EVALUATION OF HERBICIDES AND RESOURCE CONSERVATION TECHNIQUES ON DURUM WHEAT (*Triticum durum*) CULTIVARS

BY

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COLLEGE OF AGRICULTURE

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Dedicated

To Indian Farmers

CERTIFICATE - I

This is to certify that this dissertation entitled, "**Evaluation of herbicides and resource conservation techniques on durum wheat (*Triticum durum*) cultivars"** submitted for the degree of **Doctor of Philosophy** in the subject of **Agronomy** of Chaudhary Charan Singh Haryana Agricultural University, Hisar, is a bonafide research work carried out by **Raj Kumar Jat,** Admn. No. **2004A13D** under my supervision and that no part of this dissertation has been submitted for any other degree.

The assistance and help received during the course of investigation have been fully acknowledged.

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CHAPTER-I

Introduction

In the recent years, most of the nations across the world particularly developing/under developed are confronting for maintaining sustained growth in food production to achieve food security at one end, while on the other hand, to avoid ecological degradation on account of over exploitation of natural resources so that rightful natural heritage for future generation can be preserved. Alike other parts of the world, India is also facing similar dilemma as day-by-day natural resources are being depleted to provide adequate shelter, food and other amenities to ever increasing population. This has necessitated renewed research efforts for development and dissemination of cost-effective and resource efficient sustainable technologies for improving productivity, thereby production of major crops or cropping systems without or least degradation of natural assets.

Wheat is second most important crop of India. The maximum hectarage under wheat in the country is occupied by bread wheat (*Triticum aestivum* L. emend Fiori and Paol) followed by *durum* wheat (*Triticum durum* Desf.) and the lowest hectarage under *dicoccum* wheat (*Triticum dicoccum* Schulub). India is the major producer of durum wheat in the world and three major groups of durums are cultivated viz., Punjab Durum (PD), Malwa Durum Irrigated (DMI) and Malwa Dry Durum (MDD). The cultivation of durum wheat in the country is very old but it was eliminated from the North-Western region due to susceptibility to yellow rust and lodging confining mostly to the central and peninsular regions under rainfed conditions. A breakthrough achieved in the development of rust resistance and high yielding varieties like PDW 215, PDW 233, DWL 5023, RAJ 1555, WH912 and WH 896, which made its cultivation possible in the North-Western plain region. In general, durum wheat is not preferred for bread, but is used to obtain various products like spaghetti, macaroni, noodles and vermicelli, halwa, upma, idli, dosa etc. Besides such value addition potentials, durum wheat possesses vitreous and extra hard grains, higher hectoliter weight, protein and pigment contents over bread wheat. Owing to possessing of above good features, better price in the market and resistance to Karnal Bunt disease have made it an export

commodity. Therefore, to popularize the cultivation of durum wheat, preliminary work on the agronomic aspects on durum wheat have been initiated but detailed studies on weed management have not been undertaken so far. Although, the component of weed flora remains same, but the competitive ability of durum wheat is relatively more than the bread wheat. The selectivity of different herbicides and different wheat types have not been studied and the differences in selectivity pattern would require a thorough study on durum wheat. Some of durum wheat varieties have been found susceptible to isoproturon but the sensitivity of other herbicides have not been established.

The diagnostic survey have indicated that the total factor productivity of rice-wheat system has gone down due to decline in soil productivity and second generation problems associated with weeds and other pests. Weeds such as *Phalaris minor* have developed resistance. Water table has gone down in some areas because of excessive pumping of water. The nutrient removal is not matched with nutrient addition. Air pollution is a problem due to burning of crop residues. All these factors have put a question mark on the profitability, productivity and sustainability of rice-wheat cropping system. That would mean, farmers need technologies that are more favourable for lowering their cost and improving their returns. They also need technology which are more favourable to environment and have less deleterious effect on natural resources. One way to look at these issues is to work on technologies that can conserve resources at reasonable cost. New technologies like zero tillage and bed planting are being promoted in rice-wheat areas of Indo-Gangetic plains. While, zero tillage is being practiced on large scale, bed planting is yet to be perfected. This technology has a potential advantage especially in regard to water saving. Other benefits including the possibilities of mechanical weeding, fertilizer placement and bolder grain production are also important for sustained production of wheat in rice-wheat cropping system.

Since variation in planting system modifies macro and microenvironment to which plants are exposed, there is a need to identify most appropriate variety best suited/adaptable for each of the planting system. It has been reported that both *aestivum* and *durum* wheat varieties differ in physio-morphological traits, thus there is need to identify most appropriate

one from the existing recommended varieties of durum wheat species under prevailing conditions in context to changes in planting pattern.

Keeping these factors in view, it was considered appropriate to carry out a field experiment entitled "Evaluation of herbicides and resource conservation techniques on durum wheat (*Triticum durum*) cultivars" with the following objectives:

1. To assess the agronomic and economic feasibility of different resource conservation techniques in durum wheat
2. To evaluate the effect of different herbicidal treatments and resource conservation techniques on weeds, crop growth, yield and yield attributes and nutrient uptake of durum wheat,
3. To assess the weed competing ability of durum wheat cultivars under different resource conservation techniques

CHAPTER-II

Review of Literature

A brief account of work carried out at different locations in India and abroad pertaining to the problem under study has been presented in this chapter. The relevant work done is reviewed under the following heads:

2.1 Weed studies

2.1.1 Major weed flora of wheat

2.1.2 Losses caused by weeds in wheat

2.2 Effect of herbicides

2.2.1 Effect of different herbicides alone in wheat

2.2.2 Effect of herbicide combinations in wheat

2.3 Performance of wheat cultivars and their competitive ability against weeds

2.4 Resource conservation techniques(RCTs)

2.4.1 Zero tillage (ZT)

2.4.2 Furrow irrigated raised bed system (FIRBS)

2.1 Weed Studies

2.1.1 Major weed flora of wheat

Wheat fields are generally infested with both grassy and broadleaf weeds depending upon soil type, environmental conditions like temperature, humidity, moisture availability, cultural practices and crop rotations. Adoption of high yielding dwarf wheat varieties coupled with increased use of fertilizers and improved irrigation facilities have resulted in shifts in weed flora. In the crop-land ecosystem, a large variety of undesirable weeds reduce the crop productivity, as they compete with crop for resources (Bleasdale, 1960). The relative balance and importance of weed species in particular area may be affected by changing cropping pattern and management practices *viz.*, tillage, fertilizer use, sowing, irrigation,

invasion of new weed species and by the application of modern weed control practices (Muzik, 1970).

The predominant weed flora recorded in wheat fields are *Phalaris minor, Avena ludoviciana, Avena fatua, Chenopodium album, Melilotus alba, Melilotus indica, Anagallis arvensis, Asphodelus tenuifolius, Medicago denticulata, Medicago hispida, Lolium temulentum, Coronopus didymus, Lathyrus aphaca, Cirsium arvense, Fumaria parviflora, Cynodon dactylon, Vicia sativa, Vicia hirsuta, Cyperus rotundus, Rumex dentatus, R. retroflexus, Spergula arvensis* and *Trifolium flagiferum* (Malik *et al*. 1989 ; Kurchania *et al*., 1993; Saraswat, 1993; Singh *et al*., 1995; Singh *et al*., 2003a and Punia *et al*., 2006a).

In India, with the introduction of high yielding dwarf wheat varieties along with intensive cultivation of cereals, the population of grassy weeds like little seed canary grass (*Phalaris minor* Retz.) and wild oat (*Avena ludoviciana* Dur.) have increased at a much faster rate replacing broadleaf weeds in wheat fields (Malik and Singh, 1993; Singh *et al*., 1995; Balyan and Malik, 2000). The shift in weed flora in favour of wild oat and some broadleaf weeds has further intensified due to changes in input availability and crop sequences in wheat. The problem of wild oats is more severe in irrigated, well drained and light textured soils. Balyan and Malik (1991) also reported the infestation of *Avena ludoviciana* Dur. in the areas where rice-wheat rotation is not being followed. Panwar *et al*. (2000) also reported the increasing problem of wild oat in South-Western Haryana.

2.1.2 Losses caused by weeds

Infestation of weeds appears to be one of the most important factors which limits the crop yield. Weeds, not only cause significant losses in quantity, but the quality of crop is also influenced. The grain yield loss in wheat caused by weeds varies between 10 to 52 percent depending upon the nature and intensity of weeds as well as duration of crop weed competition, climate, agronomic practices and relative emergence pattern of weeds in relation to crop (Gill and Brar, 1975; Gill, 1979; Bhan and Singh, 1979; Bhan and Malik, 1983; Gupta, 1984; Malik *et al*., 1988; Pandey and Singh, 1994).

Walia and Gill (1985) reported that among grassy weeds, *P. minor* is a serious threat to wheat cultivation. Even moderate infestation of *P. minor* alone causes 15-20 per cent reduction in grain yield of wheat. Bhaskar and Vyas (1988) reported that the growth of wheat plant was severely reduced

due to infestation by *C. album* and it also significantly reduced the number of grains and grain weight per plant. Brar and Walia (1989) reported that depending upon the intensity of wild oat, reduction in grain yield of wheat was observed to an extent of 15 to 50 percent. Malik and Singh (1993) stated that in areas like Karnal and Kurukshetra, sometimes wheat crop is harvested immature and used as fodder because of intensive population and excessive growth of grassy weeds. They also reported that a population of 200-300 plants m^{-2} of *P. minor* resulted in complete crop failure at farmers fields in Haryana State.

Dwivedi *et al*. (1996) stated that weeds compete with wheat for nutrients, soil moisture, sunlight and space. Depending upon nature and intensity of weed flora, 30 to 50 per cent reduction in grain yield of wheat is quite common. Kurchania *et al*. (2000) found that the infestation of broad leaf weeds in wheat crop may lead to the reduction of grain yield to the tune of 7-50 per cent depending upon their density. The mixed population of *P. minor* and *C. album* caused a 66 per cent reduction in wheat grain yield in weed-infested plots, whereas *C. album* alone caused a 22 per cent reduction in wheat yield (Singh and Singh, 2005). Presence of weeds throughout growing season caused 44.6 per cent (Punia *et al*., 2006b) and 31-34 per cent (Yadav *et al*., 2006) reduction in grain yield as compared to weed free check in Hisar conditions. Johari *et al*. (1992), Mishra and Gautam (1995) and, Bharat and Kachroo (2007) reported that N, P and K uptake by weeds was lower under herbicide treated plots due to less dry matter accumulation by weeds.

2.2 Effect of herbicides

In areas where labour constraints exist during the peak weed control period, herbicide use is increasing. Moreover, due to industrialization in the state, small family norms, and increase in literacy, farmers put strict focus on herbicides. Under certain specific situations where weeds are very difficult to remove manually, the use of herbicides becomes essential or unavoidable.

2.2.1 Effect of herbicides alone

2.2.1.1 Clodinafop

Clodinafop is an excellent herbicide to control grassy weeds particularly *P. minor* and *A. ludoviciana* (Dhaliwal *et al*., 1998; Bhan *et al*., 1998). Use of this herbicide in rotation has been suggested by Malik (1999) to counter the likely problem of cross-resistance in *P. minor*. Upto 100 per cent

control of this weed has been observed without any toxicity to the wheat crop with the applications of clodinafop at 60 g ha^{-1} (Brar *et al*., 1999a) and at 80 and 120 g ha^{-1} (Walia *et al*., 1998) at Ludhiana.

Saini and Singh (2001) reported that application of clodinafop at 0.15 kg ha^{-1} and 0.10 kg ha^{-1}, significantly lowered the weed dry matter, produced higher number of effective tillers per metre row length, grains per spike, 1000-grain weight and hence higher yield of wheat. Singh *et al*. (2002a) reported that the higher dose of clodinafop (50 and 60 g ha^{-1}) provided more effective control of grassy weeds and higher grain yield of wheat as compared to its lower dose (40 g ha^{-1}). Similar results were obtained at Hisar, by Kumar *et al*. (2000) and Yadav *et al*. (2004d) and at Ludhiana, by Chahal *et al*. (2003) and Walia *et al*. (2003). Tomar and Vivek (2003) recorded a weed control efficiency (WCE) of 97.3 per cent, higher number of effective tillers per plant (5.42) and higher grain yield of wheat (5507 kg ha^{-1}) with the application of clodinafop at 60 g ha^{-1} at Gwalior. Higher bioefficacy of clodinafop at 60 g ha^{-1} against grassy weeds but ineffectiveness against broad leaf weeds was also reported by Yadav *et al*. (2004c).

Shahida *et al*. (2005) reported in Pakistan that Topic 15WP (clodinafop-propagyl) significantly reduced the fresh weed biomass (1938 kg ha^{-1}) as compared to weedy control (5313 kg ha^{-1}) in wheat. Application of clodinafop at 60 g ha^{-1} provided efficient control (95-100 per cent) of grassy weeds and gave grain yield equal to weed free treatment as observed by Punia *et al.*(2006b) at Hisar, Shukla and Mishra (2006) at Pantnagar and Jain *et al.*(2006b) at Jabalpur. Bharat and Kachroo (2007) reported that it effectively reduced the density and dry matter accumulation by grassy weeds and increased the effective tillers and grain yield of wheat.

2.2.1.2 Fenoxaprop

Mirkamali (1993) evaluated fenoxaprop at 0.075 kg ha^{-1} for the control of grassy weeds such as *P. minor*, *A. ludoviciana* and *P. brachystrachys* in wheat, and observed upto 90-100 per cent control of these weed species. Montazeri (1994) reported effectiveness of this herbicide at 75-90 g ha^{-1}.

A dose range of fenoxaprop from 80-140 g ha^{-1} reduced the biomass of *P. minor* significantly. However at 140 g ha^{-1}, weed control, grain yield and yield attributes of wheat were statistically at par with weed free check (Singh *et al*., 1998b). At Ludhiana, Walia *et al*. (1998) observed complete control of *P. minor* by post-emergence application of fenoxaprop at 80 g ha^{-1} while

Brar *et al*. (1999b) observed complete control with a dose of 100 g ha^{-1} and consequently higher grain yield of wheat.

The use of fenoxaprop in rotation with other herbicides was suggested by Malik (1999) to avoid the likely problem of cross resistance in *P. minor.*

Application of this herbicide at 100 g ha^{-1} (Brar *et al*., 2002), 120 g ha^{-1} (Malik and Yadav, 1997) provided effective control of isoproturon resistant biotypes of *P. minor.* An increase of upto 200 per cent in the grain yield of wheat when compared with the weedy check was observed with the use of this herbicide at Karnal (Chhokar and Malik, 2002).

Singh and Singh (2002) while investigating the effect of fenoxaprop for weed control in wheat at Pantnagar, observed that higher application rates (80 and 90 g ha^{-1}) of the herbicide were more effective than lower doses in controlling grassy weeds and therefore, resulting in higher grain yield of wheat. Similar results were obtained by Singh *et al*. (2003a). The WCE to the tune of 97.7 per cent, higher number of effective tillers and grain yield of wheat were recorded with the application of fenoxaprop at 80 g ha^{-1} by Tomar and Vivek (2003) at Gwalior.

Application of fenoxaprop at 120 g ha^{-1} reduced the population of grassy weed (*A. ludoviciana* and *P. minor*) but was ineffective against broad leaved weeds (Yadav *et al*., 2004c) and also resulted in 82-95 per cent reduction in the dry weight of resistant as well as susceptible biotypes of *P. minor* collected from different locations in Haryana (Yadav *et al*., 2004b). Banga and Yadav (2004) found that application of fenoxaprop at 120 g ha^{-1}, being superior to its lowest dose and at par with its highest dose in terms of weed density, was very effective against *A. ludoviciana* but was ineffective against *R. retroflexus* and *C. didymus* in wheat. Singh and Singh (2005) reported that application of fenoxaprop-p-ethyl at 80 and 100 g ha^{-1} with Power Activator increased its efficacy against grassy weeds in wheat plots. Dahiya *et al*. (2005), Punia *et al*. (2006b) and, Bharat and Kachroo (2007) reported that fenoxaprop at 120 g ha^{-1} significantly reduced the population and dry matter of grassy weeds.

2.2.1.3 Sulfosulfuron

Sulfosulfuron was introduced for selective control of annual and perennial grasses and annual broad leaf weeds in wheat at 10 and 20 g ha^{-1} as post emergence (Euler *et al*., 1994).

In India, application of sulfosulfuron at 20-40 g ha^{-1} was found effective against broad leaf and grassy weeds particularly isoproturon resistant *P. minor* at Hisar, Pantnagar and IARI, Delhi (Shukla, 1996). At Jabalpur, sulfosulfuron at 45 g ha^{-1} significantly reduced the population and dry matter of grassy and broad leaf weeds (Dixit *et al*., 1998).

Use of sulfosulfuron was suggested by Malik (1999) to avoid the likely problem of cross resistance to control *P. minor* in Haryana. Walia *et al*. (1999) reported cent percent control of this weed by the application of sulfosulfuron at 25 g ha^{-1} in wheat at Ludhiana. Field studies undertaken by Malik *et al*. (2000e) at Hisar revealed that sulfosulfuron was only marginally effective (25-46 per cent) at 15, 20 or 25 g ha^{-1} against *C. album* and 33-55 per cent against *R. retroflexus*, resulting in poor grain yield of wheat while Kumar *et al*. (2003) reported excellent control of *P. minor*, *R. retroflexus, C. album, A. arvensis* and *M. indica* with the application of sulfosulfuron at 20 g ha^{-1}.

Singh *et al*. (2003b) while investigating the dose and stage of application of sulfosulfuron at Pantnagar observed that weed control efficacy at 20 g ha^{-1} was less than at 25 g ha^{-1}. Application of the herbicide at both the doses, before first irrigation or 20 days after sowing provided less weed control and there was adverse effect on grain yield of wheat.

Banga *et al*. (2003) reported that sulfosulfuron at 25 g ha^{-1} was superior to its lower doses (15 and 20 g ha^{-1}) in reducing the population and dry weight of weeds (87.3 per cent). They further added that effective tillers, spike length, number of grains per spike, 1000-grain weight and ultimately grain yield of wheat were at par with that obtained in weed free plots. Similar results were revealed by Yadav *et al*. (2004d) at Hisar. Pandey and Kumar (2005) at Samastipur, Bihar and Bisen *et al*. (2006) at Varanasi (UP) reported that, the application of sulfosulfuron (33.3 g ha^{-1}) effectively controlled the complex weed flora in wheat. Similarly, Punia *et al.* (2006b) at Hisar recorded 70-75 per cent control of grassy and 43-50 per cent of broadleaf weeds in wheat with 25 g ha^{-1} sulfosulfuron. Sulfosulfuron at 20, 25 and 30 g ha^{-1} being statistically at par with each other provided 80-96 per cent and 75-86 per cent control of grassy and broad leaf weeds, respectively (Yadav *et al.*, 2006). Shukla and Mishra (2006) recorded 54-67 per cent WCE with sulfosulfuron (25 g ha^{-1}).

2.2.1.4 Isoproturon

Substituted phenyl urea herbicides including isoproturon were introduced in 1978 for the control of grassy weeds. Isoproturon was largely accepted by the farmers and became a major input in wheat production. This herbicide has stabilized the production of wheat by shielding at least a quarter of loss in the potential yield of wheat (Malik and Singh, 1993). Isoproturon belong to the family of substituted ureas, which is widely known to inhibit hill reaction of photosynthesis. It enters in the plant system mainly by roots, although some quantities are absorbed through their leaves. The primary site of action of this herbicide is located in photosystem II involving the oxygen evolution step. It kills the weeds by inhibition of photosynthesis production of plant sugars and indirectly through inhibition of hill reaction (Ware, 1978). It controls grassy weeds and many broadleaf weeds during germinating and after emergence. It acts residually for 2-3 months (Cimerman and Babnik, 1999).

In last two decades, isoproturon was recommended and widely used by the farmers for the successful control of *P. minor* in wheat. Post- emergence spray of isoproturon at 0.94 kg ha^{-1} increased wheat yield by 43 per cent over weedy check (Gill *et al.,* 1982). Due to continuous use of isoproturon, in rice-wheat cropping system over two decades, *P. minor* has become resistant to it (Malik and Singh, 1993; Yadav *et al.,* 1996; Walia *et al.,* 1997).

It was noticed that early post-emergence application of isoproturon at around 30 days after sowing in wheat was the best time from the view point of convenience of crop selectivity and weed control efficiency (Mani, 1983). Contrarily, Singh and Sharma (1983) reported that application of isoproturon either as pre or post-emergence was equally effective against *P. minor* and broadleaf weeds. Reduction in weed dry weight and a yield increment of wheat from 27.9 to 42.9 q ha^{-1} has been reported with the application of isoproturon at 1.0 kg ha^{-1} (Prasad, 1985) and it gave mean weed control efficiency of 85.2 per cent. Prakash *et al.* (1986) reported that application of isoproturon at 0.75 kg ha^{-1} five weeks after sowing of wheat gave 42.4 q ha^{-1} grain yieid compared to 34.6 q ha^{-1} recorded under weedy check. At IARI New Delhi, Dinkar and Ahuja (1987) observed that isoproturon at 0.33, 0.55 and 0.75 kg ha^{-1} applied before and after first

irrigatio(3 weeks after sowing) significantly reduced the population of *P. minor* as compared to untreated control.

In an another study in Haryana, Phogat *et al.,* (1991) reported that application of isoproturon at 0.75 kg ha^{-1} tended to reduce weed dry matter by 58.5 per cent and corresponding increase in wheat yield by 27.5 per cent compared to weedy check (75.1g m^{-2} and 35.1 q ha^{-1}, respectively). Isoproturon at 0.75 kg ha^{-1} alone provided good control of common lambsquarter, yellow sweet clover and wild seed canary grass (Kumar and Singh, 1994). Gogoi and Kalita (1995) observed 25 per cent reduction in weed population due to application of isoprotufon at 0.75 kg ha^{-1} as post-emergence spray.

At Palampur (H.P.), Angiras and Sharma (1996) reported that application of isoproturon at 1.5 kg ha^{-1} reduced the weed dry matter as compared to control. Further, they reported more number of effective tillers m^{-2}, grains $spike^{-1}$, 1000- grain weight and higher grain yield of wheat due to application of isoproturon. In an another study carried out at Hisar, isoproturon applied at 20 DAS (before irrigation) enhanced the grain yield of wheat to the extent of 30.4 per cent over weedy check control (Yadav *et al.,* 1996). Tiwari and Vaishya (2004) reported that isoroturon was less effective as compared to clodinafop on grassy weeds.

2.2.1.5 Pendimethalin

Pendimethalin belongs to dinitroaniline group of herbicide and it effectively controls the monocot and dicot weeds but mainly used to control germinating monocot weed species. Reports of several studies (Bhan *et al.*, 1979, Gill *et al.,* 1979 ; Gill and Brar, 1982) revealed that pre-emergence application of pendimethalin gives good control of weeds.

Pandey (1981) reported that pendimethalin (pre-emergence) at 1.0 kg a.i. ha^{-1} gave the highest grain yield of both timely and late sown wheat and better control of *P. minor* and other weeds as compared to isoproturon (1.0 kg ha^{-1}) and other herbicides. Application of pendimethalin resulted in the lowest *P. minor* population and proved significantly superior to hand weeding and metoxuron, but was at par with isoproturon (Pandey, 1981). Reduction in weed density and dry matter production due to application of pendimethalin

have also been reported by Pandey and Singh (1984). Mustafee (1989) found that pre-emergence treatments of pendimethalin at 1.0-1.5 kg ha^{-1} rendered excellent control of weeds in wheat and yielded 11.6-13.8 q ha^{-1} extra yield over unweeded control as against 10.8-12.5 q ha^{-1} increase by isoproturon at 0.75- 1.0 kg ha^{-1}.

Pendimethalin at different rates resulted in significant reduction in weed population and gave better yield of wheat as compared to other treatments (Singh *et al.*, 1991). Mustafee (1991) reported that pre-emergence application of pendimethalin gives very good weed control, including *P. minor.* According to Phogat *et al.* (1991) application of pendimethalin at 1.25 kg ha^{-1} as pre-emergence was comparable to isoproturon in terms of grain yield of wheat.

Yaduraju and Ahuja (1995) working on resistant population of *P. minor,* reported that there was no evidence of cross resistance to pendimethalin in population resistant to isoproturon. Further, pendimethalin applied as pre-emergence singly or in mixtures resulted in complete kill of the resistant population of *P. minor.* Pre-emergence application of pendimethalin at 1.5 kg ha^{-1} enhanced the grain yield of wheat to the extent of 31.9 per cent over weedy check control and attributed it to the improvement in the number of effective tillers and grains $spike^{-1}$ over weedy check (Yadav *et al.*, 1996). Similarly, Singh and Singh (1996) indicated that pendimethalin at 1.0 kg ha^{-1} alone improved the yields significantly due to decrease in weed density and weed dry weight, higher spikes m^{-2}, ear length, grains ear^{-1} and test weight compared to two hand weedings. Further, it was concluded by Panda *et al.* (1996) that integrated weed management consisting of pre-emergence application of pendimethalin at 1.0 kg ha^{-1} and manual weeding at crown-root initiation might be recommended for maximum weed control efficiency and wheat yield.

Dixit and Bhan (1998) observed that pendimethalin application as pre-emergence was inferior to isoproturon and the weed population and dry matter accumulation in the plots treated with pendimethalin were significantly higher than isoproturon at 1.0 kg ha^{-1} applied just before first irrigation. Contrarily, Singh and Khole (1998) reported that density, dry matter and growth rate of

P. minor were effectively minimized by the pre-emergence application of pendimethalin at 1.0 kg ha^{-1}.

Shukla and Mishra (2006) at Pantnagar reported that pendimethalin at 1.0 kg ha^{-1} as pre-emergence was effective (WCE 62 per cent) against grassy and non grassy weeds resulting in lower total weed density and higher grain yield which was statistically at par with sulfosulfuron 25 g ha^{-1} and hand weeding at 30 DAS. Chauhan *et al*. (2007) in Australia proved that pendimethalin was effective in reducing the number of plants, spikes, dry matter, and seed production of rigid ryegrass in wheat.

2.2.1.6 2,4-D

Chemical weed control in wheat got a spurt with the introduction of phenoxy herbicides such as 2,4-D during the second world war. 2,4-D has been found effective against broadleaf weeds (Richardson, 1977; Singh and Sharma, 1984). This herbicide belongs to phenoxyalkanoic acid group. It is a synthetic growth substance which exhibits auxin like properties. At lower doses it kills the weeds slowly dew to aberrant growth (Hanson and Slife, 1969).

Singh and Malik (1994) reported that 2,4-D sodium salt at 0.75 kg a.i. ha^{-1} provided more than 90 per cent control of *C. album* whereas, the control of *L. aphaca* was only 20 to 68 per cent. However, 2,4-D sodium salt at 100 g ha^{-1} could provide significant reduction in the population and dry weight of *L. aphaca.* Pandey and Singh (1994) reported that application of 2,4-D at 0.6 kg a.i. ha^{-1} in wheat crop reduced population of *M. indica, C. album* and *A. arvensis* by 50, 100 and 100 per cent, respectively. Nanda and Patro (1996) found that application of 2,4-D Na salt at 1.5 kg a.i. ha^{-1} significantly reduced the weed population and dry matter at 90 DAS. Correspondingly, the wheat yield increased from 15.8 q ha^{-1} (control) to 18.5 q ha^{-1} through 2,4-D application. Agrawal and Jain (1998) found that application of 2,4-D Na salt (0.5 kg ha^{-1}) as post emergence was effective in controlling *Medicago denticulata, C.album, Digitaria abscendens* and total weed population compared to weedy check but failed to control *Cynodon dactylon, Cyprus rotundus* and *Cichorium intybus*. They also recorded significantly higher wheat grain yield (29.5 q ha^{-1}) compared to weedy check (20.5 q ha^{-1}). Application of 2,4-DE (0.5 kg ha^{-1}) and 2,4-D Na salt (0.5 kg ha^{-1}) at 30 DAS recorded significant control of *Medicago hispida, M. alba, Trifolium*

flagiferum, Cichorium intybus, C. album, Anagalis arvensis and *Vicia sativa* (46, 63, 32, 59, 98, 54 and 78 per cent over weedy control, respectively) at 15 days after spraying but failed to control *Indigofera linifolia* (Kurchania *et al.,* 2000). Sardana *et al.*(2001) found that post emergence application of 2,4-D at 0.5 kg ha^{-1} significantly reduced population of broadleaf weeds, their dry matter and registered 58.6 per cent weed control efficiency at 60 DAS. Application of 2,4-D at 500 g ha^{-1} effectively controlled the broadleaf weeds i.e. *C. album , M. indica* and *R. retroflexus* in wheat (Singh and singh,2005; Punia *et al.*, 2006 b ; Bharat and Kachroo, 2007).

2.2.1.7 Carfentrazone

Carfentrazone-ethyl has shown a high degree of activity on some of the harder to control broadleaf weeds such as *Malwa parviflora*, *Echium plantagineum* and *Trifolium subterraneum* and has many unique benefits, however, one of significant interest to the farming community is that it has no soil carryover and, therefore, no restrictions on succeeding crop, a particular benefit when using prior to sowing legumes or oilseeds (Cumming *et al*., 2002). Khan *et al*. (2003) based on his weed control studies in Pakistan, stated that the lowest weed density and maximum grain yield were recorded upon treatment with carfentrazone-ethyl ester at 13 g ha^{-1} in wheat.

Singh *et al*. (2004) reported that weed control efficiency of carfentrazone-ethyl at 20 g ha^{-1} ranged from 90.6 to 100 per cent and at 20 and 25 g ha^{-1} had better efficacy than 2,4-D (500g ha^{-1}) and was comparable with metsulfuron- methyl (4g ha^{-1}) against *C. album, M. alba, M. indica, L. aphaca, V. sativa, M. denticulata* and on wheat yield.

Aguilar *et al*. (2004) reported in Mexico that the carfentrazone accelerated the activity of nicosulfuron against broadleaf weeds, therefore, at 7 days after treatment, more than 90 per cent control of all weeds was obtained in maize. Santos *et al*. (2005) found that yield of wheat decreased with the application of 30-120 g ha^{-1} carfentrazone-ethyl at 35 days after flowering and at 10-30g ha^{-1} carfentrazone-ethyl advanced the harvesting date by 7 days. Brar *et al*. (2005) reported that application of carfentrazone 25g ha^{-1} produced significantly higher grain yield than the recommended treatment, i.e., 2,4-D in wheat. Punia *et al.* (2005) found that dry weight of weeds in carfentrazone treated plots was significantly lower than metsulfuron and 2,4-D treated plots. Punia *et al*. (2006a) found 92-100 per cent control of

broadleaf weeds including hard to control weeds *Malwa parviflora* and *C. arvensis* with carfentrazone.

2.2.1.8 Metsulfuron-methyl

Metsulfuron-methyl has been commercialized in Europe and North America for post-emergence broadleaf weed control in cereals (Diog *et al*., 1983). They found that metsulfuron was selective as pre and post-emergence to wheat with foliar and root activity at 4-8 g ha^{-1} and controlled a broad spectrum of weeds. Bianchi *et al*. (1988) recommended application of this herbicide at 8-10 g ha^{-1} for effective weed control.

In India, Pandey and Singh (1994) observed that metsulfuron-methyl applied at 4-8 g ha^{-1} effectively controlled all the broad leaf weeds and paralyzed the growth of grass weeds for a month and at 8 g ha^{-1} it resulted into statistically superior grain yield with higher test weight of wheat. Sharma and Sharma (1997) also reported effective control of all broad leaf weeds especially *Veronica persica* by metsulfuron-methyl at 4 g ha^{-1} at Bajaura (H.P.).

Application of metsulfuron-methyl at 5 and 10 g ha^{-1} provided effective control of *Rumex spinosus* at Ludhiana (Sidhu *et al*., 2000) while application at 4 and 6 g ha^{-1} controlled *Rumex retroflexus* to the tune of 97-98 per cent at Hisar (Balyan and Malik, 2000). Kurchania *et al*. (2000) revealed efficient control of *C. album, A. arvensis, M. alba, V. sativa, C. intybus,* but not of *P. minor* with metsulfuron-methyl at 2 and 4 g ha^{-1}. Sharma and Pahuja (2001) reported that metsulfuron-methyl at 4 g ha^{-1} was effective against broad leaf weeds only. Chopra *et al.* (2001) observed that metsulfuron-methyl at 0.008 kg ha^{-1} controlled the weed *C. arvense* completely. It significantly increased the grain yield of wheat over the unweeded control at Baraut (U.P.).

Yaduraju and Das (2002) observed excellent control of broad leaf weeds especially *C. arvense* with the application of metsulfuron-methyl at 4 g ha^{-1} with surfactant. Metsulfuron at 2 g ha^{-1} + 0.2% surfactant, metsulfuron at 2.5 g ha^{-1} and 2,4-D Na at 400 g ha^{-1} being significantly better than 2,4-D Na at 200 g ha^{-1}, were equally effective against the broadleaf weeds, while these were inferior to metsulfuron at 4 g ha^{-1} in two years of study (Yadav *et al.,* 2006).

2.2.2. Herbicidal combinations in wheat

The spectrum of weed flora is changing in such a way that many types of weeds infest wheat crop together. No single herbicide will be able to control all types of weeds without crop injury because of higher dose requirements for increasing the spectrum of weed kill. Some of the problem weeds like *Cirsium arvense* and *Convolvulus arvensis* are not controlled by grass killing herbicides and continuous use of isoproturon has increased the intensity of *Anagallis arvensis* in the treated fields (Malik and Singh, 1993). Such problem of complex weed flora can only be tackled by combining grass killing herbicides with broadleaved weed killers. The use of herbicide mixture with synergistic effects can reduce the total rate of herbicide use thereby reducing the cost of weed management, arresting weed shifts, preventing herbicide resistance in weeds and facilitating improvement in overall weed management (Rao, 1993).

Hoe 6001 (fenchlorozole-ethyl + fenoxaprop-p-ethyl) applied at 1.0, 1.25, 1.5 kg ha^{-1} in winter wheat, early and late spring wheat, respectively provided 90 per cent control of *Avena* spp. and good control of other annual grasses (Foster *et al*, 1993). Tank mixture of Grotsil (0.20 g ha^{-1}) and Puma super (fenchlorozole + fenoxaprop-p-ethyl) (1.0 kg ha^{-1}) applied at full tillering before stem elongation completely eliminated *Gallium aparine* and *A. fatua* in winter wheat (Khotulev, 1995).

Kaur *et al*. (1996) revealed that post-emergence application of isoproturon + metsulfuron–methyl 750 + 5 g ha^{-1} and 750 + 7.5 g ha^{-1} were at par with each other and significantly reduced the population of broadleaf weeds and dry matter production of wild oat. Jat *et al*. (2003) reported that tank mix application of isoproturon + metsulfuron-methyl (750 + 4 g ha^{-1}) provided effective weed control and resulted in significantly higher grain yield of wheat.

Singh *et al*. (2002a) revealed that tank mixture of clodinafop and isoproturon caused reduction in the density of *C. album* and *M. alba* and resulted in significantly higher grain yield of wheat at Pantnagar but mixing of isoproturon at 500 g ha^{-1} was less effective than at 750 g ha^{-1}. Jat (2004) at Hisar reported that application of clodinafop, fenoxaprop and sulfosulfuron followed by metsulfuron effectively controlled the complex weed flora and reduced the dry matter accumulation and nutrient (N, P and K) uptake by weeds. These treatment combinations increased the dry matter accumulation,

nutrient uptake, yield attributes and yield of wheat crop over weedy check. Singh *et al.* (2004) found that the weed control efficacy of Affinity, a ready mix formulation of isoproturon and carfentrazone, at 1.75 and 2.0 kg ha^{-1} was higher than at 1.5 kg ha^{-1} against *C. album* and Affinity at 2.0 kg ha^{-1} was comparable with 1.33 kg isoproturon, 60 g clodinafop and 20 g sulfosulfuron ha^{-1} in controlling *P. minor* in wheat.

Singh and Singh (2005) reported that clodinafop-propargyl was compatible with metsulfuron-methyl and carfentrazone-ethyl (tank mixture) with regard to the control of *P. minor* and *C. album* in wheat. Fenoxaprop-P-ethyl was compatible with carfentrazone-ethyl but not with metsulfuron-methyl. Clodinafop and fenoxaprop were not compatible with 2,4-D.

Howatt *et al*. (2005) found that carfentrazone-ethyl did not adversely affect the control of wild oat (*A. fatua*) or yellow foxtail (*Setaria glauca*) by grass killing herbicides whereas carfentrazone-ethyl alone caused 21 per cent wheat injury at 3 days after treatment but when applied with fenoxaprop-p-ethyl or clodinafop-propargyl, resulted in less wheat injury compared with carfentrazone-ethyl alone.

Shahida *et al*. (2005) reported in Pakistan that Affinity 50 WDG (isoproturon+carfentrazone ethyl ester) significantly reduced the fresh weed biomass (1875 kg ha^{-1}) compared to weedy control (5313 kg ha^{-1}) in wheat. Combinations of sulfosulfuron and 2,4-D Na (1:10) at 400 and 600 g ha^{-1}, being superior to the lower dose (200 g ha^{-1}), significantly reduced the dry weight of both grassy (91-98 per cent) and broadleaf (89-100 per cent) weeds, but yielded significantly lower than weed-free control(Yadav *et al*., 2006).

