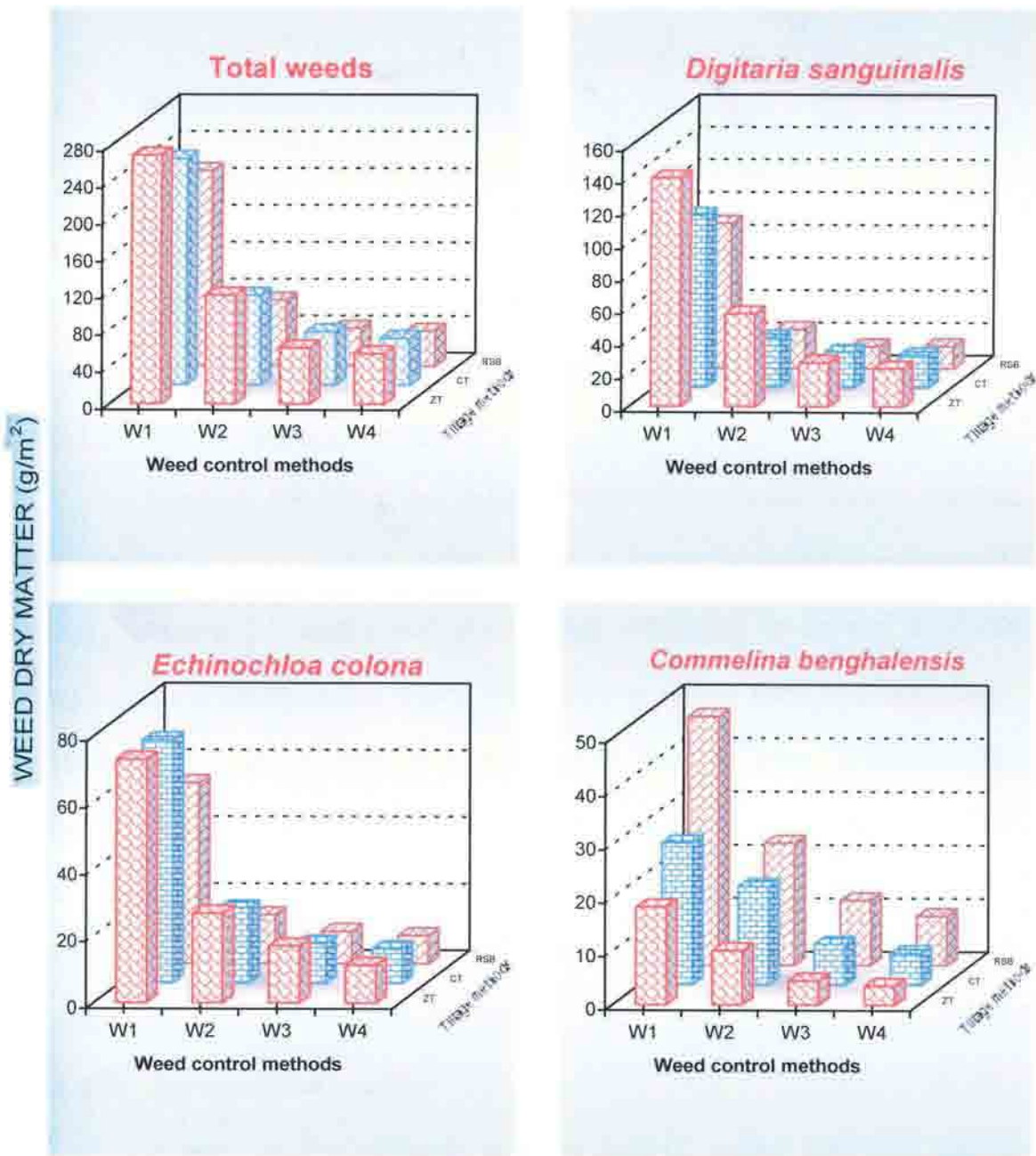


Fig. 4.3 Effect of weed control methods on total and species-wise progressive weed dry matter (g/m²) (averaged over two years)



TREATMENTS

CT - Conventional tillage
 ZT - Zero tillage
 RSB - Raised seed bed

W1 - Unweeded
 W2 - Acetachlor 0.75 kg/ha
 W3 - Acetachlor 1.25 kg/ha
 W4 - Atrazine 1.5 kg/ha

Fig. 4.4 Integrated effect of tillage and weed control methods on total and species-wise dry matter (g/m²) of weeds at 60 DAS (averaged over two years)

4.1.6 Weed control efficiency

The data on species-wise and total weed control efficiency have been embodied in Tables 4.29 and 4.30 and Fig. 4.5. A perusal of the data revealed that tillage and weed control methods influenced the species-wise and total weed control efficiency during both the years.

4.6.1.1 *Digitaria sanguinalis*

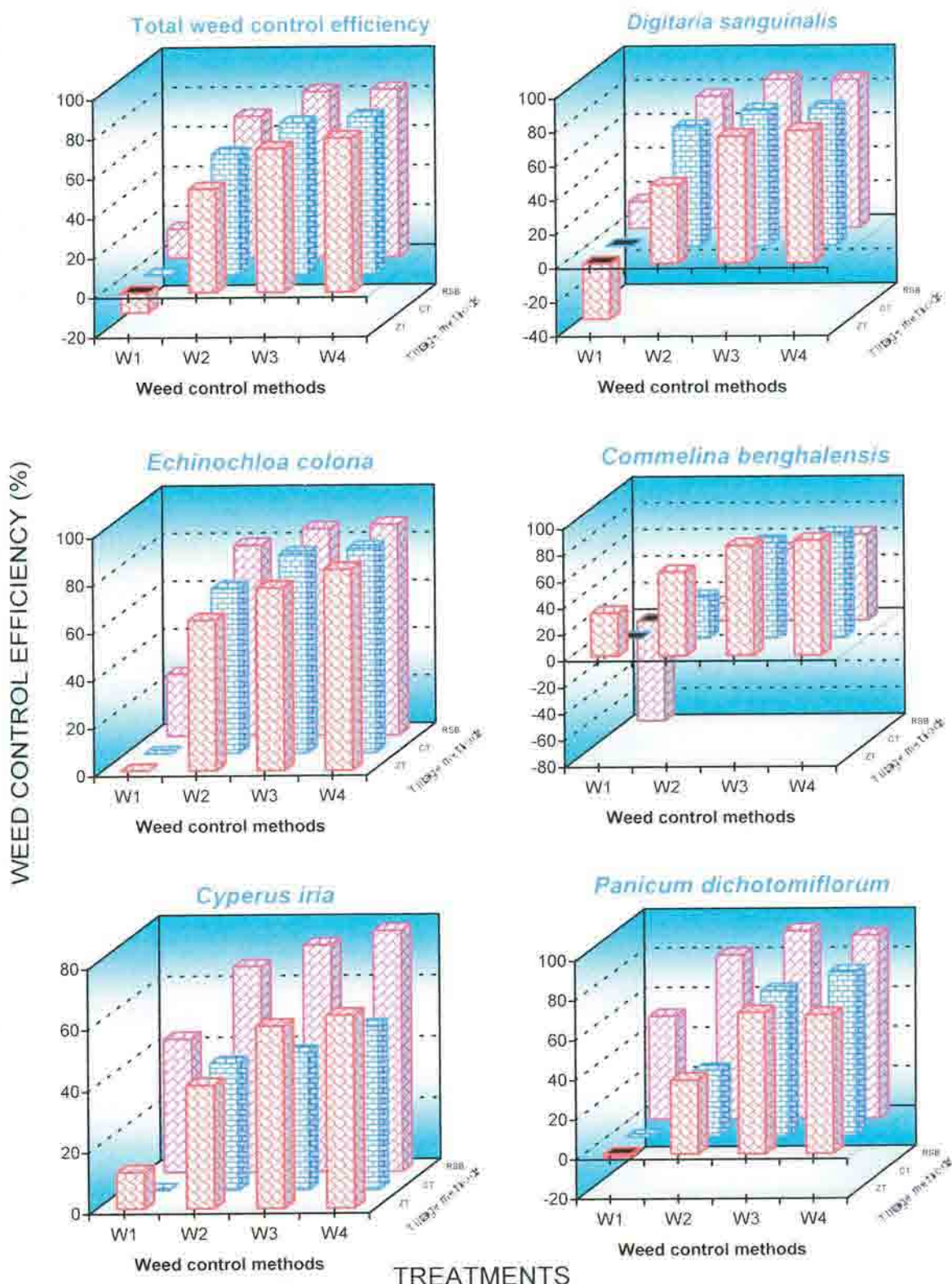
A critical perusal at the data in Table 4.29 revealed that in each of the methods of weed control, raised seed bed and in each of the methods of tillage, atrazine 1.5 kg/ha had the highest efficiency to control *Digitaria sanguinalis* during both the years. However, in raised seed bed acetachlor 1.25 kg/ha had the highest efficiency during the first year. Consequently, raised seed bed in combination with acetachlor 1.25 kg/ha during the first year and same tillage method with atrazine 1.5 kg/ha during the second year resulted in highest efficiency of 91.5 and 84.5 per cent, respectively to control *Digitaria sanguinalis*.

4.1.6.2 *Echinochloa colona*

In each of the methods of weed control, raised seed bed and in each of the methods of tillage, atrazine 1.5 kg/ha resulted in highest efficiency to control *Echinochloa colona*. Integration of atrazine 1.5 kg/ha with raised seed bed had the highest efficiency of 91.53 and 85.53 per cent to control *Echinochloa colona* during first and second year, respectively. Integration of raised seed bed with acetachlor 1.25 kg/ha was the next best during both the years (Table 4.29).

Table 4.29 Weed control efficiency (Per cent) of different treatment combinations to control *Digitaria sanguinalis*, *Echinochloa colona* and *Panicum dichotomiflorum*

Tillage method	2002				2003				Mean	
	Unweeded	Acetachlor 0.75 kg/ha	Acetachlor 1.25 kg/ha	Atrazine 1.5 kg/ha	Mean	Unweeded	Acetachlor 0.75 kg/ha	Acetachlor 1.25 kg/ha		Atrazine 1.5 kg/ha
<i>Digitaria sanguinalis</i>										
Zero tillage	-32.48	49.23	76.73	80.44	43.48	-33.05	42.75	72.25	74.98	39.23
Conventional tillage	-	72.70	81.33	81.47	58.88	-	66.52	77.16	79.46	55.79
Raised seed bed	26.03	81.78	91.50	89.26	72.14	5.60	72.87	82.98	84.50	61.49
Mean	-2.15	67.90	83.19	83.73		-9.15	60.71	77.46	79.65	
<i>Echinochloa colona</i>										
Zero tillage	2.68	67.41	78.77	87.71	59.14	-2.88	59.03	74.75	81.31	53.05
Conventional tillage	-	79.70	86.41	89.39	63.88	-	58.85	80.77	82.39	55.50
Raised seed bed	34.45	85.85	89.66	91.53	75.37	17.30	74.39	83.92	85.53	65.29
Mean	12.38	77.65	84.95	89.54		48.10	64.09	79.81	83.08	
<i>Panicum dichotomiflorum</i>										
Zero tillage	-13.45	37.79	74.38	68.28	41.75	10.89	36.87	67.98	71.61	46.84
Conventional tillage	-	43.89	80.48	92.68	54.26	-	22.67	66.17	72.21	40.26
Raised seed bed	65.84	92.68	100.00	95.12	88.41	37.77	72.21	89.13	89.13	72.06
Mean	17.46	58.12	84.95	85.36		16.22	43.92	74.43	77.65	



CT - Conventional tillage, ZT - Zero tillage, RSB - Raised seed bed
 W1 - Unweeded, W2 - Acetachlor 0.75 kg/ha, W3 - Acetachlor 1.25 kg/ha, W4 - Atrazine 1.5 kg/ha

Fig. 4.5 Effect of tillage and weed control methods on species-wise and total weed control efficiency (%) (averaged over two years)

4.1.6.3 *Panicum dichotomiflorum*

A critical perusal at the data in Table 4.29 revealed that in each of the methods of weed control, raised seed bed and in each of the methods of tillage, acetachlor 1.25 kg/ha had the highest efficiency to control *Panicum dichotomiflorum* during both the years. However, acetachlor 1.25 kg/ha had higher efficiency over atrazine 1.5 kg/ha to control *Panicum dichotomiflorum* in zero tillage and raised seed bed method during first year. Integration of raised seed bed with acetachlor 1.25 kg/ha resulted in highest efficacy of 100 and 89.13 per cent to control *Panicum dichotomiflorum* during first and second year, respectively. However, integration of raised seed bed with atrazine 1.5 kg/ha also had similar efficacy (89.13) during second year but it was next best during first year.

4.1.6.4 *Commelina benghalensis*

A critical perusal at the data presented in Table 4.30 indicated that in each of the methods of weed control, zero tillage and in each of the methods of tillage, atrazine 1.5 kg/ha had the highest efficiency to control *Commelina benghalensis* during both the years. Integration of atrazine 1.5 kg/ha with zero tillage resulted in highest efficacy of 89.46 and 85.04 per cent to control *Commelina benghalensis* during first and second year, respectively. Integration of acetachlor 1.25 kg/ha with zero tillage was found to be the next best in efficiency.

4.1.6.5 *Cyperus iria*

A perusal of the data in Table 4.30 revealed that in each of the methods of weed control, raised seed bed and in each of the methods of tillage, atrazine 1.5 kg/ha resulted in highest efficiency to control *Cyperus iria*. However, in zero tillage plots, acetachlor 1.25 kg/ha had higher efficiency than atrazine 1.5 kg/ha to control *Cyperus* during first year of experimentation. In each of the weed control methods, zero tillage was next best to control *Cyperus* during both the years. However, it was inferior to conventional tillage in acetachlor during first year.

Integration of atrazine 1.5 kg/ha with raised seed bed resulted in highest efficacy of 82.47 and 75.02 per cent to control *Cyperus iria* during first and second year, respectively.

4.1.6.6 Other weeds

A critical perusal at the data presented in Table 4.30 indicated that in each of the methods of weed control except in acetachlor 1.25 kg/ha during first year, raised seed bed resulted in highest efficiency to control other weeds during both the years. In acetachlor 1.25 kg/ha treated plots, zero tillage was superior to raised seed bed in efficiency to control other weeds during first year. In each of the methods of tillage, atrazine 1.5 kg/ha was superior to other weed control methods during both the years, except in zero tillage during first year and conventional tillage during second year where, acetachlor 1.25 kg/ha had the highest efficacy to control other weeds. Integration of atrazine 1.5 kg/ha with raised seed bed resulted in highest efficacy to control other weeds during both the years.

Table 4.30 Weed control efficiency (Per cent) of different treatment combinations to control *Commelina benghalensis*, *Cyperus iria*, other weeds and total weeds

Tillage methods	2002					2003				
	Unweeded	Acetachlor 0.75 kg/ha	Acetachlor 1.25 kg/ha	Atrazine 1.5 kg/ha	Mean	Unweeded	Acetachlor 0.75 kg/ha	Acetachlor 1.25 kg/ha	Atrazine 1.5 kg/ha	Mean
<i>Commelina benghalensis</i>										
Zero tillage	39.75	71.38	85.54	89.46	71.53	25.85	55.77	81.62	85.04	62.07
Conventional tillage	-	34.93	77.71	82.83	48.87	-	27.56	66.88	84.15	44.65
Raised seed bed	-78.34	8.12	50.59	64.15	11.13	-72.22	18.38	57.05	66.24	17.36
Mean	-12.86	38.14	71.28	78.81		-15.46	33.90	68.52	78.48	
<i>Cyperus iria</i>										
Zero tillage	-2.56	32.94	56.61	68.44	38.86	26.26	47.42	62.22	57.39	48.32
Conventional tillage	-	53.98	42.14	55.29	37.85	-	28.98	47.72	51.34	32.01
Raised seed bed	39.51	59.24	68.44	75.02	60.55	47.42	74.92	79.75	82.47	71.94
Mean	12.32	48.72	55.73	66.25		24.56	50.44	63.23	63.73	
Other weeds										
Zero tillage	-54.97	15.47	68.10	34.08	15.67	25.49	51.20	60.13	67.10	80.98
Conventional tillage	-	50.03	52.60	51.62	24.76	-	40.52	53.16	51.42	36.28
Raised seed bed	46.04	63.05	60.93	79.53	62.39	55.99	84.53	85.40	86.49	78.10
Mean	-2.98	42.85	60.54	55.08		27.16	58.75	66.23	68.34	
Total weeds										
Zero tillage	-12.36	55.10	77.85	80.21	50.20	-7.70	48.99	73.07	75.31	47.42
Conventional tillage	-	69.47	79.38	83.81	58.17	-	52.57	73.78	75.39	50.44
Raised seed bed	21.68	75.22	86.02	86.64	67.39	7.26	67.29	80.96	82.54	59.51
Mean	3.11	66.60	81.08	83.55		-0.15	56.28	75.94	77.75	

4.1.6.7 Total weeds

A perusal of the data presented in Table 4.30 revealed that raised seed bed resulted in highest total weed control efficacy during both the years. Conventional tillage was the next best in its efficacy to control all the weeds.

Among weed control methods, atrazine 1.5 kg/ha had the highest total weed control efficiency during both the years. Acetachlor 1.25 kg/ha was the next best and was superior to other weed control methods.

In each of the methods of weed control, raised seed bed and in each of the tillage methods, atrazine 1.5 kg/ha had the highest total weed control efficiency during both the years.

Integration of atrazine 1.5 kg/ha with raised seed bed resulted in highest efficiency of 86.64 and 82.54 per cent to control total weeds during first and second years, respectively. Integration of raised seed bed with acetachlor 1.25 kg/ha was the next best during both the years.

4.1.7 Phenology of weeds

4.1.7.1 Emergence

4.1.7.1.1 Grass weeds

A critical perusal of data present in Table 4.31 and Fig. 4.6 revealed that tillage methods did not significantly influence the days taken for emergence of grasses during both the years.

Emergence Flowering Tasseling Silking Maturity/senescence

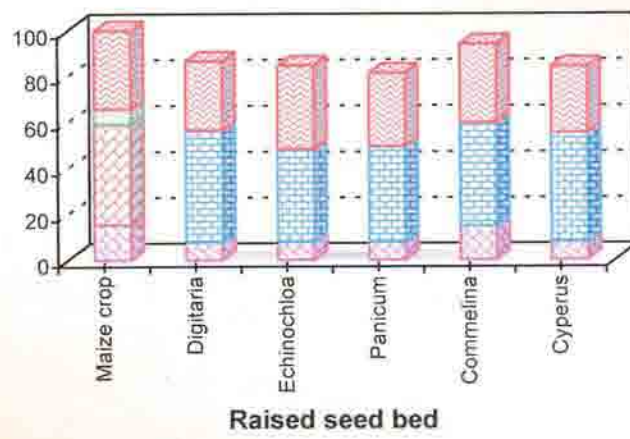
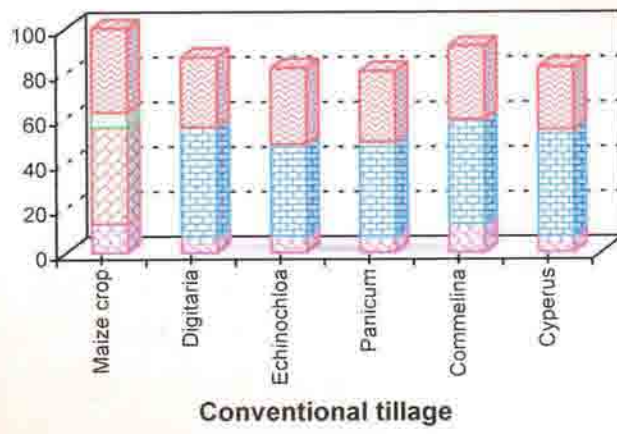
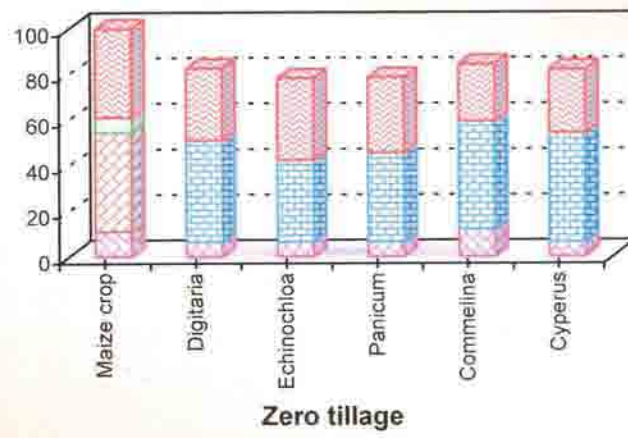


Fig. 4.6 Effect of tillage methods on phenology of maize crop and weeds

Table 4.31 Effect of tillage and weed control methods on days taken to emergence of different weed categories

Treatments	Grasses		Broad leaved		<i>Ageratum conyzoides</i>	
	2002	2003	2002	2003	2002	2003
Tillage methods						
Zero	7	6	15	14	51	44
Conventional	8	7	12	12	43	42
Raised seed bed	8	7	13	12	42	38
SEm \pm	0.5	0.4	0.7	0.7	2.0	1.8
CD (P=0.05)	NS	NS	2.0	2.0	5.6	NS
Weed control methods						
Unweeded	6	6	13	11	45	38
Acetachlor 0.75 kg/ha	7	6	12	12	44	39
Acetachlor 1.25 kg/ha	8	7	14	14	42	41
Atrazine 1.5 kg/ha	9	8	14	14	51	46
SEm \pm	0.5	0.6	0.7	0.7	1.4	1.2
CD (P=0.05)	1.1	1.2	1.4	1.5	3.0	2.4

Weed control methods influenced the days taken for emergence of grasses significantly during both the years (Fig. 4.7). Atrazine 1.5 kg/ha being statistically at par with acetachlor 1.25 kg/ha delayed the emergence of grasses during both the years.

4.1.7.1.2 Broad leaved weeds

The data presented in Table 4.31 and Figs 4.6 and 4.7 further revealed that tillage and weed control methods influenced the days taken to emergence of broad leaved weeds (other than *Ageratum*) significantly during both the years. Raised seed bed significantly delayed the emergence of broad leaved weeds during both the years. While, the other tillage methods being statistically at par were next best.

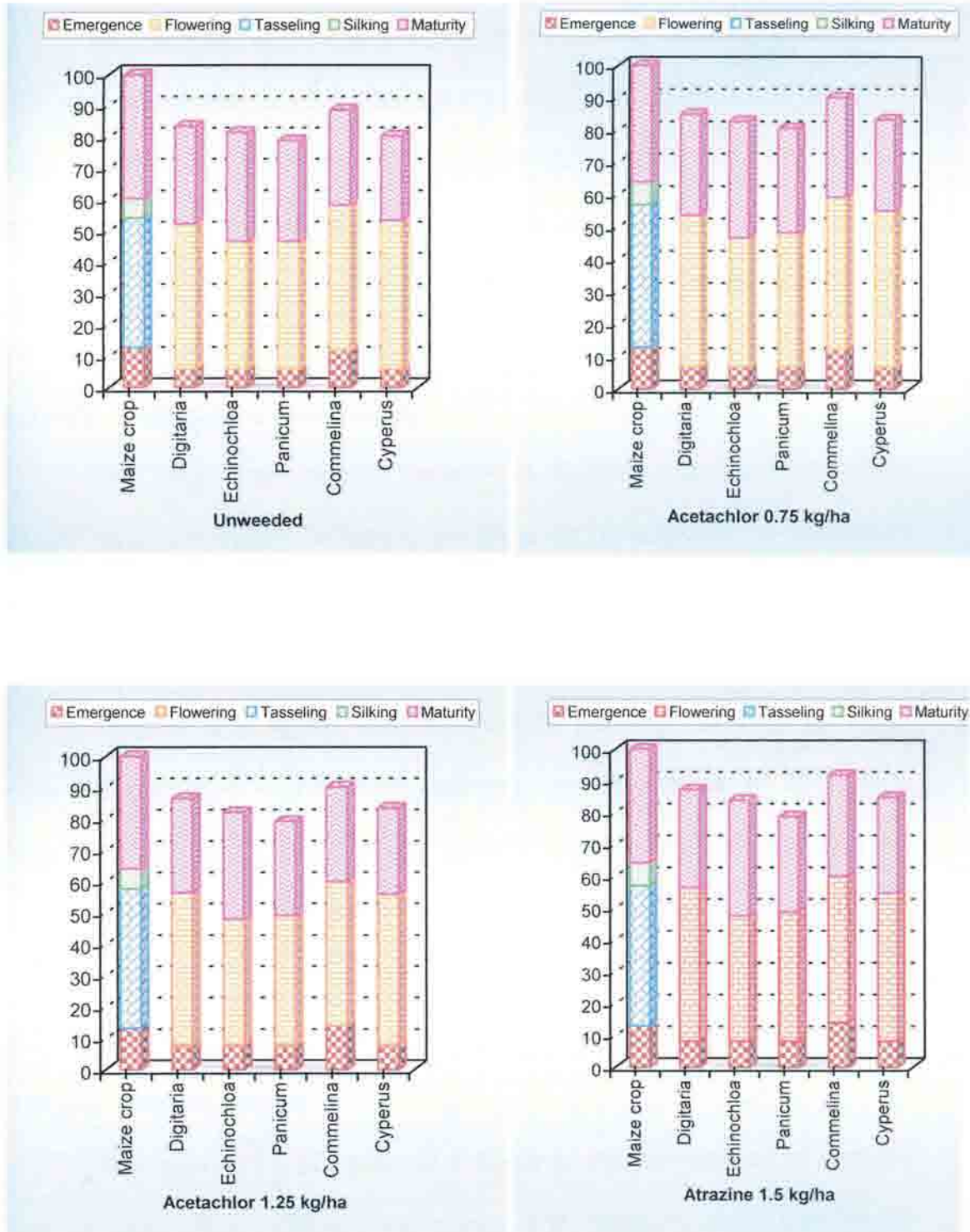


Fig. 4.7 Effect of weed control methods on phenology of maize crop and weeds

Among weed control methods atrazine 1.5 kg/ha being statistically at par with acetachlor 1.25 kg/ha significantly delayed the emergence of various broad leaved weeds during both the years. Acetachlor 0.75 kg/ha was the next best in significantly delaying the emergence of broad leaved weeds during the first year while, during the second year it was statistically at par with acetachlor 1.25 kg/ha and atrazine 1.5 kg/ha.

