EVALUATION OF SULFONYLUREA HERBICIDES FOR WEED CONTROL IN WHEAT (Triticum aestivum)

By

RAJVIR SHARMA
(95A24D)

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DOCTOR OF PHILOSOPHY

in

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Haryana Agricultural University
Hisar-125 004

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CERTIFICATE - I

This is to certify that this dissertation entitled, "**Evaluation of sulfonylurea herbicides for weed control in wheat (*Triticum aestivum*)**" submitted for the degree of **Ph.D.** in the subject of **Agronomy** of the Chaudhary Charan Singh Haryana Agricultural University, is a bonafide research work carried out by **Mr. Rajvir Sharma** 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.

24/8/2001

(S.S. PAHUJA)
MAJOR ADVISOR
PROFESSOR
Department of Agronomy
CCS HAU, Hisar-125 004

CERTIFICATE – II

This is to certify that this dissertation entitled " **Evaluation of sulfonylurea herbicides for weed control in wheat (*Triticum aestivum*)"** submitted by **Mr. Rajvir Sharma** to the Chaudhary Charan Singh Haryana Agricultural University in partial fulfillment of the requirement for the degree of **Ph. D.**, in the subject of **Agronomy,** has been approved by the Student's Advisory Committee after an oral examination on the same, in collaboration with an External Examiner.

8/11/2001
MAJOR ADVISOR

8.11.01
EXTERNAL EXAMINER

HEAD OF THE DEPARTMENT 8/11

9.XI.01
DEAN, POSTGRADUATE STUDIES

DEDICATED
TO MY
LATE FATHER
Pt. KARAN SINGH

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[RAJVIR SHARMA]

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CHAPTER - 1

INTRODUCTION

Wheat being the world's leading cereal crop is cultivated over an area of about 229.0 million hectares with production of 602.4 million tonnes. India produces about 75.6 million tonnes of wheat with an average productivity of 2621 kg ha^{-1} (Anon., 2001).

Wheat cultivation is mainly confined to North-Western part of country, comprising Haryana, Punjab, Uttar Pradesh and some parts of Rajasthan. In Haryana, it is cultivated in 21.9 lac hectares with the production and productivity of 85.7 lac tonnes and 3916 kg ha^{-1}, respectively. It accounts about 8.0 and 12.1 per cent of total area and production of wheat of the country, respectively (Anon., 2000).

Introduction of high yielding dwarf varieties along with increased fertilizer use and improved irrigation facilities has virtually revolutionised the wheat cultivation which has led to a shift in weed flora in wheat (Bhan and Malik, 1986). The shift in weed flora in favour of wild oat and some other broad leaf weeds has also been recorded in the latest survey of weeds in wheat (Anon., 1990). These conditions stimulate the growth of crop as well as weeds. Wheat is generally infested with both grassy weeds *viz.*, *Phalaris minor, Avena ludoviciana, Avena fatua* and broad leaf weeds *viz.*, *Chenopodium album, Melilotus indica. Coronopus didymus, Anagallis arvensis, Cirsium arvense, Lathyrus aphaca* and *Vicia sativa* (Malik *et al.*, 1989). Weeds compete with crop for nutrients, moisture, light, space and CO_2 causing reduction in yield to the tune of 25 to 50 per cent depending upon species, weed density and crop (Gill, 1979; Bhan and Malik, 1983 and Singh *et al.*, 1997).

Grassy and broad leaf weeds in wheat are equally important as their infestation may lead to the reduction of grain yield to the tune of 15-25 per cent (Walia and Gill, 1985) and 20-30 per cent (Wilson and Cussan, 1984 and Walia *et al.*, 1997), respectively. Among grasses, *P. minor* has become the most serious weed of wheat and results about 25 per cent loss alone in wheat grain yield.

In intensive agriculture, particularly in situations of the morphological similarity of weeds with crop plant (crop mimicry), chemical control of weeds has become obligatory. The herbicide use pattern in high productivity zone has remained focused on the use of few selected compounds during last 15 years. Herbicide like isoproturon has been frequently used without looking at its second generation problems associated with extensive use of herbicides. This type of herbicide use pattern has caused a shift in weed flora in favour of some broad-leaved weeds. It has also led to the development of resistance against target weed like *Phalaris minor* (Malik and Malik, 1994). The herbicide use pattern needs to be rationalised in such a way that the problems associated with such type of use pattern can be avoided. Amongst chemical weed control aspects, use of herbicides in rotation or as tank mixture may help not only to increase the spectrum of weed control but also to prevent or delay the development of herbicide resistance.

2,4-D provides excellent control of broad leaf weeds but causes the developmental deformities in wheat cultivars, delay the maturity and cause significant reduction in the yield (Sharma *et al.*, 1987; Balyan *et al.*, 1990; Balyan and Panwar, 1997 and Balyan and Malik, 2000). Use of non-conventional herbicide like metribuzin to control both resistant and susceptible genotype of *Phalaris minor* is not acceptable due to their injury/toxicity to wheat crop (Balyan *et al.*, 1997 and Balyan, 1999). Under such conditions, we need to evaluate suitable alternate herbicide for the control of complex weed flora in wheat amongst new herbicidal groups introduced recently against grasses and broad-leaved weeds. Some of the new herbicides from sulfonylurea group have a narrow range of weed control while some of the compounds in this group have wide range of control. To avoid use of herbicides separately for the control of broad leaves and grassy weeds, a selective herbicide with a broad spectrum of weed control is needed.

Sulfonylurea herbicides are being considered the substitute for existing herbicides because of their capability to control grassy as well as broad-leaved weeds, high potency, low dose requirement and low mammalian toxicity (Vicari *et al.*, 1994 and Singh *et al.*, 1997). Chlorsulfuron (Glean 75% DF), a new entry in sulfonylurea group needs evaluation for its weed control efficiency and crop tolerance along with residual toxicity to succeeding crops. Sulfonylurea herbicides alone and in combination with the existing herbicides need to be evaluated before their recommendation in wheat based cropping systems.

Keeping the above in view, the present investigation entitled, "Evaluation of sulfonylurea herbicides for weed control in wheat (*Triticum aestivum*)" was planned with following objectives:

1. To evaluate the effect of sulfonylurea herbicides on different weeds of wheat.
2. To study the effect of different herbicidal treatments on growth and yield of wheat.
3. To study the residual effects of different herbicidal treatments on succeeding crop.

CHAPTER - 2

REVIEW OF LITERATURE

The relevant work carried out at different locations in India and abroad pertaining to problem under study is reviewed as under:

2.1 LOSSES CAUSED BY WEEDS

Among the different factors responsible for yield losses in wheat, weeds alone cause 33 per cent yield reduction (Singh *et al.*, 1997). 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 are quite common (Diwivedi *et al.*, 1996). In areas like Karnal and Kurukshetra, sometimes wheat crop is discarded and used as fodder because of intensive population and excessive growth of grassy weeds. Malik and Singh (1995) reported that a population of 2000 plants per square metre of *Phalaris minor* resulted in complete wheat crop failure in farmers field in Haryana State. Besides, these weeds remove 30-40 kg N ha^{-1}, 10-20 kg P ha^{-1} and 20-40 kg K ha^{-1} from the soil and transpire 250-300 tonnes of water per hectare (Mishra and Gautam, 1995). Among grassy weeds, *Phalaris minor* is posing a serious threat to wheat cultivation. Even moderate infestation of *P. minor* alone causes 15-20 per cent reduction in grain yield of wheat (Walia and Gill, 1985). Grassy weeds have a potential to remove 40-50 kg N ha^{-1} in wheat. *Phalaris minor* accounted for 73, 97 and 94 per cent of the total uptake of N, P_2O_5 and K_2O, respectively, by weeds in wheat resulting to 66 per cent loss in yield (Kumar, 1987). While the infestation of wild oat was reported to reduce the grain yield of wheat to an extent of 15 to 50 per cent depending upon its intensity (Brar and Walia, 1989). The uncontrolled presence of broad leaf weeds in wheat crop is equally important. 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 (Kurchania *et al.*, 2000). Therefore, timely weed control becomes mandatory.