Application of 2,4-D (Punia *et al*., 2006 b) and Metsulfuron (Yadav *et al.*, 2002 b, Punia *et al*., 2006 b and Jat *et al*., 2007) as tank mixture or one week before application of clodinafop and fenoxaprop reduced the efficacy of these herbicides against *A. ludoviciana* and *P. minor*. Post emergence application of clodinafop at 60 g ha^{-1} *fb* 2,4-D significantly reduced the population and dry matter of weeds and increased the grain yield of wheat (Jain *et al.*, 2006).

In another study, Jain *et al.* (2007) reported that application of clodinafop followed by 2,4-D was significantly superior in reducing weed dry weight over isoproturon + 2,4-D and weedy control. Significantly higher grain yield was recorded under clodinafop followed by 2,4-D (4385 kg ha^{-1}), than isoproturon+2,4-D (2309 kg ha^{-1}). The treatments fenoxaprop + metribuzin,

sulfosulfuron + 2, 4-D, clodinafop + metsulfuron, isoproturon + 2,4-D and metribuzin (175 or 200 g ha^{-1}) significantly reduced density, dry matter accumulation by grassy and broadleaf weeds besides reducing N uptake by weeds. While isoproturon + 2,4-D proved to be the most economical among the herbicidal treatments (Bharat and Kachroo, 2007).

2.3 Performance of wheat cultivars and their competitive ability against weeds

The morphological features of a cultivar play an important role in crop-weed competition. A quick growing and early canopy covering cultivar competes better against weeds (Verschwele and Niemann, 1996).Due to differential growing habits of different wheat cultivars, their smothering potential on weeds particularly on *Phalaris minor* would be variable and these will decide the fate of *P. minor.* Lemerle *et al* (1996) suggested that for a wheat variety to be suppressive on weeds it should have rapid germination and quick initial growing habits with more tillering capacity and leaf area.

Tall growing wheat genotypes had a considerable suppressive effect on growth and development of weeds and caused more reduction in density, height and total dry matter accumulation of *P. minor, C. album* and *M. indica* than dwarf varieties, which allowed the vigorous growth of these weeds (Gill and Mehra, 1981). Studies at PAU, Ludhiana have indicated *P. minor* dry matter accumulation and population was minimum in taller genotypes and maximum in dwarf genotypes showing that tall genotypes of wheat had marked smothering effect on *P. minor* (Anonymous, 1984). Ramsel and Wicks (1988) reported that short-strawed cultivars had about four times as many as annual grass weeds just before harvest than taller cultivars and shorter cultivars provided less competition for such weeds. However, Malik *et al.* (1984) concluded that neither of two-gene dwarf varieties including HD 2009 and WH 157 significantly affected the dry matter accumulation by *P. minor* at any growth stage of wheat.

Brar and Singh (1997) obtained 23.4 and 19.1 per cent higher grain yield with bread cultivars (HD 2329 and WH 542) over *durum* wheat cultivar (PDW 34). This may be attributed to their height, dry matter production and more number of tillers, which resulted in great suppression of *P. minor.* Cristensen (1994) recorded same level of weed control in most weed

suppressive varieties of winter wheat with lower dose of herbicides and in least suppressive varieties with full dose of herbicide. Seavers and Wright (1997) observed that wheat cultivar Avalon being able to suppress the growth of G. *aparine* much more effectively than cultivar Spark. They also indicated that competitive ability was associated with a higher leaf area, resistance to loss of tillers under competitive pressure and greater height. Similarly, Grundy et *al.* (1997) reported that Moris Hunstmou (long strawed cultivar) achieved greater overall yield than Mercia (short strawed) due to more suppression of weeds.

Malik *et al* (1998a) opined that infestation of *P. minor* has increased due to the poor competitive ability of modern CIMMYT based wheat varieties since their introduction to North India. Chauhan *et al.* (2001) reported that wheat variety HD 2687 was more competitive followed by PBW 343 as compared to WH 542 and WH 157. However, Mahajan and Brar (2001) observed no significant differences in dry matter accumulation of *P. minor* in wheat cultivars PBW 343 and WH 542

Virk *et al* (2003) reported that wheat cultivars PBW 154, PBW 343 and WH 542 smothered *P. minor* more effectively as compared to PDW 233 and WH 283. Walia and Brar (2004) observed that among different varieties of wheat tested, minimum dry matter of *P. minor* was found in PBW 343 while the maximum in WH 846, indicating thereby more smothering potential of PBW 343 variety of wheat. Mahajan *et al.* (2004) found that wheat cultivar PBW 343 caused suppression in dry matter of *P. minor* by 30.7 and 48.5 per cent over WH 542 and PDW 233, respectively, due to greater competition offered by more number of tillers and resulted in 6.9 and 37.5 per cent higher grain yield over WH 542 and PDW 233, respectively. Bhat (2005) at Ludhiana found that variety PBW 343 (*T. aestivum)* recorded significantly higher values of growth and yield attributing characters resulting in significantly higher grain yield and also showed comparatively more smothering effect on *P. minor* as compared to cultivar PDW 274 (*T. durum*). Wheat variety PBW 343, being at par with HD 2687, under furrow irrigated raised bed system (FIRBS) of wheat sowing produced significantly higher number of effective tillers mrl^{-1} and 1000-grain weight and ultimately resulted in higher grain and straw yields compared to WH-147, WH-283, C-306 and WH-896 (Kumar *et al*., 2005).

2.4 Resource conservation techniques

2.4.1 Zero tillage (ZT)

2.4.1.1 Weeds

Weed population per unit area was 21.3-28.0 per cent higher in tilled plots than zero tillage in wheat crop (Meelu *et al*., 1979). Significant reduction in weed dry weight and density under ZT than conventional tillage (CT) was observed by Mishra (1984), Malik *et al*. (2000d), Bisen *et al.* (2002) and Sen *et al*. (2002). However, higher weed biomass under ZT was reported in wheat by Acciaresi *et al*. (2001). The higher weed density in CT than ZT might be due to better tilth and exposure of weed seeds to upper soil in CT (Singh *et al*., 2001). Franke *et al*. (2002), found 27 and 39 per cent weed seed emergence in ZT and CT, respectively. Feldman *et al*. (1998) reported that less disturbing tillage systems (no tillage and chisel plough) allowed the build up of a more diverse community, whereas, the most disturbing one (mould board plough) prevented high diversity in weed community. Singh *et al*. (1998a) observed significantly higher population of monocots in ZT over CT.

Blecharczyk *et al*. (1999) reported that reduced tillage promotes the establishment of grassy weeds such as downy brome (*Bromus tectorum*) and quackgrass (*Elymus repens*). Singh *et al*. (2001) found that relative density of grassy weeds increased with the advancement of crop growth while that of non-grassy reduced in ZT. This might be due to more competitive ability of grassy over non-grassy weeds. In contrast, Singh *et al*. (2002c) at Karnal observed increased intensity of broadleaved weeds and reduction in *P. minor* due to zero tillage over CT. At Patna, Prasad *et al*. (2002) reported more grassy weeds in ZT, whereas, CT had significantly higher broadleaved weeds. Sharma *et al*. (2002) reported that *P. minor* produced minimum dry weight and population under ZT and maximum under CT. These observations are in agreement with those of Verma and Srivastava (1989) and Aslam *et al*. (1993) but are at variance with Kuipers (1991) and Christian and Bacon (1990).

Experimental studies carried out in Sweden by Hallgren (1991) revealed that *Matricaria inodora* and *Capsella bursa-pastoris* had more density and dry weight in no-tillage, while *Stellaria media* and *Viola arvensis* were more abundant in conventional sowing. Hobbs *et al*. (1998) also found ZT helpful in reducing *P. minor* infestation in wheat. Because ZT reduces 30-

40 per cent of *P. minor* infestation that's why it is gaining importance in Haryana and Northwest India (Malik *et al*., 1998a). Higher population of *P. minor* at 50 DAS in CT than ZT was found by Sirohi *et al*. (1999). Malik *et al*. (1998a) have also speculated reduction in *P. minor* under ZT as soil disturbance was minimum and as such *Phalaris* seeds lying below 4-5 cm could not germinate. Long-term experiments of Malik *et al*. (2000a) showed that ZT combined with alternative herbicides decreased *P. minor* population over a period of five years. ZT techniques in combination with timely sowing of wheat had shown promising results in reducing *P. minor* infestation on research farm and farmers fields at different locations in Punjab (Brar, 2002). Yaduraju and Mishra (2002) reported that in wheat, *P. minor, C. album* and *M. hispida* reduced whereas, *A. sterilis* and *A. ludoviciana* increased under ZT compared to CT. Singh *et al*. (2002c) reported 30-40 per cent reduction in *P. minor* intensity in ZT compared to CT, whereas, the intensity of broadleaf weeds increased due to ZT practice. Sharma *et al* (2004) at Karnal reported that dicot weeds increased in zero tillage while FIRBS and conventional tillage had more monocot weeds.

2.4.1.2 Wheat growth

Hughes and Mitchelle (1987) observed a lower plant population under zero-tilled seed beds than in conventionally cultivated seed bed but the plant height remained unaffected. Merill *et al*. (1996) reported that relative to conventional till, no-till (NT) generally enhanced root length/growth of wheat more than above ground growth and in each year roots penetrated to greater soil depths under no-till than under minimal-till or conventional till. Moreno *et al*. (1997) reported that plant height and root length density were higher in the traditional tillage treatments. Singh *et al*. (1998a) also recorded taller plants in CT than ZT. Malik *et al*. (2000c) reported that there was no set back to wheat crop at first irrigation in ZT, whereas in CT, some yellowness was observed due to stagnation of water in the root zone of the wheat plant.

2.4.1.3 Yield attributes

Chia (1982) reported higher test weight and grain yield of wheat in ZT over CT. Giambelli *et al*. (1989) noticed that the number of spikes m^{-2}, seed $spike^{-1}$ and 1000-grain weight were highest with direct drilling. Vyn *et al*. (1991) reported that yield components did not differ significantly between zero, minimum or conventional tillage systems in wheat. Longer and heavier ears and more grains ear^{-1} were recorded in conventional sowing than direct

drilling (Singh *et al*., 1998a). Blecharczyk *et al*. (1999) reported that direct sowing led to decreased number of ears, but increased number of grains per ear and 1000-grain weight as compared to conventional tillage. Malik *et al*. (2000d) observed higher number of effective tillers in ZT over CT. However, Srivastava *et al*. (2002) found higher effective tillers m^{-2} and spikelets $spike^{-1}$ in CT than ZT.

2.4.1.4 Grain yield

Dhiman and Sharma (1986) reported significant increase in grain yield of wheat (13.8per cent) by using ZT over broadcasting. While, Dhillon *et al*. (1987) observed no difference in grain yield due to tillage treatments. Majid *et al*. (1988) reviewed the potential for no tillage as a crop management practice and found that no tillage is equivalent to traditional tillage technique in regard to wheat yield when the crop is sown at the same time, and superior economically in term of power use.

Sharma and Karwasra (1990) evaluated the effects of tillage and weed control in wheat, and obtained the same wheat grain yields with minimum and conventional tillage, but significantly higher than with zero-tillage. Verma *et al*. (1991) observed that no-tillage produced 12.9 per cent more grain yield of wheat than CT. Contrary to this, Janardan and Ahmed (1993) recorded 14.2 per cent higher grain yield in conventional tilled than zero tilled plots. Nagarajan (1995) observed that ZT has an edge on yield of wheat over CT due to advance sowing by ZT. In dry conditions, wheat yield was greater under ZT than under CT, while reverse was true under irrigated conditions (Lopez-Bellido *et al*., 1996). Brar *et al*. (1998) observed that in wheat no tillage, reduced tillage and conventional tillage were at par statistically in terms of seed yield and deep tillage gave the highest yields.

Hobbs *et al*. (1998) reported that under reduced tillage systems, earlier planting is the main reason for the additional yields obtained under zero tillage. Singh *et al*. (1998a) reported 16-25 per cent higher grain yield in CT than the ZT. Halvorson *et al*. (1999) recorded grain yields of wheat greater with minimum tillage (1968 kg ha^{-1}) and no-tillage (2022 kg ha^{-1}) than with conventional tillage (1801 kg ha^{-1}). Tripathi *et al*. (1999) also recorded significant higher wheat grain yield (4860 kg ha^{-1}) under ZT as compared with the yield obtained under CT (4590 kg ha^{-1}). At Karnal, average of two years data showed higher grain yield (4700 kg ha^{-1}) under NT than conventional sown crop (4120 kg ha^{-1}) of wheat (Tripathi and Chauhan,

2000). At Varanasi (UP), among the five tillage practices, ZT registered significantly higher grain yield and it increased by 56.3 and 72.9 per cent over conventional sowing in two years of study, respectively (Sen *et al*., 2002). In two years, yield of ZT sown wheat (4688 and 3527 kg ha^{-1}) outyielded CT sown wheat (3718 and 3075 kg ha^{-1}) at Patna (Prasad *et al*., 2002). An increase in yield of 4.9 per cent at Karnal (Singh *et al*. 2002c) and 12.2per cent at Masodha, Faizabad was reported (Yadav *et al*., 2002d) under ZT over conventional practice. On an average, 200 kg ha^{-1} higher wheat yield was observed with ZT than CT at different locations in Haryana (Yadav *et al*., 2002a) and similar observations were reported by Malik *et al*. (2000d) while, Sharma *et al*. (2002) observed similar yield in ZT and CT.

Yadav *et al.* (2005) studied the impact of long-term (8 years) zero-tillage (ZT) on the sustainability of wheat production at multi-locational (six) trials in Haryana from 1997-1998 through 2004-05. Based on these studies, it was realized that compared to conventional tillage (CT) continuous adoption of ZT in wheat resulted not only in the same or increased grain yield of wheat in different years but also in reduced infestation of resistant *Phalaris minor*. Grain yield of paddy after ZT or CT-wheat recorded at all the six permanent sites in different years was also similar.

Kakkar *et al.* (2005) observed that density of *P. minor* was 25 and 21 per cent lower in CT and bed planting treatments, respectively, in comparison to that of ZT sowing. But the density of broad leaf weeds was significantly higher in ZT in comparison to that of CT and BP methods of wheat sowing possibly the germination of broad leaf weeds was enhanced just after first irrigation. The total dry weight of all weeds was significantly higher at 90 DAS and at harvest in CT than ZT and BP methods.

Singh *et al.* (2005) revealed that due to adoption of ZT, the wheat sowing can be advanced 8-13 days in timely sown and 15-20 days in late sown conditions over conventional tillage with an increase in yield to the tune of 3.09 q ha^{-1} . Besides, saving in seed @ 46 kg ha^{-1} and reduction in *P. minor* intensity to the extent of 41 per cent were also observed. As such, overall profitability gains of Rs. 4893 ha^{-1} proved that the ZT technology was not only remunerative but resource friendly also.

Rawat and Verma (2006) reported that zero-tillage sowing was more time (88%) and energy-efficient (79%) compared to the conventional method of sowing. Wheat crop can be sown 10-15 days earlier compared to the

conventional method of sowing. This will result in the timely sowing of wheat crop and increase in yield. Zero-tillage sowing was more economical (79%) compared to the conventional method.

2.4.2 Furrow irrigated raised bed system (FIRBS)

In irrigated farming, although intensive agriculture has brought sustainable enhancement in production of food grains but it has also threatened the environmental safety and promoted the degradation and inefficient use of basic resources such as land, water and fertilizer. Ridge furrow and bed-furrow systems have emerged as few of the most promising sustainable crop management technologies which increase input use efficiency and crop production without environmental degradation. Research trials on use of bed planting system (also known as furrow irrigated reduced tillage bed planting (FIRBS) for growing soybean, wheat, maize and cotton in Yaqui valley of central Mexico and Indo-Gangetic plains of south Asia showed promising results in terms of increased input use efficiency and crop productivity (Yadav *et al.*, 2003).

Bed planted wheat systems offer a new alternative for the traditional wheat producers to provide opportunities for crop rotation, more efficient use of water, and new techniques of nutrient management (Freeman *et al.*, 2007). Conventional flat planting for winter wheat has some disadvantages. The use of flood irrigation can result in a low potential irrigation water use efficiency and inefficient use of nitrogen. It can also cause crusting of the soil surface following irrigation and can contribute to the degradation of some soil properties. In addition, it can result in higher levels of crop lodging.

A raised bed-planting system with a number of defined rows (usually two to four rows) planted on top of the bed with furrow irrigation was found to overcome these disadvantages. The benefits of the raised bed-planting system with furrow irrigation compared with conventional flat planting with flood irrigation were found as follows: first, there was a savings in some years of as much as 30% of applied irrigation water combined with enhanced water use efficiency by changing from flood to furrow irrigation; second, the crust problem on the soil surface was eliminated and soil physical status was greatly improved; third, nitrogen use efficiency could be improved by 10% or more because of improved nitrogen placement possibilities; fourth, the microclimate within the field was changed due to the orientation of the wheat plants in rows on the beds with the bed-planting system, which reduced crop

lodging and decreased the incidence of some wheat diseases. These advantages, interacting together, were found to improve grain quality and increase grain yield by more than 10% (Wang *et al.*, 2004). Singh (1995) reported that irrigation through furrows in bed sowing resulted in 25 per cent saving in post sowing irrigation water over border method of irrigation in flat sowing.

2.4.2.1 Weeds

Chauhan *et al*. (1999) found that furrow irrigated reduced till bed planting of wheat provided reasonably good control of *P. minor*. Malik *et al*. (2000b) found that FIRBS of wheat sowing with post-emergence herbicides is the best option for managing herbicide resistance in weeds.

The techniques, alternate to chemical measures including bed planting, sowing methods, closer spacing, row orientation and sowing rate were used to control weeds such as *P. minor* and *A. fatua* (Kaur, 2002). In FIRBS, because the weeds were in furrows hence competition was less with the main crop (Kharub and Chauhan, 2002). Less number of broadleaved weeds was found under FIRBS at Bawal (Yadav *et al*., 2004c). *P. minor* was less prolific on dry tops of raised beds than on the wetter soil found in conventional flat bed planting (Connor *et al*., 2003). *Physalis minima* and *C. album* mainly infested the field. ZT decreased both weed species compared to CT and FIRBS, but the difference was significant only in *P. minima*. ZT reduced the total weed dry weight compared to CT and FIRBS, whose total weed dry weights were at par with each other. Weed population was highest in FIRBS. Wheat grain yield was highest (4761 kg ha^{-1}) in ZT, followed by CT (4275 kg ha^{-1}) and FIRBS (3792 kg ha^{-1}) as observed by Mishra *et al*. (2005).

2.4.2.2 Wheat growth

Furrow irrigated raised bed system (FIRBS) of 67 cm width (top width of bed 37 cm, and of furrow 30 cm) is a method of planting crops on beds. It has the advantage of using lower seed rate, which is important when hybrid seed is being used. It also saves 30-35 per cent water. FIRBS under different crops has already been adopted by the majority of growers in the Yaqui Valley of Sonara, Mexico (Meisner *et al*., 1992; Sayre, 2000). Moreno *et al*. (1993) reported that planting of wheat on raised bed and applying irrigation in furrows between the beds facilitates mechanical weed control, reduces crop lodging and allows better utilization of solar radiation. In a study conducted a

Karnal, FIRBS in wheat was equally good or slightly better than conventional system, and no lodging was noticed under this system (Anonymous, 1996). At CIMMYT, Mexico, Sayre and Ramos (1997) reported high lodging (by more than 50 per cent) under conventional planting as compared to planting on 80 cm wide beds. The incidence of lodging increased as number of rows per bed increased from two to three or four. Tripathi (1999) at Mexico observed reduced lodging score of wheat planted on conventional tillage (CT) beds over CT flat planted wheat.

Batchelor *et al*. (1980) at Madison, Wisconsin (USA) revealed that sigmoidal dry matter accumulation with greatest growth rates at heading and grain fill was greater for bedded wheat than that of non-bedded wheat. Sweeney and Sission (1988) at Kansas (USA) also observed similar dry matter accumulation and number of heads per metre square in flat planting and 75 cm wide ridges. Higher number of shoots were produced when the crop was sown in narrow rows coupled with higher seeding rate (Sayre and Ramos, 1997).

Kaur *et al*. (2001) at Ludhiana reported lowest lodging score (0.2 to 1.5) and highest silica uptake in bed planted wheat but less effective tillers. In Haryana, Yadav *et al*. (2002c) recorded highest value of root length, root biomass and plant height under FIRBS compared to CT. Kumar *et al*. (2002) found that both planting systems (bed and conventional) were at par with respect to various aspects of biomass production of wheat.

Bed planting reduced the water applied during the first, second and third irrigation by 30, 20 and 5per cent, respectively (Aggarwal and Goswami, 2003). Compared with conventional flat planting, plant morphological characters related to the grain yield of winter wheat changed greatly by the raised bed planting model. The basal internodes and plant height were shortened, the areas of flag leaf and the second leaf from the top were smaller and the fifth leaves from the top were larger, all contributing to the build up of an ideal pagoda-shaped plant. Moreover, the dry weight of green leaves in canopy was heavier and the grain yield increased in the raised bed planting model (Wang *et al.*, 2007).

2.4.2.3 Yield attributes

In Arizona (USA) planting of wheat on beds, recorded significantly higher number of spikes m^{-2} and 1000-grain weight than planting in flat beds but similar yield was observed under both methods (Day *et al*., 1976).

Tripathi (1999) reported lower value of attributes viz., about 25-30 per cent lower spikes and grains m^{-2} under permanent bed system than other planting system of DT-flat and CT-beds. Yadav *et al*. (2002c) at Bawal, Haryana recorded highest values of yield attributes (No. of effective tillers, earhead length, number of grains $spike^{-1}$ and test weight) under FIRBS compared to CT. Large panicles with bold grain are produced in FIRBS (Connor *et al.*, 2003). At Karnal, FIRBS system recorded significantly higher spikes m^{-2} over conventional system, but at Ludhiana these were reduced by 17.3 per cent (Anonymous, 1997). In an another experiment at Karnal, FIRBS planting recorded less effective tillers and grains than conventional system but at Powerkheda (M.P.), wheat crop under FIRB planting system produced 13.9 per cent higher effective shoots and 3.7 per cent higher grains ear^{-1} compared to conventional system. However, non-significant variation was found in 1000-grain weight due to planting methods at all these sites (Anonymous, 1997). During the year 1998-99, across the locations of NWPZ, FIRB planting increased number of tillers by 15 over 377 effective tillers m^{-2} produced under conventional planting (Anonymous, 1999). At Pantnagar (U.P.) adoption of FIRBS with 3 wheat rows per bed recorded higher effective tillers by 30.2, 18.0, 5.6 and 4.5 per cent compared to surface seedling, zero tillage, conventional tillage and strip-till-dril methods, respectively. Similarly, at Karnal, FIRB planting with 3 wheat rows on each bed produced 25.2 and 10 per cent higher grains ear^{-1} over ZT and surface seeding. Also, 1000-grain weight was significantly higher for bed (Anonymous, 1999). In the year 1999-2000 at Karnal, amongst four tillage options, FIRB system recorded less number of earheads (421 m^{-2}) compared to conventional system (494 ear heads m^{-2}) but significantly improved grains ear^{-1} by 19.8, 12.9 and 12.5 per cent over rotavator, CT and ZT options, respectively (Anonymous, 2000). The experiment on ZT, surface seeding, strip-till drill, reduced till, CT and FIRB with 3 rows planting methods revealed that all the planting methods were at par in grains ear^{-1} at Pantnagar, but at Karnal, FIRB planting with 2 rows per bed proved significantly superior over planting of 3 rows, flat 2 rows and conventional in this respect, FIRB planted crop also produced grains having higher test weight compared to conventional system (Anonymous, 2000).

2.4.2.4 Grain yield

Gebre (1987) at CIMMYT (Mexico) revealed that wheat grain yield averaged 2.11 t ha^{-1} on raised beds and 1.25 t ha^{-1} on flat beds.

Khan *et al*. (1987) at Faisalabad (Pakistan) recorded significantly higher tillers and grain yield (5.2 t ha^{-1}) in bed planting as compared to flat sowing (4.0 t ha^{-1}). Likewise, Sweeney and Sission (1988) at Kansas found that on a Pasons silt loam soil, wheat grown on 75 cm wide ridges gave 15 to 30 per cent higher yield as compared to flat planting. Smith and Smith (1988) revealed that ridge planting produced higher wheat grain yield (4 t ha^{-1}) than under flat sowing (2 t ha^{-1}). Chauhan *et al*. (1997) recorded higher grain yield (6150 kg ha^{-1}) under 3 row-bed planting than conventional planting (5820 kg ha^{-1}). Singh (1995) at Hisar, reported that the ridge furrows system (one row in center of furrow and two on the side of ridges) and flat system of planting gave similar yields but ridge and furrows system resulted in 25per cent saving in post sowing irrigation. Similar performance of bed and conventional planted wheat was observed at Karnal (Anonymous, 1996). Ahmed *et al*. (1996) recorded better crop yields of plain planted wheat than the bed planting. Sayre and Ramos (1997) at CIMMYT, concluded that conventional planting produced approximately 5 per cent more grain yield of wheat as compared to bed planting (90 cm). However, in a yield survey of farmer's field in Yaqui valley conducted in 1994, the average yield of wheat planted on beds was 5615 kg ha^{-1} (47 farmers), whereas wheat planted as conventionally had an average yield of 4923 kg ha^{-1} (17 farmers).

Hobbs *et al*. (1997) observed higher grain yield (6150 kg ha^{-1}) under bed planting (3 rows per bed) than obtained under conventional planting (5820 kg ha^{-1}). Chauhan *et al*. (1997) reported that conventional line sowing, reduced tillage, FIRBS with 2 rows and FIRBS with 3 rows produced wheat yields of 5667, 5922, 6046 and 6392 kg ha^{-1}. In Mexico, Tripathi (1999) reported significantly higher grain yield of wheat (8.8 t ha^{-1}) under conventional tillage (CT) beds over CT flat (8.5 t ha^{-1}) under high rainfall (11.3 cm) condition. Limon *et al*. (2000) at Mexico also reported that permanent beds gave significantly higher yield of wheat over conventional tilled beds (raised beds). Agustin *et al*. (2000) found that in Yaqui Valley of Mexico permanent beds combined with retaining all crop residues in the soil as stubble have the potential to increase both wheat and maize yields in high yielding environments whereas in low yielding environment, straw burning on permanent beds produced greater wheat yields.

At Uchani, Karnal (Haryana), Khatri *et al*. (2001) obtained highest grain yield (5303 kg ha^{-1}) in 3 rows bed with 45 cm bed width than flat

sowing (4870 kg ha^{-1}). Pulatov *et al.* (2001) compared no-till and conventional tillage with bed planting in Uzbekistan and found higher wheat yield under bed planting (3.96 t ha^{-1}) than no-till (3.44 t ha^{-1}) and conventional tillage (3.57 t ha^{-1}) practices. Torbert *et al.* (2001) at Texas (USA) obtained higher yields with no-tillage system with raised beds.

Yadav *et al.* (2002c) also recorded more grain yield (5066 kg ha^{-1}) under FIRBS compared to CT (4833 kg ha^{-1}). Under tilled condition with application of herbicide, reduced tillage, FIRBS and conventional line sowing produced consistently higher grain yield than strip, ZT and surface seeding (Singh *et al.*, 2002b). At Karnal and Ludhaina, FIRB and conventional systems were at par in grain yield, but at Pantnagar this system recorded significantly higher yield by 10.7, 4.9 and 4.8 q ha^{-1} over surface seeding, strip-till-drill and zero tillage, respectively (Anonymous, 2000).

Under NWPZ (at Karnal and Ludhiana), amongst the planting methods biological yield did not vary significantly. But in an another experiment conducted at Karnal, FIRB planted wheat crop recorded highest biomass (118 q ha^{-1}) compared to 109.2 q ha^{-1} produced under conventional planting system (Anonymous, 1997).

Field studies at Faisalabad Pakistan for comparing different planting systems showed an average yield of 5.3 t ha^{-1} with bed sowing and 4.0 t ha^{-1} with flat sowing due to increased nitrogen use efficiency in the bed planting system (Khan *et at*, 1987).

Hobbs et *al.* (1997) recorded higher grain yield (6.15 t ha^{-1}) under bed planting system with three rows per bed as compared to conventional planting (5.82 t ha^{-1}) system.

Malik *et al.* (1998) advocated that furrow irrigated bed planted wheat along with post-emergence herbicide application is the best option for managing the *P. minor* in wheat. Chauhan *et al.* (1997) at Karnal, Haryana also observed reasonably good control of *P. minor* with furrow irrigated reduced till bed planting system (FIRBS) of wheat cultivation. The combination of bed planting and irrigation with tile drainage water (IWDW) at 50 per cent depletion of available water (DAW) with a leaching fraction of 0.2 gave higher grain yield under Pakistan conditions for the first year where as the combination of plain planting and IWDW at 25 per cent DAW gave higher grain yield on the basis of a three year average (Ahmed *et al.*, 1996).

Limon *et al.* (2000) advocated that permanent beds combined with retaining crop residues in the soil as stubble have the potential to increase the wheat yields in Yaqui valley.

Kaur et *al.* (2001) at Ludhiana recorded lowest lodging score (0.2-1.5) and highest silica uptake in bed planting system of wheat cultivation as compared to flat sowing (unidirectional 22.5 cm), Kaur *et al.* (2002) also observed higher leaf area index, dry matter accumulation, and grain yield in bed planting system (3 rows / bed) as compared to flat sowing (unidirectional 22 5 cm). Khatri *et al.* (2001) reported that highest wheat grain yield of 5.08 t and straw yield of 6.26 t ha^{-1} were recorded with sowing in 3-row beds as compared to flat sowing.

In unweeded crop bed sowing with three rows per bed at Ludhiana recorded significantly lower dry matter accumulation by P. *minor* than 2 rows per bed and flat sown crop both at 15 cm and 22.5 cm row spacing (Walia *et al.,* 2003)

Aggarwal and Goswami (2003) at Delhi observed significantly lower weed population in bed sowing as compared to flat planting. Chahal *et al.* (2003) in similar studies also observed lower weed dry weight, higher grain yield and net returns in wheat planted in furrow irrigated raised bed planting system with three rows per bed as compared to conventional (broadcasting). Wang *et al.* (2004) from China recorded 10 and 13.4 per cent higher grain yield in case of bed planting as compared to flat planting in Jamai 19 and Yamong 19 verieties , respectively

Kumar *et al.* (2005) reported that genotypes HD 273, PBW 343 and HP 1761 performed better and provided higher grain yields under bed planting system. However, Sharma *et al.* (2004) reported that the incidence of powdery mildew in wheat was significantly higher on furrow irrigated raised beds (FIRBS) as compared to the conventional sowing. Bed planting recorded significantly higher grain yield than flat planting which might be due to lower population pressure (14.8 per cent) and reduced final dry matter (12.7 per cent) accumulation by *P. minor* under bed planting (Bhat, 2005).

2.5 Economics

Bourdot *et al.* (1996) revealed that herbicide usage is economic in many crops in many seasons, yet there is scope for withholding herbicides, particularly in seasons with low spring rainfall. Farmers from Yaqui valley, Mexico reported that yield may be improved by at least 10 per cent with the

proper variety and production costs can fall by 20-30 per cent with bed planting compared to conventional planting (Sayre, 2000). Average net profit for farmers growing wheat on beds was \$1216 ha^{-1} but only \$561 ha^{-1} for farmers growing wheat conventionally as studied by CIMMYT economic programme (Sayre, 2000).

Zero-tillage has the potential to eliminate 6 to 10 tillage operations usually practiced under conventional tillage. This saving in time and expenses is a huge amount to adopt pre-seeding non-selective herbicides (Malik *et al*., 1998). Kumar (2000) reported a saving of Rs. 950 to 1200 ha^{-1} in zero tillage system compared to other intensively ploughed experiments during 1995-96.

Yadav and Malik (2001) reported that zero-tillage sowing of wheat saved atleast Rs. 2500 ha^{-1} incurred on an average 7 to 8 ploughings + 2 plankings given for field preparation before its sowing. It also resulted into additional gain of 250 to 750 kg ha^{-1} grain yield compared to conventional sowing. Kumar *et al.* (2002) found that average net returns were higher under the bed sowing system compared to the conventional sowing.

Jat and Singhi (2003) conducted an exeperiment to assess productivity and profitability of bread wheat (*Triticum aestivum*) and durum wheat (*T. durum*) under furrow-irrigated raised-bed planting (FIRB) compared to existing planting pattern of sole wheat on flat bed and found that cultivars, HI 8498 (durum wheat) gave the highest wheat equivalent yield (5.89 t ha^{-1}), productivity (41.4 kg ha^{-1} day^{-1}) and net profit (Rs 26306 ha^{-1}) compared with the rest of the cultivars under bed planting system.

CHAPTER-III

Materials and Methods

The investigation entitled, "Evaluation of herbicides and resource conservation techniques on durum wheat (*Triticum durum*) cultivars" was carried out during *rabi* seasons of 2005-06 and 2006-07. The details of procedures followed, criteria used for treatments, evaluation and methods adopted during entire course of investigation are presented in this chapter.

3.1 General Details

3.1.1 Experimental site and location

The experiments were conducted at research farm of Department of Agronomy, Chaudhary Charan Singh Haryana Agricultural University, Hisar (Haryana). The geographical location of Hisar is 29º10′ N latitude and 75º46′ E longitude with an elevation of 215.2 m above the mean sea level.

3.1.2 Climate and weather

The climate of Hisar region is semi-arid with hot and dry desiccating winds accompanied by frequent dust storms of high velocity in summer, severe cold during winter and humid warm during monsoon rainy months. The mean monthly maximum and minimum temperatures show a wide range of fluctuations during the year. The maximum temperature sometimes exceeds 48ºC during summer, while temperature below freezing point accompanied by frost in winter is usually experienced in this region.

The average annual rainfall varies from 350-400 mm and the total rains as well as its distribution are subjected to great variations. About 80 to 90% of total rains are received from South-West monsoon during the months of July to September. During December, January or in late spring, a few showers of cyclonic rains are also a common feature in this zone. Mean relative humidity (at 7:00am) remains nearly constant at about 80 to 90 per cent during July to March and then steadily decreases to 40 to 30 percent by the end of April and remains so till June. Mean weekly meteorological data recorded at the meteorological observatory located near Agronomy Research Farm of CCS HAU, Hisar for duration of experiments during 2005-06 and 2006-07 are presented in tables 1a and 1b and depicted in figures 1a and 1b, respectively.