4.1.7.1.3 *Ageratum conyzoides*

The data presented in Table 4.31 further indicate that tillage methods have significant influence on days for emergence of *Ageratum conyzoides* only for first year where zero tillage delayed the emergence of *Ageratum conyzoides* significantly over the remaining tillage methods.

Atrazine 1.5 kg/ha was significantly superior to rest of weed control treatments in significantly delaying the emergence of this weed during both the years. Rest of the control methods did not significantly influence the days for emergence of *Ageratum conyzoides* during both the years.

4.1.7.2 Flowering and senescence

4.1.7.2.1 Grass weeds

The data on days taken to flowering and senescence of grasses (*Digitaria sanguinalis*, *Echinochloa colona* and *Panicum dichotomiflorum*), broad leaved weeds (*Commelina benghalensis*) and sedge (*Cyperus iria*) have been presented in Tables 4.32 to 4.33 and Figs 4.6 and 4.7.

It is evident from the Table 4.32 that except *Digitaria sanguinalis* flowering and senescence of other grass weeds was not significantly influenced by weed control methods. However, the tillage methods had significant influence.

Among tillage methods, raised seed bed and conventional tillage being statistically at par delayed the flowering of different grass weeds significantly during both the years except *Panicum dichotomiflorum* during the second year. Similar trend was found with respect to influence of tillage methods on senescence of *Digitaria sanguinalis* and *Panicum dichotomiflorum* during both the years. However, raised seed bed was significantly superior over other tillage methods and was followed by conventional method in delaying the senescence of *Echinochloa colona* during both the years.

4.1.7.2.2 Broad leaved weed

Commelina benghalensis

A perusal of the data in Table 4.53 revealed that tillage and weed control methods did not influence the flowering of *Commelina benghalensis* during both the years. Except for weed control methods during first year tillage and weed control methods influenced the senescence of the weed significantly. Raised seed bed significantly delayed the senescence of *Commelina benghalensis* by 5-14 days over rest of the tillage methods during both the years. However, conventional tillage was statistically at par with raised seed bed during first year and next best during second year.

Table 4.33 Effect of tillage and weed control methods on days taken to flowering and senescence of *Commelina benghalensis* and *Cyperus iria*

Treatments	<i>C. benghalensis</i>				<i>C. iria</i>			
	Flowering		Senescence		Flowering		Senescence	
	2002	2003	2002	2003	2002	2003	2002	2003
Tillage methods								
Zero	60	58	86	83	51	57	80	84
Conventional	60	59	99	85	52	58	82	83
Raised seed bed	61	59	101	87	52	59	84	84
SEm \pm	0.8	0.8	1.3	0.5	1.1	1.5	1.1	0.6
CD (P=0.05)	NS	NS	3.6	1.5	NS	NS	NS	NS
Weed control methods								
Unweeded	59	57	95	82	50	56	80	81
Acetachlor 0.75 kg/ha	60	58	95	85	52	58	83	83
Acetachlor 1.25 kg/ha	61	59	95	86	53	59	82	85
Atrazine 1.5 kg/ha	61	59	97	87	52	58	84	86
SEm \pm	1.2	0.8	1.3	1.1	1.2	1.5	1.2	0.9
CD (P=0.05)	NS	NS	NS	2.3	NS	NS	2.4	1.8

All the weed control methods were significantly superior over unweeded check in delaying the senescence of *Commelina benghalensis* by 4 days during second year.

4.1.7.2.3 Sedge

Cyperus iria

A critical perusal at the data presented in Table 4.33 revealed that tillage methods did not have any significant influence on flowering and senescence of *Cyperus iria* during both the years.

While weed control methods influenced the senescence of the weed significantly during both the years, their influence on flowering was not significant. Atrazine 1.5 kg/ha being statistically at par with acetachlor 1.25 kg/ha significantly delayed the senescence of *Cyperus iria* during both the years. However, acetachlor 0.75 kg/ha was also statistically alike to these weed control methods during the second year, while, during the first year it was statistically at par with its higher dose.

4.1.8 Uptake of nutrients by weeds

Main and interaction effects of tillage and weed control methods on uptake of nutrients by total weeds have been presented (Table 4.34 to 4.37) in this section. It is evident from these tables that tillage and weed control method alone and in integration influenced the total nitrogen, phosphorus and potassium uptake by weeds significantly during both the years.

4.1.8.1 Uptake of nitrogen

The data in Table 4.34 revealed that raised seed bed resulted in significantly lowest uptake of nitrogen by weeds. Conventional tillage was the next best in decreasing the total uptake of nitrogen by the weeds significantly during both the years. However, zero tillage behaved statistically alike to it during the second year.

Table 4.34 Effect of tillage and weed control methods on nitrogen, phosphorus and potassium uptake (kg/ha) by weeds at maximum dry matter stage (i.e. 60 DAS)

Treatments	Nitrogen uptake		Phosphorus uptake		Potassium uptake	
	2002	2003	2002	2003	2002	2003
Tillage methods						
Zero	22.50	27.12	5.55	5.89	24.43	29.37
Conventional	18.90	25.30	4.42	5.24	20.46	27.52
Raised seed bed	14.74	20.78	3.48	4.49	15.78	22.43
SEm \pm	0.95	0.43	0.15	0.13	0.52	0.76
CD (P=0.05)	1.20	2.64	0.43	0.37	1.44	2.10
Weed control methods						
Unweeded	44.63	52.38	12.35	13.32	50.45	59.65
Acetachlor 0.75 kg/ha	15.09	22.42	2.97	3.86	14.98	22.64
Acetachlor 1.25 kg/ha	8.18	11.97	1.41	1.90	8.31	12.23
Atrazine 1.5 kg/ha	6.95	10.83	1.19	1.73	7.15	11.23
SEm \pm	0.55	0.65	0.29	0.18	1.07	0.65
CD (P=0.05)	1.37	1.15	0.60	0.39	2.25	1.36

The data further revealed that all the weed control methods were significantly superior over unweeded check in decreasing the total uptake of nitrogen by weeds during both the years. Atrazine 1.5 kg/ha and acetachlor 1.25 kg/ha being statistically at par with each other reduced the total uptake of nitrogen by weeds significantly during both the year.

The interaction data of tillage and weed control methods on total uptake of nitrogen by weeds (Table 4.35) indicate that in plots treated with each of the herbicide, raised seed bed decreased the total uptake of nitrogen by weeds significantly during both the years. However, while raised seed bed was statistically at par with other two tillage methods in atrazine

1.5 kg/ha treated plots during first year, in acetachlor treated plots at both the doses, raised seed bed was at par with conventional tillage. During second year conventional tillage being statistically at par with zero tillage resulted in significantly lower uptake of nitrogen in each of the herbicide treated plots.

Table 4.35 Integrated effect of tillage and weed control methods on nitrogen uptake (kg/ha) by weeds at 60 DAS

Tillage methods	Weed control methods			
	Unweeded	Acetachlor 0.75 kg/ha	Acetachlor 1.25 kg/ha	Atrazine 1.5 kg/ha
2002				
Zero	51.57	20.37	9.70	8.34
Conventional	46.16	13.69	8.85	6.91
Raised seed bed	36.16	11.21	5.98	5.60
2003				
Zero	58.58	26.31	13.56	12.04
Conventional	52.11	24.07	12.99	12.02
Raised seed bed	48.47	16.89	9.34	8.44
	2002		2003	
	SE(m)±	CD (P=0.05)	SE(m)±	CD (P=0.05)
To compare two weed control methods at same level of tillage methods	0.95	2.38	1.13	1.99
To compare two tillage methods at same or different level of weed control methods	1.84	3.13	1.24	2.37

While comparing weed control methods at same level of tillage methods, atrazine 1.5 kg/ha being statistically at par with acetachlor 1.25 kg/ha was significantly superior over all the remaining weed control treatments in decreasing the total uptake of nitrogen during both the years.

Integration of raised seed bed with atrazine 1.5 kg/ha or acetachlor 1.25 kg/ha resulted in significantly lower uptake of total nitrogen by weeds during both the years. However, the combinations of conventional or zero tillage with atrazine 1.5 kg/ha was statistically alike to these superior combinations mentioned above during the first year.

4.1.8.2 Uptake of phosphorus

A perusal of the data in Table 4.34 revealed that raised seed bed resulted in significantly lowest total uptake of phosphorus by weeds over remaining tillage methods during both the years. Conventional tillage was the next best in decreasing the total uptake of phosphorus by weeds during both the years.

Among weed control methods atrazine 1.5 kg/ha being statistically at par with acetachlor 1.25 kg/ha reduced the total uptake of phosphorus significantly during both the years. Acetachlor 0.75 kg/ha was the next best in decreasing the total uptake of phosphorus significantly during both the years.

A perusal of the interaction data in Table 4.36 revealed that in each of the weed control methods raised seed bed resulted in significantly lowest uptake of phosphorus by weeds during both the years. However, in atrazine 1.5 kg/ha and acetachlor 1.25 kg/ha treated plots during first year, it was statistically at par with remaining two tillage methods in decreasing the phosphorus uptake by weeds. During the second year in acetachlor 1.25 kg/ha and during first year in acetachlor 0.75 kg/ha treated plots raised seed bed statistically at par with conventional tillage resulted in significantly lower uptake of phosphorus by weeds.

The data further revealed that in each of the methods of tillage, atrazine 1.5 kg/ha being statistically at par with acetachlor 1.25 kg/ha decreased the total uptake of phosphorus by weeds significantly during both

the years. Acetachlor 0.75 kg/ha was the next best in decreasing the total uptake of phosphorus by weeds in each of the tillage methods during both the years.

Table: 4.36 Integrated effect of tillage and weed control methods on phosphorus uptake (kg/ha) by weeds at 60 DAS

Tillage methods	Weed control methods				
	Unweeded	Acetachlor 0.75 kg/ha	Acetachlor 1.25 kg/ha	Atrazine 1.5 kg/ha	
2002					
Zero	14.92	4.04	1.75	1.48	
Conventional	12.41	2.60	1.51	1.41	
Raised seed bed	9.73	2.26	0.98	0.94	
2003					
Zero	14.73	4.60	2.25	1.96	
Conventional	12.98	4.10	2.01	1.85	
Raised seed bed	12.27	2.89	1.44	1.36	
		2002		2003	
		SE(m)±	CD (P=0.05)	SE(m)±	CD (P=0.05)
To compare two weed control methods at same level of tillage methods		0.50	1.05	0.32	0.67
To compare two tillage methods at same or different level of weed control methods		0.51	1.00	0.36	0.68

Integration of atrazine 1.5 kg/ha or acetachlor 1.25 kg/ha with each of the methods of tillage except zero tillage in interaction with acetachlor 1.25 kg/ha during the second year, resulted in significantly lower uptake of phosphorus by total weeds during both the years.

4.1.8.3 Uptake of potassium

A critical perusal at the data (Table 4.34) revealed that raised seed bed decreased the total uptake of potassium by weeds significantly over the remaining tillage methods during both the years. Conventional tillage was the next best in decreasing the total uptake of potassium during both the years. However, it was statistically at par with zero tillage during the second year.

The data further revealed that atrazine 1.5 kg/ha and acetachlor 1.25 kg/ha being statistically at par with each other were significantly superior to rest of the weed control treatments in decreasing the total potassium uptake by weeds during both the years. While, acetachlor 0.75 kg/ha was significantly superior to unweeded check during second year, it was at par with unweeded check during first year in decreasing the total potassium uptake by weeds.

The data (Table 4.37) on interaction effect of tillage and weed control methods on total uptake of potassium by weeds revealed that in each of the weed control treatments, raised seed bed resulted in significantly lower uptake of potassium during both the years. However, it was statistically at par with remaining tillage methods in atrazine treated plots and at par with conventional tillage in acetachlor treated plots at both the doses during first year. Whereas during the second year conventional tillage being statistically at par with zero tillage in each of the weed control treatments except unweeded check were next best in reducing the total potassium uptake by weeds. In unweeded check, the conventional tillage was the next best during both the years.

In each of the methods of tillage, atrazine 1.5 kg/ha being statistically alike to acetachlor 1.25 kg/ha resulted in significantly lower uptake of potassium during both the years. Acetachlor 0.75 kg/ha was the next best in each of tillage methods in decreasing the total uptake of potassium significantly during both the years.

Table 4.37 Integrated effect of tillage and weed control methods on potassium uptake (kg/ha) by weeds at 60 DAS

Treatments	Weed control methods			
	Unweeded	Acetachlor 0.75 kg/ha	Acetachlor 1.25 kg/ha	Atrazine 1.5 kg/ha
2002				
Zero	58.98	20.20	9.88	8.66
Conventional	52.01	13.72	9.03	7.08
Raised seed bed	40.36	11.01	6.03	5.71
2003				
Zero	64.49	26.50	13.92	12.56
Conventional	59.62	24.64	13.32	12.50
Raised seed bed	54.84	16.78	9.46	8.63
	2002		2003	
	SE(m)±	CD (P=0.05)	SE(m)±	CD (P=0.05)
To compare two weed control methods at same level of tillage methods	1.86	3.91	1.12	2.35
To compare two tillage methods at same or different level of weed control methods	1.85	3.66	1.63	2.90

Integration of raised seed bed with atrazine 1.5 kg/ha or acetachlor 1.25 kg/ha resulted in significantly lower total uptake of potassium during both the years. However, it was significantly at par with combination of conventional tillage with atrazine 1.5 kg/ha or acetachlor 1.25 kg/ha and combination of zero tillage with atrazine 1.5 kg/ha during the first year. Whereas during the second year these combinations were next best in reducing the total uptake of potassium.

4.2 CROP STUDIES

The data pertaining to different growth, development, yield attributes as well as seed and stover yield of maize have been described in this section.

4.2.1 Growth studies

Growth characters viz. emergence count, plant height, number of functional leaves, dry matter accumulation, root distribution (lateral and vertical) recorded at monthly interval and stalk diameter at harvest are described in this section.

4.2.1.1 Emergence count

Emergence count of maize remained unaffected due to different tillage and weed control treatments during both the years of experimentation.

4.2.1.2 Plant height

The data on progressive plant height of maize as influenced by tillage and weed control methods have been embodied in Table 4.38 and 4.39. A critical perusal at the data in Table 4.38 revealed that plant height of maize increased at increasing rate upto 60 DAS and thereafter increase was at decreasing rate upto the harvest during both the years.

Tillage methods influenced the plant height of maize significantly at all the stages except at 30 DAS during 2002. Conventional tillage being statistically at par with raised seed bed resulted in significantly taller plants at all the stages of observation during both the years. However, it was statistically at par with zero tillage at 30 DAS during 2003.

All the weed control methods increased the plant height of maize significantly over unweeded check at all the stages of observation during both the years. The data further revealed that atrazine 1.5 kg/ha being statistically at par with acetachlor 1.25 kg/ha produced significantly taller plants at all the stages of observation during both the years. However, acetachlor 0.75 kg/ha was statistically at par with acetachlor 1.25 kg/ha in influencing the plant height at all the stages of observation during both the years, except at 60 and 90 DAS during 2003.

Table 4.38 Effect of tillage and weed control methods on progressive plant height (cm) of maize

Treatments	30 DAS		60 DAS		90 DAS		At harvest	
	2002	2003	2002	2003	2002	2003	2002	2003
Tillage methods								
Zero	61.28	51.39	252.05	234.35	259.32	250.07	262.57	254.37
Conventional	65.09	49.10	273.72	252.73	285.53	266.82	288.73	270.53
Raised seed bed	59.22	47.49	268.05	247.92	280.97	260.25	284.97	265.50
SEm \pm	2.11	1.03	4.42	1.88	3.05	2.71	3.74	2.48
CD (P=0.05)	NS	2.87	12.28	5.23	8.48	7.52	10.38	6.90
Weed control methods								
Unweeded	56.07	45.02	219.98	209.60	233.49	223.93	237.09	227.22
Acetachlor 0.75 kg/ha	61.86	49.64	274.93	249.51	283.58	262.46	287.53	267.62
Acetachlor 1.25 kg/ha	64.43	50.94	280.42	257.53	291.42	273.16	294.96	278.18
Atrazine 1.5 kg/ha	65.10	53.03	283.09	263.36	292.60	276.62	295.44	280.84
SEm \pm	1.46	1.10	4.06	3.03	4.04	5.10	4.84	5.98
CD (P=0.05)	3.06	2.32	8.52	6.37	8.48	10.70	10.16	12.55

The interaction data at 60 DAS for both the years presented in Table 4.39 revealed that in each of the methods of weed control, conventional tillage being statistically at par with raised seed bed resulted in significantly taller plants during both the years. However, except in unweeded check zero tillage remained statistically similar with remaining two tillage methods during first year.

Table 4.39 Integrated effect of tillage and weed control methods on plant height (cm) of maize crop at 60 DAS

Tillage methods	Weed control methods			
	Unweeded	Acetachlor 0.75 kg/ha	Acetachlor 1.25 kg/ha	Atrazine 1.5 kg/ha
2002				
Zero	191.73	266.33	273.00	277.13
Conventional	235.93	281.73	286.93	290.27
Raised seed bed	232.27	276.73	281.33	281.87
2003				
Zero	188.13	243.13	249.33	256.80
Conventional	222.40	255.87	262.93	269.73
Raised seed bed	218.27	249.53	260.33	263.53
	2002		2003	
	SE(m)±	CD (P=0.05)	SE(m)±	CD (P=0.05)
To compare two weed control methods at same level of tillage methods	7.03	14.76	5.25	11.03
To compare two tillage methods at same or different level of weed control methods	9.78	17.67	5.60	10.82

In each of the method of tillage, atrazine 1.5 kg/ha being statistically at par with acetachlor 1.25 kg/ha significantly increased the plant height during both the years. However, these were also at par with acetachlor 0.75 kg/ha in all tillage methods during 2002 in increasing the plant height.

Integration of conventional tillage or raised seed bed with atrazine 1.5 kg/ha or acetachlor 1.25 kg/ha being statistically at par produced plants with significantly taller plant height during both the years. However, integration of zero tillage with atrazine 1.5 kg/ha or acetachlor 1.25 kg/ha and the remaining two tillage methods with acetachlor 0.75 kg/ha were also statistically alike to the superior combinations during 2002.

4.2.1.3 Number of functional leaves

The data on number of functional leaves per plant of maize have been presented in Table 4.40 and 4.41. The number of functional leaves per plant of maize increased upto 60 DAS and decreased thereafter.

A perusal of the data in Table 4.40 revealed that conventional tillage being statistically at par with raised seed bed resulted in significantly more number of functional leaves per plant of maize at all the stages of observation during both the years except at 30 DAS during 2003 and at harvest during both the years where the effect was non-significant.

All the weed control treatments influenced the number of functional leaves per plant of maize significantly at all the stages of observation except at harvest during both the years. All the weed control methods were significantly superior to unweeded check in increasing the number of functional leaves. Among weed control methods atrazine 1.5 kg/ha being statistically at par with acetachlor 1.25 kg/ha resulted in significantly more number of functional leaves per plant at all the stages of

Table 4.40 Effect of tillage and weed control methods on progressive number of functional leaves per plant of maize

Treatments	30 DAS		60 DAS		90 DAS		At harvest	
	2002	2003	2002	2003	2002	2003	2002	2003
Tillage methods								
Zero	7	7	12	12	11	11	4	4
Conventional	8	7	14	14	12	12	4	4
Raised seed bed	8	7	15	13	13	11	4	4
SEm \pm	0.2	0.2	0.5	0.3	0.3	0.3	0.1	0.1
CD (P=0.05)	0.6	NS	1.3	0.9	0.8	0.5	NS	NS
Weed control methods								
Unweeded	6	5	11	10	9	8	4	4
Acetachlor 0.75 kg/ha	8	8	14	13	12	11	4	4
Acetachlor 1.25 kg/ha	9	8	15	14	13	13	4	4
Atrazine 1.5 kg/ha	9	8	15	14	13	13	4	4
SEm \pm	0.3	0.3	0.4	0.5	0.2	0.5	0.2	0.1
CD (P=0.05)	0.6	0.6	0.9	1.0	0.7	1.0	NS	NS

observation during both the years. However, functional leaves in acetachlor 0.75 kg/ha treated plots were statistically at par with both the superior treatments at 30 DAS during both the years and acetachlor 1.25 kg/ha at 60 DAS during first year.

A perusal of the data on interaction of tillage and weed control methods at 90 DAS (Table 4.41) revealed that in each of the methods of weed control, conventional tillage being statistically at par with raised seed bed resulted in significantly more number of functional leaves per plant of maize during both the years. However, in atrazine 1.5 kg/ha and acetachlor 1.25 kg/ha zero tillage was also statistically alike to remaining tillage methods during both the years.

Table 4.41 Integrated effect of tillage and weed control methods on number of functional leaves of maize crop at 90 DAS

Tillage methods	Weed control methods			
	Unweeded	Acetachlor 0.75 kg/ha	Acetachlor 1.25 kg/ha	Atrazine 1.5 kg/ha
2002				
Zero tillage	7	10	12	13
Conventional tillage	10	12	13	14
Raised seed bed	10	13	13	14
2003				
Zero tillage	7	10	12	13
Conventional tillage	10	12	13	14
Raised seed bed	10	13	13	14
	2002		2003	
	SE(m)±	CD (P=0.05)	SE(m)±	CD (P=0.05)
To compare two weed control methods at same level of tillage methods	0.6	1.2	0.8	1.7
To compare two tillage methods at same or different level of weed control methods	0.7	1.3	0.8	1.5

While comparing two weed control methods at same level of tillage methods, it is evident from the data that in each of the methods of tillage, atrazine 1.5 kg/ha being statistically at par with acetachlor 1.25 kg/ha resulted in significantly more number of functional leaves per maize plant during both the years. However, acetachlor 0.75 kg/ha was statistically similar to superior treatments in raised seed bed during first year and in conventional tillage during second year in influencing the number of functional leaves per plant of maize.

Integration of atrazine 1.5 kg/ha or acetachlor 1.25 kg/ha with either raised seed bed or conventional tillage resulted in significantly more number of functional leaves per plant of maize during both the years. However, these were statistically at par with integration of atrazine 1.5 kg/ha with zero tillage during both the years.

4.2.1.4 Dry matter accumulation

The data on periodic dry matter accumulation by maize crop have been presented in Table 4.42. A perusal of the data indicated that dry matter accumulation by maize increased at increasing rate upto 60 DAS, thereafter it increased at decreasing rate till harvest.

The dry matter accumulation by maize was influenced significantly by tillage and weed control methods at all the stages of observation during both the years except at 30 DAS during 2003 where, tillage methods did not have any significant effect.