2.2 WEED MANAGEMENT

The aim of weed management is not to achieve 100 per cent weed control but to create favourable conditions for crop growth. Weed control methods are grouped into cultural, physical, chemical and biological. Amongst these methods, chemical weed control method i.e. use of herbicides proved the most practical, effective and economic means of controlling even unapproachable or unexcessable weeds or noxious weeds. In addition, they reduce drudgery of hand weeding which is labour intensive and time consuming (Brar and Walia, 1989).

2.2.1 Effect of herbicides on weeds

Mani (1979) found isoproturon a broad spectrum selective herbicide for giving satisfactory control of both broad leaf and grassy weeds in wheat. Application of isoproturon at 0.75 kg ha^{-1} (Malik *et al.*, 1988) or 1.0 kg ha^{-1} (Gill *et al.*, 1978) have resulted in effective control of wild canary grass, wild oat and lambsquarter. Sharma *et al.* (1987) recorded more than 90 per cent control of bathu (*Chenopodium album*) and kanki (*P. minor*) with the application of isoproturon at 1.0 kg ha^{-1}. Tank mixture of isoproturon (1.25 kg ha^{-1}) and 2, 4-D (0.62 kg ha^{-1}) caused significant reduction in the dry weight of *Phalaris minor*, *Avena ludoviciana* and *Chenopodium album* in wheat (Boparai *et al.*, 1991). However, Malik and Malik (1994) reported the development of resistance in *Phalaris minor* to isoproturon due to its continuous use for the last 10-15 years in rice-wheat sequence.

In India, 2,4-D has been recommended for the control of broad leaf weeds in wheat (Singh and Sharma, 1984). Application of 2,4-D 0.36 kg ha^{-1} tank mixed with isoproturon 0.75 kg ha^{-1} provided complete control of *P. minor* and caused drastic reduction in the total weed density and dry matter of weeds (Singh *et al.*, 1996). But the use of 2,4-D alone or tank mixture on large scale has remained restricted because of developmental deformities in spike (malformed) in many wheat varieties like HD 2009, WH 283 and WH 416 and Sonak (Balyan and Panwar, 1997 and Balyan and Malik, 2000). In cotton-wheat sequence, farmers have not accepted 2,4-D as the contamination of 2,4-D with insecticides may cause malformation in cotton (Sharma *et al.*, 1987).

Gigox (1980) reported that metribuzin at 0.42 kg ha^{-1} gave excellent control of both grassy and many broad-leaved weeds in wheat. Blackshaw (1994) observed effective control of *Bromus fectorum* with post-emergence application of metribuzin at 0.42 kg ha^{-1}. Good weed control of both grassy and broad-leaved weeds was achieved with application of metribuzin at 0.28 or 0.43 kg ha^{-1} (Shaw and Wesley, 1992). Application of metribuzin alone at 200 to 400 g ha^{-1} provided 70 to 98 per cent control of grasses and broad leaf weeds in wheat (Balyan, 1999). The drastic reduction in the density and dry weight of *P. minor* was recorded with metribuzin application at 210 g ha^{-1} (Singh *et al.*, 1999).

2.2.2 Effect of sulfonylurea herbicides on weeds

Chlorsulfuron and metsulfuron-methyl (metsulfuron) are members of a new sulfonylurea group of herbicides which can effectively control many broad-leaved weeds and few grasses in different crops (Singh *et al.*, 1995). Vicari *et al.* (1994) reported the use of metsulfuron and chlorsulfuron to control annual broad leaf and some grass weeds in wheat since 1986 in Italy as pre and early post-emergence herbicide at a recommended rate of 6 g a.i. ha^{-1} and 15 g a.i. ha^{-1}, respectively. Chlorsulfuron applied at 0.005 - 0.02 kg ha^{-1} pre and post-emergence resulted in reduction of both population and dry weight accumulation of *P. minor* and broad leaved weeds compared to an unweeded control. In a field trial conducted in USSR, Smirnov and Zakharenko (1985) reported that application of 20 and 40 g Glean (chlorsulfuron) ha^{-1} at tillering stage decreased the population of annual and perennial weeds by 76.8 - 78.1 and 27.2 - 44.6 per cent, respectively. Lyzenke *et al.* (1994) recorded 98-100 per cent weed control with chlorsulfuron application at 10 g ha^{-1} which effectively controlled weeds such as *Stellaria media, Viola arvensis* and *Spergula arvensis* which are resistant against 2,4-D. Singh *et al.* (1997)

found that chlorsulfuron plus safner at 20 g ha^{-1} reduced the density of broad leaf weeds by 94.5 per cent and *P. minor* by 87.5 per cent at 60 DAS and proved best to control complex weed flora in wheat than diclofop, isoproturon and 2,4-D. Application of metsulfuron particularly at 8 g ha^{-1} is reported to provide good control of broad leaf weeds including *Cirsium arvense* (Walia *et al.*, 1997).

Panwar *et al.* (1996) recorded effective control of *C. album* and *M. indica* in wheat with application of metsulfuron at 4 g ha^{-1}. Metsulfuron-methyl (metsulfuron) and terbutron-methyl restricted the growth of grassy weeds for a month and gave good control of broad leaved weeds (Pandey and Singh, 1994). Chlorimuron-ethyl and metsulfuron (metsulfuron-methyl) have been found effective to control grasses in soybean (Bradford *et al.*, 1989) and rice (Mitra and Ghosh, 1992). Kurchania *et al.* (2000) revealed that metsulfuron-methyl at 2 and 4 g ha^{-1} was effective in controlling *Chenopodium album*, *Anagallis arvensis*, *Melilotus alba*, *Vicia sativa*, *Cichorium intybus* but not *P. minor*. Application of chlorsulfuron 25 and 30 g ha^{-1} and metsulfuron 4 and 6 g ha^{-1} resulted 97 to 98 per cent control of *Rumex retroflexus* (Jangli palak) (Balyan and Malik, 2000). Daliwal *et al.* (1998) reported the excellent control of various biotypes of *P. minor* with sulfosulfuron (Leader).

2.2.3 Effect of herbicides on crop growth and yield

Balyan and Malik (1993) recorded significantly higher grain yield (48.9 q ha^{-1}) with the application of 1.0 kg isoproturon. Application of 1-1.5 kg isoproturon proved effective in getting higher number of spikes

m^{-2} and effective tillers per metre row length as compared to the other treatments and produced statistically similar grain yield (50.0 q ha^{-1}) to weed free (50.36 q ha^{-1}) plot (Dixit and Bhan, 1997).