Table 1a. Mean weekly meteorological data recorded during crop season 2005-06

Standard weeks	Mean temperature (ºC)		Mean relative humidity (%)		Mean sunshine (hours)	Mean pan evaporation (mm)	Rainfall (mm)
	Max.	Min.	(Morn.)	(Eve.)			
42	33.4	16.7	85	32	8.0	4.0	0
43	31.9	12.4	83	24	8.6	3.9	0
44	31	12.8	77	33	7.9	4.5	3.2
45	28.3	10.2	89	43	7.5	2.5	0
46	29.1	8.7	83	23	8.9	3.5	0
47	28.2	7.4	85	27	8.5	2.7	0
48	24.4	6.7	84	42	6.8	2.7	0
49	23.4	3.1	93	41	8.2	2.1	0
50	22.2	1.6	90	33	7.8	1.6	0
51	20.7	2.2	95	44	5.4	1.1	0
52	19.7	4.3	94	49	4.4	1.3	0
1	19.1	3.6	93	50	6.0	1.6	0
2	19.7	0.6	93	37	7.7	1.7	0
3	22.1	8.5	90	47	7.8	2.0	0
4	20.3	2.6	93	39	4.3	2.9	0
5	25.2	6.6	93	42	8.2	2.1	0
6	27.2	7.7	91	44	6.8	2.0	0
7	28.4	11.7	94	53	8.1	2.4	0
8	28.4	11.3	97	54	6.7	2.5	0
9	27.2	8.5	93	42	7.0	2.4	0
10	28.6	12.2	91	53	8.1	2.9	15
11	24.2	11.6	95	60	6.5	3.3	11
12	29.6	12.8	94	46	6.0	2.5	0
13	29.9	12.2	89	43	9.3	4.5	1
14	36.3	14.9	82	34	9.1	4.3	0
15	36.2	15.4	63	23	9.9	7.1	0

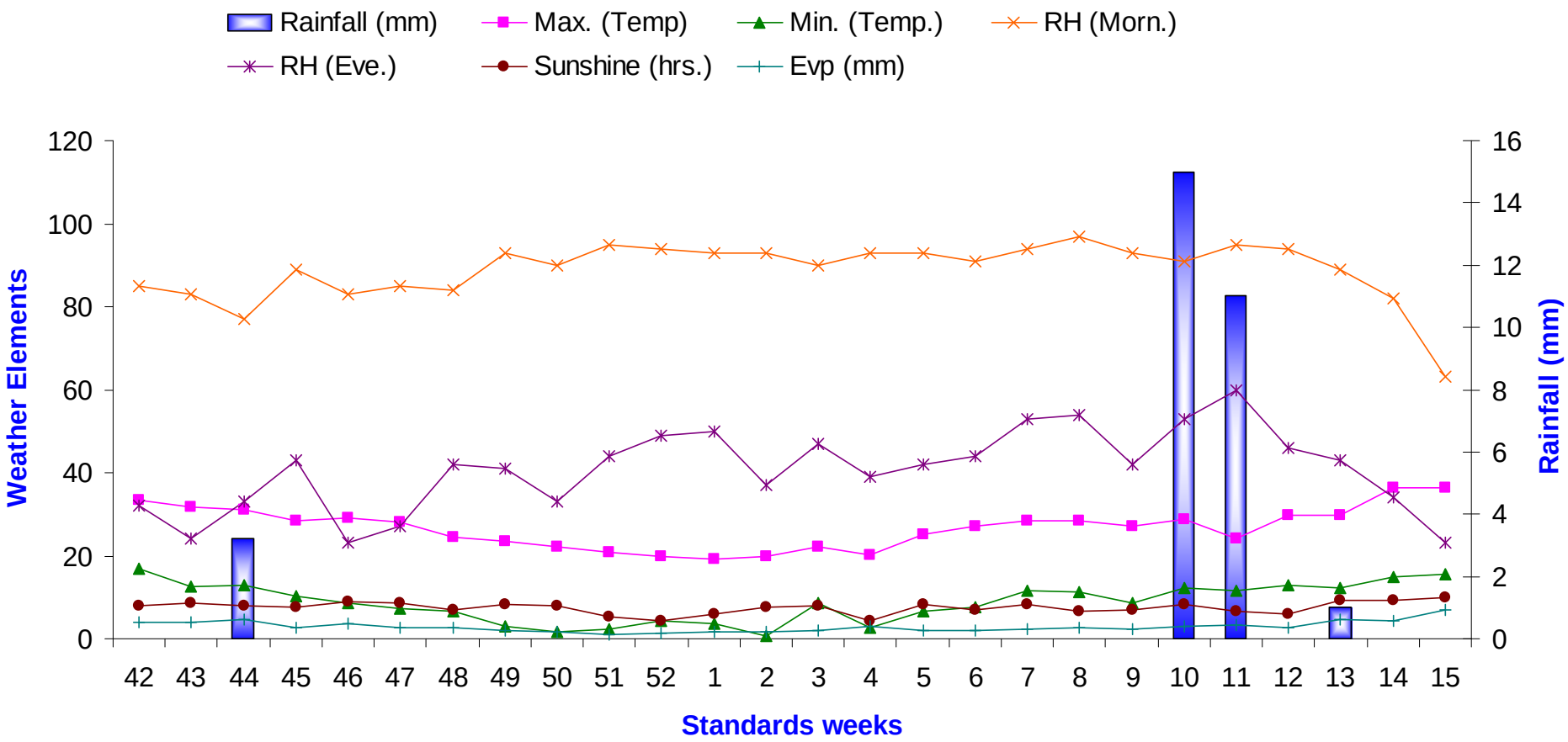


Fig. 1a. Mean weekly meteorological data during crop season (2005-06)

Table 1b. Mean weekly meteorological data recorded during crop season 2006-07

Standard weeks	Mean temperature (ºC)		Mean relative humidity (%)		Mean sunshine (hours)	Mean pan evaporation (mm)	Rainfall (mm)
	Max.	Min.	(Morn.)	(Eve.)			
42	33.7	18.0	81	39	8.1	5.6	0.0
43	30.2	15.0	90	44	5.3	4.0	0.0
44	30.7	13.9	95	38	4.0	3.1	0.0
45	32.3	13.0	83	32	7.5	2.7	0.0
46	29.4	12.8	92	53	5.7	2.5	0.0
47	25.7	9.7	96	72	6.8	2.5	0.0
48	24.4	4.8	92	50	8.3	2.8	0.0
49	22.3	7.8	91	49	5.6	2.1	2.2
50	20.8	4.3	96	46	5.8	1.4	0.0
51	23.3	6.4	95	39	7.1	2.1	0.0
52	20.5	4.2	98	53	7.0	1.5	3.8
1	17.0	1.9	97	48	5.4	1.4	0.0
2	18.0	0.7	93	41	6.9	1.3	0.0
3	20.4	3.2	94	34	7.0	1.8	0.0
4	22.8	4.5	90	39	8.2	2.1	0.0
5	25.4	7.6	97	69	5.9	2.0	0.0
6	22.0	10.2	95	80	2.7	1.5	59.3
7	20.8	8.8	97	83	6.5	1.6	16.0
8	23.2	8.4	94	55	8.4	2.8	0.0
9	23.2	9.6	97	60	6.7	2.6	4.1
10	26.0	9.8	83	36	9.2	3.9	0.0
11	23.4	10.5	97	57	6.8	2.2	40.2
12	29.5	13.0	91	45	8.5	4.2	0.0
13	33.8	13.8	80	35	9.9	5.1	0.0
14	34.1	14.0	84	28	9.6	5.3	2.0
15	37.9	16.4	66	18	10.1	7.2	0.0

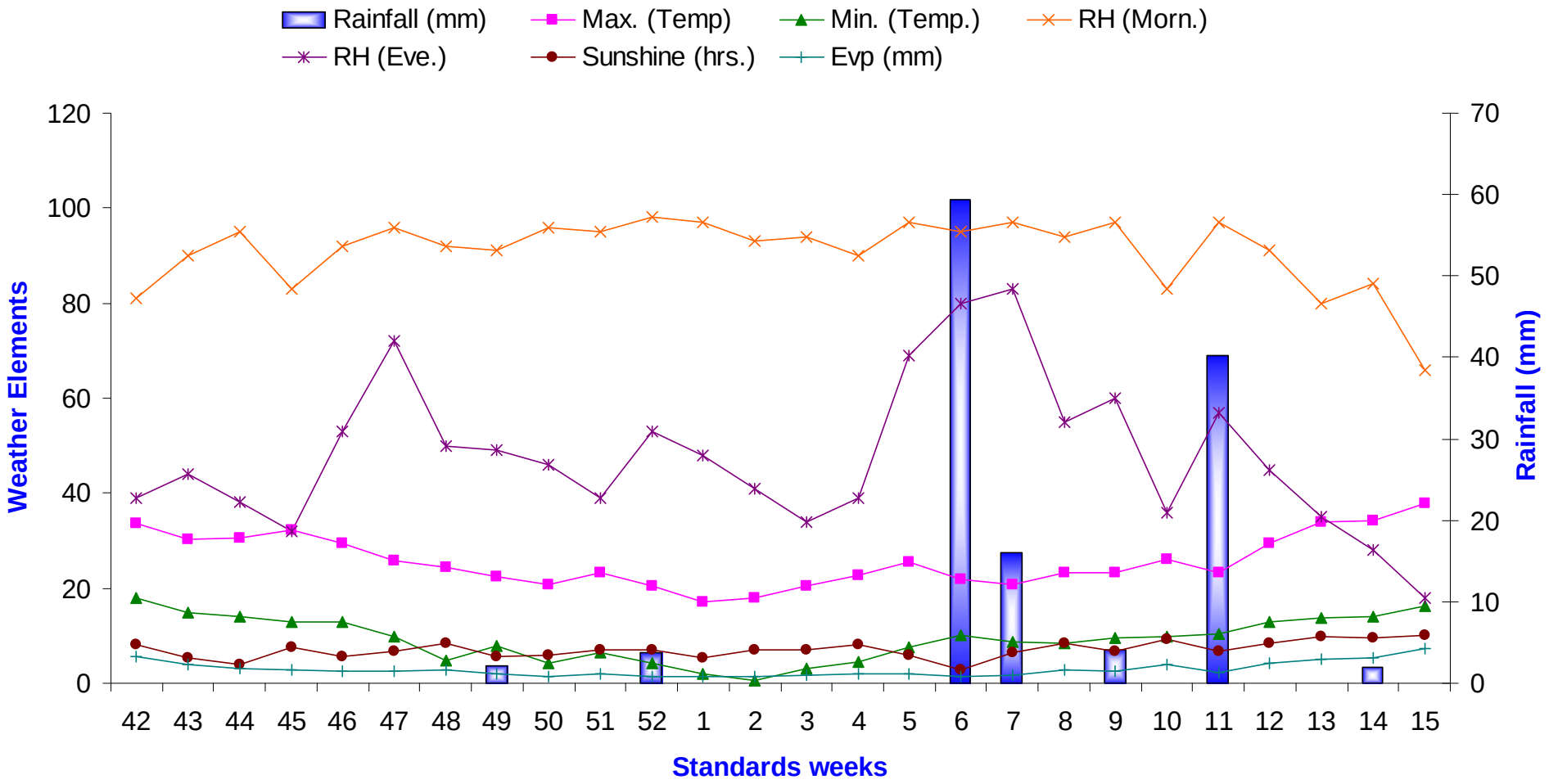


Fig. 1b. Mean weekly meteorological data during crop season (2006-07)

3.1.3 Soil analysis

The soils of Hisar are derived from Indo-Gangetic alluvium, which are very deep and sandy loam in texture and have some nodules of calcium carbonate in the profile.

For mechanical and chemical analysis of soil of experimental field, samples were drawn from different places from 0-15cm depth before sowing the crop. The samples drawn from all places were mixed thoroughly to form composite samples which were analysed for physico-chemical characteristics of the soil.

3.1.3.1 Mechanical analysis of soil

For mechanical analysis of the soil, the composite soil samples were analysed by International Pipette Method (Piper, 1966). On the basis of mechanical composition, presented in table 2, the soil is categorized as sandy loam in texture.

Table 2. Mechanical composition of soil of experimental field

Components	2005-06	2006-07
Sand (%)	61.58	61.57
Silt (%)	20. 32	20.34
Clay (%)	18.30	18.29

3.1.3.2 Chemical analysis of soil

The composite samples were also analyzed for chemical properties of the soil. The observations recorded and methods used for chemical analysis are presented in table 3. Chemical analysis revealed that soil of the experimental field was low in organic carbon and nitrogen, medium in available phosphorus, rich in potassium and slightly alkaline in reaction.

3.1.4 Cropping history of the experimental field

The information available on the cropping history of the field is presented in table 4.

Table 3. Chemical composition of soil of experimental field

Components	2005-06	2006-07	Methods employed
Organic carbon (%)	0.35	0.36	Walkley and Black's wet oxidation method (Jackson, 1973)
pH	8.2	8.2	pH meter with glass electrode in 1:2 soil water suspension (Jackson, 1973)
EC (dSm^{-1} at 25ºC)	0.43	0.44	Conductivity bridge method in 1:2 soil water suspension (Richards, 1954)
Available nitrogen (kg ha^{-1})	208.0	211.0	Alkaline permanganate method (Subbiah and Asija, 1956)
Available phosphorus (kg ha^{-1})	15.1	16.2	Olsen's method (Olsen *et al*., 1954)
Available potassium (kg ha^{-1})	407	409	Flame Photometeric method (Richards, 1954)

Table 4. Cropping history of the experimental field

Year	Kharif	Rabi
2002-03	Pearl millet	Mustard
2003-04	Mung	Mustard
2004-05	Fallow	Wheat
2005-06	Moong	Wheat (Experimental crop)
2006-07	Moong	Wheat (Experimental crop)

3.2 Experimental details

Following two field experiments were conducted during this investigation:

Experiment 1. Evaluation of herbicides against complex weed flora in durum wheat

Treatments	**Dose(g ha^{-1})**
Isoproturon	1000
Clodinafop	60
Fenoxaprop + S	100+0.1%
Sulfosulfuron	25
2,4-D E	500
Metsulfuron – methyl	4
Carfentrazone-ethyl	20
Isoproturon +2,4-D E	750+500
Isoproturon + Metsulfuron	750+4
Clodinafop *fb* 2,4-D E	60 &500
Clodinafop *fb* Metsulfuron	60 & 4
Fenoxaprop + S *fb* 2,4-D E	100 +.01% & 500
Fenoxaprop + S *fb* Metsulfuron	100 +.01% & 4
Sulfosulfuron + Metsulfuron (Ready mix)	30 + 2.2
Isoproturon + Carfentrazone	750+20
Clodinafop *fb* Carfentrazone	60&20
Fenoxaprop + S *fb* Carfentrazone	100+.01% & 20
Sulfosulfuron + Carfentrazone	20 & 20
Weedy	-
Weed free	-

Note : 1. All herbicides were applied as post emergence (35 DAS)

2. S = Surfactant and *fb* = followed by one week

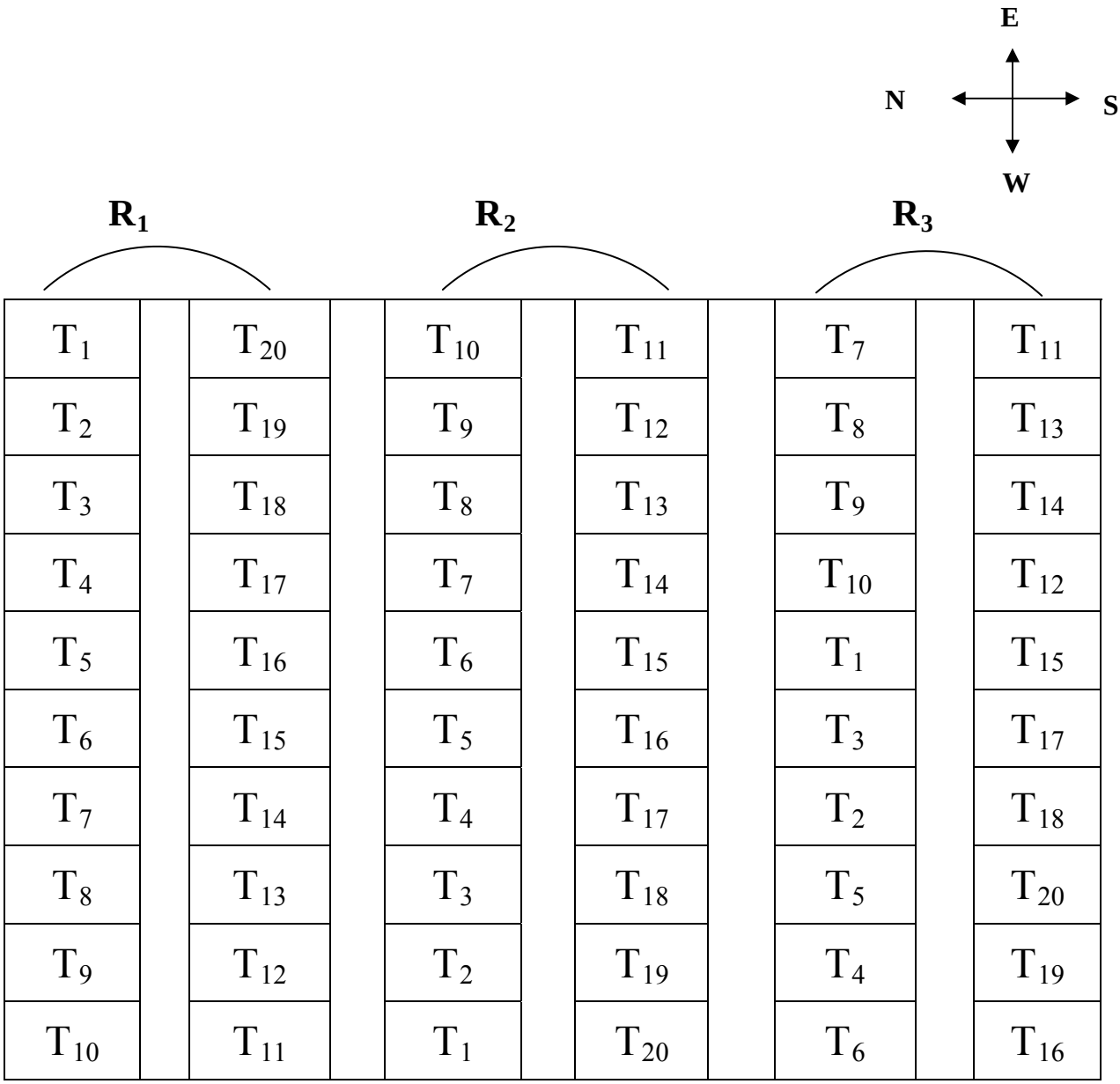
Design : RBD

Treatments : 20

Replications : 3

Plot size : 6.0 m x 3.5 m

Layout of the treatments in the experiment has been shown in fig. 2.



Design	:	Randomized Block Design
Plot size	:	6.0 m × 2.1 m
Number of treatments	:	20
Number of replications	:	3

Fig. 2. Layout of the experiment-I

Experiment 2. Evaluation of competing ability of durum wheat cultivars under different resource conservation techniques

Treatments:

Main plot: Resource Conservation Techniques (RCTs)

1. Zero tillage (ZT)
2. Furrow irrigated raised bed system (FIRBS)
3. Conventional tillage (CT line sowing)

Sub plot:

A. Cultivars

1. WH 896
2. WH 912
3. PDW 291

B. Weed control

1. Pendimethalin (1.5 kg ha^{-1} pre-emergence)
2. Weedy

Design : Split plot

Replications : 4

Plot size : 7.0 m x 2.1 m

Layout of the treatments in the experiment has been shown in fig. 3.

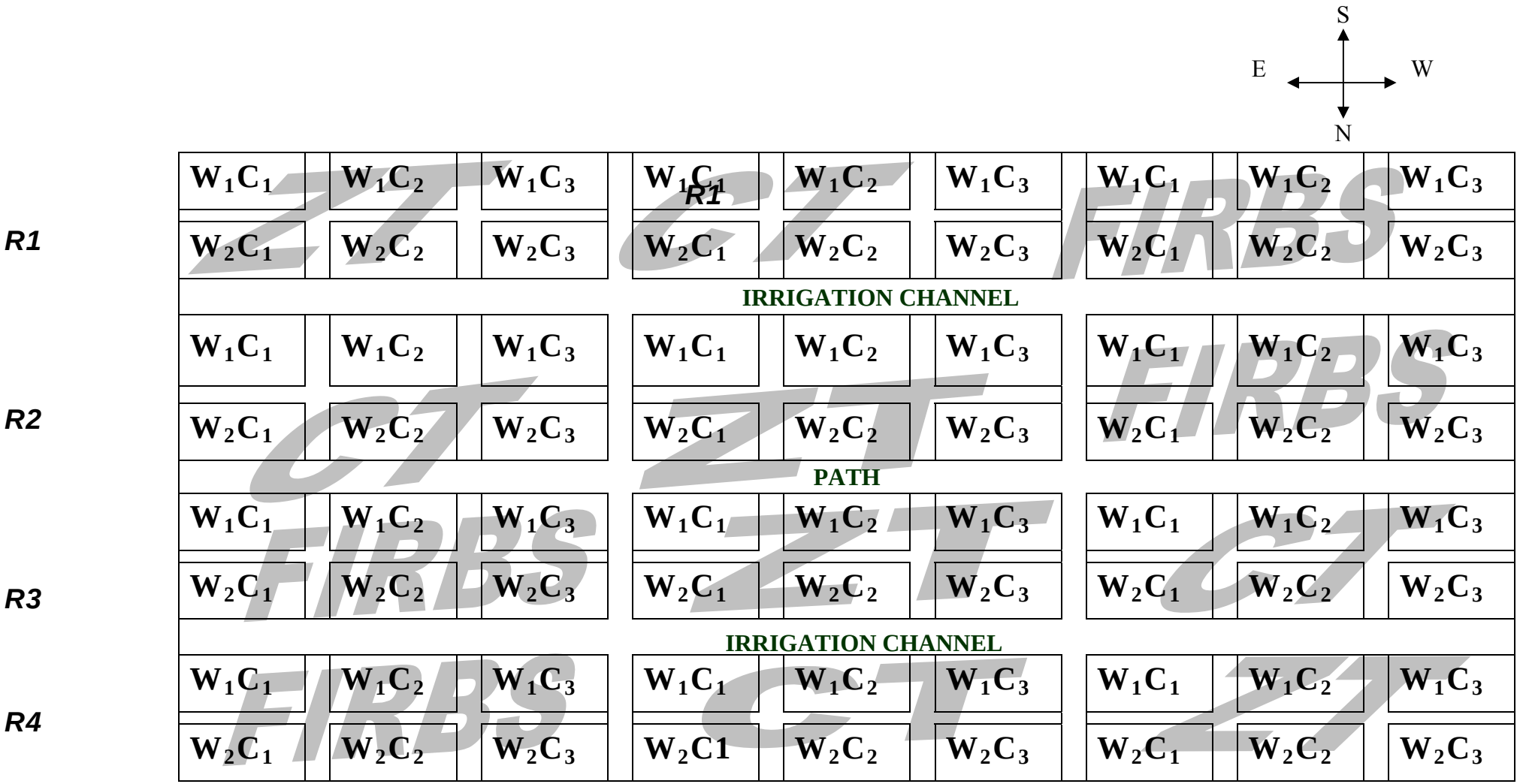
3.3 Cultural operations

3.3.1 Field preparation

Field for zero-tillage (ZT) experiment was kept undisturbed after harvesting of mungbean crop. In order to attain good tilth one pre-sowing irrigation was given to all fields. For the conventional tillage sowing, field was harrowed thrice followed by a cultivator and planking. Field marked for Furrow Irrigated Raised Bed System (FIRBS) sowing, was harrowed thrice followed by cultivator twice and a planking to prepare a finer seed bed. Before sowing, bed with 37.5 on top and 30 cm wide furrows between two beds were made with the help of bed planter.

3.3.2 Fertilizer application

In the experimental field, recommended dose of N (150 kg ha^{-1}) and P (60 kg ha^{-1}) through DAP and urea were added as per package of practices for wheat.



Design : Split plot
Plot size : 7.0 × 2.1 m^2
Number of treatments : 18
Number of replications : 4

ZT: Zero Tillage, **CT:** Conventional Tillage, **FIRBS:** Furrow Irrigated Raised Bed System, **C1:** WH 896, **C2:**WH 912, **C3:**PDW 291, **W1:**Pendimethalin (1.5 kg ha^{-1}), **W2:**Weedy check

Fig. 3 Layout plan of the experiment 2

3.3.3 Seed and sowing

Clean seed of durum wheat variety WH 896 was sown with the help of seed drill at the rate of 100 kg seed ha^{-1}in experiment- I and WH 896, WH 912 and PDW 291 were sown in experiment-II. The crop was sown on 12th November 2005 and 14th November 2006 during first and second year of experimentation, respectively. All other agronomic practices were adopted as per recommendation of package of practices.

3.3.4 Spray schedules

Herbicides were sprayed as per treatments 35 days after sowing (DAS) with the help of knapsack sprayer fitted with flat fan nozzles using 625 litres water ha^{-1}.

3.3.5 Harvesting and threshing

The crop was harvested on 7th April 2006 during the first year and 13th April 2007, during the second year. Harvesting was done manually by cutting the plants from the ground level with the help of sickles. The crop was left in the field for one week for sun drying. Before threshing, biological yield (grain + straw) was recorded with the help of portable spring balance. The crop was threshed plot wise with the help of mini-thresher grain yield was recorded.

3.4 Observations

3.4.1 Weed studies

3.4.1.1 Weed intensity

The intensity of weeds was determined by quadrat method (Mishra and Puri, 1954). The quadrat (0. 5 m^2) was thrown randomly at two places in each plot at 30, 60, 90 DAS and at crop harvest. The weeds inside the quadrat were counted and the average of two quadrats were converted to numbers m^{-2}. The actual values were subjected to square root transformation ($\sqrt{X+1}$) for analysis as suggested by Bartlett (1947) and Blackman and Roberts (1950).

3.4.1.2 Dry matter accumulation

The weeds taken with a quadrat from two places selected at random from each plot were taken for dry matter accumulation at 30, 60, 90 DAS and at crop harvest. These samples were first dried under the sun and then kept in oven at 65 ± 5ºC till a constant weight was achieved. The dried samples were weighed and the final dry weight of total weeds was expressed as g m^{-2}.

3.4.2 Crop studies

3.4.2.1 Visual phytotoxicity

Visual phytotoxicity was recorded at 15 and 30 days after spraying using 0 - 100 scale (where, 0 = no mortality and 100 = complete mortality). Since, there was no

phytotoxicity of any herbicidal treatments, the data on phytotoxicity to crop was not included herein.

3.4.2.2 Growth studies

3.4.2.2.1 Plant height

Five randomly selected plants in each plot were tagged for recording plant height at 30, 60 and 90 DAS and at harvest. The height of each plant was measured with the help of warden scale from the soil surface to fully opened top leaf of the plant before ear emergence and upto the base of earhead after heading stage.

3.4.2.2.2 Dry matter accumulation

Plants of 0.25 m row length from two places in a second row on either side in each plot were taken from close to the ground at 30,60,90 DAS and at harvest to record dry matter accumulation per metre row length. The samples were first sun dried well and then oven dried at 65 ± 5ºC till a constant weight was attained. After drying, the samples were weighed and dry weight expressed as gram per metre row length.

3.4.2.3 Yield attributes and yield

3.4.2.3.1 Number of spike m^{-2}

Spike bearing shoots were counted at harvest from one metre area at three places which were already marked for all replications and average number of spike m^{-2} area were calculated.

3.4.2.3.2 Spike length

Five spikes were randomly selected from each plot and their lengths were measured from the base of the lowest spikelets to the tip of the top spikelets leaving the awns and the average length was worked out.

3.4.2.3.3 Number of grains per spike

All the grains of five selected spikes, used for measuring spike length were separated and counted. The average number of grains per spike were calculated.

3.4.2.3.4 1000-grain weight

A random sample of grains was taken from each plot and from this weight of 1000-grains was recorded to get test weight.

3.4.2.3.5 Grain and straw yields

After harvesting, the wheat crop was left in the field plot-wise for sun drying. Then the weight of the harvested produce as such was recorded. The crop was threshed plot-wise and grain yield was recorded. The grain yield so obtained was deducted from the total biomass of the harvested crop to compute the straw yield. Grain and straw yield per plot were expressed into yield as kg per hectare.

3.4.2.3.6 Harvest index (%)

Harvest index (HI) is a ratio between grain yield and biological yield and was worked out by the following expression.

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

3.5 Characterisation of herbicides used

The information about the herbicides used in experiment are given in tables 5-12.

Table 5. Clodinafop-propargyl

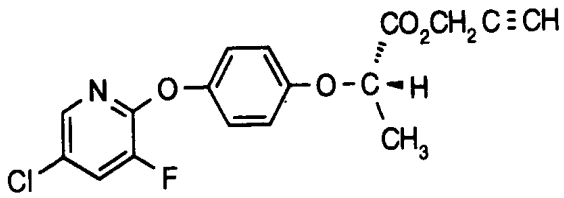
(i)	Common name	:	Clodinafop-propargyl
(ii)	Chemical structure:		
(iii)	IUPAC name	:	Prop-2-ynyl (R)-2-[4-(5-chloro-3-fluoropyridin-2-yloxy)phenoxy} = propionate
(iv)	Trade name and formulation	:	Topic 15 WP (Syngenta)
(v)	Mode of action	:	Inhibits lipid biosynthesis (ACCase). Post emergence, systemic grass herbicide. Phytotoxic symptoms appear within 1-3 weeks, affecting meristematic tissue. Used for post emergence control of annual grasses, including *Avena*, *Lolium, Phalaris* and *Alopecurus*, in cereals.

Table 6. Fenoxaprop-p-ethyl

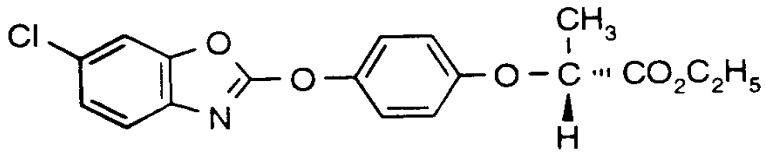
(i)	Common name	:	Fenoxaprop
(ii)	Molecular formula	:	$C_{16}H_{12}ClNO_5$
(iii)	Chemical structure: 		
(iv)	IUPAC name	:	(R)-2-[4-(6-chloro-1, 3-benzoxazol-2 yloxy) phenoxy] propionic acid; (R)-2-[4-6-chlorobenzoxazol-2-yloxy)phenoxy] propionic acid.
(v)	Trade name and formulation	:	Puma Power 10 EC (Bayer)
(vi)	Mode of action	:	Fenoxaprop-p-ethyl is selective herbicide with contact and systemic action, absorbed principally by the leaves, with translocation both acropetally and basipetally to the roots or rhizomes. Post emergence control of annual and perennial grass weeds in potatoes, beans, soybean, beets, vegetables, peanuts, flax, oilseed rape, and cotton and (when applied with the herbicide safener mefenpyr-diethyl) annual and perennial grass weeds and wild oats in wheat, rye, triticale and depending on ratio, in some varieties of barley.

Table 7. Sulfosulfuron

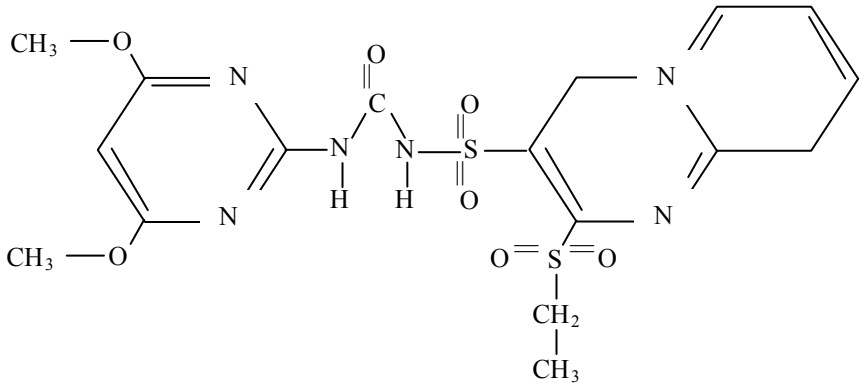
(i)	Common name	:	Sulfosulfuron (ISO proposed)
(ii)	Molecular formula	:	$C_{16}H_{18}N_6O_7S_2$
(iii)	Chemical structure: 		
(iv)	IUPAC name	:	1 – {2-Ethylsulfonylimidazo-[1,2-a] pyridin-3-yl) sulfonyl}-3-(4,6-dimethoxypyrimidin -2-yl) urea
(v)	Trade name and formulation	:	Sf – 10, 75% WG (UPL)
(vi)	Mode of action	:	It is mainly used against grassy weeds but also control broad leaf weeds to low extent. It inhibits the ALS enzyme, which is involved in the synthesis of branched chain amino acids (leucine, isoleucine and valine), essential for production of new cells. It is readily absorbed by both roots and foliage and translocated in both the xylem and phloem to the site of action. Affected plants exhibit stunting, interveinal chlorosis, cholorotic banding on grass leaves, red leaf venation, purpling, root pruning and gradual death.

Table 8. Pendimethalin

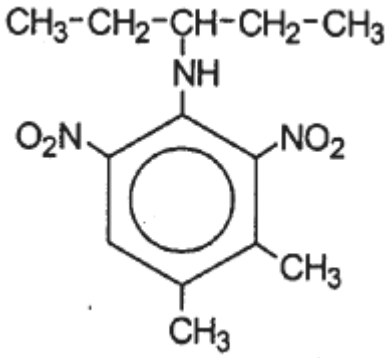
(i)	Herbicide group	Dinitroaniline
(ii)	Molecular formula	$C_{13}H_{19}N_3O_4$
(iii)	Structural formula	
(iv)	IUPAC name	N-(1-ethylpropyl)-3,4-dimethyl-2,6-dinitrobenzenamine.
(v)	Trade name and formulation	Stomp 30EC (Cynamid)
(vi)	Mode of action	Disruption of mitosis (inhibitor of microtubule synthesis)

Table 9. Isoproturon

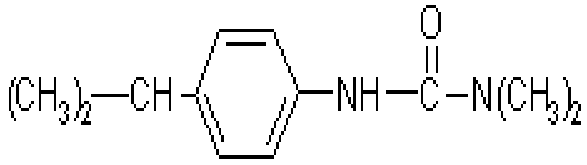
(i)	Herbicide group	Substituted phenyl urea
(ii)	Molecular formula	$C_{12}H_{18}N_{20}$
(iii)	Structural formula	
(iv)	IUPAC name	N,N-dimethyl-N'-[4-(1-methylethyl) phenyl]urea
(v)	Trade name and formulation	Isoguard 75% WP (Gharda)
(vi)	Mode of action	The primary site of action of this herbicide is located in photosystem-II involving the oxygen evolution step. It kills the weeds by inhibition of photosynthesis production of plant sugars and indirectly through inhibition of hill reaction.

Table 10. Metsulfuron- methyl

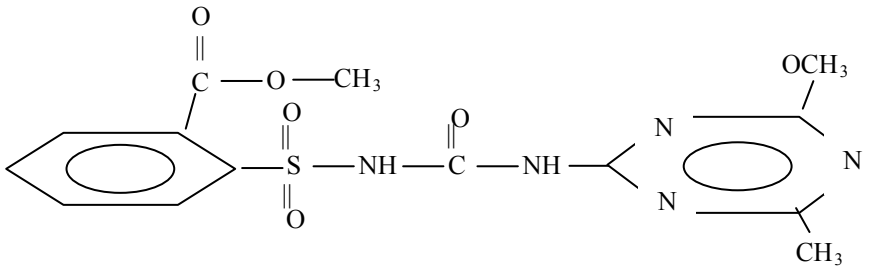
(i)	Herbicide group	:	Sulfonylurea
(ii)	Molecular formula	:	$C_{14}H_{15}N_5O_6S$
(iii)	Structural formula: 		
(iv)	IUPAC name	:	Methyl-2-[3-(4-methyoxy-6-metyl-1, 3, 5-triazin-2-yl) ureidosulphonyl] benzoate
(v)	Trade name and formulation	:	Algrip, 20% WP (Dupont)
(vi)	Mode of action	:	It enters the plant through the root zone and foliage. Inside the susceptible plants it acts by inhibiting the biosynthesis of acetolactate synthase (ALS), a key enzyme required in the biosynthesis of essential amino acids valine and isoleucine, in plants. This results in rapid inhibition of plant cell division and growth.

Table 11. 2, 4-D Ester

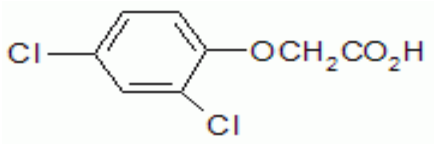
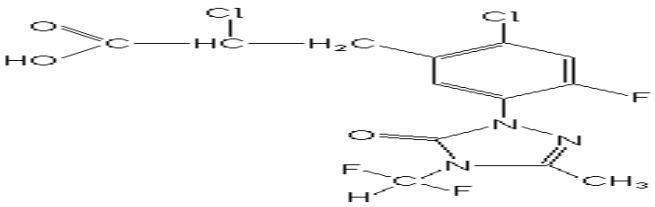
(i)	Herbicide group	Phenoxyalkanoic acid
(ii)	Molecular formula	$C_8H_6Cl_2O_3$
(iii)	Structural formula	
(iv)	IUPAC name	(2,4-dichlorophenoxy) acetic acid
(v)	Trade name and formulation	Weedmar, 38EC (Dhanuka)
(vi)	Mode of action	2,4D is a selective systemic herbicide. Salts are readily absorbed by the roots, whilst esters are readily absorbed by the foliage. Translocation occurs, with accumulation principally at the meristematic regions of shoots and roots. It is a synthetic growth substance which exhibits auxin like properties. It kill the weeds slowly dew to aberrant growth

Table 12. Carfentrazone

(i)	Herbicide group	:	Triazolinones
(ii)	Chemical name	:	α,2-dichloro-5-[4-(difluoromethyl)-4,5-dihydro-3-methyl-5-oxo-1*H*-1,2,4-triazol-1-yl]-4-fluorobenzenepropanoic acid
(iii)	Molecular formula	:	$C_{13}H_{10}Cl_2F_3N_3O_3$
(iv)	Structural formula: 		
(v)	IUPAC name	:	(RS)-2-chloro-3-{2-chloro-5-[4-(difluoromethyl)-4,5-dihydro-3-methyl-5-oxo-1H-1,2,4-triazol-1-yl]-4-fluorophenyl}propionic acid
(vi)	Trade name and Formulation	:	Affinity 40 WF (FMC)
(vii)	Mode of action	:	It enters the plant through the foliage and inhibit protoporphyrinogen oxidase; a key enzyme in the chloroplast of the plant cell that oxidizes protoporphyrinogen to produce protoporphyrin IX. This product is important because it is a precursor molecule for both chlorophyll (needed for photosynthesis) and heme (needed for electron transfer chains) in plants.

3.6 Uptake studies

Nitrogen, phosphorous and potassium content in both crop as well as weeds were determined by grinding the seed and straw samples separately in case of crop plants, and all plants parts (except roots in case of weeds). The fine material was digested in diacid mixture of concentrated sulphuric acid (H_2SO_4) and concentrated perchloric acid ($HCLO_4$) in the ratio of 4:1. The N content was estimated by Nesseler's reagent method (Lindner, 1944). In this way N concentration (percentage) was estimated. The total nitrogen uptake (kg ha^{-1}) was calculated by the following formula.

$$\text{N /P/K uptake (kg ha}^{-1}) = \frac{\text{\%N/P/K in grain/straw/weeds x dry weight of grain/straw/weeds}}{100}$$

3.7 Statistical analysis

All the observations were statistically analysed by using the statistical methods described by Panse and Sukhatme (1985). In order to see the significance of treatments effect, the data were subjected to the statistical analysis by analysis of variance technique given by Fisher (1958). The significant treatment effect was judged with the help of F-test at 5 per cent level of significance. To judge the significant differences between means of two treatments, the critical difference (C.D.) was worked out by following formula:

C.D. = $\sqrt{2E/n}$ x t at 5 per cent

Where, E = the error variance

n = the number of replications of that factor for which C.D. is to be calculated.

t = table value of "t" at 5 per cent level of significance at error degree of freedom.