Table 4.42 Effect of tillage and weed control methods on progressive dry matter accumulation (g/plant) of maize

Treatments	30 DAS		60 DAS		90 DAS		At harvest	
	2002	2003	2002	2003	2002	2003	2002	2003
Tillage methods								
Zero	10.68	9.13	123.12	110.51	141.32	120.66	149.20	129.21
Conventional	14.35	11.06	141.67	129.08	159.05	139.47	165.95	147.82
Raised seed bed	13.09	10.08	140.80	126.33	157.38	142.08	167.28	144.77
SEm \pm	0.67	0.82	3.12	3.36	2.60	5.36	3.11	3.03
CD (P=0.05)	1.85	NS	8.68	9.34	7.22	14.90	8.64	8.40
Weed control methods								
Unweeded	8.99	7.15	104.86	87.62	118.00	100.86	126.91	109.98
Acetachlor 0.75 kg/ha	11.48	9.70	127.90	117.73	148.31	129.33	155.49	136.23
Acetachlor 1.25 kg/ha	14.62	11.53	150.91	137.90	169.68	149.11	178.53	154.18
Atrazine 1.5 kg/ha	15.73	11.97	157.11	144.64	174.33	156.98	182.31	162.00
SEm \pm	0.58	0.64	3.23	2.74	2.14	5.04	3.51	5.74
CD (P=0.05)	1.21	1.34	6.79	5.76	4.49	10.59	7.37	12.05

Conventional tillage being statistically at par with raised seed bed resulted in significantly higher dry matter accumulation in maize at all the stages of observation during both the years.

A perusal of the data in Table 4.42 further revealed that all the weed control methods were significantly superior to unweeded check in increasing the dry matter accumulation by maize at all the observation stages during both the years. Among weed control methods atrazine 1.5 kg/ha being statistically at par with acetachlor 1.25 kg/ha resulted in significantly higher dry matter accumulation at all the stages of observation during both the years except at 60 DAS during second year and 90 DAS during first year, where, acetachlor 1.25 kg/ha was the next best treatment.

Tillage and weed control methods did not interacted significantly to influence dry matter accumulation of maize plant.

4.2.1.5 Stalk diameter

The tillage and weed control treatments influenced the stalk diameter of maize at harvest significantly during both the years. A perusal of the data in Table 4.43 revealed that conventional tillage and raised seed bed being statistically at par with each other resulted in significantly higher stalk diameter over zero tillage during both the years.

All the weed control methods increased the stalk diameter of maize significantly over unweeded check during both the years. Atrazine 1.5 kg/ha and acetachlor 1.25 kg/ha being statistically at par resulted in significantly higher stalk diameter during both the years.

Table 4.43 Effect of tillage and weed control methods on stalk diameter (mm) of maize at harvest

Treatments	Stalk Diameter	
	2002	2003
Tillage methods		
Zero	17.78	16.90
Conventional	19.24	18.76
Raised seed bed	19.36	18.42
SEm \pm	0.34	0.47
CD (P=0.05)	0.94	1.30
Weed control methods		
Unweeded	15.20	14.40
Acetachlor 0.75 kg/ha	18.73	18.18
Acetachlor 1.25 kg/ha	20.33	19.46
Atrazine 1.5 kg/ha	20.91	20.07
SEm \pm	0.64	0.57
CD (P=0.05)	1.34	1.20

4.2.1.6 Lodging percentage

A perusal of the data in Table 4.44 revealed that tillage and weed control methods significantly influenced the lodging percentage of maize during both the years. Conventional tillage resulted in significantly lower lodging percentage during both the years. However, it was statistically alike to raised seed bed during first year. During second year raised seed bed was next best to conventional tillage in decreasing the lodging percentage of maize.

The data further revealed that atrazine 1.5 kg/ha being statistically at par with acetachlor 1.25 kg/ha resulted in significantly lower lodging percentage during both the years. However, acetachlor 1.25 kg/ha was also statistically at par with acetachlor 0.75 kg/ha in reducing the percentage of lodged plants of maize during both the years.

Table 4.44 Effect of tillage and weed control methods on lodging percentage of maize plants

Treatments	Lodging percentage	
	2002	2003
Tillage methods		
Zero	15.51	15.33
Conventional	10.46	10.11
Raised seed bed	10.77	12.22
SEm \pm	0.59	0.69
CD (P=0.05)	1.63	1.91
Weed control methods		
Unweeded	19.45	16.70
Acetachlor 0.75 kg/ha	11.67	12.68
Acetachlor 1.25 kg/ha	9.29	10.85
Atrazine 1.5 kg/ha	8.60	9.96
SEm \pm	1.19	1.12
CD (P=0.05)	2.50	2.35

4.2.1.7 Lateral and vertical spread

The data on lateral and vertical spread of maize roots at different stages of observation have been presented in Table 4.45 and 4.46, respectively. A critical perusal at the data revealed that lateral and vertical spread of maize roots was influenced significantly by tillage and weed control methods at all the stages of observation during both the years except at 30 DAS where tillage methods failed to influence the vertical spread of maize roots significantly during both the years and lateral spread during first year.

Conventional tillage and raised seed bed being statistically at par resulted in significantly higher lateral and vertical spread of maize roots over zero tillage and all the stages of observation during both the years.

Table 4.45 Effect of tillage and weed control methods on lateral spread (cm) of maize roots

Treatments	30 DAS		60 DAS		90 DAS	
	2002	2003	2002	2003	2002	2003
Tillage methods						
Zero	15.65	14.80	21.40	20.98	20.35	20.23
Conventional	16.64	16.73	23.88	22.52	23.30	21.79
Raised seed bed	16.52	15.64	23.15	22.58	22.52	21.21
SEm \pm	0.30	0.31	0.27	0.13	0.44	0.27
CD (P=0.05)	NS	1.42	0.75	0.35	1.23	0.75
Weed control methods						
Unweeded	13.06	13.44	19.26	18.37	18.94	18.57
Acetachlor 0.75 kg/ha	15.32	14.65	21.47	22.97	21.21	20.57
Acetachlor 1.25 kg/ha	17.92	16.99	25.00	24.07	23.61	22.26
Atrazine 1.5 kg/ha	18.77	17.81	25.51	24.89	24.46	22.91
SEm \pm	0.41	0.51	0.37	0.30	0.41	0.26
CD (P=0.05)	0.87	1.07	0.77	0.63	0.87	0.55

Table 4.46 Effect of tillage and weed control methods on vertical spread (cm) of maize roots

Treatments	30 DAS		60 DAS		90 DAS	
	2002	2003	2002	2003	2002	2003
Tillage methods						
Zero	8.63	8.20	14.11	11.81	12.77	10.93
Conventional	9.69	8.78	17.40	16.50	15.49	14.94
Raised seed bed	8.92	8.52	16.68	15.83	14.98	14.72
SEm \pm	0.33	0.28	0.32	0.22	0.31	0.30
CD (P=0.05)	NS	NS	0.88	0.60	0.86	0.84
Weed control methods						
Unweeded	7.74	7.37	12.49	11.84	10.94	9.95
Acetachlor 0.75 kg/ha	8.57	8.17	15.80	14.44	13.96	13.01
Acetachlor 1.25 kg/ha	9.79	9.11	18.08	16.72	16.31	15.31
Atrazine 1.5 kg/ha	10.22	9.36	17.89	16.53	16.44	15.84
SEm \pm	0.18	0.17	0.28	0.47	0.32	0.29
CD (P=0.05)	0.38	0.35	0.59	0.98	0.68	0.61

It is evident from the data in Table 4.45 and 4.46 that atrazine 1.5 kg/ha being statistically at par with acetachlor 1.25 kg/ha resulted in significantly higher lateral and vertical spread of maize roots at all the stages of observation during both the years. However, atrazine 1.5 kg/ha was significantly superior to acetachlor 1.5 kg/ha in increasing lateral spread of maize roots at 90 DAS during second year and vertical spread of maize roots at 30 DAS during first year of experimentation.

Tillage and weed control methods interacted significantly to influence the vertical distribution of maize roots at 90 DAS during both the years. The data presented in Table 4.47 revealed that in each of the methods of weed control, conventional tillage being statistically at par with raised seed bed resulted in significantly higher vertical spread of maize roots during both the years. However, in acetachlor 1.25 kg/ha treated plots conventional tillage was significantly superior to raised seed bed during first year. In unweeded check plots all the tillage methods were equally effective to influence the vertical distribution of maize roots during first year.

In each of the methods of tillage, all the herbicide treatments were significantly superior to increase vertical spread of maize roots over unweeded check during both the years. However, in zero tilled plots during first year vertical spread in unweeded plots was statistically at par with acetachlor 0.75 kg/ha. Among the herbicides, atrazine 1.5 kg/ha being statistically at par with acetachlor 1.25 kg/ha resulted in significantly higher vertical spread of maize roots during both the years (Plate V).



Raised seed bed



Conventional tillage



Zero tillage

Plate V. Effect of tillage methods on root growth of maize.

Table 4.47 Integrated effect of tillage and weed control methods on vertical spread of maize roots at 90 DAS

Tillage methods	Weed control methods			
	Unweeded	Acetachlor 0.75 kg/ha	Acetachlor 1.25 kg/ha	Atrazine 1.5 kg/ha
2002				
Zero	10.33	11.50	14.33	14.90
Conventional	11.15	15.40	18.00	17.42
Raised seed bed	11.33	14.97	16.60	17.00
2003				
Zero	8.47	9.63	12.60	13.03
Conventional	10.45	14.70	16.83	17.77
Raised seed bed	10.93	14.70	16.50	16.73
	2002		2003	
	SE(m)±	CD (P=0.05)	SE(m)±	CD (P=0.05)
To compare two weed control methods at same level of tillage methods	0.57	1.19	0.50	1.05
To compare two tillage methods at same or different level of weed control methods	0.73	1.33	0.69	1.24

Integration of conventional tillage with either atrazine 1.5 kg/ha or acetachlor 1.25 kg/ha and integration of raised seed bed with atrazine 1.5 kg/ha being statistically at par resulted in significantly higher vertical spread of maize roots at 90 DAS during both the years.

4.2.2 Development studies

Data on number of days taken for attainment of various development stages *viz.* days taken to emergence, days taken to 50 per cent tasseling and silking and maturity of crop have been presented in Table 4.48 and Figs 4.6 and 4.7.

Table 4.48 Effect of tillage and weed control methods on number of days taken to initiation of different phenophases of maize

Treatments	Emergence		50% Tasselling		50% Silking		Maturity	
	2002	2003	2002	2003	2002	2003	2002	2003
Tillage methods								
Zero	11	11	55	54	62	60	100	101
Conventional	14	12	58	54	65	61	103	102
Raised seed bed	16	15	59	59	67	65	105	104
SEm ±	0.3	0.6	0.9	1.5	1.1	1.0	1.2	0.8
CD (P=0.05)	0.8	1.6	2.4	4.2	3.0	2.9	3.3	2.2
Weed control methods								
Unweeded	13	13	55	54	61	59	100	99
Acetachlor 0.75 kg/ha	13	13	58	56	65	63	104	103
Acetachlor 1.25 kg/ha	13	13	59	57	66	62	104	104
Atrazine 1.5 kg/ha	13	13	58	56	65	64	103	103
SEm ±	0.7	0.7	0.6	1.3	0.9	1.4	0.7	1.4
CD (P=0.05)	NS	NS	1.2	NS	1.9	2.9	1.5	3.0

Data in Table 4.48 revealed that tillage methods influenced the days taken to different phenophases of maize crop significantly during both the years. Among tillage methods, raised seed bed significantly delayed different phenophases over rest of the methods during both the years. However, it was statistically at par with conventional tillage to delay 50 per cent tasseling and silking and maturity during 2002. Conventional tillage remained statistically at par with zero tillage to influence different phenophases of crop during both the years except days taken to emergence of the crop during first year, where, it was next to delay emergence after raised seed bed.

Significant influence of weed control methods was noticed on number of days taken to attain different phenophases in maize during both the years except for days taken to emergence during both the years and days taken to 50 per cent tasseling during 2003. The data further revealed that all the weed control treatments being statistically at par to each other delayed the 50 per cent tasseling during first year and 50 per cent silking and maturity during both the years over unweeded check.

Tillage methods did not interact significantly with weed control methods in influencing the days taken to different phenophases in maize.

4.2.3 Yield contributing characters, grain yield and harvest index

The data pertaining to effect of various treatments on yield contributing characters of maize have been presented in Table 4.49.

Table 4.49 Effect of tillage and weed control methods on yield contributing characters of maize

Treatments	Effective plant population (No./ha)		Cob length (cm)		No. of rows per cob		No. of grains per row (No.)		1000-grain weight (g)		Shelling percentage	
	2002	2003	2002	2003	2002	2003	2002	2003	2002	2003	2002	2003
Tillage methods												
Zero	65972	66425	13.03	12.52	14.28	13.13	31.60	31.79	252.88	239.25	77.04	78.01
Conventional	71105	72464	14.81	14.28	15.90	14.63	35.43	36.10	266.05	250.67	79.02	79.68
Raised seed bed	71332	70275	14.58	13.97	15.83	14.23	35.70	35.17	263.87	248.35	78.80	79.99
SEM ±	1212	926	0.43	0.24	0.45	0.25	0.59	1.14	3.26	3.06	0.58	0.53
CD (P=0.05)	3370	2575	1.19	0.67	1.25	0.70	1.65	3.16	9.06	8.51	1.61	1.46
Weed control methods												
Unweeded	55354	60286	12.18	10.91	12.96	11.38	30.42	29.44	241.04	226.80	75.22	76.76
Acetachlor 0.75 kg/ha	69545	70049	13.74	13.34	15.69	13.44	33.71	34.34	259.51	243.80	77.66	78.74
Acetachlor 1.25 kg/ha	75584	73470	15.07	14.96	16.13	15.37	35.82	37.18	269.00	253.37	79.81	79.99
Atrazine 1.5 kg/ha	77396	75081	15.57	15.14	16.58	15.81	37.02	36.44	274.18	260.37	80.45	81.29
SEM ±	1530	1573	0.28	0.31	0.47	0.24	0.88	1.00	3.98	4.73	0.77	0.85
CD (P=0.05)	3214	3303	0.58	0.66	0.99	0.50	1.85	2.09	8.36	9.93	1.61	1.78

4.2.3.1 Yield contributing characters

It is evident from the data in Table 4.49 that tillage and weed control methods affected all the yield attributes of maize significantly during both the years. Conventional tillage being statistically at par with raised seed bed produced significantly higher values of all the yield contributing characters of maize during both the years.

The data in Table 4.49 further revealed that all the herbicide treatments were significantly superior to unweeded check in increasing all the yield contributing characters of maize during both the years. Among herbicides atrazine 1.5 kg/ha being statistically at par with acetachlor 1.25 kg/ha resulted in significantly higher values of various yield contributing characters of maize crop. However, acetachlor 0.75 kg/ha was statistically similar to these two treatments in increasing the number of rows per cob of maize during 2002. Acetachlor 0.75 kg/ha was also statistically at par with atrazine 1.5 kg/ha in increasing the number of grains per row and with acetachlor 1.25 kg/ha in increasing 1000-grain weight and shelling percentage of maize during 2003.

Interaction effect of tillage and weed control methods on cob length and number of rows per cob was significant during both the years and has been presented in Table 4.50 and 4.51, respectively.

Table 4.50 Integrated effect of tillage and weed control methods on length of cob (cm) of maize

Tillage methods	Weed control methods			
	Unweeded	Acetachlor 0.75 kg/ha	Acetachlor 1.25 kg/ha	Atrazine 1.5 kg/ha
2002				
Zero	10.60	12.57	13.67	15.30
Conventional	12.83	14.77	15.60	16.03
Raised seed bed	13.10	13.90	15.93	15.37
2003				
Zero	8.97	12.33	14.10	14.67
Conventional	11.30	14.13	15.97	15.73
Raised seed bed	12.47	13.57	14.80	15.03
	2002		2003	
	SE(m)±	CD (P=0.05)	SE(m)±	CD (P=0.05)
To compare two weed control methods at same level of tillage methods	0.46	0.96	0.55	1.15
To compare two tillage methods at same or different level of weed control methods	0.84	1.44	0.63	1.19

Table 4.51 Integrated effect of tillage and weed control methods on number of rows per cob of maize

Tillage methods	Weed control methods			
	Unweeded	Acetachlor 0.75 kg/ha	Acetachlor 1.25 kg/ha	Atrazine 1.5 kg/ha
2002				
Zero	10.33	14.93	15.60	16.27
Conventional	13.60	16.00	16.93	17.07
Raised seed bed	14.93	16.13	15.87	16.40
2003				
Zero	10.40	12.20	14.43	15.50
Conventional	12.07	13.87	16.43	16.17
Raised seed bed	11.67	14.27	15.23	15.77
	2002		2003	
	SE(m)±	CD (P=0.05)	SE(m)±	CD (P=0.05)
To compare two weed control methods at same level of tillage methods	0.82	1.71	0.41	0.86
To compare two tillage methods at same or different level of weed control methods	1.05	1.92	0.56	1.01

A perusal of the data in Table 4.50 revealed that in each of the weed control methods, conventional tillage being statistically at par with raised seed bed increased the cob length of maize significantly during both the years. However, zero tillage was statistically at par with remaining tillage methods in atrazine 1.5 kg/ha treated plots during both the years.

In each of the tillage methods, except zero tillage during 2002, atrazine 1.5 kg/ha being statistically at par with acetachlor 1.25 kg/ha resulted in significant increase in cob length during both the years.

Integration of conventional or raised seed bed with either atrazine 1.5 kg/ha or acetachlor 1.25 kg/ha being statistically at par among themselves resulted in significantly higher cob length during both the years. However, integration of zero tillage with atrazine 1.5 kg/ha was also statistically at par with superior combinations during the first year. Whereas during the second year it was statistically similar to all superior combinations except integration of conventional tillage with acetachlor 1.25 kg/ha.

The integration of tillage and weed control methods in influencing the number of grain rows per cob was significant during both the years. A perusal of the data in Table 4.51 revealed that in each of the methods of weed control except acetachlor 1.25 kg/ha during the second year, conventional tillage being statistically at par with raised seed bed resulted in significantly higher number of rows per cob during both the years. However, zero tillage was also statistically alike to remaining tillage methods in

increasing the number of rows per cob significantly in each of the methods of weed control except unweeded check during first year and in atrazine 1.5 kg/ha treated plots during second year.

In each of the tillage methods, atrazine 1.5 kg/ha was statistically at par with acetachlor 1.25 kg/ha in increasing the number of rows per cob significantly during both the year. However in zero tilled plots atrazine 1.5 kg/ha was significantly superior to other weed control methods during second year. Whereas, during first year acetachlor 0.75 kg/ha produced significantly similar number of rows per cob as that of superior weed control treatments in each of the tillage methods.

Integration of conventional tillage or raised seed bed with either atrazine 1.5 kg/ha or acetachlor 1.25 kg/ha resulted in significantly more number of rows per cob of maize during both the years. However, these were statistically at par with integration of zero tillage with atrazine 1.5 kg/ha during both the years. During first year, the combination of zero tillage with acetachlor 1.25 kg/ha and conventional tillage or raised seed bed with acetachlor 0.75 kg/ha was also statistically at par.

4.2.3.2 Grain yield

A perusal of the data in Table 4.52 revealed that the grain yield of maize was influenced significantly by tillage and weed control methods significantly during both the years. It is evident from the data that conventional tillage being statistically at par with raised seed bed increased the grain yield of maize significantly over zero tillage during both the years.

All the weed control methods were significantly superior to unweeded check in increasing grain yield of maize significantly during both the years. Among weed control methods atrazine 1.5 kg/ha and acetachlor 1.25 kg/ha being statistically at par produced significantly higher maize grain yield during both the years.

The tillage and weed control methods interacted significantly in influencing the maize grain yield. The data presented in Table 4.53 and Fig. 4.8 revealed that, in each of the methods of tillage, atrazine 1.5 kg/ha being statistically at par with acetachlor 1.25 kg/ha resulted in significantly higher grain yield over rest of the weed control methods during both the years. Acetachlor 0.75 kg/ha was next best in all of the tillage methods.

The data further revealed that in each of the methods of weed control, conventional tillage being statistically at par with raised seed bed produced significantly higher maize grain yield. However, zero tillage was statistically at par with these tillage methods in acetachlor 1.25 kg/ha and atrazine 1.5 kg/ha treated plots during first and second year, respectively.

Integration of conventional tillage or raised seed bed with either atrazine 1.5 kg/ha or acetachlor 1.25 kg/ha being statistically at par with each other resulted in significantly higher grain yield during both the years. However, integration of zero tillage with atrazine 1.5 kg/ha was statistically as effective as these combinations during second year in increasing grain yield of maize. Acetachlor 0.75 kg/ha in integration with conventional tillage or raised seed bed was statistically as effective as acetachlor 1.25 kg/ha or atrazine 1.5 kg/ha in integration with zero tillage in both the years.

Table 4.52 Effect of tillage and weed control methods on grain yield, stover yield, biological yield (kg/ha) and harvest index of maize

Treatments	Grain yield			Stover yield			Biological yield			Harvest Index		
	2002	2003	2003	2002	2003	2003	2002	2002	2003	2002	2002	2003
Tillage methods												
Zero	5862.30	5735.87	12633.56	11992.96	18495.86	17728.83	31.80	32.43				
Conventional	6872.07	6686.67	14697.08	14152.34	21569.15	20839.01	31.89	32.13				
Raised seed bed	6638.21	6551.86	14119.66	13926.89	20757.88	20478.74	32.01	32.00				
SEm ±	85.05	160.54	411.98	170.62	460.26	263.07	0.54	0.71				
CD (P=0.05)	236.45	446.30	1143.99	473.77	1278.00	730.46	NS	NS				
Weed control methods												
Unweeded	4379.10	4171.97	9258.67	8705.25	13637.77	12877.21	32.10	32.47				
Acetachlor 0.75 kg/ha	6382.80	6542.27	13529.04	13774.74	19911.84	20316.99	32.09	32.23				
Acetachlor 1.25 kg/ha	7527.37	7151.97	16132.73	15189.74	23660.10	22341.71	31.84	32.01				
Atrazine 1.5 kg/ha	7540.85	7432.99	16346.63	15759.89	23887.47	23192.88	31.57	32.05				
SEm ±	148.45	137.77	352.01	279.37	487.35	362.06	0.29	0.67				
CD (P=0.05)	311.74	289.31	751.81	586.67	1023.42	1316.91	NS	NS				

Table 4.53 Integrated effect of tillage and weed control methods on grain yield (kg/ha) of maize

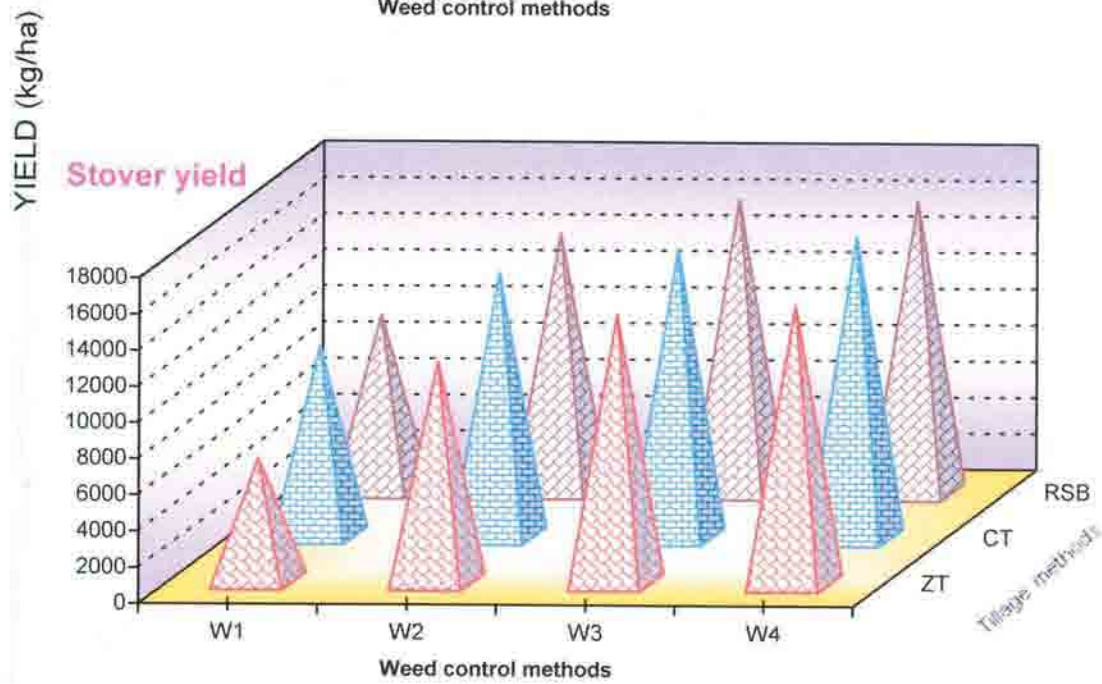
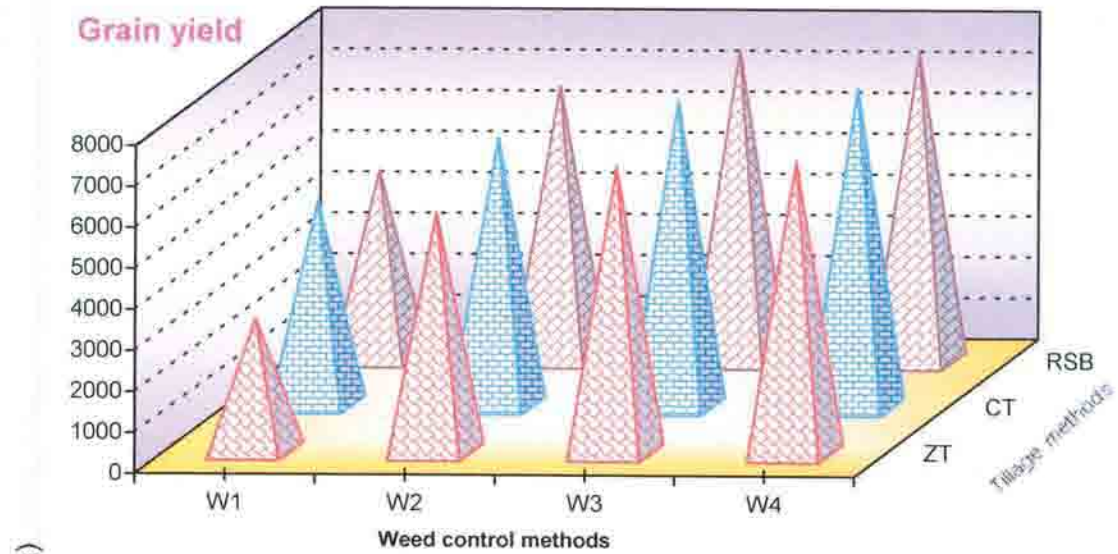
Tillage methods	Unweeded	Weed control methods		
		Acetachlor 0.75 kg/ha	Acetachlor 1.25 kg/ha	Atrazine 1.5 kg/ha
2002				
Zero	3316.23	5771.45	7200.23	7161.29
Conventional	5115.66	6812.98	7662.92	7896.73
Raised seed bed	4705.40	6513.99	7718.95	7564.52
2003				
Zero	3164.62	5905.23	6760.30	7113.30
Conventional	4863.34	6918.10	7269.52	7695.73
Raised seed bed	4487.96	6803.49	7426.05	7489.94
	2002		2003	
	SE(m)±	CD (P=0.05)	SE(m)±	CD (P=0.05)
To compare two weed control methods at same level of tillage methods	257.08	539.88	238.42	500.68
To compare two tillage methods at same or different level of weed control methods	267.13	521.34	346.61	616.63

4.2.3.3 Stover yield

A critical perusal at the data presented in Table 4.52 revealed that tillage and weed control methods affected the stover yield of maize significantly during both the years.