Anderson (1986) reported that metribuzin when applied at the rate of 360 g ha^{-1} reduced the grain yield of winter wheat. Similarly, Tollervey *et al.* (1979) also advocated that when metribuzin applied post-emergence at 0.4 kg ha^{-1} severely injured wheat and depressed wheat yield. The higher rate of metribuzin severely injured to wheat (Morrow and Young, 1982). The significant reduction in wheat grain yield was obtained with the application of metribuzin (400 g ha^{-1}). However, the grain yield of all cultivars including HD 2329 was not influenced significantly with 200 g of metribuzin compared to untreated check (Balyan *et al.*, 1997). Singh (1998) recorded 36-39 per cent reduction in grain and straw yield of wheat following the treatment of metribuzin at 400 g ha^{-1}. However, the grain yield and biological yield with metribuzin 200 g ha^{-1} was 10 per cent less than weed free condition. Application of metribuzin at 400 g ha^{-1} reduced the wheat tillering to an extent of 10-15 per cent and reduced the grain yield (Balyan, 1999). At Pantnagar, Singh *et al.* (1999) also reported the reduction in the wheat crop density by the application of metribuzin at 210 g ha^{-1} onwards. Sensitivity of a particular herbicide to wheat cultivars also depends upon the type of soil. Shaw and Wesley (1992) did not notice any injury to any variety of wheat by more than 10 per cent on a silty clay soil. But on the sandy soil, wheat injury with 0.28 or 0.43 kg ha^{-1} metribuzin was sufficient to reduce wheat yield despite good control of both grassy and broad leaf weeds.

2.2.4 Effect of sulfonylurea herbicides on crop growth and yield

Most of the studies on tolerance of wheat cultivars to chlorsulfuron have been conducted in western countries. Differential tolerance of wheat cultivars to chlorsulfuron have been reported by Dastgheib *et al.* (1993). The main reason for differences in sensitivity to chlorsulfuron is the differential rates of metabolism or detoxification (Dastgheib *et al.*, 1993). Sweetser *et al.* (1982) found that the tolerant species of wheat rapidly metabolized chlorsulfuron to a polar, nonphytotoxic product. However, perhaps no case of differences in sensitivity of wheat cultivars to applied chlorsulfuron has been reported in Indian conditions. Singh *et al.* (1997) obtained the highest grain yield (62.11 q ha^{-1}) with the application of chlorsulfuron plus safner at 40 g ha^{-1} which was very closely followed by chlorsulfuron 20 g ha^{-1} and 40 g ha^{-1} and their application proved best among other treatments especially in the presence of complex weed flora. Maximum grain yield of wheat (36.6 q ha^{-1}) was recorded by Walia *et al.* (1997) with the application of metsulfuron and tribenuron-methyl each at 10 g ha^{-1} and was significantly more than the recommended treatment of two hand hoeing. However, chlorimuron-ethyl 10 g ha^{-1} proved toxic to the wheat crop. Application of chlorsulfuron 25 and 30 g ha^{-1} and metsulfuron 4 and 6 g ha^{-1} produced more or less similar yields to that of weed free yields (Balyan and Malik, 2000).

Spiridonov (1989) reported that application of Glean (chlorsulfuron) at 10-40 g ha^{-1} decreased weed infestation in wheat by 70-94 per cent and grain yield exceeded those of the control by upto 0.4 to 0.5 t ha^{-1}. Ray *et al.* (1996) reported that application of Express (Tribenuron-methyl) at 10 g a.i. ha^{-1} resulted in the highest grain yield (27.5 t ha^{-2}) which was statistically similar to that obtained by using metsulfuron at 4 g a.i. ha^{-1}, isoproturon 1 kg a.i. ha^{-1} and 2,4-D (sodium salt) at 0.5 kg ha^{-1} at 25 DAS.

2.3 USE OF HERBICIDE MIXTURES

Herbicide mixtures are an effective tool to enhance herbicide efficiency, lower optimum doses of herbicides, reduce cost of weed management, arrest weed shift, prevent herbicide resistance in weeds and facilitate overall improvement in weed management (Rao, 1993). In a mixture, herbicides may behave and interact quite differently than their alone application on crop as well as on weeds. Sometimes a particular herbicide may not be having compatibility with other. In mixtures, the activity of herbicides may be either altered or enhanced due to presence of other herbicides and showing different interaction responses termed as synergistic, additive and antagonistic. Hence, it is important to understand the activities of new chemicals in probable tank mixtures.

Anderson (1986) reported that chlorsulfuron at 18, 35 or 70 g ha^{-1} plus metribuzin at 360 g ha^{-1} antagonized metribuzin toxicity to wheat. In other study of Gillespie and Nalewaja (1989), chlorsuifuron at 12 or 23 g ha^{-1} plus pre-plant incorporated (PPI) triallate at 1120 g ha^{-1} antagonized triallate toxicity to wheat but did not antagonize wild oat control with triallate at 140 or 280 g ha^{-1}. Thus, chlorsulfuron could be applied PPI with triallate to control wild oat and broad leaf weeds without reducing wild oat control but decreasing injury to wheat. Kaur *et al.* (1996) observed antagonism with tank mix application of diclofop-methyl + metsulfuron ($1000 + 5$ g ha^{-1}) in wheat crop.

2.4 RESIDUAL AND PERSISTENCE BEHAVIOUR OF SULFONYLUREA HERBICIDES IN SUCCEEDING CROPS

Sulfonylurea are relatively new class of herbicides. Chlorsulfuron and metsulfuron are two important members of this group used to control annual broad leaf and some grass weeds in wheat (Vicari *et al.*, 1994 and Walker *et al.*, 1989). Chlorsulfuron and metsulfuron have been marketed since 1986 in Itlay and in Germany, respectively. They exhibit high level soil activity at extra ordinarily low rates of application and give residual weed control with doses in the range of 5-20 g a.i. ha^{-1} (Walker *et al.*, 1989). Because of this high level of soil activity, the time that their residues persist is particularly important since some broad leaf crops (e.g. sugarbeet, redbeet, lettuce, lentil, peas, corn, maize, rapeseed, etc.) are sensitive to very low concentration in the soil (Walker and Brown, 1982; Beyer *et al.*, 1987). Both herbicides are degraded mainly by non-biological chemicals and by soil microorganism (Joshi *et al.*, 1985). Their biological activity and residual behaviour in soil is determined by soil and environmental factors like soil temperature, moisture pH, organic matter, microbial activity and texture (Ulrich and Miller, 1983; Anderson and Dulka, 1985; Walker and Brown, 1983). Interaction of the herbicide with the soil and environmental factors would determine its immediate phytotoxicity and subsequent degradation and hence its persistence in the soil and residual behaviour on the succeeding crops or rotational crops (Peterson and

Arnold, 1985). As the soil pH is increased to a level of 7 to 7.5, microbial degradation in combination with limited chemical hydrolysis is restricted and led to slow rates of loss of applied herbicides (Thirunarayanan *et al.*, 1985). At these higher values of soil pH, the herbicides are anionic and only weakly adsorbed by soil. Thus, they have the potential to leach under conditions of high rainfall. Herbicides are extensively mobile in the soil due to poor adsorption and higher soil moisture content and moved in to deeper layers where microbiological activity is often lower than that in soil from the surface layer. This may have important implication with respect to persistence of residues (Nicholls *et al.*, 1987). Rapid hydrolysis of these two herbicides is occurred at low pH (4-5.5) and the level of residual herbicide available for crop injury to rotational crop is greatly reduced (Peterson and Arnold, 1985). On the other hand, as soil pH approaches 7.0, the chlorsulfuron molecules become more stable, resulting in more crop injury in subsequent growing season. Highly significant negative correlation between soil pH and adsorption of chlorsulfuron was recorded by Walker *et al.* (1989). The risk of residue carry over of chlorsulfuron is expected greater in alkaline soils (Walker *et al.*, 1989), which may restrict their use in rotations where sensitive crops are included. In India, particularly in Haryana soil pH is high (about 8), organic matter content is low, rainfall is less, temperature is high, soil moisture content generally remains lower. These conditions are entirely different than those prevailing in most of the western countries where these herbicides have been used and research work on their residual effect on succeeding crop has been done. So an entirely different residual/persistence behaviour of metsulfuron and chlorsulfuron is expected in our conditions. Research work done on the residual effect of these herbicides on different subsequent crop grown in wheat based cropping system has been reviewed as follows.