3.8 Economics

The cost of cultivation and gross returns of various treatments were calculated on the basis of approved market rates for inputs and outputs. Net returns (Rs. ha^{-1}) were worked out by substracting the total cost of cultivation of each treatment from the gross income of respective treatment. B:C ratio was worked out by dividing the net return with total cost of cultivation.

CHAPTER -IV

EXPERIMENTAL RESULTS

The results of the field experiments are presented in this chapter. The data pertaining to the effects of different treatments on weeds and crop were statistically analyzed and after evaluating them for test of significance, observed results have been presented with the help of suitable tables and figures.

4.1 Evaluation of herbicides against complex weed flora in durum wheat

4.1.1 Weed studies

4.1.1.1 Weed flora of the experimental field

Key weed species present in the experimental field were collected and identified and mentioned in table 13 along with their taxonomic details.

Of many weed species present, *Phalaris minor*, *Chenopodium album, Avena ludoviciana, Melilotus indica* and *Anagallis arvensis* were the major weeds during both the years. *Convolvulus arvensis, Coronopus didymus and Rumex retroflexus* grouped under miscellaneous weeds were present at comparatively lower densities during both the years (Table 13).

4.1.1.2 Weed intensity (No. m^{-2})

The data pertaining to density of different weeds recorded at 30, 60, 90 DAS and at harvest are presented in tables 14 to 23. Before application of herbicides, weed count was taken at 30 DAS to observe infestation and distribution of weed flora in the experimental field.

4.1.1.2.1 *Phalaris minor*

All herbicidal treatments except 2,4-DE, metsulfuron-methyl and carfentrazone alone at all the stages and during both the years controlled population of *Phalaris minor* effectively as compared to weedy plots (Table 14). At harvest, herbicidal treatments including clodinafop, fenoxaprop and sulfosulfuron reduced the population of *P. minor* to the extent of 82.3 to 90.2 and 85.5 to 96.6 per cent during 2005-06 and 2006-07, respectively. Application of isoproturon 750 and 1000 g ha^{-1} controlled this weed to the extent of 38.7 to 68.4 and 48.5 to 68.7 per cent at harvest during 2005-06 and 2006-07, respectively.

Table. 13 Per cent composition of weed flora in weedy check

Weed species	English name	Local name	Family		Days after sowing							
					2005-06				2006-07			
					30	60	90	At harvest	30	60	90	At harvest
Phalaris minor Retz.	Little seed canary grass	Kanki/Mandusi	Poaceae		27.3	29.8	30.4	31	21.2	26.6	26.6	25.4
Avena ludoviciana Dur.	Wild Oat	Jungli Jai	Poaceae		13.8	16.4	17	17.1	18.2	17.8	18.3	19
			Total density of grassy weeds		**41.1**	**46.2**	**47.4**	**48.1**	**39.4**	**44.4**	**44.9**	**44.4**
Chenopodium album L.	Lambs quarters	Bathu	Chenopodiaceae	Miscellaneous weeds	18.8	17.6	15.9	13.1	16.3	15.6	14.1	14.5
Melilotus indica L.	Sweet clover	Senji	Leguminosae		12.8	12.4	12.7	12.4	15.4	14.2	13.4	13.4
Anagalis arvensis L.	Pimpernel	Krishanneel	Primulaceae		10.5	9.1	9.1	10.4	12.4	10.3	11.9	12.6
Convolvulus arvensis L.	Field bind weed	Hirankhuri	Convolvulaceae									
Coronopus didymus L.	Swine grass	Pith papra	Cruciferae		16.8	14.6	14.8	16.1	16.3	15.4	15.6	15.1
Rumex retroflexus L.	Golden dock	Jungli Palak	Polygonaceae									
			Total density of broad leaf weeds		**58.9**	**53.7**	**52.5**	**52.0**	**60.4**	**55.5**	**55.0**	**55.6**

Table. 14 Effect of herbicidal treatments on population (No. m^{-2}) of *Phalaris minor* in durum wheat

Treatments	Dose (g ha^{-1})	2005-06				2006-07			
		Days after sowing				Days after sowing			
		30	60	90	At harvest	30	60	90	At harvest
Isoproturon	1000	6.10(36.3)	4.16(16.3)	3.96(14.7)	3.60(12.0)	5.68(31.3)	4.44(18.7)	3.83(13.7)	3.21(9.3)
Clodinafop	60	6.00(35.0)	2.51(5.3)	2.30(4.3)	2.17(3.7)	5.45(28.7)	2.07(3.3)	1.64(1.7)	1.41(1.0)
Fenoxaprop +S	100+0.1%	6.02(35.3)	3.05(8.3)	3.00(8.0)	2.77(6.7)	5.54(29.7)	2.70(6.3)	2.24(4.0)	1.82(2.3)
Sulfosulfuron	25	6.20(37.7)	2.99(8.0)	2.70(6.3)	2.44(5.0)	5.46(29.0)	2.64(6.0)	2.30(4.3)	2.16(3.7)
2,4-D E	500	6.24(38.0)	7.12(49.7)	6.81(45.4)	6.34(39.3)	5.65(31.0)	6.85(46.0)	6.34(39.3)	5.59(30.3)
Metsulfuron- methyl	4	6.16(37.3)	7.13(50.3)	6.82(46.0)	6.32(39.3)	5.57(30.3)	6.94(47.7)	6.19(37.7)	5.74(32.3)
Carfentrazone-ethyl	20	6.31(39.0)	7.48(55.3)	7.07(49.3)	6.46(41.0)	5.73(32.0)	6.46(41.0)	6.04(35.7)	5.55(30.0)
Isoproturon+2,4-DE	750+500	6.19(37.3)	4.79(22.0)	4.39(18.3)	4.04(15.3)	5.59(30.3)	4.58(20.0)	4.39(18.3)	3.96(14.7)
Isoproturon+Metsulfuron	750+4	6.14(36.7)	4.93(23.3)	4.58(20.0)	4.32(17.7)	5.54(29.7)	4.72(21.3)	4.24(17.0)	4.04(15.3)
Clodinafop *fb* 2,4-DE	60&500	6.09(36.3)	2.94(7.7)	2.50(5.3)	2.07(3.3)	5.49(29.3)	2.58(5.7)	2.16(3.7)	2.07(3.3)
Clodinafop *fb* Metsulfuron	60&4	6.27(38.3)	3.05(8.3)	2.77(6.7)	2.45(5.0)	5.57(30.0)	2.70(6.3)	1.73(2.0)	1.73(2.0)
Fenoxaprop+S *fb* 2,4-DE	100+0.1%&500	6.06(35.7)	2.77(6.7)	2.70(6.3)	2.59(5.7)	5.51(29.3)	2.39(4.7)	2.17(3.7)	2.00(3.0)
Fenoxaprop +S *fb* Metsulfuron	100+0.1% &4	6.14(36.7)	3.05(8.3)	2.88(7.3)	2.65(6.0)	5.39(28.0)	2.70(6.3)	2.45(5.0)	2.30(4.3)
Sulfosulfuron +Metsulfuron(RM)	30+2.2	6.08(36.0)	2.65(6.0)	2.65(6.0)	2.51(5.3)	5.41(28.3)	2.24(4.0)	1.92(2.7)	1.64(1.7)
Isoproturon+Carfentrazone	750+20	6.18(37.3)	4.58(20.0)	4.39(18.3)	4.27(17.3)	5.62(30.7)	4.32(17.7)	3.91(14.3)	3.83(13.7)
Clodinafop *fb* Carfentrazone	60&20	6.10(36.3)	2.70(6.3)	2.59(5.7)	2.17(3.7)	5.65(31.0)	2.30(4.3)	1.92(2.7)	1.82(2.3)
Fenoxaprop+S *fb* Carfentrazone	100+0.1%+20	6.24(38.0)	3.11(8.7)	2.64(6.0)	2.59(5.7)	5.59(30.3)	2.77(6.7)	2.24(4.0)	2.17(3.7)
Sulfosulfuron+ Carfentrazone	20&20	6.29(38.5)	3.16(9.0)	2.95(7.7)	2.51(5.3)	5.75(32.0)	2.83(7.0)	2.30(4.3)	2.00(3.0)
Weedy	-	6.10(36.3)	7.16(50.3)	6.76(44.7)	6.24(38.0)	5.59(30.3)	6.68(43.7)	6.10(36.3)	5.54(29.7)
Weed free	-	1.00(0.0)	1.00(0.0)	1.00(0.0)	1.00(0.0)	1.00(0.0)	1.00(0.0)	1.00(0.0)	1.00(0.0)
SEm±		0.20	0.18	0.17	0.15	0.18	0.16	0.15	0.13
CD at 5%		0.57	0.51	0.48	0.44	0.51	0.47	0.42	0.38

Original data given in parentheses was subjected to square root ($\sqrt{x+1}$) transformation before analysis

4.1.1.2.2 *Avena ludoviciana*

The population of *Avena ludoviciana* recorded at different stages indicated that all the herbicidal treatments except 2,4-DE, metsulfuron-methyl and carfentrazone alone caused a significant reduction in the density of this weed as compared to weedy check (Table 15). Isoproturon was less effective against this weed (8.7 to 10.3 and 7.0 to 8.7 plants m^{-2}) as compared to clodinafop, fenoxaprop and sulfosulfuron (0.7 to 3.3 and 0.7 to 2.7 plants m^{-2} during 2005-06 and 2006-07, respectively).

4.1.1.2.3 Density of total grassy weeds

All herbicidal treatments except metsulfuron, 2,4-DE and carfentrazone alone significantly reduced the population of grassy weeds (Table16) as compared to weedy check.

Application of clodinafop, fenoxaprop and sulfosulfuron as well as their combinations with metsulfuron, 2,4-DE or carfentrazone alone being at par with each other and to weed free check were significantly superior in controlling grassy weeds to rest of the treatments. At harvest, the density of grassy weeds under these herbicidal treatments was 4.4 to 11.7 and 2.0 to 6.6 plants m^{-2} during 2005-06 and 2006-07, respectively.

Isoproturon alone and its combinations with metsulfuron, 2,4-DE and carfentrazone alone proved less effective against grassy weeds (23.4 to 30.0 and 16.3 to 23.4 plants m^{-2}) than clodinafop, fenoxaprop and sulfosulfuron. The maximum population of grassy weeds was recorded under metsulfuron, 2,4-DE and carfentrazone alone treated plots (61.6 to 64.3 and 54.0 to 56.0 plants m^{-2})which was higher or similar to weedy check plots (59 and 52 plants m^{-2}) during both the years of experimentation.

4.1.1.2.4 *Chenopodium album*

Application of clodinafop 60 g ha^{-1} and fenoxaprop 100 g ha^{-1} alone had no effect on *Chenopodium album* (Table 17). Population of this weed increased throughout the season under these treatments and was statistically similar to that recorded under weedy check. Application of metsulfuron-methyl(4 g ha^{-1}), 2,4-DE(500 g ha^{-1}) and carfentrazone-ethyl (20 g ha^{-1}) alone and their combinations with grassy killing herbicides effectively controlled the population of *C. album* (0.3 to 2.3 plants m^{-2}) and these were statistically at par with weed free treatment during both the years of experimentation.

Table. 15 Effect of herbicidal treatments on population (No. m^{-2}) of *Avena ludoviciana* in durum wheat

Treatments	Dose (g ha^{-1})	2005-06				2006-07			
		Days after sowing				Days after sowing			
		30	60	90	At harvest	30	60	90	At harvest
Isoproturon	1000	4.50(19.3)	3.36(10.3)	3.11(8.7)	3.00(8.0)	5.03(24.3)	3.05(8.3)	2.83(7.0)	2.83(7.0)
Clodinafop	60	4.58(20.0)	1.82(2.3)	1.30(0.7)	1.30(0.7)	4.90(23.0)	3.07(3.3)	2.07(3.3)	1.41(1.0)
Fenoxaprop +S	100+0.1%	4.55(19.7)	2.17(3.7)	1.82(2.3)	1.52(1.3)	4.93(23.3)	2.17(3.7)	1.92(2.7)	1.41(1.0)
Sulfosulfuron	25	4.54(19.7)	2.44(5.0)	2.16(3.7)	2.07(3.3)	5.15(25.7)	2.58(5.7)	2.58(5.7)	1.64(1.7)
2,4-D E	500	4.32(17.7)	5.63(30.7)	5.29(27.0)	4.82(22.3)	5.13(25.3)	5.80(32.7)	5.38(28.0)	5.03(24.3)
Metsulfuron- methyl	4	4.48(19.3)	5.45(29.0)	5.54(30.0)	4.95(23.7)	5.27(27.0)	5.66(31.3)	5.39(28.3)	4.95(23.7)
Carfentrazone-ethyl	20	4.46(19.0)	5.73(32.0)	5.40(28.3)	4.92(23.3)	5.11(25.3)	5.87(33.7)	5.53(29.7)	4.99(24.0)
Isoproturon+2,4-DE	750+500	4.32(17.7)	3.70(12.7)	3.21(9.3)	3.11(8.7)	5.07(24.7)	3.51(11.3)	3.27(9.7)	3.11(8.7)
Isoproturon+Metsulfuron	750+4	4.39(18.3)	3.51(11.3)	3.32(10.0)	3.07(8.3)	5.23(26.3)	3.42(10.7)	3.36(10.3)	3.00(8.0)
Clodinafop *fb* 2,4-DE	60&500	4.49(19.3)	2.00(3.0)	2.00(3.0)	1.82(2.3)	4.96(23.70	2.16(3.7)	1.73(2.0)	1.30(0.7)
Clodinafop *fb* Metsulfuron	60&4	4.36(18.0)	1.92(2.7)	1.80(2.3)	1.41(1.0)	5.07(24.7)	2.00(3.0)	173(2.0)	1.52(1.3)
Fenoxaprop+S *fb* 2,4-DE	100+0.1%&500	4.21(16.7)	2.07(3.3)	1.73(2.0)	1.64(1.7)	5.00(24.0)	2.30(4.3)	2.07(3.3)	1.64(1.7)
Fenoxaprop +S *fb* Metsulfuron	100+0.1% &4	4.58(20.0)	2.17(3.7)	2.07(3.3)	1.64(1.7)	5.20(26.0)	2.30(4.3)	2.24(4.0)	1.82(2.3)
Sulfosulfuron +Metsulfuron(RM)	30+2.2	4.44(18.7)	2.35(4.5)	2.17(3.7)	2.07(3.3)	5.13(25.3)	2.45(5.0)	2.17(3.7)	1.92(2.7)
Isoproturon+Carfentrazone	750+20	4.50(19.3)	3.56(11.7)	3.36(10.3)	3.16(9.0)	5.28(27.0)	3.64(12.3)	3.36(10.3)	3.05(8.3)
Clodinafop *fb* Carfentrazone	60&20	4.44(18.7)	1.92(2.7)	1.92(2.7)	1.73(2.0)	5.12(25.3)	2.07(3.3)	2.24(4.0)	1.41(1.0)
Fenoxaprop+S *fb* Carfentrazone	100+0.1%+20	4.47(19.0)	2.17(3.7)	2.00(3.0)	1.82(2.3)	4.93(23.3)	2.24(4.0)	2.00(3.0)	1.64(1.7)
Sulfosulfuron+ Carfentrazone	20&20	4.32(17.7)	2.30(4.3)	2.24(4.0)	1.73(2.0)	5.17(25.7)	2.59(5.7)	2.07(3.3)	1.52(1.3)
Weedy	-	4.39(18.3)	5.35(27.7)	5.10(25.0)	4.69(21.0)	5.19(26.0)	5.50(29.3)	5.10(25.0)	4.82(22.3)
Weed free	-	1.00(0.0)	1.00(0.0)	1.00(0.0)	1.00(0.0)	1.00(0.0)	1.00(0.0)	1.00(0.0)	1.00(0.0)
SEm±		0.14	0.13	0.13	0.11	0.16	0.14	0.13	0.11
CD at 5%		0.40	0.38	0.37	0.33	0.47	0.39	0.37	0.32

Table. 16 Effect of herbicidal treatments on population (No. m^{-2}) of grassy weeds in durum wheat

Treatments	Dose (g ha^{-1})	2005-06				2006-07			
		Days after sowing				Days after sowing			
		30	60	90	At harvest	30	60	90	At harvest
Isoproturon	1000	7.51(55.6)	5.25(26.6)	4.93(23.4)	4.58(20.0)	7.51(55.6)	5.28(27.0)	4.65(20.7)	4.15(16.3)
Clodinafop	60	7.48(55.0)	2.93(7.6)	2.45(5.0)	2.32(4.4)	7.25(51.7)	2.75(6.6)	2.44(5.0)	1.73(2.0)
Fenoxaprop +S	100+0.1%	7.47(55.0)	3.60(12.0)	3.36(10.3)	2.99(8.0)	7.34(53.0)	3.31(10.0)	2.77(6.7)	2.07(3.3)
Sulfosulfuron	25	7.61(57.4)	3.73(13.0)	3.30(10.0)	3.04(8.3)	7.43(54.7)	3.55(11.7)	3.30(10.0)	2.52(5.4)
2,4-D E	500	7.52(55.7)	9.01(80.4)	8.56(72.4)	7.90(61.6)	7.56(56.3)	8.92(78.7)	8.25(67.3)	7.45(54.6)
Metsulfuron- methyl	4	7.55(56.6)	8.91(79.3)	8.73(76.0)	7.96(63.0)	7.59(57.3)	8.89(79.0)	8.14(66.0)	7.51(56.0)
Carfentrazone-ethyl	20	7.65(58.0)	9.36(87.3)	8.83(77.6)	8.05(64.3)	7.61(57.3)	8.67(74.7)	8.12(65.4)	7.39(54.0)
Isoproturon+2,4-DE	750+500	7.47(55.0)	5.97(34.7)	5.34(27.6)	4.99(24.0)	7.47(55.0)	5.68(31.3)	5.38(28.0)	4.93(23.4)
Isoproturon+Metsulfuron	750+4	7.48(55.0)	5.96(34.6)	5.56(30.0)	5.19(26.0)	7.55(56.0)	5.74(32.0)	5.32(27.3)	4.93(23.3)
Clodinafop *fb* 2,4-DE	60&500	7.50(55.6)	3.41(10.7)	3.04(8.3)	2.56(5.6)	7.32(53.0)	3.21(9.4)	2.58(5.7)	2.23(4.0)
Clodinafop *fb* Metsulfuron	60&4	7.56(56.3)	3.46(11.0)	3.16(9.0)	2.64(6.0)	7.46(54.7)	3.20(9.3)	2.23(4.0)	2.07(3.3)
Fenoxaprop+S *fb* 2,4-DE	100+0.1%&500	7.30(52.4)	3.31(10.0)	3.05(8.3)	2.89(7.4)	7.36(53.3)	3.16(9.0)	2.82(7.0)	2.38(4.7)
Fenoxaprop +S *fb* Metsulfuron	100+0.1% &4	7.59(56.7)	3.60(12.0)	3.40(10.6)	2.95(7.7)	7.41(54.0)	3.40(10.6)	3.16(9.0)	2.75(6.6)
Sulfosulfuron +Metsulfuron(RM)	30+2.2	7.46(54.7)	3.39(10.5)	3.27(9.7)	3.09(8.6)	7.38(53.6)	3.16(9.0)	2.72(6.4)	2.32(4.4)
Isoproturon+Carfentrazone	750+20	7.57(56.6)	5.70(31.7)	5.43(28.6)	5.21(26.3)	7.64(57.7)	5.55(30.0)	5.05(24.6)	4.78(22.0)
Clodinafop *fb* Carfentrazone	60&20	7.47(55.0)	3.16(9.0)	3.06(8.4)	2.58(5.7)	7.56(56.3)	2.93(7.6)	2.77(6.7)	2.07(3.3)
Fenoxaprop+S *fb* Carfentrazone	100+0.1%+20	7.61(57.0)	3.65(12.4)	3.16(9.0)	2.99(8.0)	7.38(53.6)	3.41(10.7)	2.82(7.0)	2.52(5.4)
Sulfosulfuron+ Carfentrazone	20&20	7.56(56.2)	3.78(13.3)	3.56(11.7)	2.88(7.3)	7.66(57.7)	3.70(12.7)	2.93(7.6)	2.30(4.3)
Weedy	-	7.45(54.6)	8.88(78.0)	8.40(69.7)	7.74(59.0)	7.56(56.3)	8.59(73.0)	7.88(61.3)	7.27(52.0)
Weed free	-	1.00(0.0)	1.00(0.0)	1.00(0.0)	1.00(0.0)	1.00(0.0)	1.00(0.0)	1.00(0.0)	1.00(0.0)
SEm±		0.25	0.22	0.21	0.19	0.24	0.21	0.20	0.17
CD at 5%		0.71	0.64	0.60	0.55	0.70	0.62	0.56	0.51

Table. 17 Effect of herbicidal treatments on population (No. m^{-2}) of *Chenopodium album* in durum wheat

Treatments	Dose (g ha^{-1})	2005-06				2006-07			
		Days after sowing				Days after sowing			
		30	60	90	At harvest	30	60	90	At harvest
Isoproturon	1000	5.13(25.3)	3.46(11.0)	3.36(10.3)	3.11(8.7)	5.13(25.3)	3.78(13.3)	3.56(11.7)	3.27(9.7)
Clodinafop	60	5.29(27.0)	5.59(30.3)	5.17(25.7)	4.83(22.3)	4.79(22.0)	5.03(24.3)	4.87(22.7)	4.66(20.7)
Fenoxaprop +S	100+0.1%	5.19(26.0)	5.80(32.7)	5.41(28.3)	4.79(22.0)	5.16(25.7)	5.47(29.0)	5.13(25.3)	4.93(23.3)
Sulfosulfuron	25	5.21(26.3)	3.73(13.0)	3.50(11.3)	3.15(9.0)	5.05(24.7)	3.55(11.7)	3.26(9.7)	3.11(8.7)
2,4-D E	500	5.45(28.7)	1.82(2.3)	1.92(2.7)	1.82(2.3)	4.93(23.3)	1.64(1.7)	1.41(1.0)	1.30(0.7)
Metsulfuron- methyl	4	5.14(25.7)	1.52(1.3)	1.41(1.0)	1.41(1.0)	4.95(23.7)	1.81(2.3)	1.41(1.0)	1.14(0.3)
Carfentrazone-ethyl	20	5.28(27.0)	2.07(3.3)	2.00(3.0)	1.73(2.0)	4.81(22.3)	1.82(2.30	1.92(2.7)	1.30(0.7)
Isoproturon+2,4-DE	750+500	5.22(26.3)	1.52(1.3)	1.41(1.0)	1.30(0.7)	5.00(24.0)	1.64(1.7)	1.30(0.7)	1.30(0.7)
Isoproturon+ Metsulfuron	750+4	5.26(26.7)	2.07(2.0)	1.41(1.0)	1.41(1.0)	4.90(23.0)	1.92(2.7)	1.30(0.7)	1.14(0.3)
Clodinafop *fb* 2,4-DE	60&500	5.28(27.0)	1.52(3.3)	1.92(2.7)	1.41(1.0)	4.92(23.3)	1.73(2.0)	1.41(1.0)	1.14(0.3)
Clodinafop *fb* Metsulfuron	60&4	5.48(29.0)	1.73(2.7)	1.64(1.7)	1.41(1.0)	5.17(25.7)	1.92(2.7)	1.52(1.3)	1.30(0.7)
Fenoxaprop+ S *fb* 2,4-DE	100+0.1%&500	5.26(26.7)	2.07(4.7)	2.07(3.3)	1.64(1.7)	4.87(22.7)	2.00(3.0)	1.82(2.3)	1.41(1.0)
Fenoxaprop +S *fb* Metsulfuron	100+0.1% &4	5.41(28.3)	1.92(3.0)	1.92(2.7)	1.64(1.7)	5.07(24.7)	2.07(3.3)	1.64(1.7)	1.52(1.3)
Sulfosulfuron +Metsulfuron(RM)	30+2.2	5.10(25.0)	2.39(4.0)	2.07(3.3)	1.82(2.3)	4.80(22.0)	2.17(3.7)	1.64(1.7)	1.41(1.0)
Isoproturon+ Carfentrazone	750+20	5.53(29.7)	2.00(3.0)	1.41(1.0)	1..14(0.3)	4.92(23.3)	1.64(1.7)	1.41(1.0)	1.30(0.7)
Clodinafop *fb* Carfentrazone	60&20	5.35(27.7)	2.30(4.3)	1.41(1.0)	1.30(0.7)	4.80(22.3)	1.52(1.3)	1.30(0.7)	1.14(0.3)
Fenoxaprop+S *fb* Carfentrazone	100+0.1%+20	5.10(25.0)	2.59(5.7)	2.17(3.7)	1.82(2.3)	5.00(24.0)	2.00(3.0)	1.52(1.3)	1.41(1.0)
Sulfosulfuron+ Carfentrazone	20&20	5.23(26.3)	2.39(4.7)	1.92(2.7)	1.82(2.3)	4.90(23.0)	2.07(3.3)	1.41(1.0)	1.41(1.0)
Weedy	-	5.10(25.0)	5.54(29.7)	4.94(23.4)	4.12(16.0)	4.93(23.3)	5.16(25.7)	4.50(19.3)	4.24(17.0)
Weed free	-	1.00(0.0)	1.00(0.0)	1.00(0.0)	1.00(0.0)	1.00(0.0)	1.00(0.0)	1.00(0.0)	1.00(0.0)
SEm±		0.17	0.08	0.07	0.06	0.16	0.08	0.07	0.06
CD at 5%		0.48	0.23	0.21	0.18	0.45	0.22	0.19	0.17

Isoproturon and sulfosulfuron alone significantly reduced the population (8.7 and 9.0 plants m^{-2}) of this weed than weedy check (16 plants m^{-2}) but were less effective than metsulfuron, 2,4-DE and carfentrazone.

4.1.1.2.5 *Melilotus indica*

Population of *Melilotus indica* under fenoxaprop and clodinafop alone treated plots was statistically similar to weedy check (Table 18).

Complete control of this weed was observed with the treatments , metsulfuron, 2,4-DE and carfentrazone alone and their combinations with grass killing herbicides which were comparable with weed free treatments during both the years. Isoproturon and sulfosulfuron controlled this weed to some extent (28.8 to 48.3 per cent)

4.1.1.2.6 *Anagallis arvensis*

All herbicidal treatments except clodinafop and fenoxaprop alone significantly reduced the density of *Anagallis arvensis* at all crop growth stages during both the years (Table 19).

At harvest, up to 100 per cent control of this weed was recorded with metsulfuron, 2,4-DE and carfentrazone. Application of isoproturon and sulfosulfuron alone reduced the population of *A. arvensis* to the extent of 44.5 to 50.4 and 51.0 to 57.1 per cent during 2005-06 and 2006-07, respectively.

4.1.1.2.7 Miscellaneous broadleaf weeds

The miscellaneous broadleaf weeds including *Convolvulus arvensis, Coronopus didymus* and *Rumex retroflexus* were suppressed by all herbicidal treatments except clodinafop and fenoxaprop alone over weedy check (Table 20). Isoproturon and sulfosulfuron alone were less effective against these weeds but significantly reduced the population over weedy check at all the growth stages of crop during both the years.

4.1.1.2.8 Density of broadleaf weeds

The density of broadleaf weeds was influenced significantly due to all herbicidal treatments except clodinafop and fenoxaprop (Table 21). Broadleaf weeds were effectively controlled (88.8 to 97.9 and 92.7 to 99.0 per cent) with metsulfuron, 2,4-DE and carfentrazone alone and their combinations with other herbicides. Isoproturon and sulfosulfuron alone controlled 18.6 and 22.6 per cent broadleaf weeds during 2005-06 and 34.9 and 43.9 per

Table. 18 Effect of herbicidal treatments on population (No. m^{-2}) of *Melilotus indica* in durum wheat

Treatments	Dose (g ha^{-1})	2005-06				2006-07			
		Days after sowing				Days after sowing			
		30	60	90	At harvest	30	60	90	At harvest
Isoproturon	1000	4.39(18.3)	3.65(12.3)	3.56(11.7)	3.42(10.7)	4.69(21.0)	3.91(14.3)	3.70(12.7)	3.51(11.3)
Clodinafop	60	4.66(20.7)	4.79(22.0)	4.50(19.3)	4.28(17.3)	4.87(22.7)	4.97(23.7)	4.55(19.7)	4.28(17.3)
Fenoxaprop +S	100+0.1%	4.32(17.7)	4.76(21.7)	4.44(18.7)	4.00(15.0)	4.58(20.0)	4.76(21.7)	4.50(19.3)	4.36(18.0)
Sulfosulfuron	25	4.46(19.0)	3.35(10.3)	3.04(8.3)	2.82(7.0)	4.71(21.3)	3.50(11.3)	3.26(9.7)	3.15(9.0)
2,4-D E	500	4.39(18.3)	2.00(2.0)	1.41(1.0)	1.30(0.7)	4.58(20.0)	1.41(1.0)	1.00(0.0)	1.00(0.0)
Metsulfuron- methyl	4	4.26(17.3)	1.52(1.3)	1.00(0.0)	1.00(0.0)	4.77(22.0)	1.00(0.0)	1.00(0.0)	1.00(0.0)
Carfentrazone-ethyl	20	4.46(19.0)	1.41(1.0)	1.00(0.0)	1.00(0.0)	4.71(21.3)	1.00(0.0)	1.00(0.0)	1.00(0.0)
Isoproturon+2,4-DE	750+500	4.36(18.0)	1.41(1.0)	1.00(0.0)	1.00(0.0)	4.61(20.3)	1.00(0.0)	1.00(0.0)	1.00(0.0)
Isoproturon+Metsulfuron	750+4	4.55(19.7)	1.41(0.0)	1.00(0.0)	1.00(0.0)	4.80(22.0)	1.00(0.0)	1.00(0.0)	1.00(0.0)
Clodinafop *fb* 2,4-DE	60&500	4.23(17.0)	1.30(0.7)	1.00(0.0)	1.00(0.0)	4.68(21.0)	1.14(0.3)	1.00(0.0)	1.00(0.0)
Clodinafop *fb* Metsulfuron	60&4	4.39(18.3)	1.30(0.7)	1.14(0.3)	1.00(0.0)	4.72(21.3)	1.30(0.7)	1.00(0.0)	1.00(0.0)
Fenoxaprop+S *fb* 2,4-DE	100+0.1%&500	4.24(17.0)	1.14(0.3)	1.14(0.3)	1.00(0.0)	4.76(21.7)	1.41(1.0)	1.30(0.7)	1.14(0.3)
Fenoxaprop +S *fb* Metsulfuron	100+0.1% &4	4.47(19.0)	1.41(1.0)	1.31(0.7)	1.00(0.0)	4.80(22.0)	1.31(0.7)	1.00(0.0)	1.00(0.0)
Sulfosulfuron +Metsulfuron(RM)	30+2.2	4.39(18.3)	1.41(1.0)	1.14(0.3)	1.00(0.0)	4.72(21.3)	1.41(1.0)	1.00(0.0)	1.00(0.0)
Isoproturon+Carfentrazone	750+20	4.43(18.7)	1.52(1.3)	1.30(0.7)	1.00(0.0)	4.96(23.7)	1.52(1.3)	1.00(0.0)	1.00(0.0)
Clodinafop *fb* Carfentrazone	60&20	4.47(19.0)	1.00(0.0)	1.00(0.0)	1.00(0.0)	4.65(20.7)	1.73(2.0)	1.52(1.3)	1.00(0.0)
Fenoxaprop+S *fb* Carfentrazone	100+0.1%+20	4.44(18.7)	1.14(0.3)	1.00(0.0)	1.00(0.0)	4.72(21.3)	1.64(1.7)	1.30(0.7)	1.00(0.0)
Sulfosulfuron+ Carfentrazone	20&20	4.62(20.3)	1.30(0.7)	1.00(0.0)	1.00(0.0)	4.58(20.0)	1.00(0.0)	1.00(0.0)	1.00(0.0)
Weedy	-	4.24(17.0)	4.69(21.0)	4.44(18.7)	4.02(15.2)	4.79(22.0)	4.93(23.3)	4.39(18.3)	4.08(15.7)
Weed free	-	1.00(0.0)	1.00(0.0)	(0.0)	1.00(0.0)	1.00(0.0)	1.00(0.0)	1.00(0.0)	1.00(0.0)
SEm±		0.14	0.07	0.06	0.05	0.15	0.07	0.06	0.06
CD at 5%		0.39	0.19	0.17	0.15	0.43	0.19	0.17	0.16

Table. 19 Effect of herbicidal treatments on population (No. m^{-2}) of *Anagalis arvensis* in durum wheat

Treatments	Dose (g ha^{-1})	2005-06				2006-07			
		Days after sowing				Days after sowing			
		30	60	90	At harvest	30	60	90	At harvest
Isoproturon	1000	3.65(12.3)	3.11(8.7)	2.95(7.7)	2.83(7.0)	4.21(16.7)	2.95(7.7)	2.70(6.3)	2.70(6.3)
Clodinafop	60	3.87(14.0)	4.00(15.0)	3.83(13.7)	3.60(12.0)	3.39(18.3)	4.58(20.0)	4.39(18.3)	4.32(17.7)
Fenoxaprop +S	100+0.1%	3.74(13.0)	4.21(16.7)	3.91(14.3)	3.70(12.7)	4.00(15.0)	4.32(17.7)	3.87(14.00	3.78(13.3)
Sulfosulfuron	25	3.95(14.7)	3.11(8.7)	2.94(7.7)	2.70(6.3)	4.35(18.0)	2.58(5.7)	2.58(5.7)	2.50(5.3)
2,4-D E	500	3.70(12.7)	1.64(1.7)	1.00(0.0)	1.00(0.0)	4.16(16.3)	1.82(2.3)	1.41(1.0)	1.00(0.0)
Metsulfuron- methyl	4	3.86(14.0)	1.41(1.0)	1.00(0.0)	1.00(0.0)	3.98(15.0)	1.00(0.0)	1.00(0.0)	1.00(0.0)
Carfentrazone-ethyl	20	3.77(13.3)	1.41(1.0)	1.00(0.0)	1.00(0.0)	4.23(17.0)	1.00(0.0)	1.00(0.0)	1.00(0.0)
Isoproturon+2,4-DE	750+500	3.65(12.3)	1.00(0.0)	1.00(0.0)	1.00(0.0)	4.21(16.7)	1.00(0.0)	1.00(0.0)	1.00(0.0)
Isoproturon+Metsulfuron	750+4	3.78(13.3)	1.30(0.7)	1.00(0.0)	1.00(0.0)	4.39(18.3)	1.00(0.0)	1.00(0.0)	1.00(0.0)
Clodinafop *fb* 2,4-DE	60&500	3.60(12.0)	1.52(1.3)	1.00(0.0)	1.00(0.0)	4.08(15.7)	1.00(0.0)	1.00(0.0)	1.00(0.0)
Clodinafop *fb* Metsulfuron	60&4	3.87(14.0)	1.14(0.3)	1.00(0.0)	1.00(0.0)	4.24(17.0)	1.00(0.0)	1.00(0.0)	1.00(0.0)
Fenoxaprop+S *fb* 2,4-DE	100+0.1%&500	3.83(13.7)	1.14(0.3)	1.00(0.0)	1.00(0.0)	4.16(16.3)	1.00(0.0)	1.00(0.0)	1.00(0.0)
Fenoxaprop +S *fb* Metsulfuron	100+0.1% &4	4.04(15.3)	1.31(0.7)	1.00(0.0)	1.00(0.0)	4.32(17.7)	1.00(0.0)	1.00(0.0)	1.00(0.0)
Sulfosulfuron +Metsulfuron(RM)	30+2.2	3.61(12.0)	1.00(0.0)	1.00(0.0)	1.00(0.0)	4.21(16.7)	1.00(0.0)	1.00(0.0)	1.00(0.0)
Isoproturon+Carfentrazone	750+20	3.99(15.0)	1.00(0.0)	1.00(0.0)	1.00(0.0)	4.24(17.0)	1.00(0.0)	1.00(0.0)	1.00(0.0)
Clodinafop *fb* Carfentrazone	60&20	3.74(13.0)	1.30(0.7)	1.00(0.0)	1.00(0.0)	4.03(15.3)	1.00(0.0)	1.00(0.0)	1.00(0.0)
Fenoxaprop+S *fb* Carfentrazone	100+0.1%+20	3.96(14.7)	1.30(0.7)	1.00(0.0)	1.00(0.0)	4.24(17.0)	1.00(0.0)	1.00(0.0)	1.00(0.0)
Sulfosulfuron+ Carfentrazone	20&20	3.83(13.7)	1.14(0.3)	1.00(0.0)	1.00(0.0)	4.12(16.0)	1.00(0.0)	1.00(0.0)	1.00(0.0)
Weedy	-	3.87(14.0)	4.04(15.3)	3.78(13.3)	3.70(12.7)	4.32(17.7)	4.24(17.0)	4.16(16.3)	3.96(14.7)
Weed free	-	1.00(0.0)	1.00(0.0)	(0.0)	1.00(0.0)	1.00(0.0)	1.00(0.0)	1.00(0.0)	1.00(0.0)
SEm±		0.12	0.06	0.05	0.05	0.13	0.05	0.05	0.05
CD at 5%		0.34	0.17	0.15	0.14	0.37	0.15	0.14	0.13