It is evident from the data that conventional tillage being statistically at par with raised seed bed produced significantly higher stover yield during both the years.

The data further revealed that all the herbicide treatments increased the stover yield of maize significantly over unweeded check. Among herbicides atrazine 1.5 kg/ha resulted in significantly highest stover yield of maize. However, acetachlor 1.25 kg/ha was also statistically alike in producing significantly higher stover yield of maize.



TREATMENTS

CT - Conventional tillage
 ZT - Zero tillage
 RSB - Raised seed bed

W1 - Unweeded
 W2 - Acetachlor 0.75 kg/ha
 W3 - Acetachlor 1.25 kg/ha
 W4 - Atrazine 1.5 kg/ha

Fig. 4.8 Integrated effect of tillage and weed control methods on grain and stover yield (q/ha) of maize (averaged over two years)

Integration of conventional tillage or raised seed bed with either atrazine 1.5 kg/ha or acetachlor 1.25 kg/ha being statistically at par resulted in significantly higher stover yield during both the years. However, the integration of zero tillage with atrazine 1.5 kg/ha or acetachlor 1.25kg/ha was also equally effective during first year. Acetachlor 0.75 kg/ha in integration with conventional or raised seed bed was statistically as effective as acetachlor 1.25 kg/ha or atrazine 1.5 kg/ha in integration with zero tillage in influencing stover yield during both the years. However, during first year raised seed bed in integration acetachlor 0.75 kg/ha was statistically inferior to zero tillage in integration with atrazine 1.5 kg/ha and higher dose of acetachlor.

4.2.3.4 Biological yield

It is evident from the data in Table 4.52 that biological yield of maize was significantly influenced by tillage and weed control methods. Conventional tillage being statistically alike to raised seed bed resulted in significantly higher biological yield of maize during both the years.

The data further revealed that among weed control treatments atrazine 1.5 kg/ha being statistically at par with acetachlor 1.25 kg/ha increased the biological yield of maize significantly during both the years. Acetachlor 0.75 kg/ha being statistically superior to unweeded check was the next best.

A critical perusal on interaction data presented in Table 4.55 indicate that in each of the methods of weed control, conventional tillage and raised seed bed being statistically at par with each other resulted in significantly higher biological yield of maize over zero tillage during both the years. However, in atrazine 1.5 kg/ha and acetachlor 1.25 kg/ha treated plots, zero tillage was equally effective to conventional tillage and raised seed bed in increasing stover yield during second year.

In each of the methods of tillage, atrazine 1.5 kg/ha being statistically at par with acetachlor 1.25 kg/ha increased the biological yield of maize significantly during both the years. Acetachlor 0.75 kg/ha was the next in significantly increasing the biological yield over unweeded check.

Integration of atrazine 1.5 kg/ha or acetachlor 1.25 kg/ha with either conventional tillage or raised seed bed being statistically at par resulted in significantly higher biological yield of maize during both the years. However, integration of atrazine 1.5 kg/ha with zero tillage was statistically at par with these superior combination in increasing the biological yield of maize during first year of experimentation. Acetachlor 0.75 kg/ha in integration with conventional tillage or raised seed bed was statistically as effective as acetachlor 1.25 kg/ha or atrazine 1.5 kg/ha in integration with zero tillage in influencing the biological yield of maize during both the years.

Table 4.55 Integrated effect of tillage and weed control methods on biological yield (kg/ha) of maize crop

Tillage methods	Weed control methods			
	Unweeded	Acetachlor 0.75 kg/ha	Acetachlor 1.25 kg/ha	Atrazine 1.5 kg/ha
2002				
Zero	10352.45	17893.22	22771.29	22966.47
Conventional	15942.44	21368.38	24067.06	24898.72
Raised seed bed	14618.41	21473.92	24141.94	23797.23
2003				
Zero	9703.12	18172.88	20907.79	22131.52
Conventional	15012.17	21512.98	22797.20	24033.70
Raised seed bed	13916.33	21265.10	23320.15	23413.40
	2002		2003	
	SE(m)±	CD (P=0.05)	SE(m)±	CD (P=0.05)
To compare two weed control methods at same level of tillage methods	844.11	1772.62	627.10	1316.91
To compare two tillage methods at same or different level of weed control methods	1081.62	1980.83	708.91	1345.22

4.2.3.5 Harvest index

A critical evaluation of the data presented in Table 4.52 indicate that harvest index was not influenced significantly by tillage and weed control methods during both the years of experimentation.

4.2.4 Nutrient uptake by crop

4.2.4.1 Uptake of nitrogen

A critical perusal at the data Table 4.56 indicated that both weed control and tillage methods significantly influenced the nitrogen uptake by maize plant. Conventional tillage being statistically at par with raised seed bed resulted in significantly higher nitrogen uptake by grains, stover and total plant over zero tillage during both the years.

All the weed control methods were significantly superior to unweeded check in increasing the uptake of nitrogen by grains, stover and total maize plant during both the years. The data further revealed that among herbicides, atrazine 1.5 kg/ha being statistically at par with acetachlor 1.25 kg/ha resulted in significantly higher nitrogen uptake by grains, stover and total plant during both the years.

Table 4.56 Effect of tillage and weed control methods on nitrogen uptake (kg/ha) by maize crop at harvest

Treatments	Nitrogen uptake					
	Grain		Stover		Total	
	2002	2003	2002	2003	2002	2003
Tillage methods						
Zero	90.03	90.26	57.98	52.42	148.01	142.68
Conventional	106.17	106.08	68.47	62.78	174.65	168.66
Raised seed bed	102.89	104.36	66.62	6.59	169.51	167.95
SEm \pm	1.25	3.10	2.15	1.32	3.03	4.33
CD (P=0.05)	3.47	8.63	5.97	3.68	8.42	12.04
Weed control methods						
Unweeded	64.32	62.47	38.57	37.17	102.88	99.64
Acetachlor 0.75 kg/ha	97.54	103.17	61.66	60.50	159.19	163.67
Acetachlor 1.25 kg/ha	117.54	115.05	77.18	68.76	194.92	183.81
Atrazine 1.5 kg/ha	119.20	120.24	80.01	71.96	199.21	192.20
SEm \pm	2.60	3.65	3.63	2.54	5.49	4.80
CD (P=0.05)	5.39	7.67	7.62	5.35	11.52	10.07

4.2.4.2 Uptake of phosphorus

A perusal of the data in Table 4.57 revealed that the phosphorus uptake by grain, stover and total maize plant was significantly influenced by tillage and weed control methods during both the years. However, total phosphorus uptake by maize plant was not influenced significantly by tillage and weed control methods during first year. Conventional tillage being statistically at par with raised seed bed resulted in significantly higher uptake of phosphorus by grains, stover and total maize plant during both the years. However, conventional tillage was significantly superior to raised seed bed in increasing phosphorus uptake by maize stover during second year.

Table 4.57 Effect of tillage and weed control methods on phosphorus uptake (Kg/ha) by maize crop at harvest

Treatments	Phosphorus uptake					
	Grain		Stover		Total	
	2002	2003	2002	2003	2002	2003
Tillage methods						
Zero	17.02	15.58	12.10	9.26	29.12	24.84
Conventional	20.97	18.39	15.98	12.22	36.95	30.60
Raised seed bed	19.79	18.93	16.65	11.63	43.49	30.56
SEm \pm	0.79	0.46	0.99	0.21	1.38	0.54
CD (P=0.05)	2.20	1.28	2.75	0.57	NS	1.51
Weed control methods						
Unweeded	10.76	9.63	7.73	5.41	27.89	15.04
Acetachlor 0.75 kg/ha	17.82	17.65	13.55	10.27	31.37	27.92
Acetachlor 1.25 kg/ha	23.75	20.62	18.20	13.54	41.95	34.16
Atrazine 1.5 kg/ha	24.73	22.64	20.15	14.91	44.88	37.55
SEm \pm	1.09	0.76	0.94	0.97	1.52	1.21
CD (P=0.05)	2.28	1.59	1.97	2.03	NS	2.54

The data further revealed that all herbicide treatments increased the phosphorus uptake by grains, stover and total maize plant significantly over unweeded check during both the years. Among herbicides, atrazine 1.5 kg/ha resulted in significantly higher phosphorus uptake by grain, stover and total plant during both the years. However, it was statistically at par with acetachlor 1.25 kg/ha in increasing the uptake of phosphorus by maize stover during both the years and by grains during first year.

4.2.4.3 Uptake of potassium

Tillage and weed control methods significantly influenced the potassium uptake by maize grains, stover and total plant during both the years.

Table 4.58 Effect of tillage and weed control methods on potassium uptake (Kg/ha) by maize crop at harvest

Treatments	Potassium uptake					
	Grain		Stover		Total	
	2002	2003	2002	2003	2002	2003
Tillage methods						
Zero	20.77	19.06	85.02	79.70	105.79	98.77
Conventional	24.80	24.84	97.10	98.96	121.70	123.80
Raised seed bed	24.92	23.63	93.95	95.82	118.87	119.45
SEm \pm	0.78	0.68	2.92	3.16	3.56	3.81
CD (P=0.05)	2.17	1.90	8.13	8.78	9.89	10.58
Weed control methods						
Unweeded	14.79	14.12	57.39	56.76	72.18	70.88
Acetachlor 0.75 kg/ha	22.71	22.61	86.49	93.05	109.20	115.66
Acetachlor 1.25 kg/ha	27.67	25.83	110.67	106.12	138.34	131.96
Atrazine 1.5 kg/ha	28.55	27.48	113.54	110.04	142.09	137.52
SEm \pm	1.46	0.93	3.76	2.80	4.51	3.19
CD (P=0.05)	3.06	1.96	7.89	5.88	9.47	6.69

It is evident from the data in Table 4.58 that conventional tillage and raised seed bed behaved statistically alike in significantly increasing the potassium uptake by grains, stover and total plant during both the years. However, conventional tillage was the next best and significantly superior to zero tillage in increasing potassium uptake by maize stover during first year.

The data further revealed that all the weed control treatments were significantly superior to unweeded check in increasing potassium uptake during both the years. Among herbicides, atrazine 1.5 kg/ha being statistically at par with acetachlor 1.25 kg/ha resulted in significantly higher uptake of potassium by maize grains, stover and thus total plant during both the years. However, acetachlor 0.75 kg/ha was the next best in increasing potassium uptake by maize grains, stover and total plant during second year.

4.2.5 Biochemical studies

4.2.5.1 Protein content

It is evident from the data in Table 4.59 that while, tillage methods did not influence the protein content of maize grains significantly, the weed control methods influenced it significantly during both the years.

All the herbicide treatments increased the protein content in maize grains significantly over unweeded check during both the years. Among herbicides, atrazine 1.5 kg/ha being statistically at par with acetachlor 1.25 kg/ha resulted in significantly higher protein content in maize grains during both the years. However, acetachlor 1.25 kg/ha was also statistically at par with its 0.75 kg/ha dose in significantly increasing the protein content during second year.

4.2.5.2 Starch content

A perusal of the data in Table 4.59 revealed that tillage methods did not influence the starch content in maize grains significantly. Weed control methods influenced the starch content significantly during both the years. All the herbicide treatments being statistically at par were significantly superior to unweeded check in increasing the starch content in maize grains significantly during both the years.

Table 4.59 Effect of tillage and weed control methods on protein and starch content (%) of maize grains

Treatments	Protein content		Starch content	
	2002	2003	2002	2003
Tillage methods				
Zero	9.74	9.52	57.13	56.76
Conventional	9.86	9.74	58.75	58.15
Raised seed bed	9.90	9.64	59.32	58.93
SEm \pm	0.19	0.13	0.81	0.64
CD (P=0.05)	NS	NS	NS	NS
Weed control methods				
Unweeded	9.33	9.20	55.78	55.06
Acetachlor 0.75 kg/ha	9.84	9.57	58.00	57.59
Acetachlor 1.25 kg/ha	10.05	9.84	59.60	59.38
Atrazine 1.5 kg/ha	10.11	9.94	60.21	59.77
SEm \pm	0.20	0.15	1.24	1.20
CD (P=0.05)	0.45	0.32	2.61	2.53

4.2.6 Studies on soil physical properties

4.2.6.1 Soil moisture content

It is evident from the data in Table 4.60 that tillage methods influenced the soil moisture content in different layers significantly at the time of sowing. Zero tillage resulted in significantly highest soil moisture content at each of the soil depths (i.e. 0-5 cm and 5-10 cm) during both the years. However, in influencing the soil moisture at 0-5 cm soil depth during both the years conventional tillage being statistically at par with raised seed bed were the next best in influencing the soil moisture content in both the depths during both the years.

Table 4.60 Effect of tillage methods on moisture content (%) of soil at the time of sowing of maize

Tillage methods	Moisture content (%)			
	0-5 cm		5-10 cm	
	2002	2003	2002	2003
Zero	23.50	25.00	26.20	28.77
Conventional	21.77	22.40	23.63	24.23
Raised seed bed	20.30	21.23	22.13	23.97
SEm \pm	0.80	0.98	0.73	1.37
CD (P=0.05)	2.23	2.72	2.03	3.82

4.2.6.2 Bulk density

Tillage methods significantly influenced the bulk density of soil after harvest of maize crop at each of the soil depths during both the years. Weed control methods influenced it significantly only at 0-15 cm soil depth during first year of experimentation (Table 4.61).

A perusal of the data revealed that while zero tillage resulted in significantly highest bulk density of the soil, raised seed bed being statistically at par with conventional tillage were next best in influencing bulk density at 0-15 cm and 15-30 cm soil depths during both the years. However, numerically raised seed bed resulted in lowest soil bulk density at each of the soil depths during both the years.

Weed control methods did not influence the bulk density of soil at different depths of the soil significantly during both the years. However, during first year, herbicide treatments increased the bulk density significantly over unweeded check in 0-15 cm layer of the soil.

Table 4.61 Effect of tillage and weed control methods on bulk density (Mg/m^3) at different depths of soil in maize after harvest

Treatments	0-15 cm		15-30 cm	
	2002	2003	2002	2003
Tillage methods				
Zero	1.209	1.216	1.238	1.248
Conventional	1.178	1.179	1.214	1.193
Raised seed bed	1.172	1.156	1.198	1.181
SEm \pm	0.006	0.013	0.008	0.014
CD (P=0.05)	0.016	0.036	0.021	0.039
Weed control methods				
Unweeded	1.177	1.173	1.214	1.201
Acetachlor 0.75 kg/ha	1.181	1.176	1.213	1.203
Acetachlor 1.25 kg/ha	1.194	1.184	1.218	1.209
Atrazine 1.5 kg/ha	1.192	1.196	1.221	1.217
SEm \pm	0.007	0.010	0.016	0.008
CD (P=0.05)	0.014	NS	NS	NS

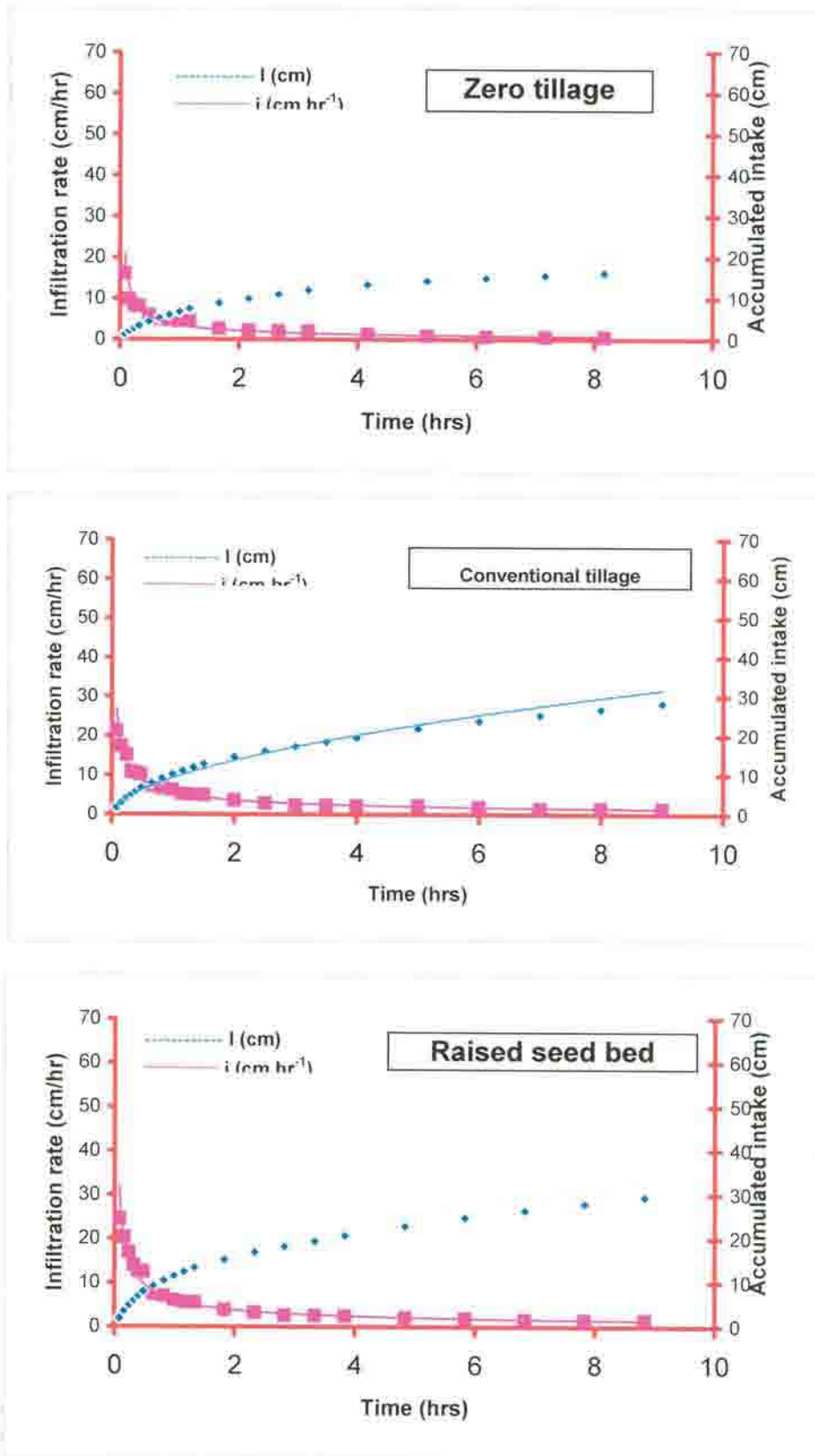


Fig. 4.9 Infiltration-time curve under zero tillage, conventional tillage and raised seed bed at harvest of maize crop (2002)

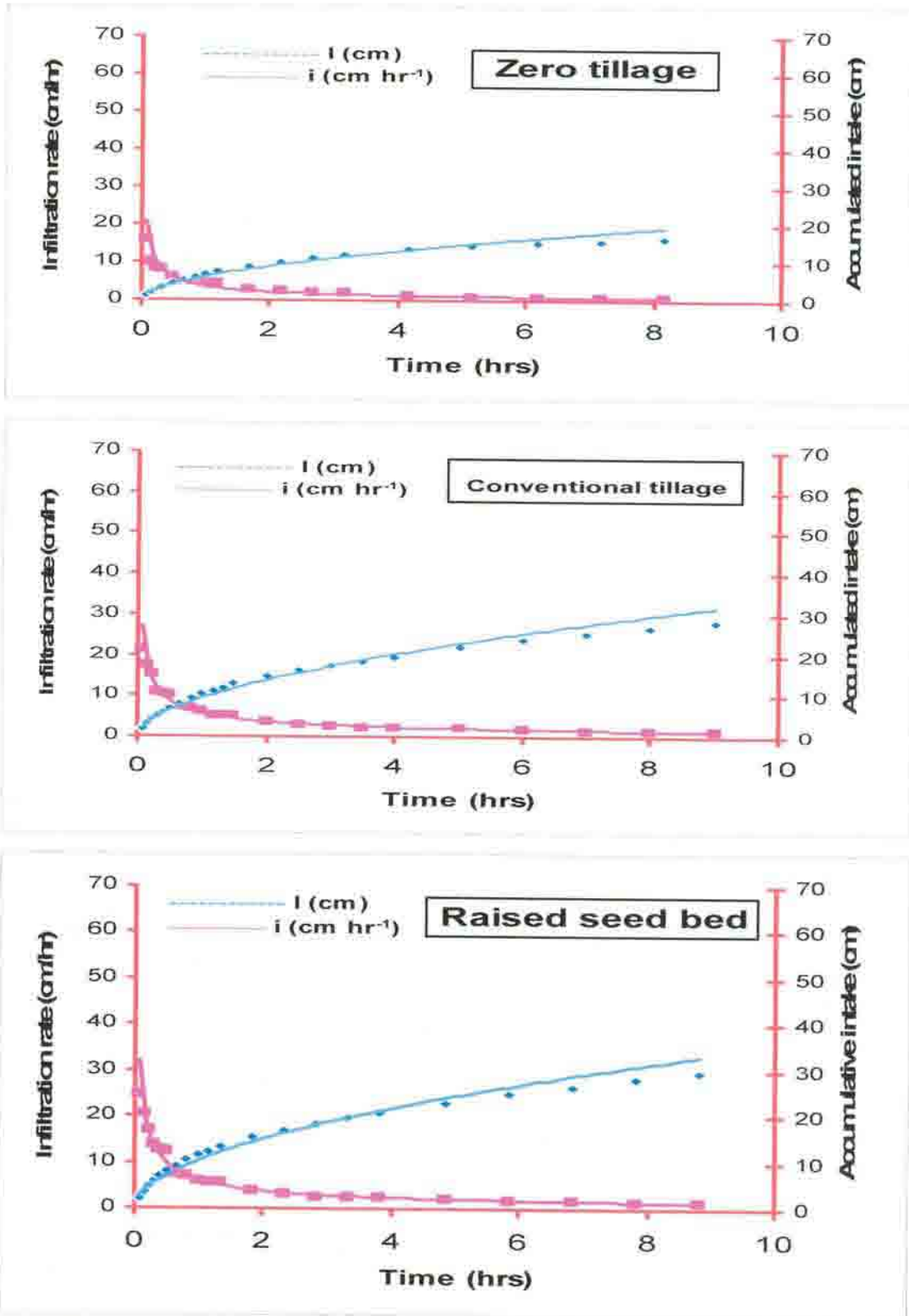


Fig. 4.10 Infiltration-time curve under zero tillage, conventional tillage and raised seed bed at harvest of maize crop (2003)

4.2.6.3 Infiltration rate

The effect of different tillage treatments on infiltration rate after harvest of maize crop are depicted in Fig. 4.9 and 4.10. These figures present typical infiltration-time curves of the study area. The final infiltration rate and accumulated intake during both years of study were lower under zero tillage as compared to other tillage methods.