Brewster and Appleby (1983) have found injury to snap beans (*Phaseolus vulgaris* L.), alfalfa (*Medicago sativa* L.), sweet corn (*Zea mays* L.), *Italian ryegrass* (*Lolium multiflorum*), sugarbeets (*Beta vulgaris*) and rape (*Brassica napus*) from residues remaining in the soil following a 35 g ha^{-1} application of chlorsulfuron in wheat crop. Chlorsulfuron residues reduced foliage weight of sugarbeet seeded even after 26 months of application. Spiridonov *et al.* (1989) found rape as most susceptible crop to the residues of Glean remaining in soil after wheat harvest and also recorded yield losses for potatoes and maize. Walker and Welch (1989) reported that chlorsulfuron is largely confined to the upper (40-50 cm) soil even after 148 days of application and residues left in the surface soil layer with an initial dose of 32 g ha^{-1} which was sufficient to affect the growth of lettuce and sugarbeet sown approximately one year after application. Bioassay studies carried out at New Delhi by Yaduraju *et al.* (1989) indicated that persistency of chlorsulfuron in soil at the time of wheat harvest was not sufficient to affect the growth of maize but there was a 80 per cent reduction in the growth of sugarbeet at 90 days after pre-emergence application of chlorsulfuron (0.020 kg ha^{-1}). Carda *et al.* (1991) reported that chlorsulfuron applied at 19 g ha^{-1} to spring wheat caused significant reduction in dry weight production of sugarbeet and lucerne grown after wheat harvest on clay loam soil in USA. Chlorsulfuron residues are reported to reduce the fresh weight of cabbage, onion and maize (Vicari *et al.*, 1991). Kinfe and Peeper (1993) reported that the persistence of chlorsulfuron varies with soil type and observed different half lives period (6.0 and 3.2 months in the clay loam soil and sandy loam soil, respectively). Both maize and sorghum were reported sensitive to sulfonylurea herbicides by Hwang *et al.* (1995).

A bioassay study conducted in Australia indicated that residues of chlorsulfuron in the range of 0.1 to 0.4 ng g^{-1} of soil were found phytotoxic to leguminous crop, pasture species and oil seed crop species (Stork, 1995). Vicari *et al.* (1994) conducted an experiment in USA to study the persistence of chlorsulfuron and metsulfuron applied in wheat at 15 and 30 g ha^{-1} and 8 g ha^{-1} metsulfuron, respectively. They did not detect any residues by the maize bioassay at 15 g ha^{-1} but residues equivalent to 2.38 g ha^{-1} was found at the higher rate of chlorsulfuron (30 g ha^{-1}) soon after wheat harvest. However, no residues of metsulfuron at 8 g ha^{-1} was detected at each location after one month of treatment. Residues of chlorsulfuron were distributed upto the depth of 30-50 cm whereas of metsulfuron residues were mainly confined to the surface layer. Upstone (1991) observed no effect of residues on yield or quality of sugarbeet and potatoes following metsulfuron application even at 1, 2 and 3 times the recommended rate of 6 g ha^{-1} to wheat crop.

Yadav *et al.* (1995) conducted an experiment at Hisar to study the residual carry over of metsulfuron-methyl on the onion plant at two different soil moisture. Their results revealed that significantly higher reduction in dry weight of onion was recorded at 25 per cent available soil moisture at all doses than at 75 per cent available soil moisture after 120 days of herbicide application. In other studies they recorded 147, 108 and 70 days half life of metsulfuron at 15, 25 and 35°C, respectively indicating increased chemical and microbial degradation. Thus, resulting more breakdown of the sulfonylurea herbicides due to higher mean temperatures. They also reported rapid dissipation in microbially active soil (half life 70 days) than in sterilized soil (half life 163 days) (Yadav *et al.*, 1997).

CHAPTER - 3

MATERIALS AND METHODS

The investigation entitled, "Evaluation of sulfonylurea herbicides for weed control in wheat (*Triticum aestivum*)" was carried out during *rabi* seasons of 1996-97 and 1997-98. The details of the materials used and the methodologies adopted during the course of investigation are described in this chapter. The general climate, soil and cropping pattern of the experimental field have also been depicted herein.

3.1 GENERAL DETAILS

3.1.1 Experimental site

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 29°10' N latitude and 75°46'E longitude with an elevation of 215.2 metre above mean sea level.

3.1.2 Climate and weather

The climate of Hisar region is semi-arid with hot and dry summer and cold winter having 300-400 mm annual rainfall. The temperature shows a wide degree of fluctuation ranging from freezing point to as high as 48°C during the year. Mean relative humidity (at 7.0 a.m.) remains nearly

Table 1. **Weekly weather data for crop seasons 1996-97 and 1997-98 at CCS HAU, Hisar**

Months/ Standard week	Temperature (°C)				Relative humidity (%)				Sunshine (hrs)		Evaporation (mm)		Rainfall (mm)	
	1996-97		1997-98		1996-97		1997-98		1996-97	1997-98	1996-97	1997-98	1996-97	1997-98
	Max.	Min	Max.	Min	M	E	M	E						
November														
45	39.9	9.2	27.6	12.8	77	22	90	53	8.7	5.5	4.1	2.1	0.0	0.0
46	29.1	8.8	25.5	9.1	82	26	90	37	8.2	7.2	3.3	1.9	2.0	0.0
47	26.0	6.5	24.3	10.0	87	37	88	48	8.0	3.6	3.4	1.7	0.0	2.0
48	24.9	4.5	21.3	6.2	82	28	92	57	8.3	5.4	2.3	2.6	0.0	2.0
December														
49	22.9	3.4	20.1	8.4	77	28	93	68	7.6	3.9	2.7	1.6	0.0	14.5
50	22.6	-0.5	16.2	9.4	79	20	95	87	8.3	0.4	2.3	1.1	0.0	5.0
51	24.0	1.9	13.7	5.3	84	29	95	74	7.6	1.7	1.6	1.1	0.0	0.0
52	22.8	3.9	13.6	4.4	90	34	94	84	7.0	2.1	1.9	0.8	0.0	9.5
January														
1	22.7	2.0	19.2	2.8	95	41	93	43	5.9	7.9	1.5	1.5	0.0	0.0
2	20.7	-0.4	17.9	6.7	93	36	95	63	6.7	8.2	1.6	0.9	0.0	2.0
3	19.3	3.1	18.7	1.5	93	51	87	39	5.2	8.3	2.1	2.0	13.6	0.0
4	17.9	3.0	19.4	2.3	93	49	93	41	6.1	7.4	1.7	1.7	0.0	0.0
5	20.4	4.1	21.2	8.7	97	51	94	58	7.4	3.0	0.0	1.6	1.0	10.0
February														
6	21.7	2.6	22.2	4.0	86	39	86	40	8.4	9.1	2.5	2.3	0.0	0.0
7	22.4	4.3	25.4	11.0	80	28	81	45	8.5	6.7	3.2	2.8	0.0	0.0
8	25.3	5.5	21.7	7.7	85	31	92	61	9.2	6.5	3.2	3.4	0.0	16.9
9	26.9	7.2	21.4	8.2	79	31	92	60	8.0	6.2	4.3	2.4	0.0	0.8