Table. 20 Effect of herbicidal treatments on population (No. m^{-2}) of miscellaneous weeds in durum wheat

Treatments	Dose (g ha^{-1})	2005-06				2006-07			
		Days after sowing				Days after sowing			
		30	60	90	At harvest	30	60	90	At harvest
Isoproturon	1000	4.90(23.0)	4.32(17.7)	4.04(15.3)	3.83(13.7)	4.82(22.3)	3.91(14.3)	3.74(13.0)	3.51(11.3)
Clodinafop	60	5.07(24.7)	5.10(25.0)	4.83(22.3)	4.55(19.7)	4.90(23.0)	5.10(25.0)	4.87(22.7)	4.50(19.3)
Fenoxaprop +S	100+0.1%	4.58(20.0)	4.82(22.3)	4.47(19.0)	4.39(18.3)	5.07(24.7)	5.26(26.7)	5.07(24.7)	4.69(21.0)
Sulfosulfuron	25	4.78(22.0)	4.07(15.7)	3.82(13.7)	3.41(10.7)	5.08(25.0)	3.64(12.3)	3.35(10.3)	2.99(8.0)
2,4-D E	500	4.72(21.3)	2.70(6.3)	2.45(5.0)	2.26(4.1)	5.26(26.7)	2.70(6.3)	2.24(4.0)	2.24(4.0)
Metsulfuron- methyl	4	4.59(20.3)	2.44(5.0)	2.44(5.0)	2.23(4.0)	4.98(24.0)	2.29(4.3)	1.92(2.7)	1.73(2.0)
Carfentrazone-ethyl	20	4.68(21.0)	1.41(1.0)	1.41(1.0)	1.30(0.7)	4.92(23.3)	1.52(1.3)	1.41(1.0)	1.14(0.3)
Isoproturon+2,4-DE	750+500	4.87(22.7)	2.77(6.7)	2.30(4.3)	2.24(4.0)	4.87(22.7)	2.59(5.7)	1.92(2.7)	1.92(2.7)
Isoproturon+Metsulfuron	750+4	4.58(20.0)	2.59(5.7)	2.59(5.7)	2.30(4.3)	4.93(23.3)	2.59(5.7)	1.82(2.3)	1.73(2.0)
Clodinafop *fb* 2,4-DE	60&500	4.60(20.3)	2.87(7.3)	2.58(5.7)	2.23(4.0)	4.78(22.0)	2.58(5.7)	2.16(3.7)	1.52(1.3)
Clodinafop *fb* Metsulfuron	60&4	4.80(22.0)	2.65(6.0)	2.51(5.3)	2.39(4.7)	5.00(24.0)	2.30(4.3)	1.73(2.0)	1.52(1.3)
Fenoxaprop+S *fb* 2,4-DE	100+0.1%&500	4.69(21.0)	2.77(6.7)	2.65(6.0)	2.45(5.0)	5.13(25.3)	2.45(5.0)	2.07(3.3)	1.82(2.3)
Fenoxaprop +S *fb* Metsulfuron	100+0.1% &4	4.72(21.3)	2.51(5.3)	2.45(5.0)	2.30(4.3)	4.80(22.0)	2.70(6.3)	2.17(3.7)	2.00(3.0)
Sulfosulfuron +Metsulfuron(RM)	30+2.2	4.66(20.7)	2.45(5.0)	2.30(4.3)	2.17(3.7)	4.83(22.3)	2.30(4.3)	1.92(2.7)	1.82(2.3)
Isoproturon+Carfentrazone	750+20	4.72(21.3)	1.64(1.7)	1.41(1.0)	1.41(1.0)	4.99(24.0)	1.92(2.7)	1.30(0.7)	1.30(0.7)
Clodinafop *fb* Carfentrazone	60&20	4.58(20.0)	2.07(3.3)	1.82(2.3)	1.41(1.0)	4.90(23.0)	1.41(1.0)	1.30(0.7)	1.14(0.3)
Fenoxaprop+S *fb* Carfentrazone	100+0.1%+20	4.79(22.0)	1.82(2.3)	1.41(1.0)	1.30(0.7)	4.93(23.3)	1.82(2.3)	1.14(0.3)	1.14(0.3)
Sulfosulfuron+ Carfentrazone	20&20	4.72(21.3)	2.07(3.3)	1.52(1.3)	1.14(0.3)	4.87(22.7)	1.73(2.0)	1.41(1.0)	1.41(1.0)
Weedy	-	4.82(22.3)	5.07(24.7)	4.76(21.7)	4.55(19.7)	4.93(23.3)	5.13(25.3)	4.72(21.3)	4.32(17.7)
Weed free	-	1.00(0.0)	1.00(0.0)	1.00(0.0)	1.00(0.0)	1.00(0.0)	1.00(0.0)	1.00(0.0)	1.00(0.0)
SEm±		0.15	0.09	0.08	0.07	0.16	0.08	0.07	0.06
CD at 5%		0.43	0.26	0.24	0.21	0.45	0.24	0.21	0.18

Table. 21 Effect of herbicidal treatments on population (No. m^{-2}) of broadleaf weeds in durum wheat

Treatments	Dose (g ha^{-1})	2005-06				2006-07			
		Days after sowing				Days after sowing			
		30	60	90	At harvest	30	60	90	At harvest
Isoproturon	1000	8.93(78.9)	7.11(49.7)	6.77(45.0)	6.40(40.1)	9.28(85.3)	7.10(49.6)	6.68(43.7)	6.28(38.6)
Clodinafop	60	9.34(86.4)	9.65(92.3)	9.05(81.0)	8.49(71.3)	9.32(86.0)	9.69(93.0)	9.18(83.4)	8.71(75.0)
Fenoxaprop +S	100+0.1%	8.81(76.7)	9.71(93.4)	9.01(80.3)	8.30(68.0)	9.29(85.4)	9.79(95.1)	9.17(83.3)	8.74(75.6)
Sulfosulfuron	25	9.08(82.0)	6.95(47.7)	6.45(41.0)	5.81(33.0)	9.45(89.0)	6.45(41.0)	6.01(35.4)	5.63(31.0)
2,4-D E	500	9.05(81.0)	3.77(13.3)	3.11(8.7)	2.84(7.1)	9.33(86.3)	3.50(11.3)	2.64(6.0)	2.38(4.7)
Metsulfuron- methyl	4	8.80(77.3)	3.08(8.6)	2.63(6.0)	2.44(5.0)	9.21(84.7)	2.74(6.6)	2.16(3.7)	1.81(2.3)
Carfentrazone-ethyl	20	8.99(80.3)	2.69(6.3)	2.23(4.0)	1.92(2.7)	9.18(83.9)	2.14(3.6)	2.16(3.7)	1.41(1.0)
Isoproturon+2,4-DE	750+500	8.95(79.3)	3.16(9.0)	2.50(5.3)	2.38(4.7)	9.19(83.7)	2.89(7.4)	2.09(3.4)	2.09(3.4)
Isoproturon+Metsulfuron	750+4	8.98(79.7)	3.22(9.4)	2.77(6.7)	2.51(5.3)	9.35(86.6)	3.06(8.4)	2.00(3.0)	1.81(2.3)
Clodinafop *fb* 2,4-DE	60&500	8.76(76.3)	3.67(12.6)	3.05(8.4)	2.44(5.0)	9.08(82.0)	2.99(8.0)	2.38(4.7)	1.61(1.6)
Clodinafop *fb* Metsulfuron	60&4	9.18(83.3)	3.27(9.7)	2.88(7.3)	2.58(5.7)	9.43(88.0)	2.94(7.7)	2.07(3.3)	1.73(2.0)
Fenoxaprop+S *fb* 2,4-DE	100+0.1%&500	8.91(78.4)	3.60(12.0)	3.25(9.6)	2.77(6.7)	9.32(86.0)	3.16(9.0)	2.70(6.3)	2.14(3.6)
Fenoxaprop +S *fb* Metsulfuron	100+0.1% &4	9.21(83.9)	3.31(10.0)	3.06(8.4)	2.64(6.0)	9.34(86.4)	3.36(10.3)	2.53(5.4)	2.30(4.3)
Sulfosulfuron +Metsulfuron(RM)	30+2.2	8.77(76.0)	3.31(10.0)	2.98(7.9)	2.64(6.0)	9.12(82.3)	3.16(9.0)	2.32(4.4)	2.07(3.3)
Isoproturon+Carfentrazone	750+20	9.24(84.7)	2.64(6.0)	1.92(2.7)	1.51(1.3)	9.41(88.0)	2.58(5.7)	1.64(1.7)	1.54(1.4)
Clodinafop *fb* Carfentrazone	60&20	8.97(79.7)	3.04(8.3)	2.07(3.3)	1.64(1.7)	9.06(81.3)	2.30(4.3)	1.92(2.7)	1.26(0.6)
Fenoxaprop+S *fb* Carfentrazone	100+0.1%+20	9.01(80.4)	3.16(9.0)	2.38(4.7)	2.00(3.0)	9.30(85.6)	2.82(7.0)	1.81(2.3)	1.51(1.3)
Sulfosulfuron+ Carfentrazone	20&20	9.08(81.6)	3.16(9.0)	2.23(4.0)	1.89(2.6)	9.09(81.7)	2.51(5.3)	1.73(2.0)	1.73(2.0)
Weedy	-	8.90(78.3)	9.57(90.7)	8.83(77.1)	8.03(63.6)	9.33(86.3)	9.60(91.3)	8.72(75.2)	8.12(65.1)
Weed free	-	1.00(0.0)	1.00(0.0)	1.00(0.0)	1.00(0.0)	1.00(0.0)	1.00(0.0)	(0.0)	1.00(0.0)
SEm±		0.29	0.16	0.14	0.12	0.30	0.15	0.13	0.12
CD at 5%		0.84	0.45	0.40	0.36	0.87	0.42	0.37	0.34

cent broadleaf weeds during 2006-07, respectively. Clodinafop and fenoxaprop were not at all effective against broadleaf weeds.

4.1.1.3 Dry matter accumulation by weeds

4.1.1.3.1 Dry matter accumulation by grassy weeds

Dry matter accumulation by grassy weeds increased with the advancement of crop growth stages under weedy check and it was maximum at harvest (Table 22).

Herbicidal treatments greatly influenced the dry matter accumulation of grassy weeds. All the herbicidal treatments except metsulfuron, 2,4-DE and carfentrazone applied alone significantly reduced dry matter of grassy weeds in both the years. Dry matter accumulated by grassy weeds in plots treated with clodinafop, fenoxaprop and sulfosulfuron was 8.6 to 13.2 and 3.1 to 10.2 g m^{-2} during 2005-06 and 2006-07, respectively, which was significantly lower than that obtained under weedy check (91.5 and 81.8 g m^{-2}).

Isoproturon significantly reduced the dry matter accumulation by grassy weeds (30.8 to 40.5 and 25.1 to 36.0 g m^{-2} during 2005-06 and 2006-07, respectively) than weedy check but the dry matter under this treatment was significantly higher than that obtained in plots treated with other grass killing herbicides. The dry matter accumulations of grassy weeds were recorded under metsulfuron, 2,4-DE and carfentrazone alone treated plots (97.6 to 100.6 and 89.1 to 92.4 g m^{-2} during 2005-06 and 2006-07, respectively) was even higher than that recorded under weedy check.

4.1.1.3.2 Dry matter accumulation by broadleaf weeds

The dry matter accumulated by broadleaf weed species in the weedy check plots increased with advancement of crop growth reaching maximum at harvest in both the years (Table 23).

All the herbicidal treatments except clodinafop and fenoxaprop alone resulted in significant decrease in dry matter accumulated by broadleaf weeds in comparison to weedy check during both the years. Sulfosulfuron and isoproturon reduced the mean dry matter accumulation of broadleaf weeds by 24.2 and 40.4 per cent, respectively compared to weedy check but still the dry matter accumulation of broadleaf weeds in these plots was significantly higher than that obtained under metsulfuron, 2,4-DE and carfentrazone treated plots. Metsulfuron, 2,4-DE and carfentrazone applied alone or in combination with other herbicides showed great reduction in dry matter of broadleaf weeds (83.9 to 95.5 and 86.8 to 96.8 per cent during

Table. 22 Effect of different treatments on dry matter accumulation (g m^{-2}) by grassy weeds in durum wheat

Treatments	Dose (g ha^{-1})	2005-06				2006-07			
		Days after sowing				Days after sowing			
		30	60	90	At harvest	30	60	90	At harvest
Isoproturon	1000	5.6	10.3	25.8	30.8	5.4	10.4	22.8	25.1
Clodinafop	60	5.6	2.9	5.5	6.8	5.0	2.5	5.5	3.1
Fenoxaprop +S	100+0.1%	5.6	4.6	11.4	12.3	5.1	3.9	7.4	5.1
Sulfosulfuron	25	5.8	5.0	11.0	12.8	5.3	4.5	11.0	8.3
2,4-D E	500	5.6	31.0	79.9	97.6	5.4	30.4	74.2	90.1
Metsulfuron- methyl	4	5.7	30.6	83.8	98.5	5.5	30.5	72.8	92.4
Carfentrazone-ethyl	20	5.9	33.7	85.6	100.6	5.5	28.8	72.1	89.1
Isoproturon+2,4-DE	750+500	5.6	13.4	30.4	36.9	5.3	12.1	30.9	36.0
Isoproturon+Metsulfuron	750+4	5.6	13.4	33.1	40.0	5.4	12.4	30.1	35.9
Clodinafop *fb* 2,4-DE	60&500	5.6	4.1	9.2	8.6	5.1	3.6	6.3	6.2
Clodinafop *fb* Metsulfuron	60&4	5.7	4.2	9.9	9.2	5.3	3.6	4.4	5.1
Fenoxaprop+S *fb* 2,4-DE	100+0.1%&500	5.3	3.9	9.2	11.4	5.1	3.5	7.7	7.2
Fenoxaprop +S *fb* Metsulfuron	100+0.1% &4	5.7	4.6	11.7	11.9	5.2	4.1	9.9	10.2
Sulfosulfuron +Metsulfuron(RM)	30+2.2	5.5	4.1	10.7	13.2	5.2	3.5	7.1	6.8
Isoproturon+Carfentrazone	750+20	5.7	12.2	31.5	40.5	5.6	11.6	27.1	33.9
Clodinafop *fb* Carfentrazone	60&20	5.6	3.5	9.3	8.8	5.4	2.9	7.4	5.1
Fenoxaprop+S *fb* Carfentrazone	100+0.1%+20	5.8	4.8	9.9	12.3	5.2	4.1	7.7	8.3
Sulfosulfuron+ Carfentrazone	20&20	5.7	5.1	12.9	11.2	5.6	4.9	8.4	6.6
Weedy	-	5.5	26.0	67.6	91.5	5.7	24.4	59.5	81.8
Weed free	-	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
SEm±		0.5	1.5	3.8	4.6	0.4	1.4	3.3	4.2
CD at 5%		1.5	4.2	11.0	13.0	1.2	3.9	9.5	11.9

Table. 23 Effect of herbicidal treatments on dry matter accumulation (g m^{-2}) by broadleaf weeds in durum wheat

Treatments	Dose (g ha^{-1})	2005-06				2006-07			
		Days after sowing				Days after sowing			
		30	60	90	At harvest	30	60	90	At harvest
Isoproturon	1000	5.6	9.8	23.5	38.4	6.2	10.3	25.2	29.1
Clodinafop	60	6.3	21.7	39.0	54.2	6.3	18.3	34.5	41.2
Fenoxaprop +S	100+0.1%	5.4	22.0	43.2	51.8	6.2	19.3	35.2	42.3
Sulfosulfuron	25	5.9	9.3	21.4	32.5	6.6	8.2	15.2	21.0
2,4-D E	500	5.8	3.7	5.5	6.3	6.3	3.1	4.9	5.3
Metsulfuron- methyl	4	5.5	2.4	4.9	4.2	6.2	1.8	3.0	3.0
Carfentrazone-ethyl	20	5.8	1.8	3.2	3.5	6.1	1.0	3.0	1.3
Isoproturon+2,4-DE	750+500	5.7	2.5	4.3	5.2	6.1	2.1	2.8	4.4
Isoproturon+Metsulfuron	750+4	5.7	2.6	4.1	5.6	6.4	2.3	2.4	3.0
Clodinafop *fb* 2,4-DE	60&500	5.4	3.5	3.5	4.4	5.9	2.2	3.8	2.1
Clodinafop *fb* Metsulfuron	60&4	6.0	2.7	4.3	5.8	6.5	2.1	2.7	2.6
Fenoxaprop+S *fb* 2,4-DE	100+0.1%&500	5.6	3.3	4.0	5.6	6.3	2.5	5.1	4.7
Fenoxaprop +S *fb* Metsulfuron	100+0.1% &4	6.1	2.8	5.4	6.3	6.3	2.9	4.4	5.6
Sulfosulfuron +Metsulfuron(RM)	30+2.2	5.3	2.8	5.2	7.8	5.9	2.5	3.6	4.3
Isoproturon+Carfentrazone	750+20	6.2	1.7	2.2	2.3	6.5	1.6	1.4	1.8
Clodinafop *fb* Carfentrazone	60&20	5.7	2.3	2.7	2.2	5.8	1.2	2.2	0.8
Fenoxaprop+S *fb* Carfentrazone	100+0.1%+20	5.8	2.5	2.5	3.9	6.3	2.0	1.9	1.7
Sulfosulfuron+ Carfentrazone	20&20	5.9	2.5	2.1	3.4	5.9	1.5	1.6	2.6
Weedy	-	5.6	22.3	42.2	48.5	6.3	16.0	34.2	40.2
Weed free	-	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
SEm±		0.6	0.8	2.1	2.8	0.7	0.8	2.0	2.9
CD at 5%		1.7	2.3	5.9	8.1	2.0	2.3	5.8	8.2

2005-06 and 2006-07, respectively) and these treatments were comparable with weed free treatments.

4.1.2. Crop studies

4.1.2.1 Crop phytotoxicity (%)

Visual phytotoxicity recorded at 15 and 30 days after spraying indicated that there was no adverse effect of herbicidal treatments on crop. The data on phytotoxicity was not included herein.

4.1.2.2 Plant height (cm)

Height of wheat plants recorded at 30, 60, 90 DAS and at harvest was statistically similar at respective stages under different weed control treatments during both years (Table 24)

4.1.2.3 Dry matter accumulation per running metre row lenth (g/r.m.l)

The data on dry matter accumulation per metre row length presented in table 25 revealed that it increased with the advancement of crop age and maximum dry matter accumulation was recorded at harvest stage in both the years. There was no significant difference in accumulation of crop dry weight upto 30 DAS during both the years. While at subsequent growth stages, there was reduction in the dry matter accumulation by durum wheat due to weeds in weedy check plots. This reduction was to the extent of 39.6 and 37.8 per cent in 2005-06 and 2006-07, respectively at harvest over weed free treatment.

Maximum dry matter accumulation was recorded in weed free plots at all the stages during both the years, closely followed by combined application of each clodinafop, fenoxaprop and sulfosulfuron with metsulfuron or 2,4-DE or carfentrazone. Alone application of metsulfuron, 2,4-DE and carfentrazone did not result in any significant increase in the dry matter accumulated by wheat over weedy check in both the years. Application of isoproturon alone or in combination with broadleaf killing herbicides did not significantly increased the dry matter accumulation by crop up to 60 DAS but at 90 DAS and at harvest stage, the differences were significant during both the years of investigation.

4.1.2.4 Yield attributes of durum wheat

4.1.2.4.1 Number of spikes (No. m^{-2})

It is evident from data (Table 26) that all herbicidal treatments significantly influenced the number of spikes produced by durum wheat during both the years. Season long weed free condition resulted into maximum number of spikes (320.0 and 338.7 m^{-2} in 2005-06 and 2006-07,

Table. 24 Effect of herbicidal treatments on plant height (cm) of durum wheat

Treatments	Dose (g ha^{-1})	2005-06				2006-07			
		Days after sowing				Days after sowing			
		30	60	90	At harvest	30	60	90	At harvest
Isoproturon	1000	9.2	24.7	68.3	93.1	9.4	27.0	69.1	93.0
Clodinafop	60	8.9	25.2	70.1	93.8	8.7	24.9	72.0	93.6
Fenoxaprop +S	100+0.1%	9.0	25.0	69.3	93.7	8.6	25.3	68.7	93.8
Sulfosulfuron	25	8.8	24.9	69.8	93.9	8.9	25.0	71.9	93.5
2,4-D E	500	8.9	24.7	69.4	93.0	8.3	25.4	69.7	92.2
Metsulfuron- methyl	4	9.1	24.8	68.1	93.0	9.4	24.9	69.0	93.5
Carfentrazone-ethyl	20	9.2	24.5	68.0	92.9	8.6	24.8	70.0	93.4
Isoproturon+2,4-DE	750+500	9.1	24.9	69.8	93.5	8.7	25.4	70.3	93.6
Isoproturon+Metsulfuron	750+4	9.0	24.6	70.1	93.6	9.3	25.9	72.0	93.6
Clodinafop *fb* 2,4-DE	60&500	8.9	25.3	70.3	94.2	8.9	25.7	71.6	94.3
Clodinafop *fb* Metsulfuron	60&4	9.3	25.0	70.5	94.3	9.5	26.8	71.3	94.0
Fenoxaprop+S *fb* 2,4-DE	100+0.1%&500	9.1	25.3	69.8	94.2	9.1	26.2	71.1	94.0
Fenoxaprop +S *fb* Metsulfuron	100+0.1% &4	9.0	25.2	69.9	94.0	9.2	25.9	70.0	93.8
Sulfosulfuron +Metsulfuron(RM)	30+2.2	8.9	25.0	70.0	93.9	8.9	24.9	72.0	94.2
Isoproturon+Carfentrazone	750+20	9.1	25.0	69.0	93.2	9.3	25.4	71.5	93.8
Clodinafop *fb* Carfentrazone	60&20	9.1	25.3	70.1	93.9	9.2	25.6	72.0	93.7
Fenoxaprop+S *fb* Carfentrazone	100+0.1%+20	8.9	25.2	70.3	93.7	9.0	25.0	71.8	94.0
Sulfosulfuron+ Carfentrazone	20&20	9.2	24.9	69.4	93.8	8.9	24.8	71.6	93.8
Weedy	-	9.1	24.8	68.1	90.5	9.0	25.0	70.0	92.4
Weed free	-	9.2	25.8	70.4	94.2	9.3	26.7	72.2	94.1
SEm±		0.41	1.13	3.11	4.17	0.41	1.15	3.19	4.21
CD at 5%		NS	NS	NS	NS	NS	NS	NS	NS

Table. 25 Effect of herbicidal treatments on dry matter accumulation (g) per running metre row length of durum wheat

Treatments	Dose (g ha^{-1})	2005-06				2006-07			
		Days after sowing				Days after sowing			
		30	60	90	At harvest	30	60	90	At harvest
Isoproturon	1000	10.8	32.1	135.2	266.2	11.6	35.2	151.4	289.1
Clodinafop	60	10.6	35.4	150.6	288.5	11.4	38.8	168.7	313.3
Fenoxaprop +S	100+0.1%	11.0	37.4	149.1	291.6	11.9	41.0	167.0	316.7
Sulfosulfuron	25	11.0	37.8	152.0	295.0	11.9	40.7	170.2	320.4
2,4-D E	500	10.9	30.1	120.3	211.2	11.9	33.0	134.7	229.4
Metsulfuron- methyl	4	10.9	30.2	126.2	215.8	11.8	33.1	141.3	234.4
Carfentrazone-ethyl	20	11.0	31.5	121.6	205.6	12.0	34.5	136.2	223.3
Isoproturon+2,4-DE	750+500	10.6	33.1	140.0	245.1	11.5	36.3	156.8	266.2
Isoproturon+Metsulfuron	750+4	10.2	31.4	145.8	260.4	11.1	34.4	163.3	282.8
Clodinafop *fb* 2,4-DE	60&500	11.3	38.0	155.5	308.2	12.3	41.6	174.2	334.7
Clodinafop *fb* Metsulfuron	60&4	10.5	38.3	158.6	311.7	11.3	42.0	177.6	338.5
Fenoxaprop+S *fb* 2,4-DE	100+0.1%&500	11.0	37.8	154.7	304.5	11.9	41.4	173.3	327.6
Fenoxaprop +S *fb* Metsulfuron	100+0.1% &4	10.7	37.9	158.7	312.7	11.7	41.5	177.7	342.7
Sulfosulfuron +Metsulfuron(RM)	30+2.2	10.8	36.5	160.3	306.6	11.8	40.0	18.3	336.0
Isoproturon+Carfentrazone	750+20	10.6	30.3	130.0	256.4	11.6	33.2	14.6	281.0
Clodinafop *fb* Carfentrazone	60&20	10.8	36.4	151.3	312.2	11.8	39.9	169.5	342.2
Fenoxaprop+S *fb* Carfentrazone	100+0.1%+20	11.2	37.8	156.1	308.0	12.3	41.4	174.8	337.6
Sulfosulfuron+ Carfentrazone	20&20	11.0	36.4	155.4	301.0	12.1	39.9	174.0	329.9
Weedy	-	10.8	28.3	102.6	190.5	11.9	31.0	114.9	212.9
Weed free	-	10.9	38.2	161.8	315.4	11.9	41.9	181.2	342.5
SEm±		0.51	1.59	6.62	12.80	0.55	1.74	7.09	13.95
CD at 5%		NS	4.54	18.89	36.52	NS	4.98	20.23	39.81

Table. 26 Effect of herbicidal treatments on yield attributes of durum wheat

Treatment	Dose (g ha^{-1})	Number of spikes (m^{-2})		Spike length (cm)		Grains per spike		1000-grain weight (g)	
		2005-06	2006-07	2005-06	2006-07	2005-06	2006-07	2005-06	2006-07
Isoproturon	1000	293.3	298.0	7.6	7.8	45.0	44.7	42.9	42.7
Clodinafop	60	301.3	308.0	7.8	7.8	47.3	47.0	43.2	43.4
Fenoxaprop + S	100+0.1%	306.0	314.3	7.7	7.9	47.3	48.0	43.1	42.9
Sulfosulfuron + A	25	308.0	310.7	7.8	8.0	48.3	48.3	42.9	42.7
2,4-D E	500	270.7	276.0	7.0	7.3	43.7	44.6	42.5	43.1
Metsulfuron- methyl + S	4	273.3	277.3	6.9	7.0	44.0	44.3	42.7	43
Carfentrazone-ethyl	20	274.7	274.7	6.9	6.9	44.0	43.0	42.5	43
Isoproturon+2,4-DE	750+500	298.0	302.3	7.4	7.5	45.0	46.3	42.8	42.9
Isoproturon+Metsulfuron	750+4	280.0	292.0	7.2	7.2	46.3	48.0	42.7	43.1
Clodinafop *fb* 2,4-DE	60&500	321.3	328.0	8.1	8.2	46.7	48.0	43.2	43.4
Clodinafop *fb* Metsulfuron	60&4	324.0	332.7	8.0	8.0	49.0	49.6	43.5	43.3
Fenoxaprop+S *fb* 2,4-DE	100+0.1%&500	314.3	321.3	7.9	8.0	49.3	49.3	43.4	43.5
Fenoxaprop +S *fb* Metsulfuron	100+0.1% &4	317.3	325.0	8.0	8.2	49.0	50.0	43.5	42.9
Sulfosulfuron +Metsulfuron(RM)	30+2.2	322.7	333.0	8.1	8.2	49.7	50.0	43.4	43.1
Isoproturon+Carfentrazone	750+20	289.7	298.7	7.2	7.4	48.0	49.0	42.2	42.9
Clodinafop *fb* Carfentrazone	60&20	309.3	316.0	7.9	7.9	45.7	47.3	43.3	43.2
Fenoxaprop+S *fb* Carfentrazone	100+0.1%+20	302.0	309.7	7.8	8.0	48.3	48.3	43.3	43.5
Sulfosulfuron+ Carfentrazone	20&20	313.3	322.0	7.9	7.8	48.3	48.6	43.2	43.6
Weedy	-	265.7	278.7	6.7	6.8	43.2	45.0	42.2	42.9
Weed free	-	320.0	338.7	8.1	8.1	49.7	50.0	43.5	44.1
SEm±		10.15	10.38	0.41	0.41	2.49	2.53	2.1	2.31
CD at 5%		28.97	29.63	1.16	1.17	NS	NS	NS	NS

respectively). Application of clodinafop, fenoxaprop and sulfosulfuron alone orapplication of each *fb* metsulfuron or 2,4-DE or carfentrazone being at par with each other and weed free treatment, significantly increased the number of spikes (301 to 324 and 308 to 333 m^{-2} in 2005-06 and 2006-07, respectively) over weedy check (265 and 278) during both the years of investigation. Individual or combination of isoproturon with metsulfuron or 2,4-DE or carfentrazone increased the number of spikes over weedy check but differences were non-significant.

4.1.2.4.2 Spike length (cm)

Spike length of durum wheat (Table 26) was statistically similar under different herbicidal treatments while the spike length recorded under weedy check plots (6.7 and 6.8 cm) was significantly lower than that recorded under weed free plots (8.1 and 8.1cm) in 2005-06 and 2006-07, respectively.

4.1.2.4.3 Grains per spike (No.)

Grains per spike of durum wheat did not differ significantly under different herbicidal treatments during both the years (Table 26). Season long weed free conditions resulted into highest number of grains per spike (49.7 and 50.0) in both the years.

4.1.2.4.4 1000-grain weight (g)

Maximum 1000-grain weight (43.5 and 44.1 g) was recorded in weed free treatment and minimum under weedy check (42.2 and 42.9 g) during both the years. Herbicidal treatments did not differ significantly for 1000- grain weight (Table 26).

4.1.2.5 Grain and straw yields (kg ha^{-1})

4.1.2.5.1 Grain yield (kg ha^{-1})

Grain yield of wheat was significantly influenced by different herbicidal treatments in both the years (Table 27). Maximum grain yield was recorded in season long weed free plots (5739 and 6198 kg ha^{-1}). All herbicidal treatment except metsulfuron, 2,4-DE and carfentrazone alone significantly increase the grain yield of durum wheat over weedy check. Application of clodinafop, fenoxaprop and sulfosulfuron *fb* either metsulfuron, 2,4-DE or carfentrazone being at par with each other and weed free treatment significantly increased the grain yield of wheat. Isoproturon alone or in combination with broadleaf weed killing herbicides significantly increased grain yield (37.5 to 45.3 and 29.2 to 40.9 per cent during 2005-06 and 2006-07, respectively) over weedy check but the

Table. 27 Effect of herbicidal treatments on grain and straw yields, and harvest index of durum wheat

Treatment	Dose (g ha^{-1})	Grain yield (kg ha^{-1})		Straw yield (kg ha^{-1})		Harvest Index (%)	
		2005-06	2006-07	2005-06	2006-07	2005-06	2006-07
Isoproturon	1000	4085	4272	6865	6754	37.3	38.7
Clodinafop	60	5020	5132	7312	7501	40.7	40.6
Fenoxaprop +S	100+0.1%	4952	5140	7376	7275	40.2	41.4
Sulfosulfuron	25	5140	5232	7509	7525	40.6	41.0
2,4-D E	500	3277	3539	5610	5805	36.9	37.9
Metsulfuron- methyl	4	3436	3511	5734	5834	37.5	37.6
Carfentrazone-ethyl	20	3352	3521	5710	5543	37.0	38.8
Isoproturon+2,4-DE	750+500	4106	4535	6605	7294	38.3	38.3
Isoproturon+Metsulfuron	750+4	4208	4544	6621	6876	38.9	39.8
Clodinafop *fb* 2,4-DE	60&500	5490	5929	7354	7263	42.7	44.9
Clodinafop *fb* Metsulfuron	60&4	5610	6059	7495	7605	42.8	42.5
Fenoxaprop+S *fb* 2,4-DE	100+0.1%&500	5470	5908	7425	7524	42.4	43.9
Fenoxaprop +S *fb* Metsulfuron	100+0.1% &4	5576	6022	7477	7645	42.7	44.0
Sulfosulfuron +Metsulfuron(RM)	30+2.2	5512	5953	7465	7557	42.5	44.1
Isoproturon+Carfentrazone	750+20	4315	4660	6941	6893	38.3	40.3
Clodinafop *fb* Carfentrazone	60&20	5407	5739	7505	7342	41.9	43.9
Fenoxaprop+S *fb* Carfentrazone	100+0.1%+20	5272	5694	7472	7435	41.4	43.4
Sulfosulfuron+ Carfentrazone	20&20	5446	5782	7452	7654	42.3	43.0
Weedy	-	2969	3306	5208	5325	36.3	38.3
Weed free	-	5739	6198	7550	7703	43.2	44.6
SEm±		241	258	347	350	2.5	2.6
CD at 5%		688	738	989	1000	NS	NS

magnitude of this increase was lower than that under clodinafop, fenoxaprop and sulfosulfuron treated plots (66.8 to 88.9 and 55.2 to 82.2 per cent). Season long weed infestation caused the yield losses to the extent of 48.3 and 46.7 per cent in 2005-06 and 2006-07, respectively.

4.1.2.5.2 Straw yield (kg ha^{-1})

The application of various herbicidal treatments significantly enhanced the straw yield of wheat (Table 27).

The maximum straw yield of 7550 and 7703 kg ha^{-1} was recorded in weed free plots during both the years. All the herbicidal treatments were statistically at par among themselves and with weed free treatment in this respect during both the years except metsulfuron, 2,4-DE and carfentrazone alone. The straw yield of wheat was lowest under weedy plots during both the years (4208 and 5325 kg ha^{-1}).

4.1.2.5.3 Harvest Index (%)

Harvest Index of durum wheat varied between 36.3 to 43.3 per cent during 2005-06 and 38.3 to 44.6 per cent during 2006-07 (Table 27). Different weed control treatments did not differ significantly for harvest index.

4.2 Evaluation of competing ability of durum wheat cultivars under different resource conservation techniques

4.2.1 Weed studies

4.2.1.1 Weed flora in the experimental field

The weed flora along with their infestation in the experimental field is given in table 28. Among the complex weed flora, grassy weeds accounted for 30.2, 41.1 and 39.4 per cent during 2005-06 and 32.1, 40.6 and 42.2 per cent during 2006-07 in zero tillage (ZT), conventional tillage (CT) and furrow irrigated raised bed system (FIRBS), respectively. The corresponding values for broad-leaved weeds were 69.8, 58.9 and 60.6 per cent, during 2005-06 and 67.9, 59.4 and 57.8 per cent during 2006-07.

4.2.1.2 Weed intensity (No. m^{-2})

The data pertaining to density of different weed species were recorded at 30, 60, 90 DAS and at harvest and have been explained as under;

4.2.1.2.1 *Phalaris minor*

The population of *Phalaris minor* was found to be maximum at 30 DAS which was 35.0 plants m^{-2} during 2005-06 and 34.3 m^{-2} during 2006-07 in weedy check (Table 29), however, it declined thereafter till harvest. At 60 DAS, it constituted 24.2 and 24.9 per cent of total weed flora in 2005-06 and 2006-07, respectively in weedy check.