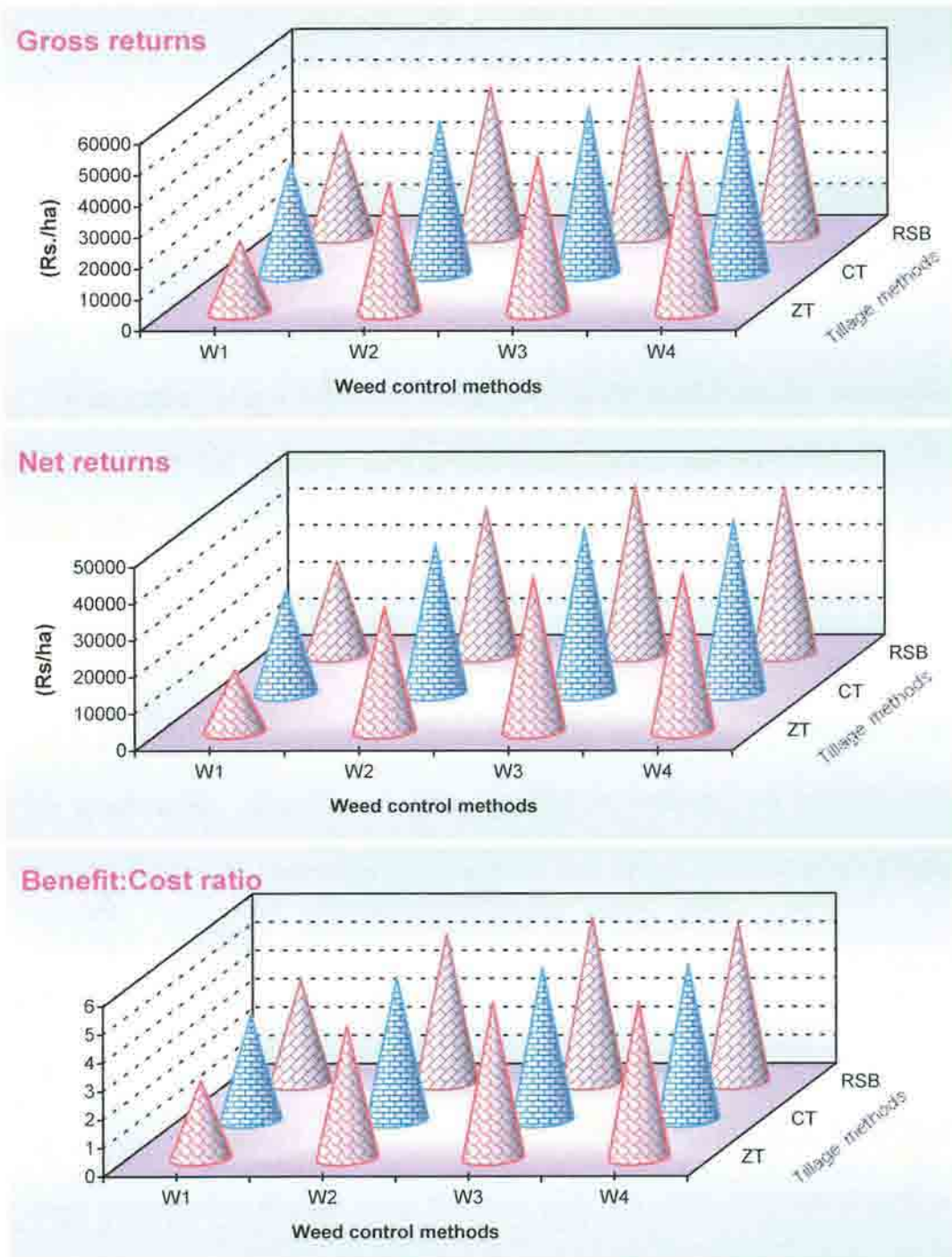
During first maize crop season, while, the steady-state infiltration rate (cm/hr) at harvest was higher in raised seed bed (1.75 cm/hr) with minor difference in conventional tillage (1.34 cm/hr) as compared to zero tillage (0.55 cm/hr). Similar, trend was observed during second year with steady-state infiltration rate of 1.55, 1.47 and 0.62 cm/hr in raised seed bed, conventional tillage and zero tillage, respectively.

4.3 ECONOMICS STUDIES

The treatment wise gross returns, net returns and benefit cost ratio was calculated and the data thus obtained have been presented in Table 4.62. The details of cost of cultivation of different treatments have been appended in Appendix II.

4.3.1 Gross returns and net returns

A critical perusal at the data presented in Table 4.62 and Fig. 4.11 revealed that in each of the methods of weed control except acetachlor 1.25 kg/ha, conventional tillage resulted in highest gross and net returns during both the years. In acetachlor 1.25 kg/ha treated plots, raised seed bed resulted in highest gross and net returns during both the years and was the next best in remaining weed control treatments.



TREATMENTS

CT - Conventional tillage
 ZT - Zero tillage
 RSB - Raised seed bed

W1 - Unweeded
 W2 - Acetachlor 0.75 kg/ha
 W3 - Acetachlor 1.25 kg/ha
 W4 - Atrazine 1.5 kg/ha

Fig. 4.11 Effect of tillage and weed control methods on gross return (Rs./ha), net returns (Rs./ha) and benefit:cost ratio of maize

In each of the methods of tillage, atrazine 1.5 kg/ha resulted in highest gross and net returns during second year of experimentation. During first year while atrazine resulted in highest gross and net returns in conventional tillage and zero tillage plots, acetachlor 1.25 kg/ha produced highest gross and net returns in raised seed bed plots.

Integration of conventional tillage with atrazine 1.5 kg/ha produced highest gross and net returns during both the years. Raised seed bed in integration with acetachlor 1.25 kg/ha during first year and with atrazine 1.5 kg/ha during second year was the next best in increasing gross and net returns.

4.3.2 Benefit:cost ratio

A perusal of the data in Table 4.62 indicated that in each of the herbicide treatments, raised seed bed resulted in highest net returns per rupee invested (Benefit cost ratio) during both the years. In unweeded check plots conventional tillage resulted in highest net returns per rupee invested followed by raised seed bed during both the years. While in acetachlor 1.25 kg/ha treated plots, zero tillage was the next best during both the years, in atrazine 1.5 kg/ha treated plots, conventional tillage during first year and zero tillage during second year were the next best. In remaining weed control treatments conventional tillage was the next best during both the years.

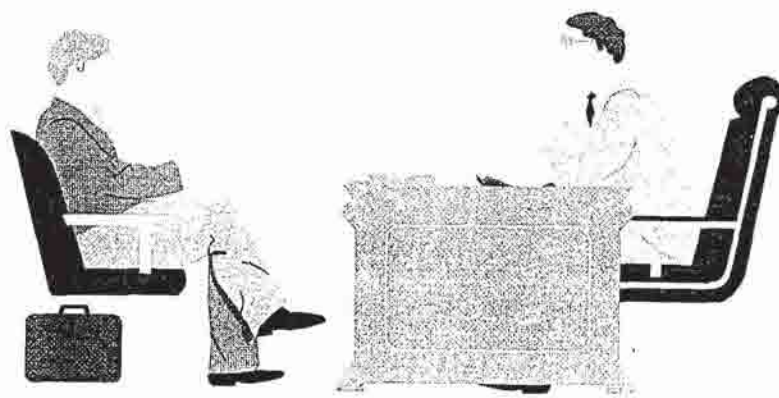
While in raised seed bed, acetachlor 1.25 kg/ha produced highest benefit:cost ratio of 6.04 and 5.59 during first and second year, respectively, atrazine 1.5 kg/ha resulted in highest benefit:cost ratio in conventional tillage

Table 4.62 Effect of tillage and weed control methods on gross, net returns (Rs./ha) and benefit cost ratio of maize

Treatments	2002					2003				
	Unweeded	Acetachlor 0.75 kg/ha	Acetachlor 1.25 kg/ha	Atrazine 1.5 kg/ha	Mean	Unweeded	Acetachlor 0.75 kg/ha	Acetachlor 1.25 kg/ha	Atrazine 1.5 kg/ha	Mean
Gross returns (Rs/ha)										
Zero tillage	23617	40979	51572	51612	51592	22362	41794	47949	50585	49267
Conventional tillage	36405	48620	54719	56486	55603	34466	49185	51875	54817	53346
Raised seed bed	33440	46730	55018	54055	54537	31868	48479	53024	53373	53199
Mean	31154	45443	53770	54051		29565	46486	50949	52925	
Net returns (Rs/ha)										
Zero tillage	17508	33645	43959	43793	43876	16149	34341	40217	42647	41432
Conventional tillage	29045	40677	46495	48057	47276	26813	40933	43343	46079	44711
Raised seed bed	26485	39191	47199	46032	46616	24706	40717	44982	45126	45054
Mean	24346	37838	45884	45961		22556	38664	42847	44617	
Benefit cost ratio										
Zero tillage	2.87	4.59	5.77	5.60	5.69	2.60	4.61	5.20	5.37	5.29
Conventional tillage	3.95	5.12	5.65	5.70	5.68	3.50	4.96	5.08	5.27	5.18
Raised seed bed	3.81	5.20	6.04	5.74	5.89	3.45	5.24	5.59	5.47	5.53
Mean	3.54	4.97	5.82	5.68		3.18	4.94	5.29	5.37	

plots during both the years. In zero tillage plots acetachlor 1.25 kg/ha during first year and atrazine 1.5 kg/ha during second year produced highest benefit:cost ratio.

Integration of raised seed bed with acetachlor 1.25 kg/ha produced highest benefit:cost ratio of 6.04 and 5.59 during first and second year, respectively. Integration of zero tillage with acetachlor 1.25 kg/ha and integration of raised seed bed with atrazine 1.5 kg/ha were the next best with benefit:cost ratio of 5.77 and 5.47 during first and second year, respectively.



***D**iscussion*

DISCUSSION

In this chapter an attempt has been made to highlight the important findings of the study described in the preceding chapter and to establish the cause and effect relationship based upon the available evidences. The effects of different treatments on weeds and crop have been discussed under the following heads:

- 5.1 Crop-weather interactions
- 5.2 Distribution of weed flora
- 5.3 Effect of tillage methods
- 5.4 Effect of weed control methods
- 5.5 Integrated effect of tillage and weed control methods
- 5.6 Economic studies

5.1 CROP-WEATHER INTERACTIONS

The performance of any crop depends on the interaction of genetic and environmental factors. The environment plays a significant role in influencing the growth, development and final yields of the crop. Among the various environmental factors weather parameters like sunshine hours, rainfall, relative humidity and soil and ambient temperature play an important role.

The meteorological data depicted in figure 3.1 and appended in appendix I, revealed that while the mean weekly maximum temperature during the crop season ranged from 24.6°C to 31.6°C and 25.9°C and 33.1°C during 2002 and 2003 respectively, the mean weekly minimum temperature were in the range of 14.9°C to 20.4°C and 14.6°C to 20.7°C during 2002 and 2003, respectively. The mean temperature ranged between 20.8°C to 25.3°C and 20.2°C to 26.5°C during first and second year, respectively. It indicates that temperature during the crop cycle were favourable for germination, growth, development and yield of maize crop as ideal temperature range for successful maize cultivation has been reported to be between 10 to 35°C (Chang, 1981). The crop experienced well distributed higher rainfall of 914.2 mm and 1820.0 mm in first and second year, respectively which was more than the optimum range of 500-750 mm of rainfall. The highest weekly total rainfall of 482.8 mm during 31st week and higher rainfall of 231.6 mm during 29th week resulted in almost double value of total rainfall during second year as compared to first year. Overall, other weather conditions during both the years were near optimum for growth and development of crop and associated weeds.

5.2 DISTRIBUTION OF WEED FLORA

The kind and extent of dominance of weeds in an area vary with the soil, biotic and abiotic conditions. Survey of the weed flora in unweeded check plots of the experiment conducted at maximum weed population stage

i.e. 60 DAS (Table 4.1) revealed that *Digitaria sanguinalis*, *Echinochloa colona* and *Panicum dichotomiflorum* were the dominant grass weeds and constituted 45.3, 26.2 and 15.1 per cent, respectively of total weed flora during 2002 and 30.9, 24.6 and 12.6 per cent, respectively of the total weed flora during 2003. These weeds constituted 86.6 and 68.0 per cent of the total weeds during 2002 and 2003, respectively. Among broad leaved weeds *Commelina benghalensis* was dominant and constituted 5.4 and 17.7 per cent of total weed flora during first and second year, respectively. The other weed species including *Oxalis latifolia*, *Polygonum alatum*, *Ageratum conyzoides* and *Ipomoea* sp. together constituted only 3.7 and 7.7 per cent of the total weed flora during first and second year, respectively. Almost similar type of weed composition in maize crop has also been reported by Angiras and Singh (1988) and Singh *et al.* (1992) under Palampur conditions and by Kalia and Singh (1993) under Dhaulakuan conditions of Himachal Pradesh.

A critical glance of the data (Tables 4.5 to 4.15 and 4.16 to 4.28) revealed that the species wise and total weed population and dry matter was comparatively higher during second year compared to the first year of study. This increase could be ascribed to the addition of considerable amount of seeds of these weeds in first year of experimentation to the soil before the harvest of the crop and comparatively higher temperature and rainfall which created favourable conditions for germination, growth and development of weeds during second year.

A critical perusal of the data in Tables 4.5 to 4.15 and 4.16 to 4.28 and Figs 4.2 and 4.3 on distribution of weeds over time indicate that the population and dry matter of grass and broad leaved weeds increased at the increasing rates upto 60 DAS and declined thereafter at a decreasing rate. Smothering effect of maize plant with good functional leaves (Tables 4.38 and 4.40) on the late emerging weeds, the senescence of most of the weeds and shattering of weed seeds could be the possible reasons for decrease in dry matter and population of weeds beyond 60 DAS.

5.3 EFFECT OF TILLAGE METHODS

5.3.1 Effect on weeds

Tillage methods influenced the species-wise and total weed population and dry matter, their seed bank, phenology and nutrient uptake significantly during both the years.

Among tillage methods, raised seed bed decreased the population (Tables 4.7, 4.8 and 4.14) and dry matter accumulation (Tables 4.16, 4.18 and 4.27 and Fig. 4.2) of *Digitaria sanguinalis*, *Echinochloa colona* and total weeds significantly over remaining tillage methods at all the stages of observation during both the years and dry matter of *Panicum dichotomiflorum* (Table 4.20 and Fig. 4.2) and other weeds (Table 4.26) during both the years. The superiority of raised seed bed to decrease population and dry matter of these weeds could be ascribed to presence of significantly lowest number of seeds of these weeds (Table 4.2) in the top 0-10 cm soil layer of raised seed bed as compared to other tillage methods in

the seed bank studies conducted before sowing of maize crop. Wicks and Somerhalder (1971) also reported better distribution of weed seeds on ridge and furrow portion of the raised seed bed.

On the contrary, population (Table 4.10) and dry matter (Table 4.23 and Fig. 4.2) of *Commelina benghalensis* was significantly decreased by zero tillage over other tillage methods at all the stages of observation during both the years. This reduction could be attributed to minimum disturbance to the soil under zero tillage conditions which created unfavourable conditions for its emergence from rhizomes lying in deeper layer. However, more number of seeds of *Commelina* in upper (0-10 cm) soil layer as per seed bank studies (Table 4.3) were either not viable or were killed effectively by the herbicides.

However, the zero tillage enhanced the population and dry matter of *Digitaria sanguinalis* (Tables 4.5 and 4.16) and thereby total weeds (Tables 4.14 and 4.27) over other tillage methods. It can be ascribed to more of its seed bank in upper soil layer (Table 4.2). Maksymowicz *et al.* (1986) and Teasdale *et al.* (1991) also reported more proportion of *Digitaria sanguinalis* in zero tillage.

A critical perusal of the data in Tables 4.9 and 4.22 reveal that inconsistent trend in dynamics of population and dry matter accumulation of *Brachiaria ramosa* was observed but the zero tillage resulted in significantly higher population and dry matter of this weed. These findings are in direct conformity with those of Mueller and Hayes (1997).

Although the effect of conventional and zero tillage on population and dry matter of grass weeds and total weeds was statistically similar at various stages of observation during both the years but numerically zero tillage resulted in higher values. This may be ascribed to comparatively higher number of seeds of these weeds in the 0-10 cm layer of soil depth (Table 4.2) as per seed bank studies, which emerged first in greater number as soon as they received the optimum moisture conditions after receipt of rains immediately after sowing. Similar, type of results where zero tillage had higher proportion of various weed seeds in top layer were also reported by Mester and Buhler (1986) and Pareja and Staniforth (1985).

Tillage methods influenced the phenology of *Digitaria sanguinalis*, *Echinochloa colona* and *Panicum dichotomiflorum* significantly (Table 4.32 and Fig. 4.6). The zero tillage resulted in their early flowering and senescence by 2-7 days over conventional tillage and raised seed bed. It indicates that these weeds emerged early in zero tillage plots because of location of their seeds on surface and thereby completed their subsequent phases early.

Nutrient uptake being a function of dry matter and nutrient concentration followed the trend of dry matter of weeds. Raised seed bed reduced the uptake of nitrogen, phosphorus and potassium significantly (Table 4.34) by decreasing the dry matter of total weeds (Table 4.27) significantly, during both the years.

5.3.2 Effect on crop

5.3.2.1 Effect on crop growth and development

The emergence count of maize was not influenced significantly by tillage methods due to favourable conditions of moisture provided by rainfall received immediately after sowing of maize. Vyn *et al.* (1980) also obtained non-significant effect of tillage methods on emergence count of maize.

Conventional tillage being statistically at par with raised seed bed produced significantly higher plant height (Table 4.38), dry matter (Table 4.42) and number of functional leaves (Table 4.40) at each of the stage of observations after 30 DAS during both the years. This increase in all these parameters could be ascribed to significantly lower population and dry matter of total weeds (Tables 4.14 and 4.27) in raised seed bed and significant reduction in population and dry matter of *Digitaria sanguinalis* (Tables 4.5 and 4.16) (which was present in maximum proportion) in conventional tillage over zero tillage during both the years. Moreover, improved physical properties of soil (Table 4.61 and Figs. 4.9 and 4.10) in raised seed bed and conventional tillage methods might have helped in better aeration, soil moisture and nutrient availability and root growth resulting in significant higher values of all the parameters of crop growth over zero tillage. Dwyer *et al.* (1995) also reported higher dry matter accumulation of maize with ridge tillage than zero tillage. Chassot *et al.* (2001) and Cox *et al.* (1990) also reported increase in growth and development of maize with conventional tillage and ridge tillage, respectively.

Conventional tillage being statistically at par with raised seed bed resulted in significantly higher lateral and vertical spread of maize roots (Tables 4.45 and 4.46) over zero tillage during both the years. This may be due to the fact that loose soil tilth due to tillage make space for proper root growth by reducing the physical soil strength and increasing the macroporosity. Moreover improved soil physical properties (Table 4.61 and Figs. 4.9 and 4.10) due to these methods increases free exchange of gases in soil and atmosphere system which in turn helps in better root growth and their penetration to deeper soil layers. Schumran (1965) also reported decrease in root growth of maize due to higher bulk density under zero tillage. Similarly Acharya and Bhagat (1984) and Xi Ying *et al.* (2004) also reported reduction in root growth of rice and wheat, respectively due to zero tillage.

Conventional tillage and raised seed bed resulted in significantly lower per cent of lodged plants during first year only (Table 4.44). This may be attributed to better anchorage of plants due to placement of seed at proper depth and growth and development of root system (Tables 4.45 and 4.46) in raised seed bed and conventional tillage over zero tillage. However, comparatively the heavy rains received immediately after sowing of maize during second year partially leveled the raised seed bed and thus provided poor soil anchorage to the seed and emerged seedlings resulted in significantly higher lodging over conventional tillage.

Raised seed bed significantly delayed the appearance of different phenophases of maize over conventional and zero tillage methods which were statistically at par with each other during both the years (Table 4.48 and Fig. 4.6). The delay in emergence of seedlings in raised seed bed by 4-5 days over zero tillage and by 2-3 days over conventional tillage may be due to placement of seed in deeper depth and relatively less contact of the seed with the soil due to less compaction. This delay in seedling emergence in raised seed bed caused almost similar delay in 50% tasseling, 50% silking and maturity of the maize crop during both the years.

5.3.2.2 Effect on yield and yield attributes

The better growth of the crop due to reduced crop weed competition and improved soil physical properties in raised seed bed and conventional tillage methods resulted in significantly higher effective plant population, shelling percentage, cob length, number of rows per cob, number of grain per row and 1000-grain weight (Table 4.49) during both the year. The grain yield being a function of yield attributes was also significantly increased by raised seed bed and conventional tillage methods which were statistically at par with each other during both the years of experimentation. The raised seed bed and conventional tillage increased grain yield of maize by 13.2 and 17.2 per cent, respectively over zero tillage during first year and by 14.2 and 16.6 per cent, respectively during second year. Sharma *et al.* (1988) and Barry and Miller (1986) also reported

significantly higher yield of maize with conventional tillage over no-tillage and with ridge/raised seed bed over zero tillage (Brar and Cheema, 1988; Lal, 1988 and Fausey, 1990).

5.3.2.3 Effect on nutrient uptake

Since nutrient uptake is the function of dry matter (grain + stover yield) and nutrient content, conventional tillage being statistically similar to raised seed bed resulted in significantly higher uptake of nitrogen, phosphorus and potassium (Tables 4.56 to 4.58) by maize by causing significant increase in dry matter (Table 4.42) of the crop over zero tillage during both the years.

5.3.2.4 Effect on grain quality

Tillage methods did not influence the protein and starch content significantly during both the years. However, numerically raised seed bed and conventional tillage increased the protein and starch content of maize grains during both the years.

5.3.2.5 Effect on soil physical properties

Studies in bulk density of soil conducted after harvest of maize crop revealed that no-tillage resulted in significantly highest bulk density of the soil at 0-15 cm and 15-30 cm depths (Table 4.61). The bulk density due to raised seed bed and conventional tillage was statistically at par. The higher bulk density due to zero tillage may be ascribed to decrease in volume of the soil due to less disturbance of the soil. Similar trend in higher bulk density values due to zero tillage have been reported by Ball-Coelho *et al.* (1998) and Martino and Shaykewich (1994).

The steady state infiltration rate determined at harvest of crop during both the years was higher in raised seed bed and conventional tillage as compared to zero tillage (Figs. 4.9 and 4.10) due to increase in macroporosity caused by loosening of soil to a greater depths.

5.5 EFFECT OF WEED CONTROL METHODS

5.4.1 Effect on weeds

Pre-emergence application of atrazine 1.5 kg/ha decreased the population and dry matter (Fig. 4.3) of *Digitaria sanguinalis* (Tables 4.5 and 4.16), *Echinochloa colona* (Tables 4.7 and 4.18), *Panicum dichotomiflorum* (Tables 4.8 and 4.20), *Commelina benghalensis* (Tables 4.10 and 4.23), *Cyperus iria* (Tables 4.12 and 4.25) and total weeds (Tables 4.14 and 4.27) significantly at all the stages of observation over remaining weed control treatments during both the years. However, it was statistically at par with acetachlor 1.25 kg/ha (Pre.) in decreasing the population and dry matter of *Digitaria sanguinalis*, *Echinochloa colona* and total weeds and in decreasing population of *Panicum dichotomiflorum* at all the stages of observation during both the years and *Commelina benghalensis* at all the stages of observation except 60 DAS during first year. The superiority of pre-emergence application of atrazine to control various weeds is in direct conformity with the findings of Rout and Satapathy (1996), Sharma *et al.* (2000) and Pandey *et al.* (2001). The findings of Nikolova and Baeva (2004) and Krausz *et al.* (2000) to control *Echinochloa colona* effectively and of Lynn (1980) to control *Panicum dichotomiflorum* through acetachlor

application were similar to these results. The results of Miklos (1981) to control monocotyledonous weeds effectively with acetachlor in maize are in direct conformity with the findings of present study.