Months/ Standard week	Temperature (°C)				Relative humidity (%)				Sunshine (hrs)		Evaporation (mm)		Rainfall (mm)	
	1996-97		1997-98		1996-97		1997-98		1996-97	1997-98	1996-97	1997-98	1996-97	1997-98
	Max.	Min	Max.	Min	M	E	M	E						
March														
10	28.5	9.8	23.0	8.5	83	34	88	46	7.2	6.9	3.5	2.8	0.0	15.7
11	27.0	13.1	25.9	9.9	86	50	89	50	4.6	8.2	3.4	3.7	7.0	11.0
12	26.4	11.7	28.0	12.3	90	41	82	35	7.3	7.6	3.1	4.3	47.6	0.0
13	28.1	13.2	30.9	14.2	83	50	71	28	6.0	9.3	3.2	5.3	0.5	0.0
April														
14	27.4	13.0	33.4	18.4	86	42	73	33	8.2	6.9	4.0	5.5	21.5	1.0
15	33.6	17.8	34.3	14.2	73	32	72	31	9.6	10.0	6.2	6.9	0.0	0.0
16	33.8	14.9	38.9	17.3	85	51	48	15	9.2	10.3	6.6	7.8	0.0	0.0
17	38.9	19.5	38.7	20.8	77	34	54	20	9.1	7.3	9.0	7.9	1.2	0.0
18	34.0	18.1	40.3	22.7	91	45	51	20	5.5	8.3	5.2	8.3	26.2	0.0
May														
19	35.6	19.8	35.9	19.7	73	38	64	28	10.5	9.2	8.0	8.2	0.0	1.5
20	38.3	18.3	43.3	23.6	68	30	40	16	10.2	9.9	9.2	9.8	0.0	4.2
21	41.0	24.4	45.9	25.5	67	31	33	12	9.3	10.1	11.2	11.7	0.0	0.0
22	36.5	20.8	45.0	26.3	79	45	38	20	6.2	8.5	6.7	13.8	59.8	0.0
June														
23	37.0	22.1	41.0	24.5	71	37	40	26	8.6	6.4	7.7	10.1	34.0	4.5
24	39.0	23.8	34.2	23.2	67	38	73	47	9.4	7.1	8.6	6.5	0.0	54.0
25	38.7	25.8	41.8	26.3	67	43	55	23	6.3	9.5	9.8	9.3	0.0	0.0
26	37.3	24.8	40.8	28.8	80	54	62	41	4.8	7.4	5.9	8.0	7.7	13.7

Months/ Standard week	Temperature (°C)				Relative humidity (%)				Sunshine (hrs)		Evaporation (mm)		Rainfall (mm)	
	1996-97		1997-98		1996-97		1997-98		1996-97	1997-98	1996-97	1997-98	1996-97	1997-98
	Max.	Min	Max.	Min	M	E	M	E						
July														
27	41.0	26.6	35.7	26.4	65	38	79	53	10.0	3.2	9.5	4.6	0.3	90.6
28	38.3	25.4	33.7	26.7	76	47	83	67	4.9	2.3	8.2	3.4	19.0	15.8
29	36.1	24.8	36.0	26.0	81	59	83	49	3.6	4.7	4.8	5.2	101.5	40.2
30	34.7	25.6	38.9	27.0	84	67	67	43	7.2	8.6	5.4	7.6	41.7	0.0
31	31.6	23.6	37.1	28.5	90	76	73	50	3.5	7.3	3.7	7.7	22.0	0.0
August														
32	34.3	24.8	37.4	27.5	81	59	69	45	6.5	5.0	5.9	7.5	5.2	0.0
33	34.9	23.3	35.5	26.0	85	57	78	53	7.2	3.9	4.7	5.9	39.0	22.2
34	34.2	24.8	36.1	26.3	85	67	82	55	6.7	5.4	6.3	6.3	99.3	24.0
35	33.1	24.0	35.5	25.7	93	63	80	54	7.5	7.2	4.1	5.9	63.7	3.5
September														
36	35.1	24.1	37.3	25.2	82	62	74	51	9.3	8.4	5.4	5.6	0.0	14.0
37	34.1	24.0	33.8	24.3	88	67	84	63	6.6	6.1	4.5	5.2	0.5	34.7
38	36.2	23.2	32.9	24.2	85	58	87	68	9.5	4.9	5.4	5.2	0.0	86.0
39	36.0	20.2	32.9	24.0	80	46	85	55	9.3	7.3	5.6	3.3	19.0	11.0
October														
40	28.1	17.6	33.2	21.9	95	76	87	58	5.5	7.5	3.3	4.0	70.0	11.0
41	30.4	18.2	34.4	20.5	91	61	89	49	7.8	7.9	3.0	3.4	0.5	0.0
42	29.1	16.1	27.1	19.8	91	67	88	71	5.2	2.8	2.7	2.2	20.0	129.5
43	25.7	14.0	31.4	17.9	92	62	85	38	5.6	8.9	3.8	3.2	0.0	0.0
44	26.5	12.8	29.6	14.6	88	49	82	40	6.7	7.3	2.3	2.3	15.50	0.0