Table. 28 Per cent composition of weed flora in weedy check

Weed species	English name	Local name	Family		Percent composition in weedy check (30 DAS)					
					2005-06			2006-07		
					ZT	CT	FIRBS	ZT	CT	FIRBS
Phalaris minor Retz.	Little seed canary grass	Kanki/Mandusi	Poaceae		16.5	27.2	26.5	17.1	27.2	29.0
Avena ludoviciana Dur.	Wild Oat	Jungli Jai	Poaceae		13.7	13.9	12.9	14.9	13.4	13.2
			Total density of grassy weeds		30.2	41.1	39.4	32.1	40.6	42.2
Chenopodium album L.	Lambs quarters	Bathu	Chenopodiaceae		19.5	16.3	17.9	21.3	16.0	16.5
Melilotus indica L.	Sweet clover	Senji	Leguminosae		16.2	15.5	14.1	16.5	15.9	14.0
Anagallis arvensis L.	Pimpernel	Krishanneel	Primulaceae		17.3	14.4	13.4	13.4	13.2	13.2
Convolvulus arvensis L.	Field bind weed	Hirankhuri	Convolvulaceae	Miscellaneous weeds						
Rumex retroflexus L.	Golden dock	Jungli Palak	Polygonaceae		16.7	12.7	15.3	16.8	14.3	14.1
Coronopus didymus L.	Swine grass	Pith papra	Cruciferae							
			Total density of broad leaf weeds		69.8	58.9	60.6	67.9	59.4	57.8

Table. 29 Effect of cultivars, herbicide and resource conservation techniques on population (No. m^{-2}) of *Phalaris minor* in durum wheat

Treatment	2005-06				2006-07			
	Days after sowing				Days after sowing			
	30	60	90	At harvest	30	60	90	At harvest
RCT's								
ZT	3.38(12.1)	3.67(14.5)	3.38(12.6)	3.13(11.0)	3.40(12.2)	3.66(13.7)	3.39(12.0)	3.08(10.1)
CT	4.38(20.8)	4.70(23.6)	4.43(21.1)	4.17(19.0)	4.39(20.6)	4.80(24.5)	4.41(20.9)	4.15(18.7)
FIRBS	4.84(24.7)	5.10(27.4)	4.76(23.8)	4.50(21.4)	4.71(23.5)	5.08(27.2)	4.75(23.7)	4.43(20.7)
SEm±	0.04	0.05	0.05	0.04	0.04	0.05	0.04	0.04
CD at 5%	0.14	0.16	0.15	0.14	0.14	0.17	0.15	0.14
Cultivars								
WH 896	4.24(19.8)	4.65(23.3)	4.44(21.4)	4.16(19.0)	3.23(19.4)	4.71(23.7)	4.39(20.6)	4.11(18.5)
WH 912	4.07(18.5)	4.47(22.1)	4.17(19.6)	3.92(17.5)	6.20(18.4)	4.46(21.6)	4.12(18.7)	3.81(16.3)
PDW 291	4.87(19.3)	4.35(20.0)	3.95(16.6)	3.72(14.9)	4.71(18.6)	4.38(20.00	4.03(17.2)	3.73(14.8)
SEm±	0.07	0.08	0.07	0.07	0.07	0.07	0.07	0.07
CD at 5%	NS	0.21	0.20	0.19	NS	0.21	0.20	0.19
Herbicide								
Pendimethalin(1.5 kg ha^{-1})	2.75(7.1)	3.04(8.6)	2.74(6.9)	2.48(5.6)	2.78(7.0)	3.17(9.3)	2.82(7.2)	2.51(5.6)
Weedy check	5.61(31.2)	5.94(35.0)	5.64(31.5)	5.39(28.7)	5.56(30.6)	5.86(34.3)	5.54(30.5)	5.26(27.5)
SEm±	0.06	0.06	0.05	0.05	0.06	0.06	0.06	0.05
CD at 5%	0.16	0.17	0.16	0.15	0.16	0.17	0.16	0.15

Resource conservation techniques (RCT's) significantly influenced the population of *P. minor*. Zero tillage (ZT), significantly reduced the population of this weed (11.0 to 14.5 and 10.1 to 13.7 plants m^{-2}) as compared to FIRBS (21.4 to 27.4 and 20.7 to 27.2 plants m^{-2}) and CT (19.0 to 23.6 and 18.7 to 24.5 plants m^{-2}) at different crop growth stages during both the years.

The density of *P. minor* reduced significantly after 30 DAS under cultivar PDW 291 sown plots. At harvest stage, on an average, the population of *P. minor* was reduced by 25.0 and 14.2 per cent under the cultivar PDW 291 sown plots as compared to cultivar WH 896 and WH 912, respectively.

Pre-emergence application of pendimethalin at 1.5 kg ha^{-1} significantly lowered the density of *P. minor* in comparison to weedy check plots at all growth stages during both the years. Pendimethalin reduced the density of *P. minor* to the extent of 77.2 , 75.4, 78.1 and 80.5 per cent in 2005-06 and 77.1, 72.8, 76.4 and 79.6 per cent in 2006-07 at 30, 60, 90 DAS and at harvest, respectively as compared to weedy check.

4.2.1.2.2 *Avena ludoviciana*

The data on density of *Avena ludoviciana* recorded at 30, 60, 90 DAS and at harvest revealed that density of this weed in field increased upto 60 DAS and decreased thereafter (Table 30). Different tillage treatments did not influenced the population of *A. ludoviciana* significantly at all crop growth stages during both the years of experimentation. At harvest stage, on an average the density of this weed under ZT, CT and FIRBS was 10.8, 10.8 and 10.6 plants m^{-2}, respectively.

Similar to tillage practices, cultivars also did not influence the population of *A. ludoviciana* during both the years of experimentation. The average density of this weed at 90 DAS under the cultivar WH 896, WH 912 and PDW 291 sown plots was 13.1, 12.1 and 12.5 plants m^{-2}, respectively.

Pendimethalin significantly lowered the population of *A. ludoviciana* which was 7.3, 8.6, 8.0 and 6.8 plants m^{-2} in 2005-06 and 7.0, 7.9, 7.3 and 6.2 plants m^{-2} in 2006-07 at 30, 60, 90 DAS and at harvest, respectively as compared to weedy check (14.8 to 19.1 and 15.0 to 19.3 plants m^{-2} in 2005-06 and 2006-07, respectively).

4.2.1.2.3 Total grassy weeds

Among resource conservation techniques, ZT reduced the population of grassy weeds significantly (Table 31). On an average, ZT reduced the population of grassy weeds to the extent of 24.9, 26.2, 24.4 and 27.7 per cent

Table. 30 Effect of cultivars, herbicide and resource conservation techniques on population (No. m^{-2}) of *Avena ludoviciana* in durum wheat

Treatment	2005-06				2006-07			
	Days after sowing				Days after sowing			
	30	60	90	At harvest	30	60	90	At harvest
RCT's								
ZT	3.64 (12.7)	3.82(14.1)	3.70(13.2)	3.40(10.9)	3.55(12.3)	3.75(13.9)	3.63(12.9)	3.33(10.7)
CT	3.51 (12.0)	3.76(13.9)	3.57(12.5)	3.33(10.7)	3.60(12.4)	3.82(14.0)	3.63(12.6)	3.38(10.8)
FIRBS	3.50 (11.8)	3.75(13.6)	3.60(12.4)	3.38(10.9)	3.46(11.6)	3.62(12.9)	3.48(11.8)	3.27(10.3)
SEm±	0.06	0.07	0.07	0.05	0.06	0.07	0.08	0.04
CD at 5%	NS	NS	NS	NS	NS	NS	NS	NS
Cultivars								
WH 896	3.66 (12.8)	3.90(14.6)	3.76(13.5)	3.49(11.5)	3.56(12.2)	3.77(13.8)	3.63(12.7)	3.36(10.8)
WH 912	3.51(11.8)	3.69(13.1)	3.53(11.9)	3.31(10.4)	3.54(12.2)	3.72(13.6)	3.56(12.3)	3.34(10.7)
PDW 291	3.49(11.9)	3.73(13.8)	3.58(12.7)	3.31(10.7)	3.50(11.9)	3.70(13.3)	3.55(12.3)	3.28(10.3)
SEm±	0.06	0.08	0.06	0.08	0.06	0.06	0.06	0.05
CD at 5%	NS	NS	NS	NS	NS	NS	NS	NS
Herbicide								
Pendimethalin(1.5 kg ha^{-1})	2.87(7.3)	3.08(8.6)	2.97(7.9)	2.77(6.8)	2.82(7.0)	2.97(7.9)	2.87(7.27)	2.67(6.2)
Weedy check	4.23(17.1)	4.47(19.1)	4.27(17.4)	3.98(14.9)	4.25(17.2)	4.49(19.3)	4.29(17.6)	3.99(15.0)
SEm±	0.05	0.05	0.05	0.04	0.05	0.05	0.05	0.04
CD at 5%	0.13	0.14	0.13	0.12	0.13	0.14	0.13	0.12

Table. 31 Effect of cultivars, herbicide and resource conservation techniques on population (No. m^{-2}) of total grassy weeds in durum wheat

Treatment	2005-06				2006-07			
	Days after sowing				Days after sowing			
	30	60	90	At harvest	30	60	90	At harvest
RCT's								
ZT	4.90(24.8)	5.24(28.6)	4.97(25.8)	4.58(21.9)	4.84(24.5)	5.16(27.5)	4.89(24.9)	4.45(20.8)
CT	5.55(32.8)	5.95(37.5)	5.62(33.6)	5.27(29.7)	5.62(33.0)	6.08(38.6)	5.65(33.4)	5.30(29.5)
FIRBS	5.91(36.5)	6.27(40.9)	5.90(36.3)	5.56(32.2)	5.77(35.2)	6.17(40.1)	5.81(35.5)	5.42(31.0)
SEm±	0.04	0.04	0.04	0.03	0.04	0.04	0.04	0.03
CD at 5%	0.13	0.13	0.13	0.12	0.13	0.14	0.13	0.12
Cultivars								
WH 896	5.56(32.6)	6.03(38.0)	5.78(34.9)	5.39(30.4)	5.45(31.6)	5.98(37.5)	5.64(33.3)	5.26(29.2)
WH 912	5.33(30.3)	5.76(35.2)	5.44(31.5)	5.09(27.9)	5.36(30.6)	5.75(35.2)	5.39(31.0)	5.01(27.0)
PDW 291	5.47(31.2)	5.67(33.8)	5.28(29.3)	4.92(25.5)	5.41(30.4)	5.69(33.4)	5.32(29.4)	4.90(25.1)
SEm±	0.04	0.05	0.04	0.04	0.04	0.05	0.04	0.04
CD at 5%	0.12	0.13	0.13	0.12	NS	0.13	0.12	0.11
Herbicide								
Pendimethalin(1.5 kg ha^{-1})	3.91(14.4)	4.24(17.2)	3.95(14.9)	3.62(12.3)	3.86(14.0)	4.25(17.2)	3.92(14.5)	3.55(11.8)
Weedy check	6.99(48.3)	7.40(54.1)	7.42(48.9)	6.65(43.5)	6.96(47.8)	7.35(53.6)	6.98(48.1)	6.56(42.5)
SEm±	0.04	0.04	0.04	0.03	0.04	0.04	0.04	0.03
CD at 5%	0.10	0.11	0.10	0.10	0.10	0.11	0.10	0.09

than CT and 31.1, 30.7, 29.4 and 32.5 per cent than FIRBS at 30, 60, 90 DAS and at harvest, respectively.

Cultivars significantly influenced the population of grassy weeds. At harvest stage, on an average, the population of grassy weeds was reduced by 15.1 and 7.9 per cent under the cultivar PDW 291 sown plots as compared to cultivar WH 896 and WH 912 sown plots, respectively.

Pre-emergence application of pendimethalin significantly lowered the density of grassy weeds in comparison to weedy check plots during both the years. Pendimethalin, on an average, reduced the density of grassy weeds to the extent of 70.4, 68.1, 69.7 and 71.9 per cent at 30, 60, 90 DAS and at harvest, respectively as compared to weedy check.

4.2.1.2.4 *Chenopodium album*

RCT's significantly influenced the population of *Chenopodium album* during each year (Table 32). CT at harvest stage, reduced the population of *C. album* to the extent of 10.0 and 12.2 per cent in 2005-06 and 12.4 and 24.3 per cent in 2006-07 as compared to FIRBS and ZT, respectively.

The effect of cultivars on population of *C. album* was non-significant during both the years. However, on an average numerically less population of this weed at harvest stage was recorded in cultivar PDW 291 sown plots (9.9) as compared to cultivar WH 896 (10.4) and WH 912 (10.6) sown plots

Pre-emergence application of pendimethalin resulted into significant reduction in the density of *C. album* compared to weedy check. At harvest stage, the density of this weed under pendimethalin treated plots was 4.5 to 6.6 in 2005-06 and 3.6 to 5.3 in 2006-07 while corresponding values under weedy check plots were 17.4 to 24.4 and 15.4 to 23.5, respectively.

4.2.1.2.5 *Anagallis arvensis*

The data in table 33 showed that tillage treatments influenced the population of *Anagallis arvensis* significantly during both the years at all crop growth stages except 30 DAS in 2006-07. At harvest stage, FIRBS being at par with CT, reduced the population of this weed to the extent of 14.0 and 13.0 per cent during respective years as compared to ZT.

Cultivars significantly influenced the population of *A. arvensis* during both the years. On an average, cultivar PDW 291 sown plots recorded 22.4, 15.2, 16.6 and 13.6 per cent less population of *A. arvensis* than the cultivar WH 896 at 30, 60, 90 DAS and at harvest stage, respectively.

Table. 32 Effect of cultivars, herbicide and resource conservation techniques on population (No. m^{-2}) of *Chenopodium album* in durum wheat

Treatment	2005-06				2006-07			
	Days after sowing				Days after sowing			
	30	60	90	At harvest	30	60	90	At harvest
RCT's								
ZT	3.83(15.2)	3.99(16.6)	3.64(13.8)	3.34(11.5)	3.70(14.9)	3.82(15.8)	3.46(12.8)	3.19(10.8)
CT	3.44(12.3)	3.72(14.1)	3.38(11.5)	3.20(10.2)	3.41(12.0)	3.59(13.1)	3.24(10.3)	2.93(8.2)
FIRBS	3.76(14.5)	3.95(15.9)	3.63(13.2)	3.39(11.3)	3.52(12.9)	3.73(14.2)	3.32(11.0)	3.12(9.5)
SEm±	0.04	0.04	0.03	0.03	0.04	0.04	0.03	0.03
CD at 5%	0.11	0.13	0.11	0.11	0.12	0.13	0.11	0.10
Cultivars								
WH 896	3.67(14.0)	3.88(15.7)	3.47(12.3)	3.24(10.6)	3.62(13.7)	3.79(14.8)	3.42(11.8)	3.15(10.1)
WH 912	3.70(14.2)	3.87(15.1)	3.63(13.4)	3.37(11.4)	3.55(13.6)	3.70(14.5)	3.34(11.5)	3.10(9.7)
PDW 291	3.66(13.9)	3.90(15.8)	3.55(12.8)	3.31(11.0)	3.46(12.5)	3.65(13.9)	3.25(10.7)	2.99(8.7)
SEm±	0.06	0.07	0.06	0.06	0.06	0.06	0.06	0.05
CD at 5%	NS	NS	NS	NS	NS	NS	NS	NS
Herbicide								
Pendimethalin(1.5 kg ha^{-1})	2.52(5.4)	2.75(6.6)	2.49(5.2)	2.34(4.5)	2.29(4.3)	2.51(5.3)	2.31(4.4)	2.14(3.6)
Weedy check	4.84(22.7)	5.02(24.4)	4.61(20.4)	4.28(17.4)	4.79(22.2)	4.92(23.5)	4.37(18.3)	4.02(15.4)
SEm±	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.04
CD at 5%	0.15	0.16	0.14	0.13	0.14	0.15	0.13	0.12

Table. 33 Effect of cultivars, herbicide and resource conservation techniques on population (No. m^{-2}) of *Anagalis arvensis* in wheat

Treatment	2005-06				2006-07			
	Days after sowing				Days after sowing			
	30	60	90	At harvest	30	60	90	At harvest
RCT's								
ZT	3.67(13.8)	3.98(16.3)	4.11(18.2)	3.93(16.7)	3.30(10.7)	3.68(13.8)	3.57(13.0)	3.37(11.4)
CT	3.49(12.1)	3.86(15.2)	3.85(15.8)	3.69(14.3)	3.28(10.5)	3.55(12.8)	3.42(11.9)	3.22(10.2)
FIRBS	3.38(11.3)	3.79(14.6)	3.84(15.5)	3.69(14.2)	3.24(10.4)	3.83(12.7)	3.41(11.6)	3.15(9.9)
SEm±	0.04	0.04	0.04	0.04	0.03	0.03	0.03	0.03
CD at 5%	0.13	0.13	0.13	0.13	NS	0.12	0.11	0.1
Cultivars								
WH 896	3.72(14.3)	3.95(16.1)	4.10(18.0)	3.92(16.3)	3.44(11.5)	3.83(14.9)	3.68(13.9)	3.42(11.7)
WH 912	3.53(12.3)	3.93(15.6)	3.94(16.1)	3.65(14.5)	3.31(10.8)	3.56(12.7)	3.40(11.6)	3.16(10.0)
PDW 291	3.29(10.7)	3.74(14.4)	3.77(15.5)	3.73(14.4)	3.07(9.3)	3.38(11.6)	3.31(11.1)	3.17(9.8)
SEm±	0.06	0.06	0.07	0.07	0.05	0.06	0.06	0.06
CD at 5%	0.16	0.17	0.2	0.19	0.15	0.17	0.17	0.16
Herbicide								
Pendimethalin(1.5 kg ha^{-1})	2.43(5.8)	2.77(6.7)	2.57(5.7)	2.46(5.1)	2.44(5.0)	2.56(5.6)	2.45(5.1)	2.34(4.5)
Weedy check	4.44(19.1)	4.98(24.0)	5.08(27.3)	5.08(25.0)	4.11(16.1)	4.62(20.5)	4.48(19.3)	4.16(16.5)
SEm±	0.05	0.05	0.06	0.06	0.04	0.05	0.05	0.05
CD at 5%	0.13	0.15	0.16	0.16	0.12	0.14	0.14	0.13

Pendimethalin reduced the density of *A. arvensis* to the extent of 69.7, 71.9, 79.2 and 79.5 per cent in 2005-06 and 68.7, 72.5, 73.7 and 72.5 in 2006-07 at 30, 60, 90 DAS and at harvest, respectively.

4.2.1.2.6 *Melilotus indica*

The periodic data pertaining to population of *Melilotus indica* presented in table 34 revealed that among resource conservation technique, CT resulted into significantly less population of this weed at 90 DAS during both the years as compared to ZT, while ZT and FIRBS remained at par during each year.

Different cultivars of durum wheat did not influence the population of *M. indica* significantly during both the years. At 90 DAS, the average population of this weed was 14.9, 15.1 and 14.3 under cultivar WH 896, WH 912 and PDW 291 sown plots, respectively.

The effect of weed control on *M. indica* population was significant at all the growth stages during both the years. Average population of *M. indica* under pendimethalin treated plots was 4.7, 5.5, 4.7 and 4.2 plant m^{-2} at 30, 60, 90 DAS and at harvest stage, respectively. The corresponding values under weedy check plots were 19.3, 20.8, 24.7 and 21.5 plant m^{-2}.

4.2.1.2.7 Miscellaneous broadleaf weeds

The miscellaneous broadleaf weeds (Table 35) showed that CT allowed significantly less population of these weeds as compared to ZT and FIRBS at all crop growth stages during each year, while, CT and FIRBS remained at par in this respect. At 60 DAS, on an average, CT recorded 15.5 and 12.9 per cent less population of these weeds as compared to ZT and FIRBS, respectively.

Durum wheat cultivars did not influence the population of these weeds significantly at all crop growth stages during both the years. The average population of these weeds at harvest stage was 12.4, 12.7 and 11.5 under cultivar WH 896, WH 912 and PDW 291 sown plots, respectively.

Pre-emergence application of pendimethalin significantly reduced the population of miscellaneous broadleaf weeds over weedy check. At harvest ,the population of these weeds under pendimethalin treated plots was 6.6 and 4.5 plants m^{-2} as compared 22.0 and 15.6 plats m^{-2} under weedy check plots in 2005-06 and 2006-07, respectively.

4.2.1.2.8 Total broadleaf weeds

Resource conservation techniques significantly influenced the population of broadleaf weeds during each year (Table 36). Under CT, mean

Table. 34 Effect of cultivars, herbicide and resource conservation techniques on population (No. m^{-2}) of *Melilotus indica* in durum wheat

Treatment	2005-06				2006-07			
	Days after sowing				Days after sowing			
	30	60	90	At harvest	30	60	90	At harvest
RCT's								
ZT	3.48(12.5)	3.66(13.7)	3.86(16.2)	3.62(14.0)	3.45(12.2)	3.64(13.5)	3.86(16.2)	3.55(13.6)
CT	3.41(11.4)	3.56(12.8)	3.59(13.7)	3.43(12.3)	3.38(11.5)	3.56(12.8)	3.63(13.8)	3.28(10.7)
FIRBS	3.37(12.0)	3.59(13.0)	3.79(15.8)	3.60(14.0)	3.45(12.1)	3.56(12.8)	3.52(12.5)	3.47(12.5)
SEm±	0.03	0.03	0.03	0.03	0.03	0.04	0.03	0.03
CD at 5%	NS	NS	0.11	0.11	NS	NS	0.12	0.11
Cultivars								
WH 896	3.46(12.1)	3.62(13.2)	3.73(15.3)	3.46(13.1)	3.43(11.8)	3.58(13.2)	3.68(14.4)	3.43(12.2)
WH 912	3.45(12.1)	3.61(13.2)	3.78(15.3)	3.60(13.7)	3.48(12.2)	3.64(13.3)	3.75(14.6)	3.49(12.5)
PDW 291	3.35(11.6)	3.57(13.2)	3.74(15.0)	3.60(13.5)	3.38(11.8)	3.53(12.6)	3.57(13.6)	3.39(12.2)
SEm±	0.06	0.06	0.07	0.06	0.06	0.06	0.06	0.06
CD at 5%	NS	NS	NS	NS	NS	NS	NS	NS
Herbicide								
Pendimethalin(1.5 kg ha^{-1})	2.35(4.6)	2.55(5.6)	2.32(4.4)	2.25(4.1)	2.38(4.7)	2.53(5.4)	2.42(4.9)	2.28(4.2)
Weedy check	4.49(19.3)	4.65(20.8)	5.17(26.0)	4.85(22.7)	4.47(19.2)	4.64(20.7)	4.92(23.5)	4.59(20.3)
SEm±	0.05	0.05	0.06	0.05	0.05	0.05	0.05	0.05
CD at 5%	0.13	0.14	0.16	0.15	0.14	0.14	0.15	0.14

Table. 35 Effect of cultivars, herbicide and resource conservation techniques on population (No. m^{-2}) of miscellaneous broadleaf weeds in durum wheat

Treatment	2005-06				2006-07			
	Days after sowing				Days after sowing			
	30	60	90	At harvest	30	60	90	At harvest
RCT's								
ZT	3.71(13.8)	3.92(15.5)	4.21(18.1)	3.81(14.8)	3.70(13.6)	3.66(13.3)	3.54(12.5)	3.26(10.5)
CT	3.22(10.3)	3.52(12.3)	3.96(16.1)	3.67(13.6)	3.46(11.8)	3.49(12.1)	3.38(11.4)	3.09(9.5)
FIRBS	3.65(13.3)	3.82(14.6)	4.18(17.6)	3.80(14.6)	3.51(12.1)	3.64(13.3)	3.50(12.1)	3.21(10.1)
SEm±	0.03	0.04	0.04	0.03	0.04	0.03	0.03	0.03
CD at 5%	0.12	0.12	0.14	0.11	0.12	0.12	0.11	0.1
Cultivars								
WH 896	3.56(12.7)	3.83(14.8)	4.13(17.4)	3.80(14.6)	3.59(12.7)	3.65(13.3)	3.50(12.1)	3.22(10.1)
WH 912	3.58(12.5)	3.78(14.0)	4.22(18.1)	3.81(14.6)	3.59(12.9)	3.61(13.1)	3.48(12.0)	3.27(10.8)
PDW 291	3.46(12.1)	3.66(13.6)	3.99(16.2)	3.67(13.8)	3.49(12.0)	3.54(12.3)	3.43(12.0)	3.09(9.2)
SEm±	0.06	0.06	0.09	0.06	0.06	0.06	0.06	0.05
CD at 5%	NS	NS	NS	NS	NS	NS	NS	NS
Herbicide								
Pendimethalin(1.5 kg ha^{-1})	2.62(6.0)	2.83(7.1)	3.04(8.3)	2.74(6.6)	2.70(6.4)	2.70(6.4)	2.55(5.6)	2.33(4.5)
Weedy check	4.44(18.9)	4.69(21.2)	5.15(26.1)	4.78(22.0)	4.42(18.7)	4.50(19.4)	4.39(18.4)	4.05(15.6)
SEm±	0.05	0.05	0.06	0.05	0.05	0.05	0.05	0.04
CD at 5%	0.15	0.15	0.16	0.14	0.13	0.14	0.13	0.12

Table. 36 Effect of cultivars, herbicide and resource conservation techniques on population (No. m^{-2}) of total broadleaf weeds in durum wheat

Treatment	2005-06				2006-07			
	Days after sowing				Days after sowing			
	30	60	90	At harvest	30	60	90	At harvest
RCT's								
ZT	7.16(55.4)	7.59(62.1)	7.70(65.4)	7.15(56.7)	6.89(51.4)	7.22(56.4)	6.87(51.2)	6.36(43.9)
CT	6.56(46.6)	7.13(54.4)	7.19(57.0)	6.78(50.4)	6.55(46.3)	6.87(50.8)	6.60(47.4)	6.08(40.0)
FIRBS	6.88(50.5)	7.39(58.0)	7.59(63.0)	7.06(54.2)	6.67(47.7)	7.04(53.2)	6.82(50.4)	6.31(43.0)
SEm±	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.04
CD at 5%	0.16	0.17	0.17	0.16	0.16	0.17	0.16	0.15
Cultivars								
WH 896	7.01(53.1)	7.46(59.7)	7.55(62.7)	7.10(55.0)	6.85(50.0)	7.21(55.5)	6.89(51.4)	6.40(44.0)
WH 912	6.93(51.0)	7.40(57.9)	7.62(62.9)	7.05(54.1)	6.75(49.6)	7.01(52.9)	6.78(49.6)	6.19(41.2)
PDW 291	6.67(48.3)	7.25(57.0)	7.32(59.9)	6.84(52.4)	6.50(45.7)	6.91(51.9)	6.62(48.1)	6.17(41.7)
SEm±	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.05
CD at 5%	0.16	NS	0.18	0.17	0.16	0.17	0.16	0.15
Herbicide								
Pendimethalin(1.5 kg ha^{-1})	4.75(21.7)	5.19(26.0)	4.96(23.7)	4.61(20.4)	4.61(20.4)	4.87(22.8)	4.57(19.9)	4.22(16.8)
Weedy check	8.99(80.0)	9.55(90.4)	10.03(99.9)	9.38(87.3)	8.79(76.5)	9.21(84.1)	8.96(79.5)	8.28(67.7)
SEm±	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.04
CD at 5%	0.13	0.14	0.15	0.14	0.13	0.13	0.13	0.12

population of broadleaf weeds was 9.2 and 7.8 per cent lower than that recorded under ZT and FIRBS, respectively at harvest stage

Comparing the cultivars, the density of broadleaf weeds was significantly lower under PDW 291 as compared to WH 896. Mean population of these weeds at harvest stage was 49.5, 47.6 and 47.0 plant m^{-2} under cultivar WH 896, WH 912 and PDW 291 sown plots, respectively.

Pre-emergence application of pendimethalin resulted into significant reduction in the density of broadleaf compared to weedy check. Two years mean population of these weeds was 21.0, 24.4, 21.8 and 18.6 plants m^{-2} under pendimethalin treated plots and 78.3, 87.2, 89.7 and 77.5 plants m^{-2} under weedy check plots at 30, 60, 90 DAS and at harvest, respectively.

4.2.1.3 Dry matter accumulation by grassy weeds

The data on dry matter accumulation by grassy weeds recorded at 30, 60, 90 DAS and at harvest (Table 37) showed that among resource conservation techniques, ZT recorded significantly lower dry matter accumulation by grassy weeds as compared to CT and FIRBS. At harvest, average reduction in dry matter of grassy weeds in ZT was 26.8 and 31.4 per cent over CT and FIRBS, respectively.

Dry matter accumulation by grassy weeds was significantly lower in cultivar PDW 291 sown plots than that recorded under WH 896 and WH 912 during both the years. At harvest stage, cultivar PDW 291 on an average reduced the dry matter accumulation by grassy weeds to the extent of 13.5 and 7.3 per cent over the cultivar WH 896 and WH 912, respectively

Pendimethalin, on an average, reduced the dry matter accumulation by grassy weeds to the extent of 68.0 and 69.6 per cent, respectively in 2005-06 and 2006-07 as compared to weedy check at harvest stage.

4.2.1.3 Dry matter accumulation by broadleaf weeds

The dry weight of broadleaf weeds increased from 30 DAS to harvest (Table 38). CT recorded significantly lower dry matter accumulation by broadleaf weed as compared to ZT and FIRBS while later two remained at par between themselves in this respect during both the years. At harvest stage, the average dry matter accumulation by broadleaf weeds was 55.5, 49.0 and 54.7 g m^{-2} under ZT, CT and FIRBS, respectively.

Cultivars did not influence the dry matter accumulation by broadleaf weeds significantly during both the years. Average dry matter accumulation

Table. 37 Effect of cultivars, herbicide and resource conservation techniques on dry matter accumulation (g m^{-2}) by grassy weeds in durum wheat

Treatment	2005-06				2006-07			
	Days after sowing				Days after sowing			
	30	60	90	At harvest	30	60	90	At harvest
RCT's								
ZT	3.1	13.3	33.1	38.3	3.1	12.8	31.9	36.4
CT	4.0	17.8	42.8	51.2	4.0	18.4	42.6	50.9
FIRBS	4.5	19.5	46.2	55.5	4.4	19.1	45.2	53.4
SEm±	0.1	0.3	0.8	1.0	0.1	0.4	0.8	1.0
CD at 5%	0.2	1.1	2.8	3.3	0.3	1.2	2.8	3.4
Cultivars								
WH 896	4.2	18.0	44.4	52.1	4.1	17.8	42.4	50.0
WH 912	3.9	16.7	40.5	48.3	3.8	16.7	39.9	46.9
PDW 291	3.5	16.0	37.2	44.5	3.6	15.8	37.4	43.7
SEm±	0.2	0.8	2.0	2.3	0.2	0.8	1.9	2.2
CD at 5%	0.6	2.4	5.8	6.9	0.5	2.3	5.6	6.6
Herbicide								
Pendimethalin(1.5 kg ha^{-1})	1.4	7.0	17	23.2	1.2	8.1	20.5	24.2
Weedy check	6.3	26.8	64.4	72.4	6.5	26.5	59.3	79.5
SEm±	0.1	0.1	0.3	0.6	0.1	0.1	0.3	0.4
CD at 5%	0.2	0.2	0.7	1.7	0.2	0.4	0.9	1.3

Table. 38 Effect of cultivars, herbicide and resource conservation techniques on dry matter accumulation (g m^{-2}) by broadleaf weeds in durum wheat

Treatment	2005-06				2006-07			
	Days after sowing				Days after sowing			
	30	60	90	At harvest	30	60	90	At harvest
RCT's								
ZT	4.6	14.2	42.8	63.1	4.6	12.8	33.0	48.9
CT	4.0	12.5	36.5	54.6	4.0	11.7	30.4	43.4
FIRBS	4.4	13.6	39.0	60.5	4.1	12.5	31.7	47.8
SEm±	0.1	0.3	0.9	1.2	0.1	0.2	0.6	0.9
CD at 5%	0.3	1.0	2.9	4.2	0.3	0.7	2.2	2.9
Cultivars								
WH 896	4.5	13.7	40.4	60.4	4.5	12.7	33.1	48.5
WH 912	4.4	13.7	40.9	60.4	4.3	12.5	32.2	45.9
PDW 291	4.2	13.0	37.0	57.4	4.0	11.8	29.7	45.7
SEm±	0.2	0.7	2.0	3.0	0.2	0.3	1.6	2.4
CD at 5%	NS	NS	NS	NS	NS	NS	NS	NS
Herbicide								
Pendimethalin(1.5 kg ha^{-1})	2.1	6.8	18.6	32.5	1.6	8.1	12.3	22.6
Weedy check	6.7	20	60.2	86.3	6.9	16.6	51.1	70.8
SEm±	0.0	0.1	0.4	0.7	0.0	0.1	0.2	0.5
CD at 5%	0.1	0.3	0.7	1.7	0.1	0.2	0.8	1.1

by broadleaf weeds at 90 DAS was 36.7, 36.5 and 33.4 g m^{-2} in cultivar WH 896, WH 912 and PDW 291 sown plots, respectively.

At 60 DAS, dry matter accumulation by broadleaf weeds reduced by 66.0 and 51.2 per cent in 2005-06 and 2006-07, respectively under pendimethalin applied plots as compared to weedy check.

4.2.2 Crop studies

4.2.2.1 Crop phytotoxicity

There was no phytotoxicity of pendimethalin on durum wheat cultivars during both the years (data not recorded).

4.2.2.2 Plant height (cm)

The data on plant height under different treatments recorded at 30, 60, 90 DAS and at harvest given in table 39 revealed that it was not influenced by resource conservation techniques at any crop growth stage during both the years. The average plant height at harvest stage, under ZT, CT and FIRBS was 95.4, 95.2 and 96.0 cm, respectively

Among different cultivars, significantly higher plant height was attained by the cultivar WH 912 than WH 896 and PDW 291 through out crop growth cycle in both years. At 60 DAS, mean height of cultivar WH 896, WH 912 and PDW 291 was 43.6, 46.5 and 44.0 cm, respectively.

Application of pendimethalin did not influence the plant height of durum wheat crop during both the years and at all crop growth stages. The average plant height under pendimethalin treated plots was 45.2, 87.7 and 96.3 cm at 60, 90 DAS and at harvest stage, respectively. Corresponding values under weedy check were 44.2, 85.8 and 94.8.

4.2.2.3 Dry matter accumulation (g mrl^{-1})

The data pertaining to dry matter accumulation per running metre at different stages of crop growth are presented in table 40. In general, dry matter accumulation increased at a slow rate up to initial 60 DAS and then it increased at a faster rate up to harvest.

The dry matter accumulation was not influenced significantly by various resource conservation techniques at all growth stages. At harvest, the average dry matter accumulation by crop was 250.4, 249.5 and 254.5 g mrl^{-1} under ZT, CT and FIRBS, respectively.

Cultivars differed significantly among themselves for dry matter accumulation per running metre row length during both the years. The cultivar PDW 291 recorded significantly higher dry matter accumulation than

Table. 39 Effect of cultivars, herbicide and resource conservation techniques on plant height (cm) of wheat at different growth stages

Treatment	2005-06				2006-07			
	Days after sowing				Days after sowing			
	30	60	90	At harvest	30	60	90	At harvest
RCT's								
ZT	10.3	43.4	84.7	93.7	10.6	44.8	87.3	97.1
CT	10.4	43.7	85.0	92.7	10.7	44.8	87.2	97.7
FIRBS	10.6	45.5	87.7	94.4	10.7	46.0	88.5	97.5
SEm±	0.1	0.6	1.2	1.3	0.2	0.6	1.2	1.4
CD at 5%	NS	NS	NS	NS	NS	NS	NS	NS
Cultivars								
WH 896	10.1	42.9	84.0	94.8	10.4	44.3	86.8	95.4
WH 912	10.8	46.1	89.4	95.5	11.0	46.8	90.8	100.6
PDW 291	10.3	43.6	84.0	90.5	10.5	44.4	85.5	96.4
SEm±	0.2	0.8	1.5	1.6	0.2	0.8	1.5	1.7
CD at 5%	0.5	2.3	4.4	4.8	0.6	2.3	4.5	5.0
Herbicide								
Pendimethalin(1.5 kg ha^{-1})	10.5	44.6	86.6	94.4	10.7	45.7	88.8	98.2
Weedy check	10.4	43.8	85.0	92.8	10.6	44.6	86.6	96.8
SEm±	0.1	0.2	0.7	1.1	0.1	0.3	1.1	1.2
CD at 5%	NS	NS	NS	NS	NS	NS	NS	NS

Table. 40 Effect of cultivars, herbicide and resource conservation techniques on dry matter accumulation (g mrl^{-1}) by crop at different growth stages

Treatment	2005-06				2006-07			
	Days after sowing				Days after sowing			
	30	60	90	At harvest	30	60	90	At harvest
RCT's								
ZT	10.0	69.0	153.7	246.0	10.2	71.8	167.0	254.7
CT	10.1	68.4	153.5	245.6	10.2	71.4	166.7	253.5
FIRBS	10.3	70.8	155.8	249.3	10.5	73.2	169.2	259.6
SEm±	0.1	1.1	2.4	3.8	0.1	1.1	2.6	3.9
CD at 5%	NS	NS	NS	NS	NS	NS	NS	NS
Cultivars								
WH 896	9.9	68.7	154.1	246.6	10.1	71.8	167.4	254.8
WH 912	9.9	67.2	147.2	235.5	10.1	70.0	159.9	248.2
PDW 291	10.5	72.3	161.7	258.7	10.7	74.6	175.6	264.7
SEm±	0.2	1.2	2.7	4.4	0.2	1.3	3.0	4.5
CD at 5%	0.5	3.6	8.0	12.9	0.5	3.7	8.7	13.3
Herbicide								
Pendimethalin(1.5 kg ha^{-1})	10.2	74.8	165.3	264.4	10.4	77.8	179.5	275.9
Weedy check	10.0	64.1	143.4	229.5	10.2	66.5	155.8	236.0
SEm±	0.1	0.4	0.7	1.2	0.1	0.4	0.8	1.3
CD at 5%	NS	1.1	2.1	3.4	NS	1.1	2.3	3.8

cultivar WH 912 but at par with WH 896 at all crop growth stages during both the years. The average dry matter accumulation of cultivar PDW 291 was 6.0, 7.1, 9.8 and 8.2 per cent higher than that recorded by cultivar WH 912 at 30, 60, 90 DAS and at harvest stage, respectively.

Application of pendimethalin produced significantly higher crop dry matter than weedy check during both the years at all crop growth stages except 30 DAS. Pendimethalin increased the dry matter accumulation by crop to the extent of 16.8, 15.2 and 16.1 per cent over weedy check at 60, 90 DAS and at harvest stage, respectively.

4.2.2.4 Yield attributes

The data pertaining to the impact of cultivars, weed control treatment and resource conservation techniques on yield attributes on viz. number of spikes, spike length,1000-grain weight and number of grains per spike were recorded at harvest and presented in table 41.

4.2.2.4.1 Number of spikes (No. m^{-2})

The data on number of spikes m^{-2} (Table 41) showed that resource conservation techniques did not influenced the number of spikes significantly during both the years. The average number of spikes produced by durum wheat crop under ZT, CT and FIRBS was 261.5, 255.4 and 262.5, respectively.