Consequently, atrazine 1.5 kg and acetachlor 1.25 kg/ha resulted in efficacy of more than 77 per cent in controlling *Digitaria sanguinalis* and *Echinochloa colona* during both the years (Table 4.29 and Fig. 4.5). The weed control efficiency of both the herbicides to control *Commelina benghalensis* ranged between 71-77 per cent and of total weeds ranged between 81-84 per cent during first year and 74-78 per cent and 76-78 per cent, respectively during second year (Table 4.30).

These results clearly indicated that lower dose of acetachlor were though significantly superior to unweeded check but were significantly inferior to their higher dose to control these weeds.

Brachiaria ramosa weed which was tolerant to atrazine 1.5 kg/ha was effectively controlled by acetachlor 1.25 kg/ha. Even the lower dose of acetachlor 0.75 kg/ha was significantly superior to atrazine 1.5 kg/ha in reducing the population and dry matter of *Brachiaria ramosa* at many stages of observation (Tables 4.9 and 4.22). Mueller and Hayes (1977) also reported effective control of *Brachiaria* sp. by pre-emergence application of acetachlor.

The weeds in unweeded check removed nitrogen, phosphorus and potassium in the range of 44.6-52.4 kg/ha, 12.4-13.3 kg/ha and 50.5-59.7 kg/ha, respectively during two years of experimentation. The nutrient uptake

being a function of nutrient content and dry matter accumulation, atrazine 1.5 kg/ha being statistically at par with acetachlor 1.25 kg/ha decreased the total uptake of nitrogen, phosphorus and potassium by weeds significantly (Table 4.34) over other weed control treatments by decreasing the total weed dry matter (Table 4.14 and Fig. 4.3) at maximum dry matter state. These results are similar to findings of Sangwan *et al.* (1989).

5.4.2 Effect on crop

5.4.2.1 Effect on crop growth and development

Atrazine 1.5 kg/ha resulted in significantly taller plants (Table 4.38) with higher dry matter accumulation (Table 4.42) and number of functional leaves per plant (Table 4.40) at all the stages of observation during both the years except number of functional leaves at harvest. However, it was statistically at par with acetachlor 1.25 kg/ha in increasing the plant height and number of functional leaves at all stages of observation and dry matter accumulation at all the stages of observation except at 60 DAS during the first year and 90 DAS during the second year. The superior performance of both these herbicides could be ascribed to their higher weed control efficiency (Fig. 4.5) which decreased the crop weed competition by decreasing the population and dry matter of weeds and nutrient uptake by them at all the stages of observation. The effective control of weeds by atrazine 1.5 kg/ha and acetachlor 1.25 kg/ha retained significantly higher number of functional leaves upto 90 DAS resulting in more photosynthetic

area and significantly higher dry matter accumulation by the crop. Similar, increase in growth parameters like plant height, number of functional leaves per plant and dry matter per plant of maize has also been reported by Shinde *et al.* (2001) with atrazine and by Nikolova and Baeva (2004) with acetachlor.

The competition free environment created by atrazine 1.5 kg/ha and acetachlor 1.25 kg/ha at critical period of competition resulted in development of maize plants with better root system (Tables 4.45 and 4.46) and more stalk diameter (Table 4.43) which helped the crop plants to resist lodging.

Data on development studies presented in Table 4.48 indicate that all the weed control treatments significantly delayed the attainment of 50 per cent tasseling, 50 per cent silking and maturity stage over unweeded check during both the years except 50 per cent tasseling during the second year, where the treatment effects were not significant. This delay in reproductive phase could be ascribed to prolonged vegetative phase under low weed competition environment which might have helped in production of more photosynthates for longer period and their translocation to the grains.

5.4.2.2 Effect on yield and yield contributing characters

The better growth and development of the crop due to effective weed control (Tables 4.14 and 4.27) by atrazine 1.5 kg/ha and acetachlor 1.25 kg/ha reflected in better development of yield attributes of maize during both the years (Table 4.49) which acted as strong sink for

accumulation of photosynthates. This ultimately resulted in better sink formation due to increased photosynthesis and translocation of photosynthates. The translocation of carbohydrates is more important as it is directly reflected in the yield and yield contributing characters. Similar increase in yield contributing characters of maize due to effective control of weeds by atrazine was also reported by Paradkar and Sharma (1993).

Consequently the significant increase in sink formation in the form of yield attributes by both these herbicides increased the grain yield, straw yield and biological yield of maize significantly (Table 4.52) during both the years. Weeds in unweeded check reduced the grain yield of maize by 41.9 per cent and 43.9 per cent over effective control of weeds by atrazine 1.5 kg/ha during first and second year, respectively and by 41.7 per cent and 41.8 per cent over effective control of weeds with acetachlor 1.25 kg/ha during first and second year, respectively and by 31.4 and 36.2 per cent over acetachlor 0.75 kg/ha during first and second year, respectively. Mishra *et al.* (1996), Thakur and Sharma (1996) and Sharma *et al.* (1998) also reported increase in grain yield of maize with atrazine 1.5 kg/ha (Pre.) and by Tomordi (1987) and Geriev (1996) with acetachlor below 3 kg/ha.

5.4.2.3 Effect on nutrient uptake

The effective control of weeds by atrazine 1.5 kg/ha and acetachlor 1.25 kg/ha created competition free environment which led to increased growth of the crop and thereby increased nutrient uptake (Tables 4.56 to 4.58) by increasing the grain and stover yield (Table 4.52) of maize during both the years.

5.4.2.4 Effect on grain quality

The data on grain quality in terms of protein and starch content reveal that atrazine 1.5 kg/ha being statistically at par with acetachlor 1.25 kg/ha (Table 4.59) during both the years resulted in significantly higher protein and starch content in maize grains. The higher protein content could be ascribed to the reduced crop weed competition by these treatments which helped the crop to grow better and absorb and assimilate more nitrogen in grains and synthesize more starch.

5.5 INTEGRATED EFFECT OF TILLAGE AND WEED CONTROL METHODS

5.5.1 Integrated effect on weeds

Integrated effect of tillage and weed control methods resulted in significant variation in population of total weeds, *Digitaria sanguinalis* and *Commelina benghalensis* (Tables 4.15, 4.6 and 4.11 and Fig. 4.1) and dry matter of *Digitaria sanguinalis*, *Echinochloa colona*, *Panicum dichotomiflorum*, *Commelina benghalensis* and total weeds (Tables 4.17, 4.19, 4.21, 4.24 and 4.28 and Fig. 4.4) during both the years.

Irrespective of the methods of weed control, raised bed decreased the population of *Digitaria sanguinalis* and total weeds (Tables 4.6 & 4.15 and Fig. 4.1) and dry matter of *Digitaria sanguinalis*, *Echinochloa colona*, *Panicum dichotomiflorum* and total weeds (Tables 4.17, 4.19, 4.21 and 4.28 and Fig. 4.4) significantly during both the years. However it was statistically at par with conventional tillage in atrazine 1.5 kg/ha treated plots in

decreasing the population of *Digitaria sanguinalis* (Table 4.6) and total weeds (Table 4.15) and dry matter of *Digitaria sanguinalis*, *Echinochloa colona* and *Panicum dichotomiflorum* (Tables 4.17, 4.19 and 4.21 and Fig. 4.4) during both the years. Conventional tillage in combination with acetachlor 1.25 kg/ha and zero tillage in combination with atrazine 1.5 kg/ha being statistically similar were as effective as their combination with raised seed bed in decreasing the population of *Digitaria sanguinalis* (Table 4.6) and total weeds (Table 4.15) and dry matter of *Echinochloa colona* (Table 4.19) during both the years. However, raised seed bed and conventional tillage were statistically at par in acetachlor 0.75 kg/ha treated plots in decreasing the population of *Digitaria sanguinalis* and total weed (Tables 4.6 and 4.15).

Irrespective of weed control methods, zero tillage decreased the population and dry matter of *Commelina benghalensis* (Tables 4.11 and 4.24) significantly during both the years. However, it was statistically at par with conventional tillage in combination with atrazine 1.5 kg/ha, acetachlor 1.25 kg/ha and acetachlor 0.75 kg/ha during both the years except for dry matter of *Commelina benghalensis* in acetachlor 0.75 kg/ha treated plots during the first year.

Irrespective of tillage methods, atrazine 1.5 kg/ha being statistically at par with acetachlor 1.25 kg/ha decreased the dry matter of *Digitaria sanguinalis*, *Panicum dichotomiflorum* and total weeds (Tables 4.17,

4.21 and 4.26) and population of *Commelina benghalensis* (Table 4.11) significantly during both the years. Similar trend was observed for decreasing population of *Digitaria sanguinalis* and total weeds (Tables 4.6 and 4.15) and dry matter accumulation of *Echinochloa colona* (Table 4.19) during both the years. However, in zero tilled plots, atrazine 1.5 kg/ha was significantly superior to reduce the population of *Digitaria sanguinalis* and total weeds during second year and dry matter of *Echinochloa colona* during both the years. The dry matter of *Commelina benghalensis* was significantly reduced by integration of atrazine 1.5 kg/ha or acetachlor 1.25 kg/ha with each of the tillage methods during both the years. However, in raised seed bed, atrazine 1.5 kg/ha proved to be significantly superior over other weed control methods during second year (Table 4.24).

Integration of raised seed bed with either atrazine 1.5 kg/ha or acetachlor 1.25 kg/ha being statistically at par with each other resulted in significantly lower dry matter of *Digitaria sanguinalis*, *Echinochloa colona*, *Panicum dichotomiflorum* and total weeds (Tables 4.17, 4.19, 4.21 and 4.26) during both the years. These combinations were also statistically alike to combination of atrazine 1.5 kg/ha with conventional tillage in reducing the dry matter of *Panicum dichotomiflorum* during both the years (Table 4.21) and of *Digitaria sanguinalis* and total weeds during second and first year, respectively (Tables 4.17 and 4.26).

Integration of atrazine 1.5 kg/ha with each of the methods of tillage being statistically at par with acetachlor 1.25 kg/ha in integration with raised seed bed decreased the dry matter of *Echinochloa colona* (Table 4.19) and population of *Digitaria sanguinalis* and total weeds (Tables 4.6 and 4.15) during both the years. However, integration of acetachlor 1.25 kg/ha with conventional tillage also decreased the dry matter of *Echinochloa colona* and population of total weeds during second year. However, this combination was statistically at par with combination of acetachlor 0.75 kg/ha and raised seed bed in decreasing the population of *Digitaria sanguinalis* (Table 4.6) significantly during both the years.

The population and dry matter of *Commelina benghalensis* was significantly reduced by integration of zero or conventional tillage with either atrazine 1.5 kg/ha or acetachlor 1.25 kg/ha during both the years (Tables 4.11 and 4.24). However, raised seed bed in integration with acetachlor 1.25 kg/ha reduced population of *Commelina* but integration of raised seed bed with atrazine 1.5 kg/ha reduced its dry matter significantly during second year.

The overall perusal of the results of integrated effect of tillage and weed control methods indicate that raised seed bed by virtue of reducing the seed bank of grass weeds in upper (0-10 cm) seed layers and zero tillage by its effect in checking the exposure of rhizomes of *Commelina benghalensis* to upper depths resulted in significant reduction of population and dry

matter of almost all the grass weeds and *Commelina benghalensis*, respectively. Integration of these tillage methods either with atrazine 1.5 kg/ha or acetachlor 1.25 kg/ha further improved their efficacy to manage these weeds. However, the better efficacy of atrazine 1.5 kg/ha and acetachlor 1.25 kg/ha in conventional tillage plots resulted in management of grass weeds and *Commelina benghalensis* at par with their combination with raised seed bed or zero tillage, respectively.

Since nutrient uptake by weeds is a function of their dry weight and content, it followed almost a similar trend as that of dry matter accumulation by weeds during both the years.

5.5.2 Integrated effect on crop

Tillage methods interacted significantly with weed control methods in influencing the plant height at 60 DAS (Table 4.39), number of functional leaves at 90 DAS (Table 4.41), vertical distribution of maize roots at 90 DAS (Table 4.47), length of the cob (Table 4.50), number of rows per cob (Table 4.51), grain yield (Table 4.52 and Fig. 4.8), straw yield (Table 4.53 and Fig. 4.8) and biological yield (Table 4.54) of crop during both the years.

5.5.2.1 Integrated effect on crop growth and development

In each of the methods of weed control, raised seed bed being statistically at par with conventional tillage increased the plant height and number of functional leaves per plant during both the years (Tables 4.39 and 4.41). However, by effective control of weeds with acetachlor 1.25 kg/ha

and atrazine 1.5 kg/ha even zero tillage was statistically at par with these two tillage methods in increasing plant height and number of functional leaves during both the years except plant height during second year. Atrazine 1.5 kg/ha in each of the tillage method being statistically at par with acetachlor 1.25 kg/ha increased these parameters significantly during both the years. Integration of atrazine 1.5 kg/ha or acetachlor 1.25 kg/ha with raised seed bed or conventional tillage resulted in significantly higher plant height and number of functional leaves per plant by increasing the weed control efficiency (Fig. 4.5) and lower weed population during both the years. However, combination of atrazine 1.5 kg/ha with zero tillage being statistically alike to these combinations also resulted in more number of functional leaves per plant of maize during both the years and plant height during first year.

5.5.2.2 Integrated effect on yield and yield contributing characters

In each of the methods of weed control, conventional tillage being statistically at par with raised seed bed significantly increased the length of cob, number of rows per cob (Tables 4.50 to 4.51), grain yield, stover yield and biological yield (Tables 4.53 to 4.55 and Fig. 4.8). However, effective control of weeds with atrazine 1.5 kg/ha in zero tillage plots also behaved statistically similar to these two tillage methods in increasing number of rows per cob and length of cob and biological yield of maize during both the years.

In each of the methods of tillage, atrazine 1.5 kg/ha and acetachlor 1.25 kg/ha behaved statistically similar to increase the number of rows per cob, length of cob and consequently grain yield, stover yield and biological yield (Tables 4.53 to 4.55 and Fig. 4.8) of the crop by increasing growth of the crop through reduced crop weed competition during both the years except number of rows per cob during second year and cob length during first year in zero tillage, where atrazine 1.5 kg/ha was significantly superior for both these parameters.

Integration of atrazine 1.5 kg/ha or acetachlor 1.25 kg/ha with either raised seed bed or conventional tillage resulted in significantly higher length of cob, number of rows per cob (Tables 4.50 and 4.51), during both the years and consequently higher grain, stover and biological yield (Tables 4.53 to 4.55 and Fig. 4.8). The weeds in combination of unweeded check and conventional tillage resulted in reduction in grain yield of maize by 32.40 and 35.07 per cent during first and second year, respectively over combination of raised seed bed with atrazine 1.5 kg/ha and by 33.75 and 34.51 per cent during first and second year, respectively over combination of raised seed bed with acetachlor 1.25 kg/ha. This reduction in maize yield was 35.24 and 36.80 per cent during first and second year, respectively over combination of atrazine 1.5 kg/ha with conventional tillage and by 33.27 and 33.10 per cent during first and second year, respectively over combination of acetachlor 1.25 kg/ha with conventional tillage. However, combination of

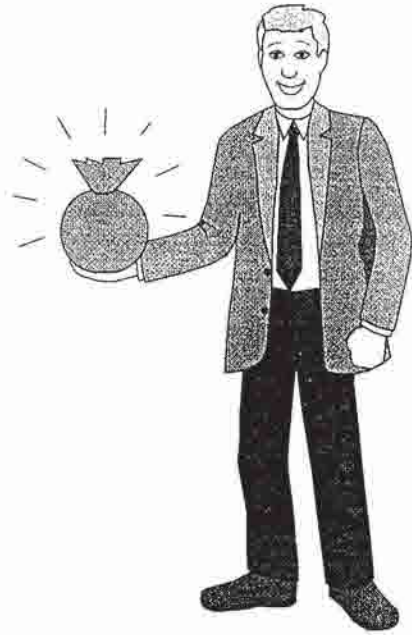
atrazine 1.5 kg/ha with zero tillage also behaved statistically similar to these combinations in significantly increasing number of rows per cob and biological yield of maize during both the years and cob length and stover yield during first year.

The superiority of atrazine 1.5 kg/ha or acetachlor 1.25 kg/ha in combination with raised seed bed or conventional tillage and atrazine 1.5 kg/ha in combination with zero tillage in increasing the crop growth, yield and yield attributes of maize could be ascribed to their higher weed control efficiency (Tables 4.29 and 4.30 and Fig. 4.5) by reducing the population and dry matter of weeds from the beginning (Tables 4.15 and 4.26) which reduced the crop weed competition right from the sowing of the crop.

5.6 ECONOMIC STUDIES

The data on comparative economics of different integrated weed management treatments (Table 4.62 and Fig. 4.11) reveal that conventional tillage in integration with atrazine 1.5 kg/ha resulted in highest gross returns (Rs. 56486 and 54817) and net returns (Rs. 48057 and 46079) during first and second year, respectively. The superiority of atrazine with conventional tillage in influencing the economic parameters is in direct conformity with the findings of Shah and Koul (1990) and Khajanji *et al.* (2002). However, integration of raised seed bed with acetachlor 1.25 kg/ha resulted in gross returns of Rs. 55018 and net returns of Rs. 47199 during first year and its integration with atrazine 1.5 kg/ha resulted in gross returns of Rs. 53373 and net returns of Rs. 45126 during second year and were the next best.

With regards to benefit:cost ratio, raised seed bed in combination with acetachlor 1.25 kg/ha resulted in highest benefit:cost ratio of 6.04 and 5.59 during first and second year, respectively. The combination of zero tillage with acetachlor 1.25 kg/ha during first year and combination of raised seed bed with atrazine 1.5 kg/ha during second year was the next best with benefit:cost ratio of 5.77 and 5.47, respectively.



***S*ummary**

SUMMARY

The present study entitled, "Integrated effect of tillage and weed control methods on weed dynamics and weed management in maize (*Zea mays* L.)" was conducted at the experimental farm of Department of Agronomy, CSK Himachal Pradesh Krishi Vishvavidyalaya, Palampur during *Kharif* 2002 and 2003, with the following objectives:

1. To study the integrated effect of tillage and weed control methods on dynamics of weed flora and its management,
2. to study the integrated effect of these treatments on growth, development and productivity of maize, and
3. to find out the comparative economics of different treatments.

The experiment consisted of 12 treatment combinations of three tillage methods (Zero tillage, conventional tillage and raised seed bed) in main plots and four weed control methods (unweeded check, acetachlor 0.75 kg/ha, acetachlor 1.25 kg/ha and atrazine 1.5 kg/ha) in sub plots. The treatments were laid out in split plot design with 3 replications. The field was first divided into 3 main plots in each of the replications and main plot treatments were imposed. Each main plot was further sub divided into 4 subplots to impose weed control treatments. The herbicides treatments were given immediately after sowing with Maruyama Power Sprayer as per the treatments using 600 litres of water per

hectare. Observations on effect of various treatments on weeds and crop were recorded and comparative economics was calculated. The important findings of the study have been summarized in this chapter.

6.1 DISTRIBUTION OF WEED SPECIES

The major grassy weeds of the experimental field were *Digitaria sanguinalis*, *Echinochloa colona* and *Panicum dichotomiflorum* which constituted 86.6 and 68.0 per cent of the total weed flora during 2002 and 2003, respectively. *Commelina benghalensis* was the major broad leaf weed and constituted about 5.4 and 17.7 per cent during first and second year, respectively. The other weeds constituted 3.7 and 7.7 per cent of total weed flora during first and second year, respectively.

6.2 EFFECT OF TILLAGE METHODS

6.2.1 Effect on weeds

1. Raised seed bed significantly decreased the population and dry matter accumulation of *Digitaria sanguinalis*, *Echinochloa colona* and total weeds and was also significantly superior over remaining tillage methods to reduce the dry matter of *Panicum dichotomiflorum* and other weeds during both the years. However, significantly lower population and dry matter of *Commelina benghalensis* was recorded in Zero tillage.
2. Raised seed bed significantly delayed the emergence of broad leaved weeds (other than Ageratum) during both the years and of *Ageratum* only in first year.

3. Raised seed bed and conventional tillage being statistically at par delayed the flowering of *Digitaria sanguinalis* and *Echinochloa colona* and maturity of *Digitaria sanguinalis* and *Panicum dichotomiflorum* significantly during both the years and *Commelina benghalensis* during first year. However, raised seed bed was significantly superior over other tillage methods and was next to conventional tillage in delaying the maturity of *Echinochloa colona* during both the years and *Commelina benghalensis* during second year. .
4. The seed bank studies conducted just before sowing revealed that raised seed bed resulted in significantly lowest number of seeds of *Digitaria sanguinalis*, *Echinochloa colona* and *Panicum dichotomiflorum* at soil depths of 0-10 cm. On the contrary zero tillage plots had significantly highest number of seeds of *Digitaria sanguinalis*, *Echinochloa colona*, *Panicum dichotomiflorum* and *Commelina benghalensis* at 0-10 cm depths and lower population at 10-20 cm and 20-30 cm depths during both the year.
5. While raised seed bed had the highest weed control efficiency to control *Digitaria sanguinalis*, *Echinochloa colona*, *Panicum dichotomiflorum*, *Cyperus iria* and total weeds during both the years, the zero tillage had highest efficacy to control *Commelina benghalensis*.
6. Raised seed bed resulted in significantly lowest uptake of nitrogen, phosphorus and potassium by weeds. Conventional tillage was the next best in decreasing the total uptake of nitrogen by the weeds during both the years.

6.2.3 Effect on crop

1. Conventional tillage being statistically at par with raised seed bed resulted in significantly higher plant height, number of functional leaves, dry matter accumulation, stalk diameter and root distribution of maize during both the years.
2. Conventional tillage resulted in significantly lower lodging percentage over remaining tillage methods during both the years.
3. Raised seed bed significantly delayed different phenophases of the crop over rest of the tillage methods during both the years.
4. Conventional tillage being statistically at par with raised seed bed produced significantly higher values of all the yield contributing characters of maize. However, harvest index was not influenced significantly by tillage methods during both the years.
5. Conventional tillage being statistically at par with raised seed bed increased the grain yield, stover yield and biological yield of maize significantly over zero tillage during both the years.
6. Conventional tillage and raised seed bed behaved statistically alike in significantly increasing the nitrogen, potassium and phosphorus uptake by total plant during both the years.
7. Tillage methods did not influence the protein and starch content of maize grains significantly.

8. Conventional tillage increased the gross and net returns during both the years and raised seed bed was the next best with minor differences in respect of these economic parameters. However, highest benefit cost ratio was obtained with raised seed bed followed by conventional tillage during both the years.

6.3 EFFECT OF WEED CONTROL METHODS

6.3.1 Effect on weeds

1. Pre-emergence application of atrazine 1.5 kg/ha decreased the population and dry matter of *Panicum dichotomiflorum*, *Commelina benghalensis*, *Cyperus iria* and total weeds significantly during both the years. However, it was statistically at par with acetachlor 1.25 kg/ha in decreasing dry matter and population of *Digitaria sanguinalis*, *Echinochloa colona* and total weeds and population of *Panicum dichotomiflorum* at all the stages of observation during both the years and *Commelina benghalensis* at all stages except 60 DAS during first year. Population and dry matter accumulation of *Brachiaria ramosa* was significantly and completely reduced by acetachlor 1.25 kg/ha during both the years.
2. Atrazine 1.5 kg/ha and acetachlor 1.25 kg/ha resulted in weed control efficiency of more than 74 per cent in controlling *Digitaria sanguinalis*, *Echinochloa colona* and *Panicum dichotomiflorum* during both the years. The weed control efficiency of both the herbicides to control

Commelina benghalensis ranged between 71.3-78.8 per cent and 78.5 per cent during first and second year, respectively. These herbicides had weed control efficiency in the range of 55.7 to 66.3 per cent and 55.1 to 68.3 per cent, to control *Cyperus iria* and other weeds, respectively. Highest total weed control efficiency of 83.6 and 77.8 per cent was obtained with atrazine 1.5 kg/ha during first and second year, respectively and was closely followed by acetachlor 1.25 kg/ha with weed control efficiency of 81.1 and 75.9 per cent during first and second year, respectively.