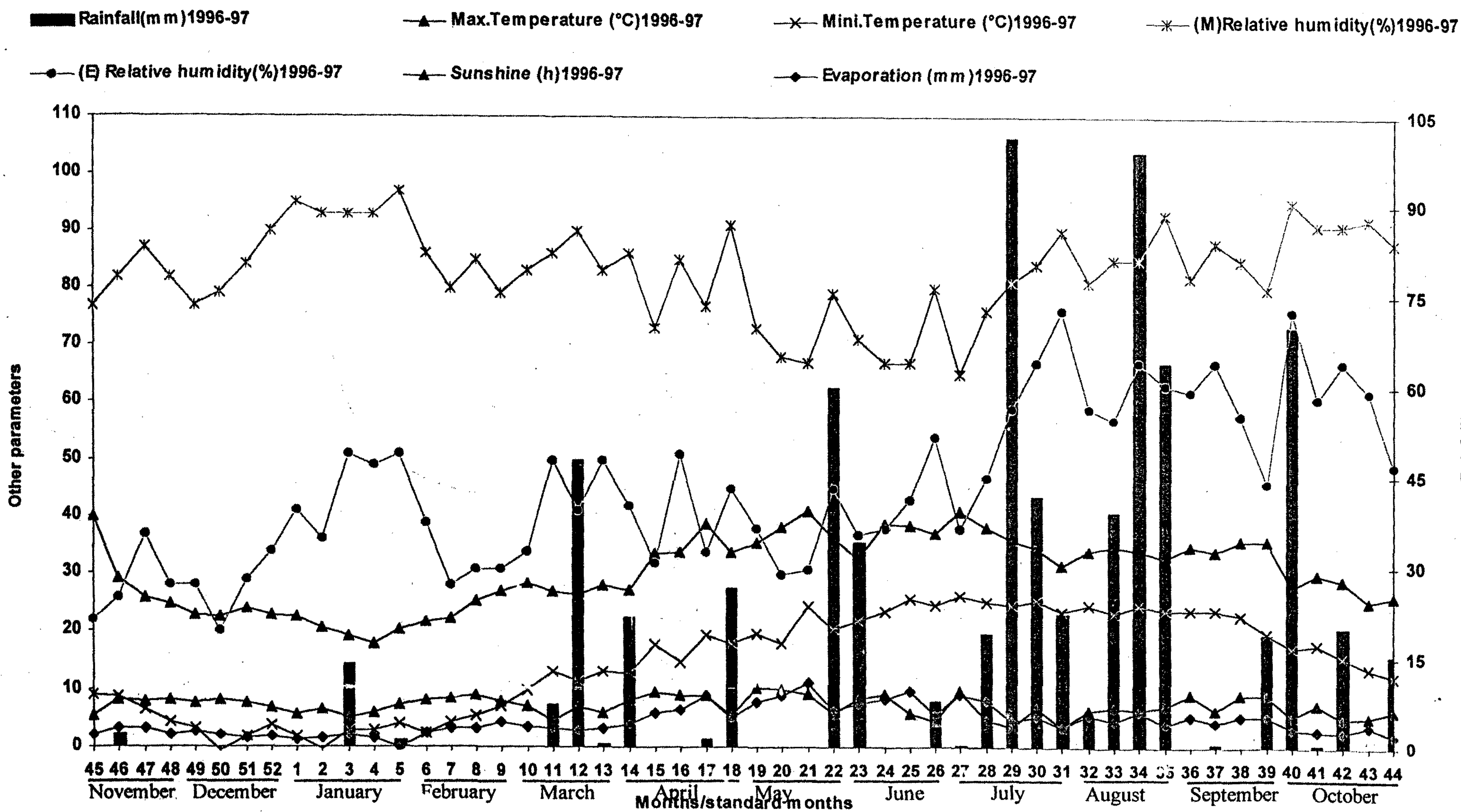


Fig.1. Weekly weather data for crop seasons 1996-97

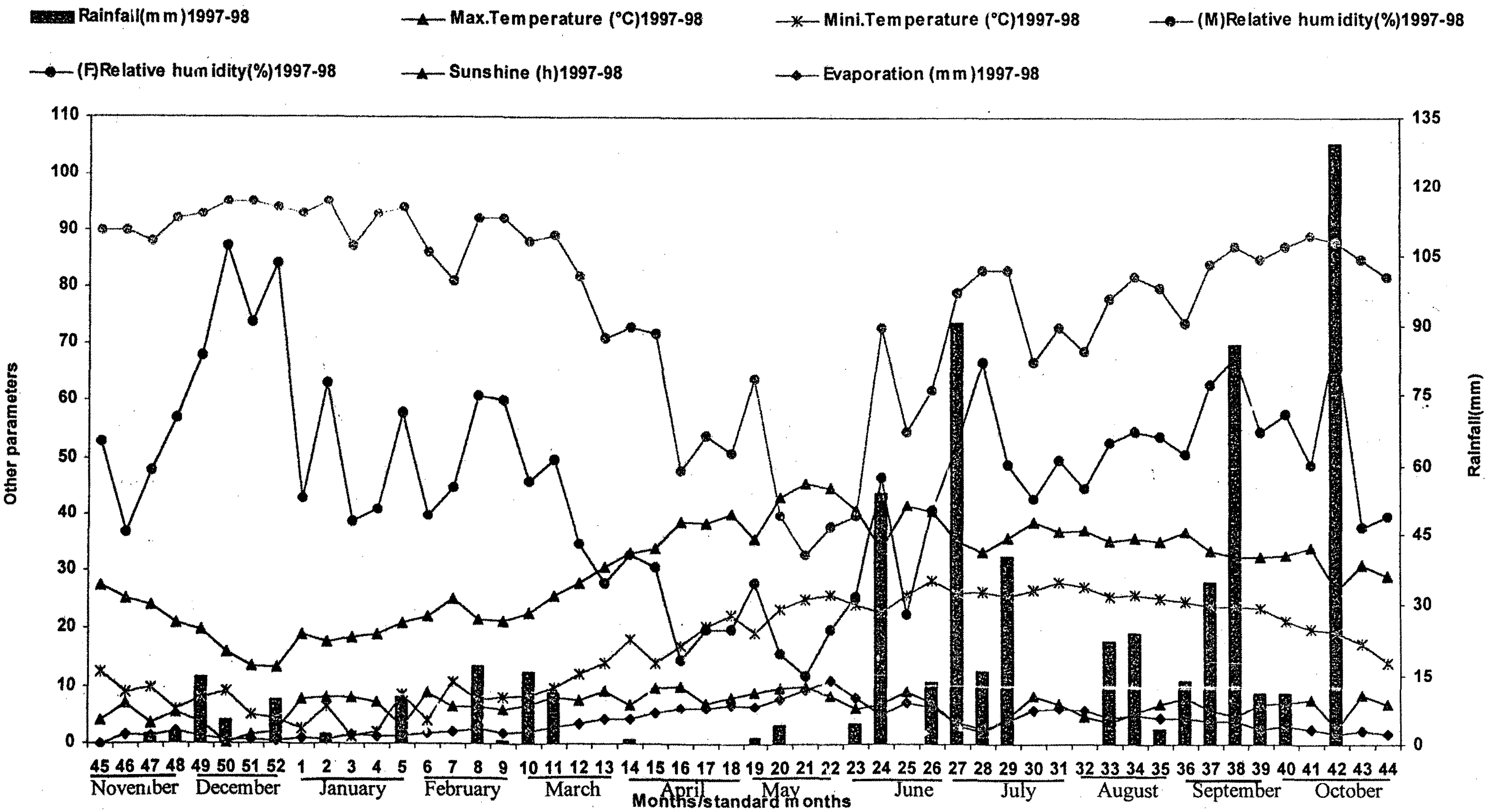


Fig.2. Weekly weather data for crop seasons 1997-98

Table 2. **Mechanical and chemical composition of soil of the experimental field and of soil used for pot experiment**

Particulars	Values (Field experiment) 1996-97	Values (Field experiment) 1997-98	Values (Pot experiment) 1997-98	Method employed
A. Mechanical analysis				
(i) Coarse sand (%)	0.40	0.42	0.60	International Pipeptte method (Piper, 1966)
(ii) Fine sand (%)	64.52	64.40	67.30	
(iii) Silt (%)	18.40	18.53	15.90	
(iv) Clay (%)	16.68	16.65	16.20	
B. Chemical analysis				
(i) EC (mmhos/cm)	0.32	0.32	0.33	1:2 soil water ratio (USDA Handbook No. 60)
(ii) Organic carbon (%)	0.35	0.30	0.31	Rapid titration method (Walkley and Black, 1934)
(iii) pH (soil to water, 1:2.5)	8.1	7.8	8.0	Beckman glass electrode method (Jackson, 1973)
(iv) Available nitrogen (kg ha^{-1})	207.00	201.00	201	Alkaline permanganate method (Subiah and Asija, 1956)
(v) Available phosphorus (kg ha^{-1})	15.50	13.00	12.50	Olsen's method (Olsen *et al.*, 1954)
(vi) Available potassium (kg ha^{-1})	406	402	400	Flame photometer method (Jackson, 1973)

constant at about 80-90 per cent from July to March and decreases steadily to 40 to 50 per cent from April onwards. The meteorological mean weekly data for the duration of experiments (Nov., 1996 to Oct., 1997 and Nov. 1997 to Oct. 1998) were recorded at the observatory located in Agronomy Research Area of University Farm, Hisar and are presented in Table 1 and depicted in Fig. 1 and 2.

3.1.3 Soil of the experimental field

The physico-chemical properties of the soil of the experimental field were studied by taking composite soil samples from the upper 30 cm layer before sowing the crop. The mechanical and chemical constituents of the soil given in Table 2 showed that soil was sandy loam, slightly alkaline in reaction, low in organic carbon and nitrogen, medium in available phosphorus and rich in potash.