Among cultivars, PDW 291 produced significantly higher number of spikes than that produced by WH 896 and WH 912. The number of spikes m^{-2} produced by different cultivars were 267.2 and 279.4 in PDW 291, 251.0 and 262.4 in WH 896 and 243.5 and 254.6 in WH 912 during 2005-06 and 2006-07, respectively.

Pendimethalin treated plots produced significantly higher number of spikes than that produced under weedy check plots during each year. The average number of spikes in pendimethalin treated and weedy checks plots were 290.1 and 229.3, respectively.

Interaction

Interaction effect of resource conservation techniques, cultivars and weed control treatment on number of spikes (Table 42 and Fig. 4) revealed that during 2005-06 cultivar PDW 291 under ZT and treated with pendimethalin gave significantly more number of spikes (310) than when it was sown under CT and treated with pendimethalin (280). Further interaction effect showed that cultivars WH 896 under ZT and WH 912 under CT

Table. 41 Effect of cultivars, herbicide and resource conservation techniques on yield attributes of wheat

Treatment	Number of spikes (m^{-2})		Spike length (cm)		Grains $spike^{-1}$		1000-grain weight (g)	
	2005-06	2006-07	2005-06	2006-07	2005-06	2006-07	2005-06	2006-07
RCT's								
ZT	255.4	267.1	9.4	9.7	47.3	49.5	41.2	42.2
CT	248.4	262.3	9.3	9.5	45.7	48.3	39.9	40.5
FIRBS	257.9	267.1	9.5	9.8	46.2	47.8	40.9	41.9
SEm±	4.0	4.2	0.1	0.1	0.7	0.8	0.6	0.6
CD at 5%	NS	NS	NS	NS	NS	NS	NS	NS
Cultivars								
WH-896	251.0	262.4	9.4	9.7	46.0	48.0	40.3	41.3
WH-912	243.5	254.6	9.1	9.4	44.1	46.1	39.2	40.1
PDW-291	267.2	279.4	9.7	9.9	49.2	51.5	42.4	43.3
SEm±	4.4	4.7	0.2	0.2	0.8	0.9	0.7	0.7
CD at 5%	13.2	13.8	0.5	0.5	2.4	2.5	2.1	2.1
Herbicide								
Pendimethalin(1.5 kg ha^{-1})	283.6	296.5	9.7	10.0	50.3	51.8	41.1	42.0
Weedy check	224.2	234.4	9.1	9.3	42.5	45.2	40.1	41.0
SEm±	0.9	0.9	0.1	0.1	0.1	0.1	0.5	0.6
CD at 5%	2.6	2.7	0.1	0.2	0.4	0.4	NS	NS

Table. 42 Interaction effect of resource conservation techniques, cultivars and weed control treatments on spikes (No. m^{-2}) of durum wheat

Treatments	WH-896		WH-912		PDW-291	
	Pendimethalin (1.5 kg^{-1})	Weedy check	Pendimethalin (1.5 kg^{-1})	Weedy check	Pendimethalin (1.5 kg^{-1})	Weedy check
			2005-06			
ZT	295	223	250	217	310	238
CT	265	207	291	213	280	236
FIRBS	281	235	277	213	304	237
CD at 5%	42.4					
			2006-07			
ZT	308	233	262	227	324	248
CT	280	218	306	225	296	249
FIRBS	291	243	287	221	315	245
CD at 5%	36.3					

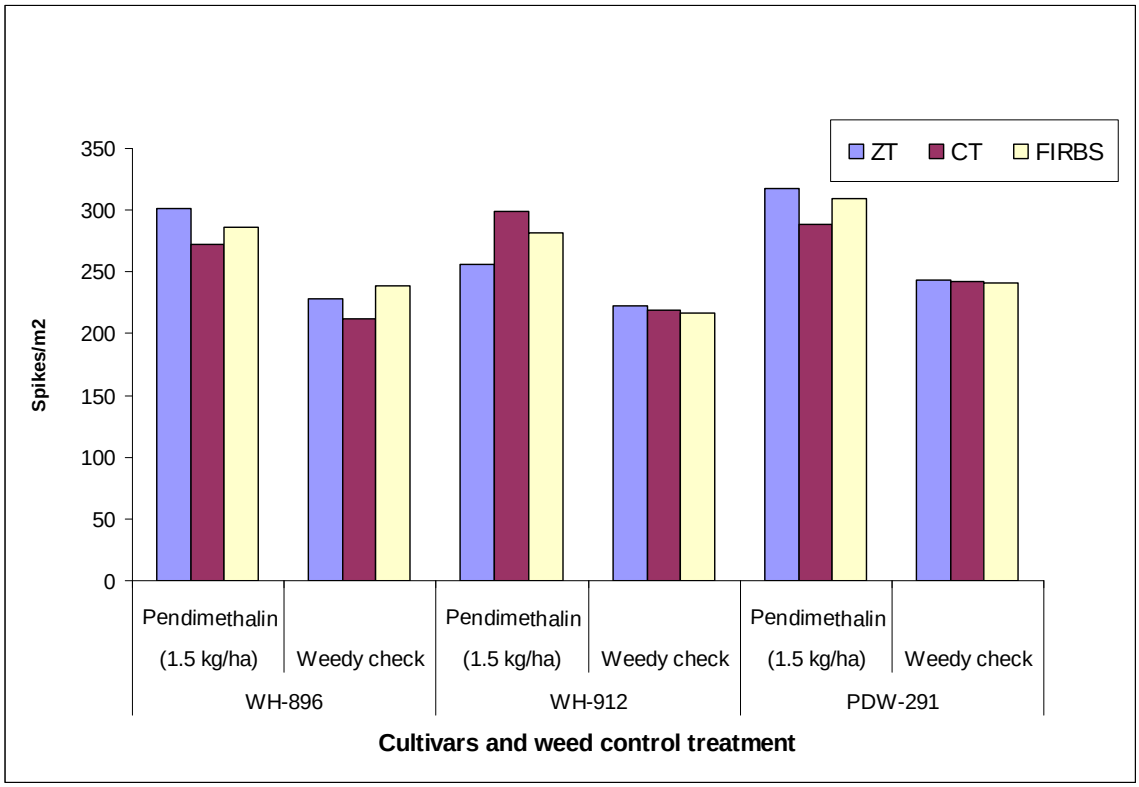


Fig.4 Interaction effect of resource conservation techniques, cultivars and weed control treatments on No. of spikes m^{-2} of durum wheat (Two year mean)

produced significantly more number of spikes i. e. 295 and 291 than the number of spikes produced by them under CT (265) and ZT (250), respectively when treated with pendimethalin. Lowest number of spikes (207) was recorded in cultivar WH 896 under CT and weedy check plots. The similar trend was noticed in 2006-07.

4.2.2.4.2 Spike length (cm)

The differences in spike length due to different resource conservation techniques were not significant during both the years (Table 41). Spike length of durum wheat under ZT, CT and FIRBS was 9.4, 9.3 and 9.5 cm during 2005-06 and 9.7, 9.5 and 9.8 during 2006-07, respectively.

Cultivars differed significantly for spike length. The cultivar PDW 291 produced significantly longer spikes than that produced by cultivar WH 912. Average spike length of cultivars, PDW 291, WH 912 and WH 896 was 9.8, 9.2 and 9.5 cm, respectively.

Application of pendimethalin significantly increased the spike length of durum wheat cultivars over weedy check. The increase was 7.1 and 7.3 per cent in 2005-06 and 2006-07, respectively.

4.2.2.4.3 Grains per spike

Grains per spike were not influenced significantly by resource conservation techniques during both the years (Table 41). However, ZT produced on an average more grains per spike (48.4) than that produced under CT (47.0) and FIRBS (47.0).

Different cultivars of durum wheat differed significantly for grains per spike. Cultivar PDW 291 produced significantly more grains per spike (49.2 and 51.5) than that produced by cultivars WH 912 (44.1 and 46.1) and WH 896 (46.0 and 48.0) during each year.

Weed control treatment significantly influenced the grains per spike of durum wheat. Pendimethalin treated plots produced 18.4 and 15.0 per cent more grains per spike over weedy check during 2005-06 and 2006-07, respectively.

4.2.2.4.4 1000-grain weight (g)

During both years, the resource conservation techniques did not show significant influence on weight of individual grains estimated in terms of 1000-grain weight (Table 41). The average 1000-grain weight recorded under ZT, CT and FIRBS was 41.7, 40.2 and 41.4 g, respectively.

During each year of study, cultivar, PDW 291 produced significantly highest 1000-grain weight and least was recorded under WH 912. Two year mean indicated that compared to lowest test weight (39.6 g) under cultivar WH 912, the other

cultivars namely PDW 291 and WH 896 recorded increase of 8.0 and 3.0 per cent, respectively.

Weed control treatment also found non-significant for 1000-grain weight during each year. The average 1000-grain under pendimethalin treated plots and weedy check was 41.6 and 40.6 g, respectively.

4.2.2.5 Grain and straw yields (kg ha^{-1})

4.2.2.5.1 Grain yield (kg ha^{-1})

The influence of different resource conservation techniques on grain yield of durum wheat was non-significant during both the years (Table 43). The two years average grain yield of durum wheat under ZT, CT and FIRBS was 5458, 5333 and 5310 kg ha^{-1}, respectively

Comparing the durum wheat cultivars, PDW 291 produced significantly more grain yield (5457 and 5849 kg ha^{-1}) than that produced under cultivars WH 896 (5129 and 5527 kg ha^{-1}) and WH 912 (4957 and 5296kg ha^{-1}) during 2005-06 and 2006-07, respectively, while later two cultivars remained at par between themselves.

Application of pendimethalin significantly increased the grain yield of durum wheat over weedy check. The increase in grain yield due to pendimethalin application was 25.1 and 24.9 per cent in 2005-06 and 2006-07, respectively.

Interaction

The concomitant effect of resource conservation techniques, cultivars and weed control significantly influenced the grain yield of durum wheat during both the years (Table 44 and Fig. 5). During 2005-06 cultivar, WH 896 under ZT and FIRBS, when treated with pendimethalin gave statistically same yield of 5920 and 5744 kg ha^{-1}, however, the grain yield significantly decreased when cultivar WH 896 (5512 kg ha^{-1}) sown under CT and treated with pendimethalin. Similarly, cultivar, WH 912 under CT and cultivar PDW 291 under ZT gave significantly higher grain yield of 5725 and 6325 kg ha^{-1} compared to the situation when these cultivars were sown under ZT and CT, respectively at same weed control treatment (pendimethalin). Highest grain yield of 6325 kg ha^{-1} was produced by cultivar PDW 291 under ZT when treated with pendimethalin. This treatment combination produced 46.2 per

Table. 43 Effect of cultivars, herbicide and resource conservation techniques on yield and harvest index of wheat

Treatment	Grain yield (kg ha^{-1})		Straw yield (kg ha^{-1})		Harvest index (%)	
	2005-06	2006-07	2005-06	2006-07	2005-06	2006-07
RCT's						
ZT	5282	5635	7546	8126	41.12	40.89
CT	5124	5542	7660	8248	40.05	40.16
FIRBS	5136	5485	7385	7971	40.98	40.71
SEm±	82	88	117	126	0.59	0.59
CD at 5%	NS	NS	NS	NS	NS	NS
Cultivars						
WH-896	5129	5527	7319	7900	41.16	41.13
WH-912	4957	5296	7426	7997	39.99	39.80
PDW-291	5457	5840	7846	8448	41.00	40.85
SEm±	91	98	133	144	0.71	0.71
CD at 5%	270	291	395	426	NS	NS
Herbicide						
Pendimethalin(1.5 kg ha^{-1})	5759	6169	8253	8787	41.09	40.97
Weedy check	4603	4939	6808	7443	40.34	40.21
SEm±	12	13	21	24	0.03	0.03
CD at 5%	36	38	61	70	0.09	0.08

Table. 44 Interaction effect of resource conservation techniques, cultivars and weed control treatments on grain yield of durum wheat (kg ha^{-1})

Treatments	WH-896		WH-912		PDW-291	
	Pendimethalin (1.5 kg^{-1})	Weedy check	Pendimethalin (1.5 kg^{-1})	Weedy check	Pendimethalin (1.5 kg^{-1})	Weedy check
			2005-06			
ZT	5920	4656	5316	4525	6325	4952
CT	5512	4325	5725	4451	5816	4912
FIRBS	5744	4615	5465	4258	6006	4730
CD at 5%	372					
			2006-07			
ZT	6309	4967	5684	4827	6741	5283
CT	5943	4657	6149	4837	6330	5338
FIRBS	6243	5046	5775	4500	6347	4999
CD at 5%	358					

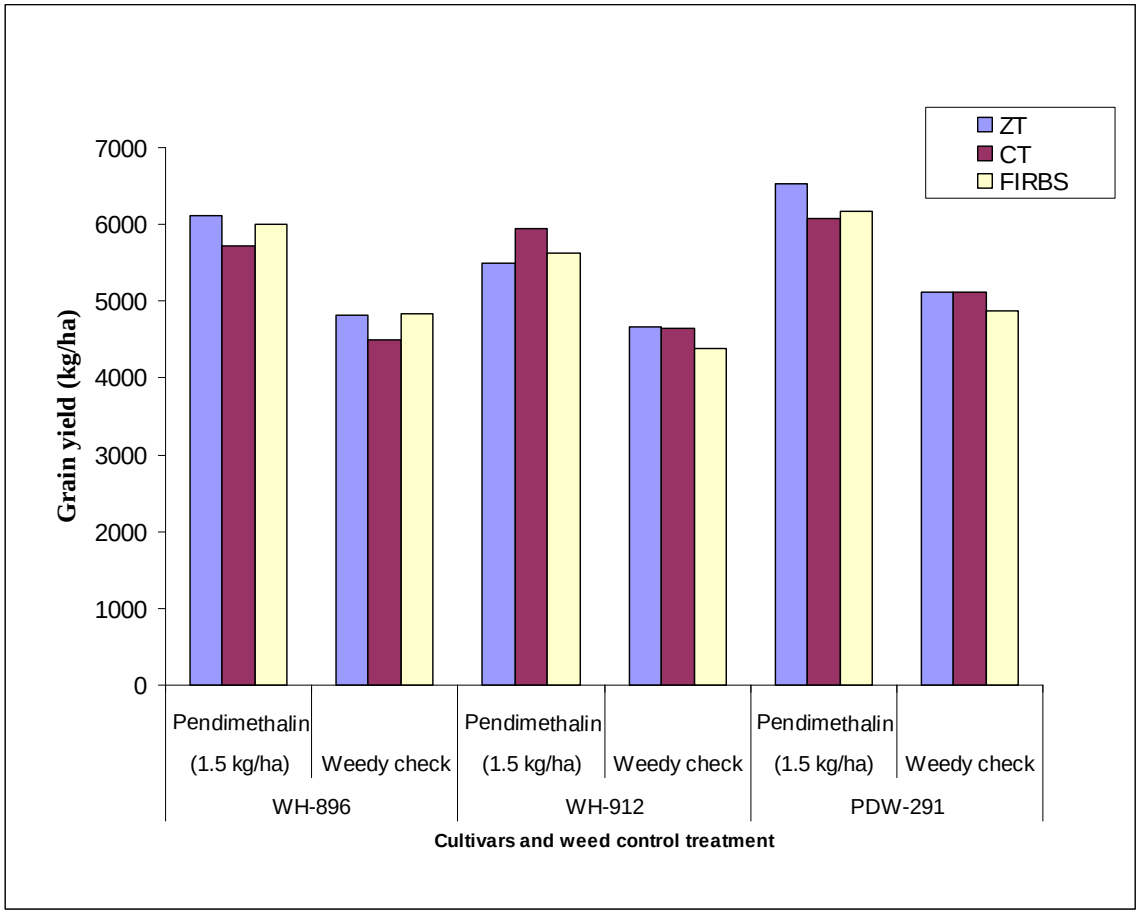


Fig. 5 Interactive effect of resource conservation techniques, cultivars and weed control treatments on grain yield of durum wheat (Two year mean)

cent higher grain yield than that produced under cultivar WH 912 under CT without weed control (4325 kg ha^{-1}). Similar interaction effects among resource conservation techniques, cultivars and weed control were observed in 2006-07.

4.2.2.5.2 Straw yield (kg ha^{-1})

Data on straw yield of durum wheat (Table 43) revealed that it was also not influenced significantly by different resource conservation techniques during both the years of investigation. Mean straw yield produced under ZT, CT and FIRBS was 7836, 7954 and 7678 kg ha^{-1}, respectively.

During both the years, cultivar PDW 291 exhibited significant superiority in straw yield over other cultivars. The extent of increase in mean straw yield was to the tune of 7.1 and 5.6 per cent over WH 896 and WH 912, respectively.

Pendimethalin significantly increased the straw yield of durum wheat over weedy check during each year. The increase was to the tune of 21.2 and 18.1 per cent during 2005-06 and 2006-07, respectively.

4.2.2.5.3 Harvest index (%)

Harvest index of durum wheat cultivars on an average varied between 40.1 to 41.0, 39.9 to 41.1 and 40.3 to 41.0 per cent under different resource conservation techniques, cultivars and weed control treatment, respectively (Table 43).

Harvest index was not influenced significantly by resource conservation techniques, cultivars and weed control treatment during each year.

4.2.3 Nutrient studies

4.2.3.1 N content (%) and uptake (kg ha^{-1}) by crop

An examination of data (Table 45) reveal that nitrogen content in grain and straw was not influenced significantly by different resource conservation technique (RCT's) as well as cultivars and weed control treatment during both the years of investigation. Average N content in grain and straw ranged between 1.79 to 1.80 and 0.410 to 0.417 per cent under resource conservation techniques, 1.79 to 1.80 and 0.412 to 0.415 per cent under different cultivars and 1.79 to 1.81 and 0.411 to 0.416 per cent under weed control treatments.

Similarly, total N uptake (grain + straw) was also remained statistically at par among different RCT's. Average total N uptake by crop was 129.8, 129.2 and 127.7 kg ha^{-1} under ZT, CT and FIRBS, respectively.

Table .45 Effect of cultivars, herbicide and resource conservation techniques on N content in grain and straw and uptake by durum wheat

Treatments	2005-06			2006-07		
	N content (grain) %	N Content (straw) %	Total N uptake (grain + straw) Kg ha^{-1}	N content (grain) %	N Content (straw) %	Total N uptake (grain + straw) Kg ha^{-1}
RCT's						
ZT	1.79	0.409	125.5	1.80	0.410	134.1
CT	1.80	0.414	124.3	1.79	0.414	134.1
FIRBS	1.80	0.417	123.3	1.80	0.417	132.1
SEm±	0.04	0.008	2.8	0.04	0.009	3.0
CD at 5%	NS	NS	NS	NS	NS	NS
Cultivars						
WH 896	1.80	0.413	122.7	1.78	0.415	132.2
WH 912	1.79	0.415	119.8	1.81	0.415	128.3
PDW 291	1.80	0.411	130.6	1.80	0.412	139.8
SEm±	0.04	0.009	2.7	0.04	0.009	2.9
CD at 5%	NS	NS	7.9	NS	NS	8.5
Herbicide						
Pendimethalin(1.5 kg ha^{-1})	1.81	0.416	138.4	1.80	0.416	148.4
Weedy check	1.79	0.411	110.4	1.80	0.411	118.5
SEm±	0.05	0.011	3.3	0.05	0.011	3.5
CD at 5%	NS	NS	9.4	NS	NS	10.1

Among different cultivars, PDW 291 being at par with WH 896 recorded significantly higher total N uptake compared to WH 912 during each year. Average total N uptake by cultivar PDW 291 was 6.1 and 9.0 per cent higher than that recorded under cultivars WH 896 and WH 912, respectively.

Application of pendimethalin as pre emergence significantly increased the total N uptake by durum wheat crop over weedy check. The increase was 25.4 and 25.2 per cent in 2005-06 and 2006-07, respectively.

4.2.3.2 P content (%) and uptake (kg ha^{-1}) by crop

Phosphorus content in durum wheat grain and straw was not influenced by various resource conservation techniques, cultivars and weed control treatment during both the years of experimentation (Table 46). Mean P content in grain was 0.363, 0.364 and 0.366 per cent under ZT, CT and FIRBS, respectively. Corresponding values for straw were 0.808, 0.825 and 0.840. Among cultivars, P content in grain and straw ranged between 0.363 to 0.365 and 0.823 to 0.828 per cent, respectively. Under pendimethalin treated plot and weedy check, the average P content in grain and straw was 0.365 and 0.363 per cent, respectively.

RCT's did not influence the total P uptake (grain + straw) significantly during each year. Average total P uptake by crop under ZT, CT and FIRBS WAS 83.2, 85.2 and 84.0 kg ha^{-1}, respectively.

Among cultivars, PDW 291 on an average removed 8.0 per cent more total P as compared to WH 912, which was statistically significant.

During both the years, pendimethalin treated plots recorded significantly higher total P uptake (90.1 and 96.7 kg ha^{-1}) as compared to weedy check (72.0 and 77.6 kg ha^{-1}).

4.2.3.3 K content (%) and uptake (kg ha^{-1}) by crop

Data (Table 47) showed that alike N and P content, K content in grain and straw remained unaffected due to by various resource conservation techniques (RCT's), cultivars and weed control treatment. Under these treatments, K content in grain and straw varied between 0.98 to 1.01 and 2.03 to 2.07 per cent, respectively.

RCT's did not show significant variation in total K uptake by durum wheat grain and straw during both the years. On an average, total K uptake was 214.2, 215.1 and 212.0 kg ha^{-1} under ZT, CT and FIRBS, respectively.

Table. 46 Effect of cultivars, herbicide and resource conservation techniques on P content in grain and straw and uptake by durum wheat

Treatments	2005-06			2006-07		
	P content in grain (%)	P content in straw (%)	Total P uptake (grain+straw) kg ha^{-1}	P content in grain (%)	P content in straw (%)	Total P uptake (grain+straw) kg ha^{-1}
RCT's						
ZT	0.363	0.808	80.2	0.362	0.808	86.1
CT	0.364	0.823	81.9	0.363	0.827	88.5
FIRBS	0.365	0.843	81.1	0.366	0.837	86.8
SEm±	0.007	0.017	1.8	0.007	0.017	2.0
CD at 5%	NS	NS	NS	NS	NS	NS
Cultivars						
WH 896	0.363	0.820	77.9	0.362	0.825	84.5
WH 912	0.364	0.833	80.0	0.364	0.822	85.9
PDW 291	0.365	0.822	81.4	0.364	0.825	91.0
SEm±	0.008	0.018	1.8	0.008	0.018	1.9
CD at 5%	NS	NS	5.2	NS	NS	5.6
Herbicide						
Pendimethalin(1.5 kg ha^{-1})	0.365	0.838	90.1	0.364	0.836	96.7
Weedy check	0.363	0.812	72.0	0.363	0.812	77.6
SEm±	0.009	0.021	2.1	0.009	0.022	2.3
CD at 5%	NS	NS	6.1	NS	NS	6.7

Table. 47 Effect of cultivars, herbicide and resource conservation techniques on K content in grain and straw and uptake by durum wheat

Treatments	2005-06			2006-07		
	K content in grain (%)	K content in straw (%)	Total K uptake (grain+straw) kg ha^{-1}	K content in grain (%)	K content in straw (%)	Total K uptake (grain+straw) kg ha^{-1}
RCT's						
ZT	0.98	2.05	206.8	0.99	2.05	221.6
CT	0.99	2.05	207.5	0.99	2.03	222.7
FIRBS	1.01	2.07	204.5	1.00	2.06	219.5
SEm±	0.02	0.04	4.5	0.02	0.04	4.9
CD at 5%	NS	NS	NS	NS	NS	NS
Cultivars						
WH 896	0.99	2.06	200.8	0.99	2.06	216.1
WH 912	1.00	2.06	201.8	0.99	2.05	216.3
PDW 291	0.99	2.05	216.3	1.00	2.04	231.5
SEm±	0.02	0.04	4.4	0.02	0.04	4.8
CD at 5%	NS	NS	13.2	NS	NS	14.1
Herbicide						
Pendimethalin(1.5 kg ha^{-1})	1.00	2.06	227.4	1.00	2.06	244.6
Weedy check	0.99	2.05	185.1	0.98	2.04	198.0
SEm±	0.03	0.05	5.4	0.03	0.05	5.8
CD at 5%	NS	NS	15.7	NS	NS	16.8

Amongst cultivars, PDW 291 significantly increased the K uptake over WH 896 and WH 912. On mean basis, cultivar PDW 291 uptaken more K by 6.0 and 7.2 per cent over WH 896 and WH 912, respectively.

Total K uptake also showed similar trend under the influence of pendimethalin application as it was with N and P uptake. During both the years, significantly higher uptake of K (227.4 and 224.6 kg ha^{-1}) by the durum wheat crop was recorded under the pendimethalin treated plots over weedy check (185.1 and 198.0 kg ha^{-1}).

4.2.3.4 N content (%) and total uptake (kg ha^{-1}) in grassy and broadleaf weeds

It is evident from data (Table 48) that nitrogen content in grassy and broadleaf weeds was not affected significantly due to different resource conservation techniques (RCT's), cultivars and weed control treatments during both the years of investigation. Average N content ranged between 1.81 to 1.82, 1.81 to 1.82 and 1.80 to 1.82 in grassy and 2.54 to 2.57, 2.54 to 2.56 and 2.54 to 2.55 per cent in broadleaf weeds under different RCT's, cultivars and weed control treatments, respectively.

Under the influence of various RCT's, ZT significantly reduced the nitrogen uptake by total weeds (grassy + broadleaf) both to FIRBS during first year and as compared FIRBS and CT during second year. The average reduction in total N uptake by all weeds under ZT was 12.1 and 4.1 per cent as compared to CT and FIRBS, respectively.

Different cultivars of durum wheat did not show any significant variation in N uptake by total weeds during each year. Mean N uptake by total weeds (grassy + broadleaf) was 23.2, 22.2 and 22.2 kg ha^{-1} under the cultivar WH 896, WH 912 and PDW 291, respectively.

Weed control treatment significantly affected the total N uptake by weeds. Pendimethalin application reduced total nitrogen uptake by 73.3 and 72.0 per cent compared to weedy check during 2005-06 and 2006-07, respectively.

4.2.3.5 P content (%) and total uptake (kg ha^{-1}) in grassy and broadleaf weeds

It is inferred from data (Table 49) that different resource conservation techniques, cultivars and weed control treatment did not cause significant difference in phosphorus content of both grassy and broadleaf weeds during each year. Mean P content ranged between 0.217 to 0.220, 0.216 to 0.220 and 0.217 to 0.218 per cent in grassy and 0.251 to 0.254, 0.252 to 0.253 and 0.252

Table. 48 Effect of cultivars, herbicide and resource conservation techniques on N content and uptake by weeds

Treatments	2005-06			2006-07		
	N content in grassy weeds (%)	N content in broadleaf weeds (%)	Total N uptake (grassy+broadleaf weeds) kg ha^{-1}	N content in grassy weeds (%)	N content in broadleaf weeds (%)	Total N uptake (grassy+broadleaf weeds) kg ha^{-1}
RCT's						
ZT	1.81	2.43	23.09	1.83	2.53	18.78
CT	1.79	2.56	24.24	1.82	2.53	21.38
FIRBS	1.80	2.67	25.44	1.82	2.55	22.19
SEm±	0.04	0.05	0.55	0.04	0.05	0.47
CD at 5%	NS	NS	1.89	NS	NS	1.61
Cultivars						
WH 896	1.80	2.54	24.84	1.82	2.53	21.40
WH 912	1.81	2.55	24.12	1.83	2.55	20.35
PDW 291	1.79	2.57	23.81	1.83	2.54	20.59
SEm±	0.04	0.06	0.65	0.04	0.06	0.56
CD at 5%	NS	NS	NS	NS	NS	NS
Herbicide						
Pendimethalin(1.5 kg ha^{-1})	1.79	2.54	10.20	1.81	2.53	9.07
Weedy check	1.80	2.56	38.32	1.83	2.54	32.50
SEm±	0.05	0.07	0.86	0.05	0.07	0.73
CD at 5%	NS	NS	2.50	NS	NS	2.13

Table . 49 Effect of cultivars, herbicide and resource conservation techniques on P content and uptake by weeds

Treatments	2005-06			2006-07		
	P content in grassy weeds (%)	P content in broadleaf weeds (%)	Total P uptake (grassy+broadleaf weeds) kg ha^{-1}	P content in grassy weeds (%)	P content in broadleaf weeds (%)	Total P uptake (grassy+broadleaf weeds) kg ha^{-1}
RCT's						
ZT	0.219	0.252	2.44	0.219	0.249	2.00
CT	0.216	0.256	2.63	0.218	0.252	2.32
FIRBS	0.217	0.254	2.74	0.218	0.252	2.40
SEm±	0.004	0.005	0.06	0.004	0.005	0.05
CD at 5%	NS	NS	0.20	NS	NS	0.17
Cultivars						
WH 896	0.219	0.254	2.67	0.221	0.251	2.32
WH 912	0.216	0.254	2.58	0.216	0.252	2.18
PDW 291	0.218	0.254	2.56	0.218	0.250	2.22
SEm±	0.005	0.006	0.07	0.005	0.005	0.06
CD at 5%	NS	NS	NS	NS	NS	NS
Herbicide						
Pendimethalin(1.5 kg ha^{-1})	0.216	0.253	1.11	0.218	0.251	0.99
Weedy check	0.219	0.254	4.09	0.218	0.252	3.49
SEm±	0.006	0.007	0.09	0.006	0.007	0.08
CD at 5%	NS	NS	0.27	NS	NS	0.23

to 0.253 per cent in broadleaf weeds under different RCT's, cultivars and weed control treatments, respectively.

Total P uptake (2.44 kg ha^{-1}) by grassy and broadleaf weeds was significantly lower under zero tillage technique than that recorded under FIRBS (2.74 kg ha^{-1}) while it was at par with CT (2.63 kg ha^{-1}) during 2005-06. During 2006-07, FIRBS and CT were statistically at par for P uptake by total weeds whereas, ZT again recorded significantly lower P uptake by total weeds than other two techniques.

The varieties did not show any significant variation in P uptake by total weeds during both the years. Average P uptake by total weeds ranged between 2.38 to 2.50 kg ha^{-1}.

During each year, application of pendimethalin significantly reduced the P uptake by total weeds. The average reduction in P uptake by total weeds due to pendimethalin application was 72.2 per cent.

4.2.3.6 K content (%) and total uptake (kg ha^{-1}) in grassy and broadleaf weeds

Data (Table 50) show that alike N, P content of grassy and broadleaf weeds, K content was also not influenced by various resource conservation techniques (RCT's), cultivars and weed control treatment during both the years. In these treatments, mean K content in grassy and broadleaf weeds ranged between 1.51 to 1.54 and 1.93 to 1.96 per cent, respectively

During both the years, minimum K uptake by total weeds was recorded under ZT (18.1 and 14.9 kg ha^{-1}), which was significantly lower than FIRBS (20.0 kg ha^{-1}) during 2005-06 and lower than FIRBS (17.8 kg ha^{-1}) and CT (17.3 kg ha^{-1}) during 2006-07.

Different cultivars did not show any significant variation in K uptake by total weeds during both the years. Under different cultivars, K uptake by total weeds ranged between 17.6 to 18.4 kg ha^{-1}.

Pre-emergence application of pendimethalin significantly lowered the total K uptake (8.1 and 7.3 kg ha^{-1}) by total weeds (grassy + broadleaf) as compared to weedy check (30.1 and 26.0 kg ha^{-1}).

4.2.4 Economics

Data on economic evaluation of resource conservation techniques, cultivars and weed control treatments presented in table 51 showed that highest mean cost of cultivation was incurred in FIRBS (Rs 13506 ha^{-1}) followed by CT (Rs 13006 ha^{-1}) and ZT (Rs 10639 ha^{-1}). Highest mean gross return (Rs 45654 ha^{-1}), net return (Rs 35318 ha^{-1}) and B:C ratio (3.7) was

Table. 50 Effect of cultivars, herbicide and resource conservation techniques on K content and uptake by weeds

Treatments	2005-06			2006-07		
	K content in grassy weeds (%)	K content in broadleaf weeds (%)	Total K uptake (grassy+broadleaf weeds) kg ha^{-1}	K content in grassy weeds (%)	K content in broadleaf weeds (%)	Total K uptake (grassy+broadleaf weeds) kg ha^{-1}
RCT's						
ZT	1.52	1.95	18.09	1.54	1.95	14.91
CT	1.51	1.93	19.18	1.55	1.96	17.27
FIRBS	1.49	1.92	20.01	1.52	1.95	17.78
SEm±	0.03	0.04	0.43	0.03	0.04	0.37
CD at 5%	NS	NS	1.49	NS	NS	1.29
Cultivars						
WH 896	1.53	1.96	19.60	1.54	1.95	17.16
WH 912	1.50	1.93	18.97	1.53	1.95	16.25
PDW 291	1.51	1.91	18.71	1.54	1.95	16.55
SEm±	0.03	0.04	0.51	0.03	0.04	0.45
CD at 5%	NS	NS	NS	NS	NS	NS
Herbicide						
Pendimethalin(1.5 kg ha^{-1})	1.51	1.92	8.09	1.53	1.94	7.29
Weedy check	1.51	1.94	30.10	1.54	1.96	26.02
SEm±	0.04	0.05	0.68	0.04	0.05	0.60
CD at 5%	NS	NS	1.96	NS	NS	1.72

Table. 51 Effect of cultivars, herbicide and resource conservation techniques on economics durum wheat

Treatment	2005-06				2006-07			
	Cost of cultivation (Rs. ha^{-1})	**Gross return (Rs. ha^{-1})**	**Net return (Rs. ha^{-1})**	**B.C ratio**	**Cost of cultivation (Rs. ha^{-1})**	**Gross return (Rs. ha^{-1})**	**Net return (Rs. ha^{-1})**	**B.C ratio**
RCT's								
ZT	10336	45654	35318	3.4	10943	55212	44270	4.0
CT	12463	44554	32091	2.6	13551	54534	40984	3.0
FIRBS	12963	44431	31467	2.4	14051	53796	39745	2.8
Cultivars								
WH 896	11921	44321	32400	2.8	12848	54093	41245	3.3
WH 912	11921	43116	31195	2.7	12848	52210	39362	3.1
PDW 291	11921	47203	35282	3.0	12848	57240	44392	3.5
Herbicide								
Pendimethalin(1.5 kg ha^{-1})	12203	49793	37590	3.1	13142	60434	47292	3.7
Weedy check	11639	39967	28328	2.5	12553	48594	36041	2.9

observed in ZT. Zero tillage sowing of durum wheat gave more mean net return of Rs 3257 and 4158 over CT and FIRBS, respectively.

Among cultivars, PDW 291 gave highest mean gross return and net return of Rs 52222 and 39837, respectively. Cultivar PDW 291 gave mean more net return of Rs 3015 and 4559 over the cultivars WH 896 and WH 912, respectively. The mean B:C ratio was found 3.1, 2.9 and 3.3 due to cultivar WH 896, WH 912 and PDW 291, respectively.

Pendimethalin application recorded more mean net return of Rs 10257 over weedy check, which was 31.9 per cent higher. Mean B:C ratio under pendimethalin treatment and weedy check was 3.4 and 2.7, respectively.

CHAPTER-V

DISCUSSION

The productivity of wheat improved markedly after mid-sixties, but could not be sustained due to decline in soil productivity and emergence of second generation problems including herbicide resistance (Malik *et al*., 1998). Continuous use of same herbicide or herbicides with similar mode of action in monoculture generally causes shift in weed flora and development of resistance in weeds. The first such case of herbicide resistance in wheat was reported in *Phalaris minor* Retz. against isoproturon in recent past in Haryana (India), particularly in areas where rice-wheat cropping system was continuously followed for 10-15 years (Malik and Singh, 1993). This resulted in very poor to no control of *P. minor* and consequently heavy losses to total crop failure at many locations (Malik and Singh, 1994). In addition, water productivity has become a critical issue with decline in water table in North-East Haryana and rise in water table in North-West Haryana.

Sustained production now depends on the focused attention on resource conservation technologies (RCT's) like zero-tillage and bed planting or furrow irrigated raised bed system (FIRBS). The zero-tillage is being accepted among the farmers while FIRBS is still in the developing phase. Use of competitive crop cultivar and alternative herbicides coupled with RCT's not only can manage weeds, but also can help in avoiding the herbicide resistance in weeds. Much of the research work was focused on such issues in recent past but mainly in bread wheat (*Triticum aestivum*). Since durum wheat may also find ample scope in near future in India due to changing food habits, it was realized to conduct the present investigation entitled "Evaluation of herbicides and resource conservation techniques on durum wheat (*Triticum durum*) cultivars" during the *rabi* season of 2005-06 and 2006-07. The cause and effect relationship pertaining to the important findings have been discussed in this chapter in the light of available scientific literature.

5.1 Experiment 1

5.1.1 Studies on weeds

Behaviour of weeds as influenced by the herbicidal treatments was studied in terms of weed population and dry matter accumulation at different stages of crop growth. The dominant weed flora in the experimental field comprised of *Phalaris minor*, *Chenopodium album, Avena ludoviciana, Melilotus indica* and *Anagallis arvensis* during both the years(Table 13). Some weeds species like *Convolvulus arvensis, Coronopus didymus and Rumex retroflexus* grouped under miscellaneous weeds were present at comparatively lower densities during both the years.