3. Weed control methods did not significantly influence the depth of emergence of grasses, broad leaved weeds (*Commelina benghalensis* and *Oxalis latifolia*) and *Cyperus iria* during both the years.
4. Atrazine 1.5 kg/ha and acetachlor 1.25 kg/ha being statistically at par, delayed the emergence of grasses and various broad leaved weeds during both the years. However, atrazine 1.5 kg/ha was significantly superior over remaining weed control methods in significantly delaying the emergence of *Ageratum conyzoides* during both the years.
5. Atrazine 1.5 kg/ha and acetachlor 1.25 kg/ha being statistically at

7. Among weed control methods, atrazine 1.5 kg/ha being statistically at par with acetachlor 1.25 kg/ha reduced the total uptake of nitrogen, phosphorus and potassium by weeds significantly during both the years.

6.3.2 Effect on crop

1. Atrazine 1.5 kg/ha being statistically at par with acetachlor 1.25 kg/ha produced significantly taller plants with more number of functional leaves per plant having higher dry matter accumulation, stalk diameter and good root development during both the years.
2. Atrazine 1.5 kg/ha being statistically at par with acetachlor 1.25 kg/ha resulted in significantly lower lodging percentage. However, acetachlor 1.25 kg/ha was also statistically at par with its lower dose in reducing the percentage of lodged plants of maize during both the years.
3. All weed control treatments being statistically at par to each other delayed the 50 per cent tasseling during first year and 50 per cent silking, maturity during both the years over unweeded check. Weed control methods did not significantly influence the days taken for emergence of crop.
4. Atrazine 1.5 kg/ha being statistically at par with acetachlor 1.25 kg/ha resulted in significantly higher values of effective plant population, cob length, number of rows per cob, number of grains per row, test weight and shelling percentage of maize crop.

5. Atrazine 1.5 kg/ha and acetachlor 1.25 kg/ha being statistically at par with each other produced significantly higher grain yield, stover yield and biological yield of maize during both the years. However, harvest index was not significantly influenced by weed control methods.
6. Atrazine 1.5 kg/ha resulted in significantly higher nitrogen, phosphorus and potassium uptake by grains, stover and total plant during both the years. However it was statistically at par with acetachlor 1.25 kg/ha in significantly increasing uptake of nitrogen, phosphorus and potassium by maize stover and uptake of nitrogen and potassium by maize grains and total plant during both the years.
7. Atrazine 1.5 kg/ha being statistically at par with acetachlor 1.25 kg/ha resulted in significantly higher protein content in maize grains during both the years.
8. Atrazine 1.5 kg/ha resulted in higher gross returns, net returns and benefit cost ratio during both the years. However, during the first year acetachlor 1.25 kg/ha had the highest benefit cost ratio. Acetachlor 1.25 kg/ha was the next best, with regards to other economic parameters.

6.4 INTEGRATED EFFECT OF TILLAGE AND WEED CONTROL METHODS

6.4.1 Integrated effect on weeds

1. Integration of raised seed bed or conventional tillage with atrazine 1.5 kg/ha being statistically at par with integration of raised seed bed with acetachlor 1.25 kg/ha resulted in significantly lower population of

Digitaria sanguinalis and total weeds during both the years. Integration of zero tillage or conventional tillage with either atrazine 1.5 kg/ha or acetachlor 1.25 kg/ha resulted in significantly lower population of *Commelina benghalensis* during both the years. Raised seed bed in integration with acetachlor 0.75 kg/ha was equally effective in significantly reducing the population of *Digitaria sanguinalis*. All the tillage methods in combination with atrazine 1.5 kg/ha being statistically at par reduced the population of total weeds during both the years.

2. Raised seed bed in integration with atrazine 1.5 kg/ha or acetachlor 1.25 kg/ha resulted in significantly lower dry matter of *Digitaria sanguinalis*, *Echinochloa colona*, *Panicum dichotomiflorum* and total weeds during both the years. However, conventional tillage in integration with atrazine 1.5 kg/ha was equally effective to significantly reduce the dry matter of *Echinochloa colona* and *Panicum dichotomiflorum*. Integration of zero tillage with atrazine 1.5 kg/ha was also equally effective to significantly reduce the dry matter of *Echinochloa colona* during both the years. Significantly lower dry matter accumulation of *Commelina benghalensis* was obtained with integration of zero or conventional tillage with either atrazine 1.5 kg/ha or acetachlor 1.25 kg/ha during both the years.

3. Integration of raised seed bed with atrazine 1.5 kg/ha or acetachlor 1.25 kg/ha resulted in significantly lower uptake of total nitrogen, phosphorus and potassium by weeds during both the years. However, the combinations of conventional tillage with either atrazine 1.5 kg/ha or acetachlor 1.25 kg/ha and combination of zero tillage with atrazine 1.5 kg/ha was statistically alike to these superior combinations in significantly reducing the total uptake of phosphorus by weeds during both the years.

6.4.2 Integrated effect on crop

1. Integration of conventional tillage or raised seed bed with atrazine 1.5 kg/ha or acetachlor 1.25 kg/ha being statistically at par produced plants with significantly taller plant height and having more number of functional leaves per plant of maize during both the years. However, integration of zero tillage with atrazine 1.5 kg/ha also behaved statistically alike in influencing number of functional leaves per plant of maize.
2. Conventional tillage in integration with either atrazine 1.5 kg/ha or acetachlor 1.25 kg/ha being statistically at par with integration of raised seed bed with atrazine 1.5 kg/ha resulted in significantly higher vertical spread of maize roots.
3. Integration of conventional tillage or raised seed bed with either atrazine 1.5 kg/ha or acetachlor 1.25 kg/ha resulted in significantly higher cob length and more number of grain rows per cob of maize

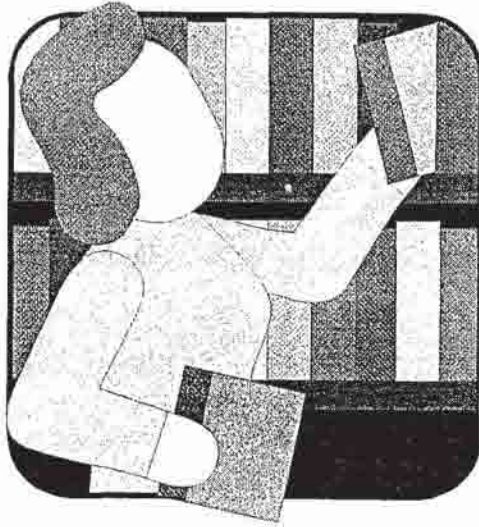
during both the years. However, these combinations were also statistically at par with combination of zero tillage with atrazine 1.5 kg/ha in influencing number of rows per cob of maize.

4. Conventional tillage or raised seed bed in integration with either atrazine 1.5 kg/ha or acetachlor 1.25 kg/ha resulted in significantly higher grain, stover and biological yield. However, integration of zero tillage with atrazine 1.5 kg/ha was equally effective in increasing biological yield of maize. Acetachlor 0.75 kg/ha in integration with conventional tillage or raised seed bed was statistically as effective as acetachlor 1.25 kg/ha or atrazine 1.5 kg/ha in integration with zero tillage in influencing the maize grain yield, stover yield and biological yield during both the years. However, raised seed bed in integration with acetachlor 0.75 kg/ha was statistically inferior to zero tillage in integration with atrazine 1.5 kg/ha or acetachlor 1.25 kg/ha in influencing the stover yield during first year.
5. Conventional tillage in integration with atrazine 1.5 kg/ha resulted in highest gross returns of Rs 56486 and Rs 54817 and net returns of Rs 48057 and Rs 46079 during first and second year, respectively. However, integration of raised seed bed with acetachlor 1.25 kg/ha produced highest benefit:cost ratio of 6.04 and 5.59 during first and second year, respectively. Raised seed bed in integration with acetachlor 1.25 kg/ha during first year and with atrazine 1.5 kg/ha

during second year was the next best in terms of all these economic parameters. However, in terms of benefit:cost ratio zero tillage in integration with atrazine 1.5 kg/ha was the next best during first year.

Conclusion

1. Raised seed bed in integration with pre emergence application of atrazine 1.5 kg/ha or acetachlor 1.25 kg/ha being statistically at par with combination of conventional tillage and atrazine 1.5 kg/ha (pre) controlled grasses and total weeds effectively with average weed control efficiency of more than 82 per cent. The *Commelina benghalensis* was effectively controlled with zero tillage or conventional tillage in integration with atrazine 1.5 kg/ha or acetachlor 1.25 kg/ha with average weed control efficiency of more than 72 per cent
2. Integration of atrazine 1.5 kg/ha or acetachlor 1.25 kg/ha (pre) with raised seed bed or conventional tillage significantly increased the growth, yield attributes and grain yield of maize.
3. While conventional tillage in integration with atrazine 1.5 kg/ha resulted in highest average gross (Rs. 55652) and net returns (Rs. 47068), the highest average benefit:cost ratio (5.82) was obtained with the combination of acetachlor 1.25 kg/ha with raised seed bed.



***L*iterature
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LITERATURE CITED

- A.O.A.C. 1970. Methods of analysis. Association of Official Agricultural Chemists, Washington D.C.
- Acharya, C.L. and Bhagat, R.M. 1984. Infiltration behaviour, root development and yield of rainfed maize (*Zea mays* L.) under different soil management practices. *In* : Proceedings of Indian National Science Academy, Part B 50 : 441-448.
- Acharya, C.L. and Sharma, P.D. 1994. Tillage and mulch effects on soil physical environment, root growth, nutrient uptake and yield of maize and wheat on an Alfisol in north-west India. *Soil and Tillage Research* 32 : 291-302.
- Angiras, N.N. and Singh, C.M. 1988. Influence of weed control methods, plant population, fertility levels and cropping systems on weed management in maize. *Indian Journal of Weed Science* 20 : 67-72.
- Angiras, N.N. and Singh, C.M. 1989. Economic analysis of integrated weed management. *Indian Journal of Weed Science* 21 : 29-36.
- Anonymous. 1995. Package of practices for *Kharif* crop. Published by Directorate of Extension Education, CSK HPKV, Palampur.
- Anonymous. 2004^a. Fertilizer statistics 2003-04. The fertilizer association of India, New Delhi. p 1-273.
- Anonymous. 2004^b. Tenth five year plan (2002-2007) and annual plan (2003-2004). Planning Department, Government of Himachal Pradesh, Shimla PP GN III : 53-54.
- Ball-Coelho, B.R., Roy, R.C. and Swanton, C.J. 1998. Tillage alters corn root distribution in coarse textural soils. *Soil and Tillage Research* 45 : 237-249.

- Barber, S.A. 1971. Effect of tillage practice on corn (*Zea mays* L.) root distributions and morphology. *Agronomy Journal* 63 : 724-726.
- Barry, D.A.J. and Miller, M.H. 1986. Corn response to restricted nodal root growth with relevance to zero tillage. *Canadian Journal of Soil Science* 66(4) : 689-699.
- Bauman, T.T. and Ross, M.A. 1983. Effect of three tillage systems on the persistence of atrazine. *Weed Science* 31 : 423-426.
- Black, C.A. 1965. Methods of soil analysis. Part-II. American Society of Agronomy, Wisconsin, USA p. 1572.
- Blackshaw, R., Larney, F.O., Lindwall, C.W. and Kozub, G.C. 1994. Crop rotation and tillage effects on weed populations on the semi-arid Canadian prairies. *Weed Technology* 8 :231-237.
- Blevins, R.L. and Frye, W.W. 1993. Conservation tillage : An ecological approach to soil management. *Advances in Agronomy* 51 : 33-78.
- Brar, H.S. and Cheema, S.S. 1988. Agronomic practices for managing excess water in maize. *Indian Journal of Agronomy* 33 : 164-166.
- Brar, L.S., Walia, U.S., Mehra, S.P. and Dhaliwal, B.K. 1991. Effect of time and method of atrazine application on weeds and grain yield of maize. *Journal of Research Punjab Agricultural University* 28(4) : 455-458.
- Buchanan, G.A. 1976. Management of the weed pests of cotton (*Gossypium hirsutum*). *In: Proceedings of U.s.-U.S.S.R. symposium on the integrated control of the arthropod, disease and weed pests of cotton, grain sorghum and deciduous fruit, Lubbock, TX pp. 168-184.*
- Buhler, D.D. 1992. Population dynamics and control of annual weeds in corn (*Zea mays*) as influenced by tillage systems. *Weed Science* 40 : 241-248.

- Buhler, D.D. 1995. Influence of tillage systems on weed population dynamics and management in corn and soybean in the central USA. *Crop Science* 35 : 1247-1258.
- Buhler, D.D. and Daniel, T.C. 1988. Influence of tillage systems on giant foxtail (*Setaria faberi*) and velvet leaf (*Abutilon theophrasti*) density and control in corn (*Zea mays*). *Weed Science* 36 : 642-647.
- Buhler, D.D. and Mester, T.C. 1991. Effect of tillage systems on the emergence depth of giant (*Setaria faberi*) and green foxtail (*Setaria viridis*). *Weed Science* 39 : 200-203.
- Buhler, D.D., Stoltenberg, D.E., Becker, R.L. and Gunsolus, J.L. 1994. Perennial weed populations after 14 years of variable tillage and cropping practices. *Weed Science* 42 : 205-209.
- Burnside, O.C. 1979. Soybean growth as affected by weed removal, cultivar and row spacing. *Weed Science* 27 : 562-565.
- Burwell, R.E., Allmaras, R.R. and Sloneker, L.I. 1966. Structural alternation of soil surface by tillage and rainfall. *Journal of Soil and Water Conservation* 21 : 61-63.
- Cannell, R. Q. 1985. Reduced tillage in North-West Europe - A review. *Soil and Tillage Research* 5: 129-177.
- Cardina, J., Regnier, E. and Harrison, K. 1991. Long-term tillage effects on seed banks in three Ohio soils. *Weed Science* 39 : 186-194.
- Castillo, S. R., Dowdy, R.H., Bradford, J. M. and Larson, W. E. 1982. Effects of applied mechanical stress on plant growth and nutrient uptake. *Agronomy Journal* 74: 526-530.
- Cavers, P.B. and Benort, D.L. 1989. Seed banks in Arabic land. *Ecology of Soil seed Banks*. Academic press, New York pp. 309-328.

- Chakor, I.S. and Awasthi, O.P. 1983. Cultural cum chemical weed control in maize under rainfed conditions of Himachal Pradesh. *Indian Journal of Weed Science* 15(1) : 65-68.
- Chang, J.H. 1981. Corn yield in relation to photoperiod, night temperature and solar radiation. *Agricultural Meteorology* 24 : 253-262.
- Chassot, A. and Richner, W. 2002. Root characteristics and phosphorus uptake of maize seedlings in a bitayered soil. *Agronomy Journal* 94 : 118-127.
- Chassot, A., Stamp, P. and Richner, W. 2001. Root distribution and morphology of maize seedlings as affected by tillage and fertilizer placement. *Plant and Soil* 231(1) :123-135.
- Chauhan, D.S., Sharma, R.K., Tripathi, S.C., Kharul, A.S. and Chhokar, R.S. 2001. New paradigms in tillage technologies for wheat production. Research Bulletin published by Directorate of Wheat Research, Karnal 7 : 16 pp.
- Clements, D.R., Benoit, D.L., Murphy, S.D. and Swanton, C.J. 1996. Tillage effects on weed seed return and seed bank composition. *Weed Science* 44 : 314-322.
- Coffman, C.B. and Frank, J.R. 1991. Weed-crop response to weed management systems in conservation tillage corn (*Zea mays*). *Weed Technology* 5 : 76-81.
- Cox, W.J., Zobel, R.W., Eo, H.M., Otis, D.J. and VanEs, H.M. 1990. Growth development and yield of maize under three tillage systems in the northeastern USA. *Soil and Tillage Research* 18(2&3) : 295-310.
- Crafts, A.S. and Robbins, W.W. 1962. A text book and manual : Weed control. McGraw-Hill Book Company, Inc. USA pp 93-94.

- Da-Silva, J.B., Fonseca, L.B., Silva, J.J.M. and Da-Silva, J. 1982. Acetachlor, a new herbicide of the acetamylide group for maize (*Zea mays* L.). In : Abstracts of the XIV Brazilian congress on herbicides and herbaceous weeds (SBHED) and the VI congress of the Latin American Weed Association (ALAM), Campinas pp. 115-116.
- Dixit, A., Gautam, K.C. and Dixit, A. 1996. Effect of atrazine on growth and yield of winter maize. *Annals of Agricultural Research* 17(2) : 121-124.
- Dogra, P., Joshi, B.P. and Sharma, N.K. 2002. Economic analysis of tillage practices for maize cultivation in the Himalayan humid subtropics. *Indian Journal of Soil Conservation* 30(2) : 172-178.
- Dubois, M., Gills, D.A., Hamilton, J.K., Rebers, P.A. and Smith, F. 1956. Colorimetric method of determination of sugars and related substances. *Analytical Chemistry* 28 : 350-356.
- Dwyer, L.M., Ma, B.L., Hayhoe, H.N. and Culley, J.L.B. 1995. Tillage effects on soil temperature, shoot dry matter accumulation and corn grain yield 5(1&2) : 85-99.
- Fausey, N.R. 1990. Experiment with ridge-till on slowly permeable soils in Ohio. *Soil and Tillage Research* 18 : 195-205.
- Felix, J. and Owen, M.D.K. 1999. Weed population dynamics in land removed from the conservation reserve program. *Weed Science* 47 : 511-517.
- Ferri, M.V.W. and Vidal, R.A. 2004. Acetachlor herbicide efficacy on tillage and no-tillage systems on straw mulch presence on absence and effect on corn yield. *Ciencia Rural* 34(2) : 351-356.
- Forcella, F. and Lindstrom, M.J. 1988. Movement and germination of weed seeds in ridge-till crop production systems. *Weed Science* 36 : 56-59.

- Frink, B. and Thomas, A.G. 1992. Weed surveys in different tillage systems in south western Ontario field crops. *Canadian Journal of Plant Science* 72(4) : 1337-1347.
- Gebhardt, M.D., Daniel, T.C., Schweizer, E.E. and Allmaras, R.R. 1985. Conservation tillage. *Science* 230 : 625-630.
- Geriev, K.T. 1996. Harness and roundup guarantee high yields of farm crops. *Zashchita-i-karantin-Rastenii* 5 : 30.
- Gill, H.S., Brar, L.S. and Walia, U.S. 1987. Comparative bioefficacy of new brand formulation of atrazine and simazine for weed control in maize. *Journal of Research Punjab Agricultural University* 24(2) : 209-214.
- Gomez, K.A. and Gomez, A.A. 1984. *Statistical procedures for agricultural research*. A Wiley Inter science Publication John Wiley and Sons.
- Goss, M. J. 1977. Effect of mechanical impedance on root growth in barley (*Hordeum vulgare* L.) I. Effects on the elongation and branching of seminal root axes. *Journal of Experimental Botany* 28: 96-111.
- Goss, M. J. and R. S. Russell 1980. Effects of mechanical impedance on root growth in barley (*Hordeum vulgare* L.) III. Observations on the mechanisms of response. *Journal of Experimental Botany* 31: 577-580.
- Griffith, D.R., Mannering, J.V., Galloway, H.M., Parsons, S.I. and Rickey, C.B. 1973. Effect of eight tillage planting systems on soil temperature, per cent stand, plant growth and yield of corn on five Indiana soils. *Agronomy Journal* 65 : 321-326.
- Hatam, M. and Khattak, A.K. 1995. Length of weed free period in relation to yield and growth of maize. *In* : Proceedings of fourth All Pakistan Weed Science Conference. UAF on Weed management for sustainable Agriculture . pp. 161-167.

- Hatfield, J.L., Allmaras, R.R., Rehm, G.W., Lwery, B., Allmaras, R.R. and Anderson, J.L. 1998. Ridge tillage for corn and soybean production : environmental quality impacts. *Soil and Tillage Research* 48 : 145-154.
- Hill, R.L. 1990. Long-term conventional and no-tillage effects on selected soil physical properties. *Soil Science Society of American Journal* 54: 161-166.
- Hoffman, M.L., Owen, M.D.K. and Buhler, D.D. 1998. Effects of crop and weed management on density and vertical distribution of weed seeds in soil. *Agronomy Journal* 90 : 793-799.
- Holt, J.S. and LeBaron, H.M. 1990. Significance and distribution of herbicide resistance. *Weed Technology* 4 : 141-149.
- Jackson, M.L. 1967. Soil chemical analysis. Prentice Hall of India Private Limited, New Delhi pp. 331-334.
- Johnson, M.D., Wyse, D.L. and Lueschen, W.E. 1989. The influence of herbicide formulation on weed control in four tillage systems. *Weed Science* 37 : 239-249.
- Johnson, W.C. and Coble, H.D. 1986. Crop rotation and herbicide effects on the population dynamics of two annual grasses. *Weed Science* 34 : 452-456.
- Kalia, B.D. and Singh, C.M. 1993. Studies on weed management in maize. *In* : Proceedings of International Symposium on Integrated weed management for sustainable agriculture held at Hisar on 18-20 November Vol III : 89-90.
- Kaul, J.N., Gill, G.S., Narang, S.D. and Dhingra, K.K. 1970. Response of maize to variable tillage. *Indian Journal of Agronomy* 15 : 169-172.

- Kells, J.J., Rieck, C.E., Blevins, R.L. and Muir, W.M. 1980. Atrazine dissipation as affected by surface pH and tillage. *Weed Science* 28 : 101-104.
- Khajanji, S.N. Gautam, R.C. and Patel, J.R. 2002. Residual effects of tillage and weed control practices applied to rainy season maize on winter wheat. *Journal of Maharashtra Agricultural Universities* 27(3) : 279-282.
- Khan, S.A., Hussain, N., Khan, I.A., Khan, M. and Iqbal, M. 1998. Study on weed control in maize. *Sarhad Journal of Agriculture* 14(6) : 581-586.
- Konstantinovic, B., Govedarica, M., Jarak, M. and Milosevic, N. 1999. Herbicide efficiency and their impact on micro biological activity in soil. *Research Progress in Plant Protection and Plant Nutrition*. pp 228-232.
- Koskinen, W.C. and McWhorter, C.G. 1986. Weed control in conservation tillage. *Journal of Soil and Water Conservation* 41 : 365-370.
- Krausz, R.F., Young, B.G., Kapusta, G. and Matthews, J.L. 2000. Application timing determines giant foxtail (*Setaria faberi*) and barnyardgrass (*Echinochloa crus-galli*) control in no-till corn (*Zea mays*). *Weed Technology* 14(1) : 161-166.
- Krishnamurthy, K., Raju, B., Reddy, V.C. and Kenchaiah, K. 1981. Critical stages for weed competition in soybean, groundnut and maize. *In* : Proceedings of Asian Pacific Weed Science Conference held at Bangalore Vol. 8 : 123-127.
- Lachno, D. R., Murray, R. S. and Audus, L. J. 1982. The effects of mechanical impedance to growth on the levels of ABA and IAA in root tips of *Zea mays* L. *Journal of Experimental Botany* 33: 943-951.

- Lal, B., Chandra, N. and Yadav, M.S. 1988. Response of waterlogged maize to planting methods and time of nitrogen application. *Indian Journal of Agronomy* 33(2) : 191-193.
- Lal, R. 1991. Tillage and agricultural sustainability. *Soil and Tillage Research* 20 : 133-146.
- Lal, S.S. 1990. Direct and residual effect of varying levels of herbicides for controlling the weed in potato blackgram crop sequence. *Indian Journal of Weed Science* 22(3&4) : 1-5.
- Logsdon, S. D., Reneau, R. B., and Parker, J. C. 1987. Corn seedling root growth as influenced by soil physical properties. *Agronomy Journal* 79: 221-224.
- Lynn, L.B. 1980. Performance of acetachlor in corn and potatoes in the north eastern United States. *In* : Proceedings of the North eastern Weed Science Society 34 : 43-50.
- Madhu, M. and Nanjappa, H.V. 1993. Chemical weed control in maize-soybean intercropping systems. Current research university of Agricultural Sciences, Bangalore 22(6&8) : 80-83.
- Maksymowicz, W., Palmer, J.H. and Whitwell, T. 1986. Effects of crop rotation and tillage practices on weed succession and crop yield. *In* : Proceedings of Southern Weed Science Society pp. 392.
- Martino, D. L. and Shaykewich, C. F. 1994. Root penetration profiles of wheat and barley as affected by soil penetration resistance in field conditions. *Canadian Journal of Soil Science* 74: 193-200.
- Masand, S.S., Kapur, O.C. and Jaggi, R.C. 1993. Effect of tillage, nitrogenous fertilizer on water use and yield of rainfed maize on sloping and level lands. *Journal of the Indian Society of Soil Science* 41 : 426-429.