3.1.4 Cropping history of the field

The cropping history of the experimental field is given in Table 3.

Table 3. Cropping history of the field

Year	*Kharif*	*Rabi*
1994-95	Cotton	Wheat
1995-96	Bajra	Wheat
1996-97	Present	Present exp.
1997-98	Present	Present exp.

3.2 EXPERIMENTAL DETAILS

Following two experiments were conducted during this investigation.

Experiment-I: Effect of sulfonylurea herbicides applied alone and in combination with metribuzin on weed control in wheat and their residual effect on growth and quality of sorghum succeeding crop (Field experiment)

Experiment-II : Bio-efficacy and selectivity of sulfonylurea herbicides against important weeds in wheat and their residual effect on mungbean and sorghum succeeding crop (Pot culture)

3.2.1 DETAILS OF EXPERIMENT-I

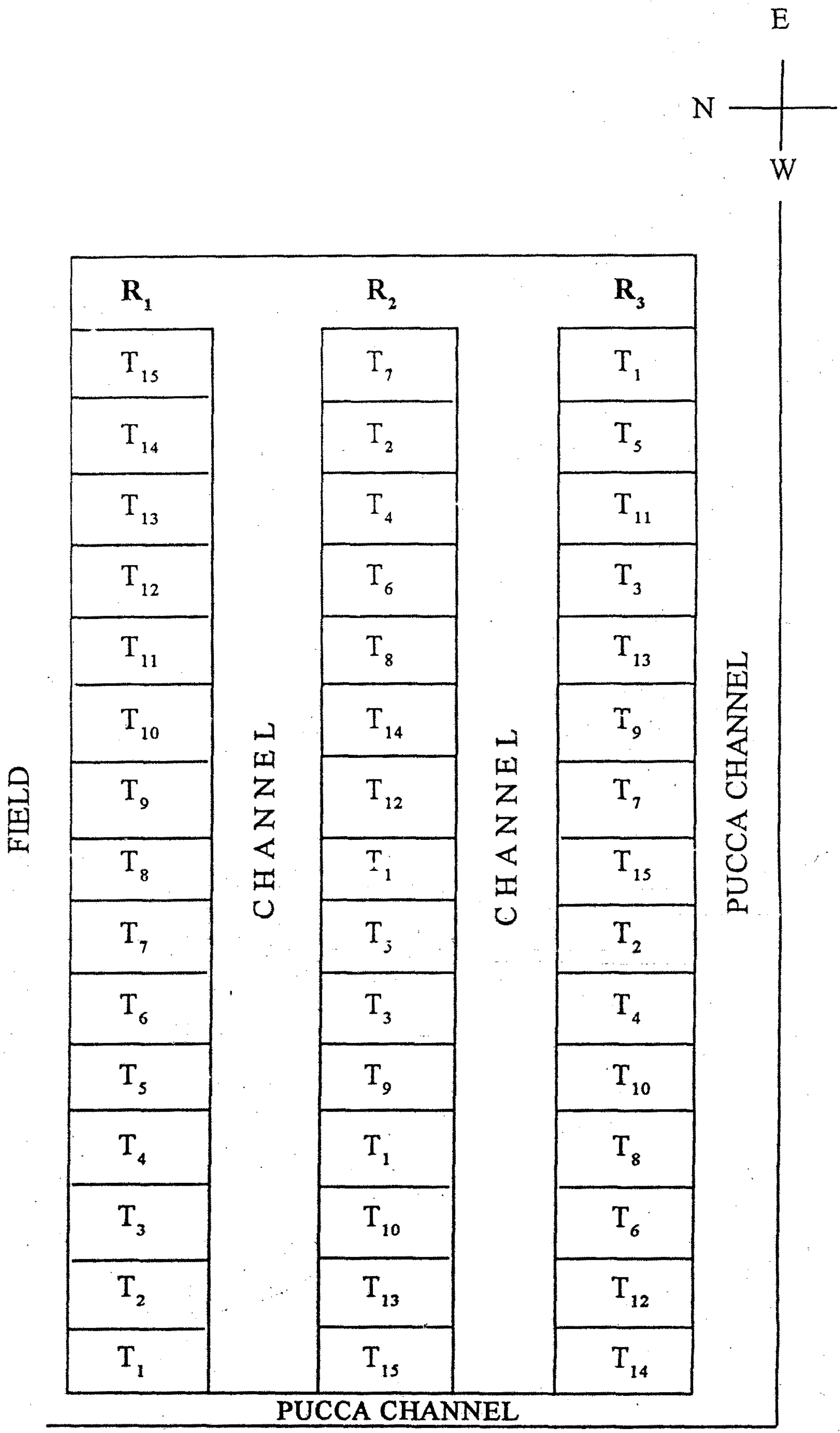
This experiment was conducted during *rabi* season of 1996-97 and 1997-98 in naturally infested field.

3.2.1.1 Treatment details

The experiment was laid out in randomized block design with fifteen weed control treatments applied in wheat at 30 DAS. Each treatment was replicated thrice. Details of the treatments are given in Table 4 and layout plan of the experiment is given in Fig. 3.

3.2.1.1.1 Chemical nature of herbicides

Chlorsulfuron: Chlorsulfuron is a new herbicide of the sulfonylurea group that controls most annual broad leaf weeds and some annual grasses in cereals. It shows good selectivity in cereals and is highly active in the soil against a wide range of broad leaf weeds (Palm *et al.*, 1980). Chlorsulfuron is considered the chemical of choice for cereal farming in



Design:	Randomized Block		
No. of Replications:	3	<u>Plot Size</u>	
No. of Treatments :	15	Gross:	6 m x 2.4 m
Total No. of plots:	45	Net :	5 m x 2.0 m

Fig. 3. Layout Plan of the Experiment - I

Table 4. Details of the treatments of experiment-I

Sr.No.	Herbicide	Dose (g a.i. ha^{-1})
T_1	Metsulfuron-methyl (M.M.)	4
T_2	Metsulfuron-methyl (M.M.)	8
T_3	Metribuzin (M.)	200
T_4	Metribuzin (M.)	400
T_5	Chlorsulfuron (CHL.)	15
T_6	Chlorsulfuron (CHL.)	30
T_7	Metsulfuron methyl + metribuzin (M.M.+M.)	2+200
T_8	Metsulfuron-methyl + metribuzin (M.M.+M.)	2+100
T_9	Chlorsulfuron + metribuzin (CHL.+ M.)	15+100
T_{10}	Chlorsulfuron + metribuzin (CHL.+ M.)	15+200
T_{11}	Isoproturon (IPU)	1000
T_{12}	Metsulfuron-methyl + isoproturon (M.M.+IPU)	2+500
T_{13}	Chlorsulfuron + isoproturon (CHL. +IPU)	15+500
T_{14}	Weedy check	-
T_{15}	Weed free	-

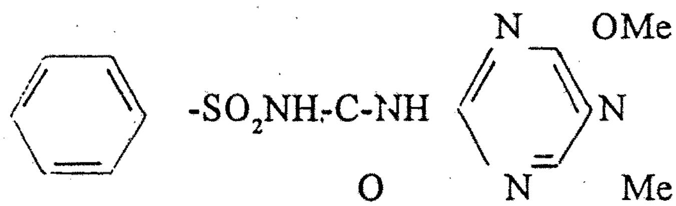
Time of application: All herbicides were applied at 30 days after sowing (DAS) in both the years of the study

Australia because of low application rates, excellent crop selectivity and low mammalian toxicity (Beyer *et al.*, 1988). Its primary mode of action in broad leaf species is inhibition of acetalactate synthase, the enzyme which catalyses the first common reaction in the synthesis of the branched chain amino acids valine, leucine and isoleucine (Ray, 1989).