Weed population though does not reflect the true magnitude of weed competition, it does indicate the extent of pressure exerted by weeds over an area, while dry matter accumulation by weeds indicate to a great extent, the level of competitive stress that a plant undergoes.

Application of clodinafop, fenoxaprop and sulfosulfuron each effectively controlled the population of grassy weeds and reduced the dry matter accumulation to the extent of 87.4 to 94.3 per cent over weedy check at harvest stage but these herbicides were not effective against broadleaf weeds. While sulfosulfuron controlled broadleaf weeds up to some extent.

Metsulfuron, 2,4-DE and carfentrazone effectively reduced the density (90.8 to 98.5 per cent) and dry matter accumulation (85.4 to 96.2 per cent) by broadleaf weeds but were not effective against grassy weeds

Isoproturon significantly reduced the density and dry matter accumulation of grassy and broadleaf weeds than weedy check, but comparatively less effective than tank mixture of broadleaf and grass killing herbicides. These results are in conformity with Gogoi and Kalita (1995), Jat (2004), Tiwari and Vaishya (2004), Singh and Singh (2005), Pandey and kumar (2005), Punia *et al*.(2006b), Bisen *et al*. (2006) and Bharat and Kachroo (2007).

5.1.2 Crop studies

5.1.2.1 Crop growth

Plant height is an index of growth, development and suppressing ability crop/ cultivar on weeds. Dry matter accumulation by the crop is one of the important growth parameters to be considered while assessing the effect of different treatments and competitive ability of the crop with weeds. These components were highest under weed free conditions (Table 25).

The dry matter accumulated by wheat increased with the advancement of crop growth upto harvest. Maximum dry matter accumulation was recorded in weed free

plots at all the growth stages during both the years, closely followed by sequential application of each clodinafop, fenoxaprop and sulfosulfuron with either metsulfuron or 2,4-DE or carfentrazone. This was possibly because the aforesaid treatments effectively controlled the weeds and hence reduced the competition for various growth resources thereby resulting in healthy crop. These results are in conformity with Singh and Singh (2002), Singh *et al*.,2003a and Jat (2004).

Application of different herbicidal treatments did not influence the plant height of the crop.

5.1.2.2 Yield attributes and yield

All the yield attributes except grains per spike and 1000-grain weight of wheat were significantly influenced by different herbicidal treatments in both the years (Table 26).

Season long weed free condition resulted in highest number of spikes (329.4 m^{-2}) and spike length (8.1 cm) of wheat, while lowest values were observed in weedy check plots (272.2 and 6.8).

Among herbicidal treatments, application of clodinafop, fenoxaprop and sulfosulfuron each in combination with any of broadleaf killing herbicides (metsulfuron, 2,4-DE and carfentrazone) produced significantly higher number of spikes (304.6 to 328.4) and spike length (7.8 to 8.2) which were comparable with weed free treatments. Individual or combination of isoproturon with metsulfuron or 2,4-DE or carfentrazone increased the number of spikes m^{-2} over weedy check but differences were non-significant.

All herbicidal treatments except metsulfuron, 2,4-DE and carfentrazone alone significantly increased the grain yield of durum wheat over weedy check. Maximum mean grain yield of 5969 kg ha^{-1} was recorded in season long weed free treatment while minimum under weedy check (3138 kg ha^{-1}). Application of clodinafop (60 g ha^{-1}), fenoxaprop (100 g ha^{-1}) and sulfosulfuron (25 g ha^{-1}) either alone or in combination with metsulfuron (4 g ha^{-1}), 2, 4-DE (500 g ha^{-1}) and carfentrazone (20 g ha^{-1}) increased the mean grain yield to the extent of 61.0 to 85.5 per cent over weedy check. Isoproturon (750 and 1000 g ha^{-1}) alone or in combination with broadleaf weed killing herbicides increased the grain yield to the extent of 33.4 to 43.1 per cent over weedy check.

All the herbicidal treatments were statistically at par among themselves and with weed free treatment for straw yield during both the years except metsulfuron, 2,4-DE and carfentrazone alone and weedy check. The maximum straw yield of 7627

and minimum of 5267 kg ha^{-1} was recorded in weed free and weedy check plots, respectively.

Similar increases in yield attributes of wheat were observed by Saini and Singh (2001), Tomar and Vivek (2003) Tiwari and Vaishya (2004), Singh and Singh (2005), Pandey and Kumar (2005), Punia *et al*.(2006b), Bisen *et al*. (2006), Bharat and Kachroo (2007).

Higher grain and straw yield of wheat in weed free conditions might be attributed to rapid growth of wheat plants efficiently utilizing growth resources in absence of weeds. Harvest index (%) was found to be non-significant among different treatments in both the years.

5.2 Experiment-2

5.2.1 Studies on weeds

During both the years, ZT, CT and FIRBS were dominated by similar weed species viz. *Phalaris minor, Avena ludoviciana, Chenopodium album, Anagallis arvensis* and *Melilotus indica*. Weeds like, *Coronopus didymus, Convolvulus arvensis* and *Rumex retroflexus* were present in lesser number and were therefore grouped as miscellaneous weeds (Table 28).

Under ZT, significantly lower population of *Phalaris minor* (10.6 to 14.2 plants m^{-2}) as compared to bed planting (21.1 to 27.3 plants m^{-2}) and conventional tillage (18.9 to 24.1 plants m^{-2}) was recorded during whole crop growth cycle (Table 29). This might be due to undisturbed inter-row space in ZT, where seeds of *P. minor* lying at lower depths could not germinate (Malik *et al*., 2000c). In FIRBS and CT repeated ploughing brings the weed seeds on upper soil surface and creates favourable conditions for weed seed emergence.

The average density of broadleaf weeds was comparatively higher under ZT (10.2 to 14.9%) than than FIRBS. Singh *et al.* (2002c) and Yadav *et al.* (2002a) also reported similar results.

ZT significantly reduced the dry matter accumulation by grassy weeds to tune of 26.8 and 31.4 per cent over CT and FIRBS, respectively. Better tilth and exposure of weed seeds to upper soil in CT and FIRBS might have

increased the population and thereby dry weight of weeds in these systems. Malik *et al*. (2000d) and Singh *et al*. (2001) also reported similar results.

The dry matter accumulation by broadleaf weeds was significantly higher under ZT in comparison to CT. This might be due to more congenial environment in

ZT for broad leaf weeds. The other possible reason was that germination of broad leaf weeds was enhanced just after first irrigation. These results are in conformity with the earlier findings elsewhere (Singh *et al*., 2002b; Yaduraju and Mishra, 2002; Malik, 2000).

Cultivars significantly influenced the population of grassy weeds. At harvest stage, on an average, the population of grassy weeds was reduced by 15.1 and 7.9 per cent under the cultivar PDW 291 sown plots as compared to cultivar WH 896 and WH 912, respectively.

Similarly, the density of broadleaf weeds was significantly lower under PDW 291 as compared to WH 896. Mean population of these weeds at harvest stage was 49.5, 47.6 and 47.0 plant m^{-2} under cultivar WH 896, WH 912 and PDW 291 sown plots, respectively.

Dry matter accumulation by grassy weeds was significantly lower in cultivar PDW 291 sown plots than that recorded under WH 896 and WH 912 during both the years. At harvest stage, cultivar PDW 291, on an average, reduced the dry matter accumulation by grassy weeds to the extent of 13.5 and 7.3 per cent over the cultivar WH 896 and WH 912, respectively. Similar results have been obtained by Walia and Brar (2004)and Bhat (2005).

Cultivars did not influence the dry matter accumulation by broadleaf weeds significantly during both the years. Average dry matter accumulation by broadleaf weeds at 90 DAS was 36.7, 36.5 and 33.4 g m^{-2} in cultivar WH 896, WH 912 and PDW 291 sown plots, respectively. Mahajan and Brar (2001) have also reported similar non-significant differences in dry matter accumulation by weeds under different cultivars.

Pre-emergence application of pendimethalin significantly lowered the density of grassy as well as broadleaf weeds in comparison to weedy check plots during both the years. Pendimethalin on an average reduced the density of grassy weeds and broadleaf weeds to the extent of 68.1 to 71.9 and 72.0 to 76.0 per cent, respectively at different growth stages. Similar 62 per cent control of both grassy and broadleaf weeds by pendimethalin was observed by Singh and Khole (1998), Shukla and Mishra (2006) at Pantnagar.

Pendimethalin on an average reduced the dry matter accumulation of grassy and broadleaf weeds to the extent of 68.8 to 79.6 and 66.0 to 75.1 per cent, respectively at different crop growth stages. These results are in conformity with earlier findings reported by Singh and Singh (1996), Dixit and Bhan (1998), Singh and Khole (1998), Shukla and Mishra (2006) and Chauhan *et al.* (2007).

5.2.2 Crop studies

5.2.2.1 Crop growth

The overall growth of wheat plant was measured in terms of plant height (cm) and dry matter accumulation (g mrl^{-1}). The dry matter accumulation by crop at various growth stages increased with the advancement of crop stage up to harvest. Plant height and dry matter accumulation was not influenced significantly by resource conservation techniques at all crop growth stages during both the years. The average plant height at harvest stage, under ZT, CT and FIRBS was 95.4, 95.2 and 96.0 cm, and the average dry matter accumulation by crop was 250.4, 249.5 and 254.5 g mrl^{-1}, respectively. This was possibly because plant height is the inherent (genetic) characteristic of cultivar. These results regarding growth parameters are in close conformity with the results reported by Merill *et al*. (1996), Kumar *et al*. (2002), Wang *et al.* (2007).

Among different cultivars, significantly higher plant height was attained by the cultivar WH 912 than WH 896 and PDW 291 at whole crop growth cycle in each year. At 60 DAS, mean height of cultivar, WH 912 was 6.7 and 5.7 per cent higher than the cultivar WH 896 and PDW 291, respectively. Cultivars differed significantly among themselves for dry matter accumulation per running metre row length during both the years. The cultivar PDW 291 recorded significantly higher dry matter accumulation than cultivar WH 912 but at par with WH 896 at all crop growth stages during both the years. The average dry matter accumulation of cultivar PDW 291 was 6.0, 7.1, 9.8 and 8.2 per cent higher than that recorded with cultivar WH 912 at 30, 60, 90 DAS and at harvest stage, respectively. Similar results were reported by Mahajan *et al.* (2004) and Bhat (2005).

Growth parameters i.e plant height and dry matter accumulation improved with advancement of crop growth stages upto harvest. The average plant height under pendimethalin treated plots was 45.2, 87.7 and 96.3 cm at 60, 90 DAS and at harvest stage, respectively. Corresponding values under weedy check were 44.2, 85.8 and 94.8 cm.

Application of pendimethalin resulted in significantly higher crop dry matter accumulation than weedy check during both the years. Pendimethalin increased the dry matter accumulation by crop to the extent of 16.8, 15.2 and 16.1 per cent over weedy check at 60, 90 DAS and at harvest stage, respectively. This was possibly because the aforesaid treatment effectively controlled the weeds and hence reduced the competition for various growth resources thereby resulting in healthy crop. These results are in conformity with Yadav *et al.* (1996) and Shukla and Mishra (2006).

5.2.2.2 Yield attributes and yield

In general, yield attributes, grain, straw and biological yields were comparatively higher in second year. This may be due to combined effect of rainfall in the month of February and March, and favorable weather condition for spike and grain development during the month of March, leading to increase in growing period of the crop.

The results showed that yield components of wheat crop viz., number of spikes mrl^{-1}, spike length, grains per spike and 1000-grain weight were not influenced significantly by various resource conservation techniques.

The average number of spikes produced by durum wheat crop under ZT, CT and FIRBS was 261.5, 255.4 and 262.5, respectively. Spike length of durum wheat under ZT, CT and FIRBS was 9.6, 9.4 and 9.7, respectively. ZT produced marginally more number of grains per spike (48.4) than that produced under CT (47.0) and FIRBS (47.0). The mean 1000-grain weight recorded under ZT, CT and FIRBS was 41.7, 40.2 and 41.4 g, respectively.

The influence of different resource conservation techniques on grain and straw yields as well as harvest index of durum wheat was non-significant. The two years average grain yield of durum wheat under ZT, CT and FIRBS was 5458, 5333 and 5310 kg ha^{-1}, respectively. Mean straw yield produced under ZT, CT and FIRBS was 7836, 7954 and 7678 kg ha^{-1}, respectively. Similar or higher yield attributes in ZT than CT were reported earlier by many reseachers (Dhiman and Sharma, 1986; Vyn *et al.*,1991; Verma *et al.,*1991; Malik *et al.*, 2000d; Yadav *et al*., 2002d; Yadav *et al.*, 2005; Kakkar *et al*., 2005).

The results showed that amongst cultivars, PDW 291 produced highest number of spikes, lower spike, more grain per spike and improved1000-grain weight. Cultivar PDW 291 on an average produced 6.5 and 9.7 per cent higher number of spikes than that produced by WH 896 and WH 912, respectively. Average spike length of cultivars, PDW 291, WH 912 and WH 896 was 9.8, 9.2 and 9.5 cm, respectively. Cultivar, PDW 291 produced 7.1 and 11.6 per cent more grains per spike than that produced by cultivars WH 912 and WH 896. During each year of study, cultivar, PDW 291 recorded significantly highest 1000-grain weight and lowest was recorded under WH 912. Two years mean indicated that compared to WH 912 (39.6 g), the other cultivars namely PDW 291 and WH 896 recorded increase of 8.0 and 3.0 per cent, respectively.

Cultivar PDW 291 produced significantly higher grain yield by 6.0 and 10.2 per cent over WH 896 and WH 912, respectively with concomitant increase in straw

yield and harvest index. Mahajan *et al.* (2004), Kumar *et al.* (2005) and Bhat (2005) also reported similar results.

The marked increase in number of spikes of PDW 291 appears due to improved growth of plants at successive stages as reflected by higher dry matter accumulation. This subscribes to view that there was adequate supply of metabolites under cultivar PDW 291 compared to other cultivars for growth and development of effective tillers. Besides number of spikes, higher grains per spike, spike length and 1000-grain weight under PDW 291 also seems to be on account of higher dry matter accumulation and its inherent characters.

It is well documented that in wheat crop, the potential number of various yield components are decided during vegetative phase while reproductive stage determines their realizable number and size. Meisner *et al.* (1992) also opined that efficient partitioning of dry matter to harvestable part (grains) from rest of the plant parts is most important for realization of higher wheat yield.

Application of pendimethalin as pre-emergence significantly increased the yield attributing parameters i.e. number of spikes , spike length and grains per spike over weedy check. The average increment of number of spikes, spike length and grains per spike was 26.5, 7.2 and 16.7 respectively. Weed control treatment did not influenced 1000-grain weight. The average 1000-grain weight under pendimethalin treated plots and weedy check was 41.6 and 40.6 g, respectively. Application of pendimethalin significantly increased the grain and straw yields of durum wheat over weedy check. The increase in grain and straw yields due to pendimethalin application was 25.0 and 19.7 per cent over weedy check, respectively. Higher yield attributes and yield with pendimethalin over weedy check also reported by Singh and Singh (1996) and Shukla and Mishra (2006).

Harvest index was not influenced significantly by any weed control treatment.

5.2.3 Nutrient study

5.2.3.1 Nutrient content (%) and uptake (kg ha^{-1}) by crop

Results reveal that differences in the nitrogen (N), phosphorus (P) and potassium (K) content in grain and straw of crop remained non-significant due to different resource conservation techniques (RCT's), cultivars and weed control treatment.

Similarly, total N, P and K uptake (grain + straw) were also remained statistically at par among different RCT's. Average total N, P and K uptake by crop ranged between 127.7 to 129.8, 83.2 to 85.2 and 212.0 to 215.1 kg ha^{-1}, respectively under different RCT's.

Among different cultivars, PDW 291 being at par with WH 896 recorded significantly higher total N, P and K uptake compared to WH 912. Cultivar PDW 291 on an average increased the total uptake of N, P and K to the extent of 9.0, 8.0 and 7.2 per cent, respectively over WH 912.

Application of pendimethalin as pre-emergence significantly increased the total N, P and K uptake by durum wheat crop over weedy check. On an average N, P and K uptake by crop increased by 25.3, 24.8 and 23.2 per cent, respectively. Similar findings were reported by Bharat and Kachroo (2007). The probable reason of these findings was that pendimethalin controlled the complex weed flora much effectively due to which nutrients availability for crop plants probably increased which resulted in higher dry matter accumulation in crop plants. As the nutrient uptake is directly related to the dry matter accumulation of plant, hence the nutrient uptake was higher by the above said treatments.

5.2.3.2 Nutrient content (%) and total uptake (kg ha^{-1}) in grassy and broadleaf weeds

Nitrogen(N), phosphorus (P) and potassium (K) content in grassy and broadleaf weeds (Tables 16, 32, 48, 64) was not influenced significantly by different resource conservation techniques (RCT's), cultivars and weed control treatments during both the years.

Under the influence of various RCT's, ZT significantly reduced the nitrogen uptake by total weeds (grassy + broadleaf) and on an average this reduction was to the extent of 12.1 and 4.1 per cent as compared to CT and FIRBS, respectively.

Mean total P uptake by grassy and broadleaf weeds was reduced by 10.3 and 13.6 per cent under ZT as compared to CT and FIRBS, respectively. Similarly, under ZT, mean total K uptake by grassy and broadleaf weeds reduced by 9.5 and 12.7 per cent as compared to CT and FIRBS, respectively.

Different cultivars of durum wheat did not show any significant variation in N, P and K uptake by total weeds. Mean N, P and K uptake by total weeds (grassy +broadleaf) ranged between 22.2 to 23.2, 2.38 to 2.50 and 17.6 to 18.4 kg ha^{-1}, respectively under different cultivars.

Weed control treatment significantly affect the total N, P and K uptake by weeds. Pendimethalin application reduced 72.7, 72.2 and 72.6 per cent of total N, P and K uptake compared to weedy check.

The removal of nutrients by the weeds is governed by their dry matter production and nutrient content. The nutrients content were not influenced significantly by the herbicide treatments. Therefore, the nutrient removal was

governed only by the dry matter production of weeds. Similar findings were reported by Johari *et al*. (1992), Mishra and Gautam (1995) and, Bharat and Kachroo (2007).

5.2.4 Economics

Economic evaluation of different resource conservation techniques revealed that highest cost of cultivation (Rs. 13506 ha^{-1}) was incurred in FIRBS (Table 74) as it needs more ploughings for finer seed bed preparation than CT. Zero-tillage recorded minimum cost of cultivation (Rs. 10639 ha^{-1}) as no tillage operations were carried out (Table 74). The gross return was maximum in ZT followed by FIRBS and CT. On an average, ZT gave highest net return (Rs. 39794 ha^{-1}) which was Rs. 3257 and Rs. 4158 higher than CT and FIRBS, respectively. It was due to minimum cost of cultivation incurred in ZT sown wheat accompanied with lowest weed dry matter and higher grain yield produced due to this tillage practice. Similar results were reported earlier by Malik *et al.* (1998), Kumar (2000) and Yadav and Malik (2001).

Cultivar PDW 291 gave mean more net return of Rs 3015 and 4559 over the cultivars WH 896 and WH 912, respectively. The mean B:C ratio was found 3.1, 2.9 and 3.3 under cultivar WH 896, WH 912 and PDW 291, respectively. Higher net return and B:C ratio under cultivar PDW 291 were due to higher grain yield.

Pendimethalin application recorded more mean net return of Rs 10257 which was 31.9 per cent higher over weedy check. Mean B:C ratio under pendimethalin treatment and weedy check was 3.4 and 2.7, respectively. Bharat and Kachroo (2007) also found higher net return and B:C ratio with different herbicidal treatments over weedy check.

CHAPTER-VI

SUMMARY AND CONCLUSION

This investigation entitled, "Evaluation of herbicides and resource conservation techniques on durum wheat (*Triticum durum*) cultivars" was undertaken during the *rabi* seasons of 2005-06 and 2006-07 at Agronomy Research Farm of Chaudhary Charan Singh Haryana Agricultural University, Hisar. The salient findings of the investigation are presented here under:

6.1 Experiment 1

6.1.1 Weed studies

1. The experimental field was dominated by *Phalaris minor, Chenopodium album*, *Avena ludoviciana*, *Melilotus indica* and *Anagallis arvensis* in both the years.
2. Some weeds species like *Convolvulus arvensis, Coronopus didymus and Rumex retroflexus* grouped under miscellaneous weeds were also present but their infestation was comparatively lower in both the years.
3. Application of clodinafop (60 g ha^{-1}), fenoxaprop (100 g ha^{-1}) and sulfosulfuron (25 g ha^{-1}) each effectively controlled the population of grassy weeds and reduced the dry matter accumulation to the extent of 87.4 to 94.3 per cent over weedy check at harvest stage but these herbicides were not effective against broadleaf weeds. Sulfosulfuron controlled broadleaf weeds up to some extent (33.2 %).
4. Isoproturon (750 and 1000 g ha^{-1}) significantly reduced the density and dry matter accumulation of grassy and broadleaf weeds than weedy check. Isoproturon used alone or as tank mixture was comparatively less effective against complex weed flora than other herbicidal combinations.
5. Density and dry matter accumulation by broadleaf weeds reduced to the extent of 90.8 to 98.5 and 85.4 to 96.2 per cent, respectively with metsulfuron (4 g ha^{-1}), 2,4-DE (500 g ha^{-1}) and carfentrazone (20 g ha^{-1}) alone and their combinations with other herbicides. These herbicides proved ineffective against grassy weeds. While, isoproturon and sulfosulfuron alone could provide only 26.8 to 33.2 per cent control of broadleaf weeds.

6.1.2. Crop studies

1. Height of wheat plants was not much influenced due to different weed control treatments during both the years.
2. Maximum dry matter accumulation by wheat was recorded in weed free plots, closely followed by sequential application of clodinafop (60g ha^{-1}), fenoxaprop (100 g ha^{-1}) and sulfosulfuron (25 g ha^{-1}) each with either metsulfuron (4 g ha^{-1}), 2,4-DE (500 g ha^{-1}) or carfentrazone (20 g ha^{-1}).
3. Different herbicidal treatments significantly improved yield attributes of wheat except test weight and grains per spike in both the years.
4. Season long weed free condition resulted in highest number of spikes (329.4 m^{-2}) and spike length (8.1 cm) of wheat, while lowest values were observed in untreated plots.
5. Among herbicidal treatments, application of clodinafop, fenoxaprop and sulfosulfuron each in combination with any of broadleaf herbicides (metsulfuron, 2,4-DE or carfentrazone) produced significantly higher number of spikes and spike length and were comparable with weed free treatments.
6. Individual or combination of isoproturon with metsulfuron, 2,4-DE or carfentrazone increased the number of spikes m^{-2} over weedy check but differences were non-significant.
7. All herbicidal treatments except metsulfuron, 2,4-DE and carfentrazone alone significantly increased the grain yield of durum wheat over weedy check.
8. Maximum grain yield of 5969 kg ha^{-1} was recorded in season long weed free treatment while minimum under weedy check (3138 kg ha^{-1}).
9. Application of clodinafop (60 g ha^{-1}), fenoxaprop (100 g ha^{-1}) and sulfosulfuron (25 g ha^{-1}) either alone or in combination with metsulfuron (4 g ha^{-1}), 2, 4-DE (500 g ha^{-1}) or carfentrazone (20 g ha^{-1}) increased the mean grain yield to the extent of 61.0 to 85.5 per cent over weedy check.
10. Isoproturon alone or in combination with broadleaf weed killing herbicides increased the grain yield to the extent of 33.4 to 43.1 per cent over weedy check.
11. The maximum straw yield of 7627 and minimum of 5267 kg ha^{-1} was recorded in weed free and weedy check plots, respectively.
12. All the herbicidal treatments were statistically at par among themselves and with weed free treatment for straw yield during both the years except metsulfuron, 2,4-DE and carfentrazone alone (which were statistically inferior).

13. Harvest index of durum wheat was not influenced by different herbicidal treatments.

6.2 Experiment 2

6.2.1 Weed studies

1. During both the years, ZT, CT and FIRBS were dominated by similar weed species viz. *Phalaris minor, Avena ludoviciana, Chenopodium album, Anagallis arvensis* and *Melilotus indica*. Weeds like, *Coronopus didymus, Convolvulus arvensis* and *Rumex retroflexus* were present in lesser number and were therefore grouped as miscellaneous weeds.
2. Population of grassy weeds under ZT was 27.7 and 32.5 per cent lower than that under CT and FIRBS, respectively. ZT significantly reduced the dry matter accumulation by grassy weeds and it was to tune of 26.8 and 31.4 per cent over CT and FIRBS, respectively.
3. The average density of broadleaf weeds was comparatively higher under ZT (10.2 to 14.9%) than CT and 1.6 to 8.7% higher than FIRBS. The dry matter accumulation by broadleaf weeds was also significantly higher under ZT in comparison to CT.
4. On an average, cultivar PDW 291 reduced the population of grassy weeds to the extent of 15.1 and 7.9 per cent and dry matter accumulation to the extent of 13.5 and 7.3 per cent as compared to cultivar WH 896 and WH 912, respectively.
5. The density of broadleaf weeds was significantly lower under PDW 291 as compared to WH 896 but dry matter accumulation was not influenced significantly.
6. Pre-emergence application of pendimethalin (1.5 kg ha^{-1}) significantly lowered the density of grassy as well as broadleaf weeds in comparison to untreated plots during both the years.
7. At different growth stages, pendimethalin on an average reduced the density of grassy weeds and broadleaf weeds to the extent of 68.1 to 71.9 and 72.0 to 76.0 per cent, respectively. The corresponding reduction in dry matter accumulation was 68.8 to 79.6 and 66.0 to 75.1 per cent, respectively.
8. Nitrogen (N), phosphorus (P) and potassium (K) content in grassy and broadleaf weeds were not influenced significantly due to different resource conservation techniques (RCT's), cultivars and weed control treatments.
9. RCT's significantly influenced the total N, P and K uptake by weeds (grassy + broadleaf). On an average , ZT reduced 12.1 and 4.1 per cent total N, 10.3 and

13.6 per cent total P and 9.5 and 12.7 per cent total K uptake as compared to CT and FIRBS, respectively.

10. Different cultivars of durum wheat did not show any significant variation in N, P and K uptake by weeds.
11. Compared to weedy check herbicidal treatment significantly affected the total N, P and K uptake by weeds. Pendimethalin application reduced total N, P and K uptake by 72.7, 72.2 and 72.6 per cent, respectively.

6.2.3 Crop studies

1. Plant height and dry matter accumulation of wheat crop was not influenced significantly by resource conservation techniques.
2. Yield components of wheat crop viz., number of spikes mrl^{-1}, spike length, grains per spike and 1000-grain weight were not influenced significantly by various resource conservation techniques.
3. Similarly, grain and straw yields as well as harvest index of durum wheat were also not influenced significantly by various RCT's. The two years average grain yield of durum wheat under ZT, CT and FIRBS was 5458, 5333 and 5310 kg ha^{-1}, respectively.
4. Among different cultivars, significantly higher plant height was attained by the cultivar WH 912 than WH 896 and PDW 291. The cultivar PDW 291 being at par with WH 896 recorded significantly higher dry matter accumulation than cultivar WH 912.
5. Cultivar PDW 291 produced highest number of spikes, spike length, grain per spike and 1000-grain weight. Cultivar PDW 291 produced significantly higher grain yield by 6.0 and 10.2 per cent over WH 896 and WH 912, respectively with concomitant increase in straw yield and harvest index.
6. Application of pendimethalin did not influence plant height significantly but the dry matter accumulation by crop increased to the extent of 15.2 to 16.8 per cent over weedy check at different crop growth stages.
7. Application of pendimethalin significantly increased the yield attributing parameters i.e. number of spikes and spike length, grains per spike over untreated check.
8. The increase in grain and straw yields due to pendimethalin application was 25.0 and 19.7 per cent over weedy check, respectively. Harvest index was not influenced significantly by weed control treatments.

9. Nitrogen (N), phosphorus (P) and potassium (K) content in grain and straw of crop remained non-significant due to different RCT's, cultivars and weed control treatment.
10. Similarly, total N, P and K uptake (grain + straw) were also remained statistically at par among different RCT's.
11. Among different cultivars, PDW 291 being at par with WH 896 recorded significantly higher total N, P and K uptake compared to WH 912.
12. Application of pendimethalin as pre-emergence significantly increased the total N, P and K uptake by durum wheat over weedy check. On an average N, P and K uptake by crop increased by 25.3, 24.8 and 23.2 per cent, respectively.
13. Highest mean gross return (Rs 45654 ha^{-1}), net return (Rs 35318 ha^{-1}) and B:C ratio (3.7) was observed in ZT. Zero tillage sowing of durum wheat gave more mean net return of Rs. 3257 and 4158 over CT and FIRBS, respectively.
14. Cultivar PDW 291 gave more mean net return of Rs 3015 and 4559 over the cultivars WH 896 and WH 912, respectively.
15. Pendimethalin application recorded more mean net return (Rs. 10257) over weedy check, which was 31.9 per cent higher.

Conclusions:

On the basis of two year (2005-06 and 2006-07) field investigation, the following inferences can be drawn:

- Application of clodinafop (60 g ha^{-1}), fenoxaprop (100 g ha^{-1}) and sulfosulfuron (25 g ha^{-1}) each followed by metsulfuron (4 g ha^{-1}) or 2,4-DE (500 g ha^{-1}) or carfentrazone (20 g ha^{-1}) effectively controlled the complex weed flora and consequently improved yield attributes and yield of durum wheat significantly over weedy check and these herbicidal treatments were comparable with weed free treatment.
- The efficacy of isoproturon alone or as tank mixture against both grassy and broadleaf weeds was comparatively lower than all other herbicidal combinations.
- ZT significantly reduced the population and dry matter of grassy weeds as compared to CT and FIRBS but both density and dry matter of broadleaf weeds was higher under ZT than that under CT and FIRBS. Grassy weeds were 5 per cent more under FIRBS then CT, but broad leaf weeds were 6-8 per cent more under CT

- Zero tillage sowing of durum wheat gave more mean net return of Rs 3257 and 4158 over CT and FIRBS, respectively.
- Cultivar PDW 291 reduced the density and dry weight of weeds more effectively and produced superior yield attributes and 6-10 per cent more grain yield over WH 896 and WH 912.
- Cultivar PDW 291 gave mean more net return of Rs 3015 and 4559 over the cultivars WH 896 and WH 912, respectively.
- Pre-emergence application of pendimethalin at 1.5 kg ha^{-1} significantly reduced the density and dry matter accumulation by grassy as well as broadleaf weeds and on an average increased the grain yield by 25% and net return by Rs. 10257 ha^{-1} over untreated check.

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ABSTRACT

Title of Thesis	:	**Evaluation of herbicides and resource conservation techniques on durum wheat (*Triticum durum*) cultivars**
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Two independent field experiments were conducted in durum wheat during *rabi* season of 2005-06 and 2006-07 in a field having sandy loam soil, low in available N, medium in available P and higher in available K at Research Farm, Department of Agronomy, CCS Haryana Agricultural University, Hisar. Experiments aimed to evaluate the effect of different herbicidal treatments, resource conservation techniques and cultivars on weeds, crop growth, yield and yield attributes and nutrient uptake of durum wheat. First experiment including 20 herbicidal treatments was laid out in a randomised block design with three replications. Second experiment comprising three resource conservation techniques (RCTs) viz., Zero tillage (ZT), Conventional tillage (CT) and Furrow Irrigated Raise Bed System (FIRBS), three cultivars (WH 896, WH 912 and PDW 291) and two weed control treatments (pendimethalin 1.5 kg ha^{-1} and weedy check) was laid out in split plot design with RCTs in the main plots and cultivars and weed control treatments in the sub plots.

. The major weeds infesting wheat field were *Phalaris minor*, *Chenopodium album, Avena ludoviciana, Melilotus indica* and *Anagallis arvensis*. *Convolvulus arvensis, Coronopus didymus and Rumex retroflexus* were also present in lesser numbers.

Application of clodinafop (60 g ha^{-1}), fenoxaprop (100 g ha^{-1}) and sulfosulfuron (25 g ha^{-1}) each followed by metsulfuron (4 g ha^{-1}), 2,4-DE (500 g ha^{-1}) or carfentrazone (20 g ha^{-1}) effectively controlled the complex weed flora and significantly increased yield attributes and yield of wheat over weedy check and were comparable with weed free treatment. The efficacy of isoproturon (750 and 1000 g ha^{-1}) alone or as tank mixture against both grassy and broadleaf weeds was comparatively lower than other herbicidal combinations. All the herbicidal treatments were found safe to durum wheat.

ZT significantly reduced the population and dry matter of grassy weeds as compared to CT and FIRBS but both density and dry matter of broadleaf weeds was higher under ZT than that under CT and FIRBS. Infestation of grassy weeds was comparatively more under FIRBS than CT but reverse was true in case of broadleaf weeds. Cultivar PDW 291 reduced the density, dry weight and nutrient uptake by weeds more effectively and, comparatively produced superior yield attributes and significantly more grain yield over WH 896 and WH 912. Application of pendimethalin reduced the density, dry matter accumulation and nutrient uptake by grassy as well as broadleaf weeds very effectively and on an average, it increased the grain yield of wheat by 25.0 per cent and net return to Rs 10257 ha^{-1} over weedy check. Zero tillage sowing of durum wheat gave more mean net return of Rs 3257 and 4158 over CT and FIRBS, respectively. Cultivar PDW 291 gave mean more net return of Rs 3015 and 4559 over the cultivars WH 896 and WH 912, respectively.

MAJOR ADVISOR

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APPENDIX-I

Economics evaluation of treatments in zero tillage

Sr. No.	Treatment combination	2005-06								2006-07							
		Treatment cost (Rs. ha^{-1})	Common cost (Rs. ha^{-1})	Total cost (Rs. ha^{-1})	Grain yield (kg ha^{-1})	Straw yield (kg ha^{-1})	Gross return (Rs. ha^{-1})	Net return (Rs. ha^{-1})	B:C ratio	Treatment cost (Rs. ha^{-1})	Common cost (Rs. ha^{-1})	Total cost (Rs. ha^{-1})	Grain yield (kg ha^{-1})	Straw yield (kg ha^{-1})	Gross return (Rs. ha^{-1})	Net return (Rs. ha^{-1})	B:C ratio
1	ZTC1W1	2750	6321	9071	5820	7962	50019	40948	4.5	2930	6681	9611	6209	8573	60490	50879	5.3
2	ZTC1W2	2250	6321	8571	4656	6731	40305	31734	3.7	2410	6681	9091	4967	7248	48742	39651	4.4
3	ZTC2W1	2750	6321	9071	5516	8010	47778	38707	4.3	2930	6681	9611	5884	8625	57781	48170	5.0
4	ZTC2W2	2250	6321	8571	4525	6813	39388	30817	3.6	2410	6681	9091	4827	7336	47634	38543	4.2
5	ZTC3W1	2750	6321	9071	6225	8635	53596	44525	4.9	2930	6681	9611	6641	9299	64816	55205	5.7
6	ZTC3W2	2250	6321	8571	4952	7126	42841	34270	4.0	2410	6681	9091	5283	7673	51810	42719	4.7
7	CTC1W1	4950	6321	11271	5612	8160	48618	37347	3.3	5620	6681	12301	6043	8786	59273	46972	3.8
8	CTC1W2	4450	6321	10771	4325	6375	37538	26767	2.5	5100	6681	11781	4657	6865	45764	33983	2.9
9	CTC2W1	4950	6321	11271	5525	8178	47980	36709	3.3	5620	6681	12301	5949	8806	58495	46194	3.8
10	CTC2W2	4450	6321	10771	4451	6909	38910	28139	2.6	5100	6681	11781	4837	7440	47813	36032	3.1
11	CTC3W1	4950	6321	11271	5916	8786	51399	40128	3.6	5620	6681	12301	6430	9461	63165	50864	4.1
12	CTC3W2	4450	6321	10771	4912	7552	42881	32110	3.0	5100	6681	11781	5338	8132	52695	40914	3.5
13	FIRBSC1W1	5450	6321	11771	5744	8114	49571	37800	3.2	6120	6681	12801	6243	8737	60925	48124	3.8
14	FIRBSC1W2	4950	6321	11271	4615	6576	39873	28602	2.5	5600	6681	12281	5046	7190	49364	37083	3.0
15	FIRBSC2W1	5450	6321	11771	5465	8136	47497	35726	3.0	6120	6681	12801	5775	8761	56976	44175	3.5
16	FIRBSC2W2	4950	6321	11271	4258	6511	37144	25873	2.3	5600	6681	12281	4500	7011	44559	32278	2.6
17	FIRBSC3W1	5450	6321	11771	6006	8294	51680	39909	3.4	6120	6681	12801	6347	8931	61989	49188	3.8
18	FIRBSC3W2	4950	6321	11271	4730	6681	40820	29549	2.6	5600	6681	12281	4999	7194	48964	36683	3.0

ZT: Zero Tillage, CT: Conventional Tillage, FIRBS: Furrow Irrigated Raised Bed System,
C1: WH 896, C2:WH 912, C3:PDW 291, W1:Pendimethalin(1.5 kg ha-1), W2:Weedy check