- Maurya, P.R. and Lal, R. 1980. Effects of no-tillage and ploughing on roots of maize and leguminous crops. *Experimental Agriculture* 16(2) : 185-193.
- Mester, T.C. and Buhler, D.D. 1986. Effect of tillage on the depth of giant foxtail germination and population densities. *In: Proceedings of North Central Weed Control Conference* 41 : 4-5.
- Miklos, D. 1981. Comparative analysis of acetachlor and metolachlor based herbicides in the weed control of maize. *Novenytermeles* 30(2) : 145-155.
- Mishra, J.S. 1997. Critical period of weed competition and losses due to weeds in major field crops. *Farmer and Parliament* 33(7) : 19-20.
- Mishra, J.S. 2004. Tillage and weed management. Technical bulletin published by National Research Centre for Weed Science.
- Mishra, S.S., Singh, S.J. and Singh, M.K. 1996. Weed management in *Kharif* maize (*Zea mays* L.). *Journal of Applied Biology* 6(1&2) : 126-127.
- Mueller, T.C. and Hayes, R.M. 1997. Effect of tillage and soil-applied herbicides on broadleaf signal grass (*Brachiaria platyphylla*) control in corn (*Zea mays*). *Weed Technology* 11(4) : 698-703.
- Nayital, S.C., Sharma, J. and Singh, C.M. 1989. Weed-crop competition studies in maize under Kullu valley conditions. *Indian Journal of Weed Science* 21 : 47-50.
- Nelson, J.E. and Bryant, W.E. 1981. Herbicide combinations for woolly cup grass and shatter cane control in corn. *In: Proceedings of North Central Weed Control Conference* 36 : 137-138.
- Nikolova, V. and Baeva, G. 2004. Effect of acetachlor on the weeds of maize plantation and soil biological activity. *Herbologia* 5(1) : 23-29.

- Olsen, S.R., Cole, C.W., Watanabe, F.S. and Dean, L.A. 1954. Estimation of available phosphorus in soils by extraction with NaHCO₃. United States Department of Agricultural Circular 939 : 19-23.
- Owen, M.D.K. 1992. Theory and practice : weed management in no-tillage soybeans. *In*: Proceedings of crop production and protection conference held at Iowa State University 4 : 91-96.
- Owen, M.D.K. and Hartzler, R.G. and Lux, J. 1993. Woolly cup grass (*Eriochloa villosa*) control in corn (*Zea mays*) with chloroacetamide herbicide. *Weed Technology* 7(4) : 925-929.
- Pandey, A.K., Kamta Prasad, Mani, V.P., Chauhan, V.S. and Singh, P. 1998. Improved maize production technology for mid-hills of North-Western Himalayas. *Technical Bulletin* 11 : 1-46.
- Pandey, A.K., Prakash, V., Singh, R.D. and Mani, V.P. 2001. Integrated weed management in maize. *Indian Journal of Agronomy* 46 : 260-265.
- Pandey, A.K., Prakash, V., Singh, R.D. and Mani, V.P. 2002. Studies on crop-weed competition and weed dynamics in maize under mid-hill conditions of N-W Himalayas. *Indian Journal of Weed Science* 34(1&2) : 63-67.
- Paradkar, V.K. and Sharma, R.K. 1993. Integrated weed management in maize. *Indian Journal of Weed Science* 25 : 81-83.
- Pareja, M.R. and Staniforth, D.W. 1985. Seed-soil microsite characteristics in relation to weed seed germination. *Weed Science* 33 : 190-195.
- Pareja, M.R., Staniforth, D.W. and Pareja, G.P. 1985. Distribution of weed seed among soil structural units. *Weed Science* 33 : 182-189.
- Parker, C. 1983. Weed management in corn. *In* : 33rd Annual Weed Conference. p. 61-65.

- Peterson, C. M., Klepper, B., Pumphrey, F. V. and Rickman, R. W. 1984. Restricted rooting decreases tillering and growth of winter wheat. *Agronomy Journal* 76: 861-863.
- Phillips, S.R., Olsen, K.R., Siemens, J.C. and Ebdhar, S.A. 1997. Economics of conservation tillage systems for CRP land in southern Illinois. *Journal of Production Agriculture* 10(3) : 483-489.
- Piper, C.S. 1966. *Soil and Plant Analysis*. Hans Publishers, Bombay. pp. 237.
- Pollard, F. and Cussans, G.W. 1976. The influence of tillage on the weed flora of four sites sown to successive crops of spring barley. *In: Proceedings of 13th British Weed Control Conference* 13 : 1019-1028.
- Randhawa, S.K., Gill, H.S. and Sandhu, K.S. and 1988. Effect of herbicides on protein content in grain of winter maize (*Zea mays* L.). *Journal of Research, Punjab Agricultural University* 25(1) : 35-36.
- Rangnapa, T. 1985. Effect of tillage system, weed control and fertilizer application methods on growth and yield of maize (*Zea mays* L.). *In: Proceedings of 13th British Weed Control Conference* 13 : 940-948.
- Risk, T.Y. and El-Bially, M.E. 1996. Integrated Weed management in maize. *Annals of Agricultural Science, Moshtohor* 34(1) : 1-12.
- Ritter, R.L., Kaufman, L.M., Monaco, T.J., Navitzky, W.P. and Moreland, D.E. 1989. Characterization of triazine resistant giant foxtail (*Setaria faberi*) and its control in no-tillage corn (*Zea mays*). *Weed Science* 37 : 591-595.
- Roberts, H.A. 1981. Seed banks in soils. *Advances in Applied Biology* 6 : 1-55.
- Roberts, H.A. and Neilson, J.E. 1981. Changes in the soil seed bank of four long-term crop/herbicide experiments. *Journal of Applied Ecology* 18 : 661-668.

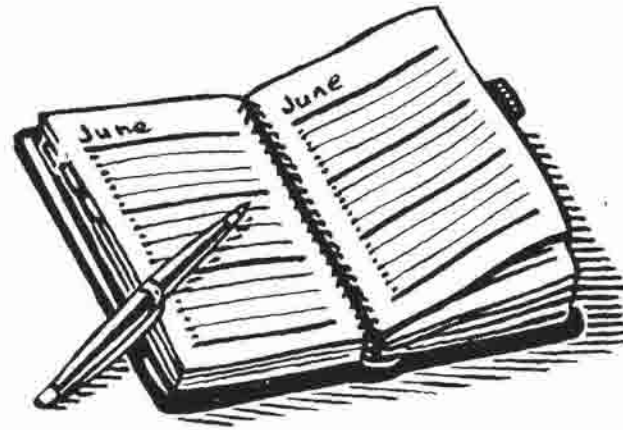
- Rout, D. and Satapathy. 1996. Chemical weed control in rainfed maize (*Zea mays*). Indian Journal of Agronomy 41 : 51-53.
- Ruckheim, F.O. and Batistela, A.A.C. 1982. Efficacy of selectivity of some new herbicides for maize crops (*Zea mays* L.). In : Abstracts of the XIV Brazilian congress on herbicides and herbaceous weeds (SBHED) and the VI congress of the Latin American Weed Association (ALAM), Campinas pp. 116-117.
- Saini, J.P. 2000. Efficacy of atrazine as post-emergence herbicide for weed control in maize (*Zea mays*) under rainfed conditions. Indian Journal of Agricultural Sciences 70(11) : 801-803.
- Saini, J.P. and Angiras, N.N. 1998. Efficacy of herbicides alone and in mixtures to control weeds in maize under mid-hill conditions of Himachal Pradesh. Indian Journal of Weed Science 30 (1-2) : 65-68.
- Sandhu, K.S., Singh, T. and Singh, S. 1999. Weed composition of maize (*Zea mays*) fields in Punjab. Indian Journal of Weed Science 31 : 18-24.
- Sandhu, M.S. and Gill, G.S. 1973. Studies on critical period of weed competition. Indian Journal of Weed Science 5 : 1-5.
- Sangwan, N., Panwar, R.S. and Malik, R.K. 1989. Effect of various herbicides in the nutrient uptake by weeds in winter maize. Pesticides 23(5) : 35-36.
- Sawat, A.C. and Dayanand. 1994. Effect of moisture-conservation practice on productivity of rainfed maize. Indian Journal of Agronomy 39 : 472-473.
- Sawhney, J.S., Bhinder, S.S., Sidhu, M.S. and Narang, R.S. 1989. Agronomic practices for higher productivity in winter maize. Indian Journal of Agronomy 34(1) : 24-26.

- Schreiber, M.M. 1992. Influence of tillage, crop rotation and weed management on giant foxtail (*Setaria faberi*) population dynamics and corn yield. *Weed Science* 40 : 645-653.
- Schumran, J.J. 1965. Influence of soil density on root development and growth of oats. *Plant and Soil* 22 : 352-374.
- Schweizer, E.E. and Zimdahl, R.L. 1984. Weed seed decline in irrigated soil after six years of continuous corn (*Zea mays*) and herbicides. *Weed Science* 32 : 76-83.
- Shah, M.H. and Koul, P.K. 1990. Fertilizer and herbicide compatibility to control weeds in maize under moisture stress conditions. *Annals of Agricultural Research* 11(1) : 21-27.
- Sharma, A.R., Toor, A.S. and Sur, H.S. 2000. Effect of interculture operations and scheduling of atrazine application on weed control and productivity of rainfed maize (*Zea mays*) in Shiwalik foothills of Punjab. *Indian Journal of Agricultural Sciences* 70(11) : 757-761.
- Sharma, P.K., De Datta, S.K. and Redulla, C.A. 1988. Response of maize (*Zea mays* L.) and mungbean (*Vigna radiate* L.) to tillage in relation to water table depth in tropical lowland rice soils. *Soil and Tillage Research* 12 : 65-79.
- Sharma, V., Thakur, D.R., Sharma, J.J. and Sharma, V. 1998. Effect of metolachlor and its combination with atrazine on weed control in maize (*Zea mays*). *Indian Journal of Agronomy* 43(4) : 677-680.
- Shinde, S.H., Kolage, A.K. and Bhilare, R.L. 2001. Effect of weed control on growth and yield of maize. *Journal of Maharashtra Agricultural Universities* 26(2) : 212-213.

- Singh, C.M., Angiras, N.N. and Suresh Kumar. 1996. Weed Management. M.D. Publications, New Delhi. pp 49.
- Singh, C.M., Singh, S.D. and Suresh Kumar. 1992. Efficacy of selective and non-selective herbicides in controlling weeds in maize. *Indian Journal of Weed Science* 24(1&2) : 85-87.
- Singh, G., Sirohi, R.M., Paul, V. and Shukla, G. 2002. Zero tillage in maize-wheat cropping system. *In* : Proceedings of International Workshop on herbicide resistance management and zero tillage in rice-wheat cropping system held at Hisar on 4-6 March.
- Singh, S.J., Sinha, K.K. and Pandey, I.B. 1998. Weed management practices in maize based cropping sequence. *Journal of Research, Birsa Agricultural University* 10(2) :145-148.
- Stefanic, E. and Stefanic, I. 1996. Interaction between tillage system and profitability of maize production in north-eastern Croatia. *In* : Proceedings of second International Weed Control Congress held at Denmark on 25-28 June. Vol. 1-4 p. 1991-196.
- Subbiah, B.V and Asija, G.L. 1956. A rapid procedure for estimation of available nitrogen in soils. *Current Science* 25 : 259-250.
- Teasdale, J.R., Beste, E.C. and Potts, W.E. 1991. Response of weeds to tillage and cover crop residues. *Weed Science* 39 : 195-199.
- Thakur, D.R. and Sharma, V. 1996. Integrated weed management in rainfed maize (*Zea mays* L.). *Indian Journal of Weed Science* 28(3&4) : 207-208.
- Tomordi, E. 1987. Selective pre-emergent herbicides for field crops. *Agrochemia* 27(12) : 374-376.
- Triplett, G.B. and Lytle, G.D. 1972. Control and ecology of weeds in continuous corn grown without tillage. *Weed Science* 20 : 453-457.

- Usman, A., Elemo, K.A., Lagoke, S.T.O., Adigun, J.A. and Misari, S.M. 1999. Critical period of weed interference in maize/rice mixture. *Agriculturera Tropica at Subtropica* 32 : 41-46.
- Van Acker, R.C., Weise, S.F. and Swanton, C.J. 1993. The critical period of weed control in soybean (*Glycine max* (L.) Merr.). *Weed Science* 41 : 194-200.
- Vannini, A., Giardini, G. and Muzzarelli, F. 1994. Ridge till, a new minimum tillage farming system II. Economic results. *In* : Proceedings of third congress of the European Society of Agronomy held at Italy on 18-22, September.
- Vencill, W.K. and Fog, C.L. 1988. Distribution of triazine-resistant smooth pigweed (*Amaranthus hybridus*) and common lambs quarters (*Chenopodium album*) in Virginia. *Weed Science* 36 : 497-499.
- Vyn, T.J., Daynard, T.B. and Ketcheson, J.W. 1980. Corn growth in relation to the size distribution of soil aggregates in the seed bed zone. *In* : 72nd annual meeting of America Society of Agronomy pp. 193.
- Walia, U.S., Dhalial, B.K. and Brar, L.S. 1991. Influence of nitrogen levels and weed control methods on grain yields of maize (*Zea mays* L.). *Journal of Research Punjab Agricultural University* 28(2) : 164-168.
- Weaver, S.E. and Tan, C.S. 1987. Critical period of weed interference in transplanted tomatoes and its relation to water stress and shading. *Canadian Journal of Plant Sciences* 67 : 575-583.
- Wicks, G.A. and Somerhalder, B.R. 1971. Effect of seed bed preparation for corn on distribution of weed seed. *Weed Science* 19 : 666-668.
- Wicks, G.A., Burnside, O.C. and Felton, W.L. 1994. Weed control in conservation tillage systems. *Managing agricultural residues*. Lewis Publishers, Boca Raton FL. P. 211-244.

- Williams, R.J., Chancellor, R.J. and Drennan, D.S.H. 1983. Influence of cultivation regime upon buried weed seeds in arable cropping systems. *Journal of Applied Ecology* 20 : 199-208.
- Wilson, R.G. 1988. Biology of weed seeds in the soil. *Weed Management in Agro ecosystems : Ecological Approaches*, CRC Press, Inc., Boca, FL. pp. 25-39.
- Wilson, R.G. 1993. Effect of pre plant tillage, post plant cultivation and herbicides on weed density in corn (*Zea mays*). *Weed Technology* 7 : 728-734.
- Wrucke, M.A. and Arnold, W.E. 1985. Weed species distribution as influenced by tillage and herbicides. *Weed Science* 33 : 853-856.
- Xi Ying, Z., Dong, P. and Su Ying, C. 2004. Root growth and soil water utilization of winter wheat in the North China Plain. *Journal of Agricultural Research of China* 63(1) : 210-217.
- Yang, C.M., Lu, H.S. and Chang, F.C. 1993. Influence of weed interference on the growth and yield of no-tillage corn (*Zea mays* L.). *Journal of Agricultural Research of China* 42(2) : 146-153.
- Yenish, J.P., Doll, J.D. and Buhler, D.D. 1992. Effects of tillage on vertical distribution and viability of weed seed in soil. *Weed Science* 40 : 429-433.
- Zhai, R., Kachanoski, R.G. and Voroney, R.P. 1990. Tillage effects on the spatial and temporal variations of soil water. *Soil Science Society of American Journal* 54 : 186-192.



***A**ppendices*

APPENDIX-I(a)

Mean weekly weather data of Palampur from June to September, 2002

Standard week	Week interval	Temperature (°C)			Relative humidity (%)	Rainfall (mm)	Bright sunshine (hrs)
		Max.	Min.	Mean			
24	11-17	31.6	17.1	24.4	53	25.1	7.6
25	18-24	30.9	19.7	25.3	59	14.7	8.5
26	25-01 July	29.0	20.2	24.6	75	10.8	6.2
27	02-08	29.8	18.9	24.4	77	52.5	7.1
28	9-15	30.1	19.8	25.0	66	16.5	8.8
29	16-22	28.3	20.4	24.4	86	140.5	4.3
30	23-29	27.8	18.3	23.1	72	40.6	7.4
31	30-5 Aug	27.7	19.3	23.5	76	73.7	6.2
32	6--12	28.5	19.2	23.9	88	117.9	2.2
33	13-19	25.9	19.2	22.6	84	36.8	3.9
34	20-26	25.1	19.7	22.4	88	92.2	1.7
35	27-2 Sep	25.5	19.0	22.3	91	137.1	1.2
36	3--9	24.6	16.5	20.6	78	72.5	5.8
37	10-16	25.2	16.9	21.1	82	64.4	7.1
38	17-23	25.2	16.4	20.8	76	13.7	7.6
39	24-30	26.8	14.9	20.9	59	1.2	8.5

APPENDIX-I(b)

Mean weekly weather data of Palampur from June to September, 2003

Standard week	Week interval	Temperature (°C)			Relative humidity (%)	Rainfall (mm)	Bright sunshine (hrs)
		Max.	Min.	Mean			
24	11-17	33.1	19.8	26.5	52	34.3	6.9
25	18-24	30.7	18.6	24.7	64	53.0	6.9
26	25-01 July	29.5	19.6	24.6	74	139.6	6.7
27	02-08	27.9	19.6	23.8	81	84.8	7.1
28	9-15	27.5	18.5	23.0	81	126.3	6.0
29	16-22	26.5	19.5	23.0	88	231.6	2.1
30	23-29	28.4	20.7	24.6	84	38.4	5.0
31	30-5 Aug	26.9	20.4	23.7	90	482.8	2.4
32	6--12	28.0	18.6	23.3	78	67.3	5.4
33	13-19	28.3	17.5	22.9	84	31.0	5.6
34	20-26	27.5	19.8	23.7	83	152.3	4.6
35	27-2 Sep	27.5	19.5	23.5	88	159.6	4.5
36	3--9	26.5	18.3	22.4	85	110.0	4.7
37	10-16	27.4	18.6	23.0	79	23.4	3.7
38	17-23	27.4	18.6	23.0	83	52.7	5.6
39	24-30	25.9	14.6	20.3	68	32.9	5.3

APPENDIX-II

PARTICULARS	Quantity	Unit	Rate (Rs.)		Amount (Rs.)	
			2002	2003	2002	2003
INPUT/OPERATION						
A) Constant expenses for all treatments						
1) Seed						
Seed	20	kg	25	25	500	500
2) Fertilizer and their application						
Urea	260	kg	4.78	4.83	1242.8	1255.8
SSP	375	kg	3.57	3.38	1338.75	1267.5
MOP	67	kg	4.45	4.46	298.15	298.82
Mandays for fertilizer application and top dressing	8	mandays	55	60	440	480
3) Thinning and gap filling	2	mandays	55	60	110	120
4) Harvesting and cob removal	10	mandays	55	60	550	600
5) Shelling and threshing	11	mandays	55	60	605	660
6) Land revenue					50	50
7) Overhead charges					200	200
Total					5334.7	5432.12
B) Variable expenses under different treatments						
1) Land preparation and sowing under different tillage methods						
i) Conventional tillage						
a) Ploughing with tractor with two harrowing and planking	8	hours	150	165	1200	1320
b) Sowing with bullock pair	5	BPD	100	100	500	500
c) with 2 labour in conventional tillage	10	mandays	55	60	550	600
					2025	2220
ii) Zero tillage						
a) Sowing with power tiller operated zero-tillage maize planter	6	hours	80	80	480	480

b	Labour	5	mandays	55	60	275	300
						755	780
iii)	Raised seed bed						
a	Ploughing with tractor with one harrowing	6	hours	150	165	900	990
b	Planting with power-tiller operated raised seed bed planter	6.25	hours	80	80	500	500
c	Labour	4	mandays	55	60	220	240
						1620	1730
2)	Weed management treatments						
i)	MON 8435 (Acetachlor 0.75 kg/ha)	0.83	Lit.	400	400	332	332
ii)	MON 8435 (Acetachlor 1.25 kg/ha)	1.39	Lit.	400	400	556	556
iii)	HIMTAF (Atrazine 1.5 kg/ha)	3	Kg	300	300	900	900
iv)	GRAMAXONE (Paraquat 2.5 kg/ha)	3.125	Lit.	320	320	1000	1000
	Application cost with Maruyama sprayer						
i)	Petrol	2	liter	29.43	32.65	58.86	65.3
ii)	Labour	2	mandays	55	60	110	120
						168.86	185.3
	Output						
1)	Grain	1	qt	500	500	500	500
2)	Straw	1	qt	100	100	100	100

Appendix-III

b) Analysis of variance table

Source	Degree of freedom (d.f.)	
Replications	(r-1)	2
Main-plots	(m-1)	2
Error (a)	(r-1)(m-1)	4
Sub-plots	(s-1)	3
Main x sub-plots	(m-1)(s-1)	6
Error (b)	m(r-1)(s-1)	18

For comparing CD (P=0.05)

i) Two main plot treatments : $\sqrt{\frac{2EMS_a}{rs}} \times t_a$

ii) Two sub-plot treatments : $\sqrt{\frac{2EMS_b}{rm}} \times t_b$

iii) Two sub-plot treatment means at a given main plot treatment $\sqrt{\frac{2EMS_b}{r}} \times t_b$

iv) Two main plot treatments means either at a given sub-plot treatment or at different sub-plot treatments $\sqrt{\frac{2[EMS_a + (s-1) EMS_b]}{rs}} \times \frac{t_a \times EMS_a + t_b [(s-1) EMS_b]}{EM_a + (s-1) EMS_b}$

where,

t_a and t_b are the tabular t-values corresponding to error (a) and error(b) d.f. and a given level of significance, respectively.

EMS_a = Error (a) mean sum of squares

EMS_b = Error (b) mean sum of squares

m = Number of main plot treatments

s = Number of sub-plot treatments

a = Number of replications



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Title of the thesis : Integrated effect of tillage and weed control methods on weed dynamics and weed management in maize (*Zea mays* L.)

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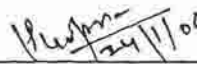
Total pages in thesis : 210

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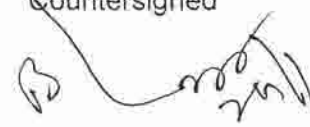
Major advisor : Dr. N.N. Angiras

ABSTRACT

To study the integrated effect of tillage and weed control methods on weed dynamics, growth, productivity and economics of maize crop, a field experiment consisting of twelve treatment combinations of three tillage methods (zero tillage, conventional tillage and raised seed bed) in main plots and four weed control methods (unweeded check, acetachlor 0.75kg/ha, acetachlor 1.25kg/ha and atrazine 1.5kg/ha) in sub plots was conducted at the Research Farm of Department of Agronomy, CSK Himachal Pradesh Krishi Vishvavidyalaya, Palampur during *kharif* 2002 and 2003. The experiment was laid out in split plot design with three replications. The soil of the experimental field was silty clay loam in texture, acidic in reaction and medium in available nitrogen, available phosphorus and available potassium. The maize hybrid variety PSCL-3438 was sown on 11th June, during both the years. In zero tillage and raised bed sowing was done with power tiller drawn zero till maize planter and raised seed bed planter, respectively. The results revealed that raised seed bed in integration with atrazine 1.5kg/ha (Pre.) or acetachlor 1.25 kg/ha (Pre.) being statistically at par with combination of conventional tillage and atrazine 1.5 kg/ha (pre.) controlled grasses and total weeds effectively with an average weed control efficiency of more than 82 per cent. However, the *Commelina benghalensis* was effectively controlled with zero tillage or conventional tillage in integration with atrazine 1.5 kg/ha or acetachlor 1.25 kg/ha with average weed control efficiency of more than 72 per cent. Consequently, integration of raised seed bed or conventional tillage with atrazine 1.5 kg/ha or acetachlor 1.25 kg/ha resulted in significantly better growth, higher yield attributes and grain yield of maize. In terms of economic parameters, while, conventional tillage in integration with atrazine 1.5kg/ha resulted in highest average gross returns (Rs. 55652) and net returns (Rs. 47068), the highest average benefit: cost ratio (5.82) was obtained with the combination of raised seed bed with acetachlor 1.25kg/ha.


Signature of the student with date


Signature of Major Advisor

Countersigned

Head of Department