Chemical name: 1-(2-chlorophenyl sulfonyl)-3-(4-methoxy-6-methyl-1,3,5-triazin-2-yl) urea (IUPAC)

Trade name : DPX 4189, Glean 75% WP

Structural formula :



Empirical formula : $C_{12}H_{12}ClN_5O_4S$

Molecular weight : 357.8

Melting point : 174-178°C

Solubility : In water at 25°C, 27.9 g l^{-1} at pH 7.0

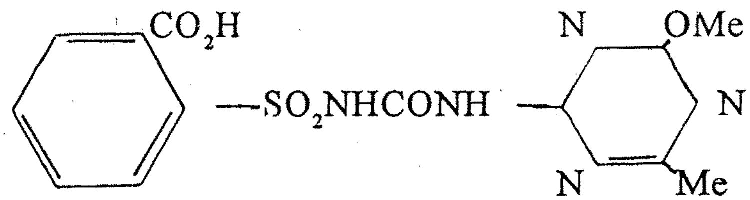
Metsulfuron-methyl: It is also one of the members of the sulfonylurea group of herbicides and is having great potential to be used for selective control of annual broad leaf weeds in cereals like wheat, barley, oats, etc. (Beyer *et al.*, 1988). It exhibits high soil activity at extra-ordinarily low rates of application and gives residual weed control with the doses in the range of 5-20 g a.i./ha.

Chemical name : {methyl 2-[[[[(4-methoxy-6-methyl-1, 3, 5-triazin-2-yl) amino] carbonyl] amino] sulfonyl]benzoate}

Trade name : Ally, Allie, Gropper, Escort,

Ally-20%, Algrip (20% WP)

Structural formula :



Empirical formula : $C_{14}H_{15}N_2O_6S$

Molecular weight . 381.37

Melting point : 158°C

Solubility : In water at 25°C, 9.5 g l^{-1} at pH 7.0.

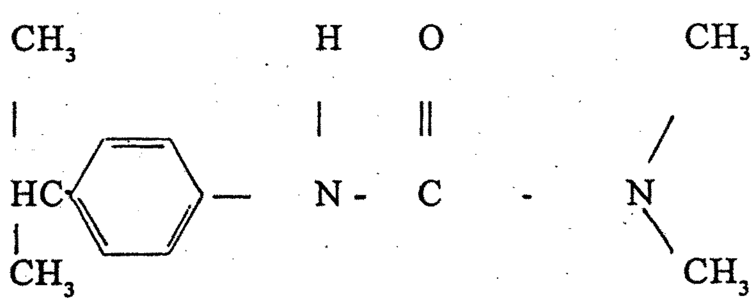
Isoproturon: It is most commonly used substituted urea herbicide in India in wheat crop. It is widely used as post-emergence against annual grasses like *Phalaris minor* and *Avena* spp. It controls some common broad leaf weeds as well.

Chemical name : [N-N-dimethyl-N-1(3-isoprophyl) phenyl urea]

Trade name : Arelon 75 WP, Nocilon 50 WP, Ronak 50 WP

Graminon 50 WP

Structural formula :



Empirical formula : $C_{12}H_{18}N_2O$

Molecular weight : 206.29

Melting point : 151-153°C

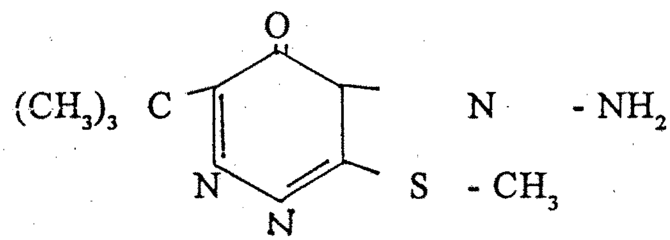
Solubility : In water at 20°C, 70 ml l^{-1} readily soluble in organic solvents

Metribuzin: It is a broad spectrum herbicide especially notable for its powerful action against both grass and broad-leaved weeds. It acts only through the roots as a soil applied herbicide. But varietal tolerances in wheat to metribuzin are variable.

Chemical name : [4 amino-6 (1, 1-dimethylethyl)-3-(methylthio)-1, 2,4-triazin-5 (4H)-one

Trade name : Sencor 70% WP

Structural formula :



Empirical formula : $C_8H_{14} N_4O_5$

Molecular weight : 214.29

Melting point : 120-125°C

Solubility In water at 20°C, 122 mg/100 g. In xylene 11.3, ethanol 24.0, methylene chloride 33.3 and methanol 45.6 (all in g/100 g at 20°C).

3.2.1.2 Cultural operations

The details of all the field operations followed from preparatory tillage to harvesting during *rabi* (wheat) and *kharif* (sorghum) season in both the years of experimentation are given in chronological order in Table 5.

Table 5. **Details of field operations**

	Operation		Date 1996-97	Date 1997-98
1	Presowing irrigation		21.11.96	8.11.97
2	Preparatory tillage			
	a) Ploughing		2.12.96	15.11.97
	b) Discing and levelling		3.12.96	16.11.97
3	Layout		5.12.96	17.11.97
4	Soil sampling (composite)		5.12.96	17.11.97
5	Sowing		6.12.96	19.11.97
6	Fertilizer application			
	a) Basal		6.12.96	19.11.97
	b) Top dressing (N only)		27.12.96	9.12.97
7	Thinning		15.12.96	31.12.97
8	Herbicide spraying		6.1.97	19.12.97
9	Irrigation			
	First		27.12.96	10.12.97
	Second		22.1.97	2.1.98
	Third		13.2.97	22.1.98
	Fourth		4.3.97	15.2.98
	Fifth		24.3.97	10.3.98
10	Hand weeding treatment (in weed free plots)			
	First		5.1.97	18.12.97
	Second		6.2.97	17.1.98
	Thrid		7.3.97	19.2.98
11	Sampling (observations)			
	First		6.1.97	19.12.97
	Second		5.2.97	18.1.98
	Third		7.3.97	17.2.98
	Fourth		7.4.97	20.3.98
	Fifth		29.4.97	25.4.98
12	Harvesting		29.4.97	25.4.98
13	Field bioassay study			
	Observations on kharif season weeds		-	12.7.98
14	Sowing of sorghum		10.7.97	15.7.98
	i) Sampling	First	30.7.97	5.8.98
		Second	19.8.97	25.8.98
		Third	30.9.97	4.10.98
	ii) Harvesting		30.9.97	4.10.98

3.2.1.2.1 Field operation

The field was ploughed and tilth well. A pre-sowing irrigation was given before the land was finally prepared by giving three disc harrowing followed by planking. After harvesting of wheat, the field was prepared with the help of power tiller for sowing of sorghum (fodder) without disturbing the original layout.

3.2.1.2.2 Fertilizer application

Recommended doses of nitrogen and phosphorus were given to wheat and its succeeding crop (sorghum) separately in the form of urea and diammonium phosphate. Half of the recommended nitrogen was applied as basal dose and remaining half was top dressed into two equal splits in both crops.

3.2.1.2.3 Seeds and sowing

Clean seed of wheat cultivar HD 2329 was sown with the help of tractor driven seed-cum-fertilizer drill which was calibrated for the recommended seed rate of 100 kg ha^{-1} and adjusted for the spacing of 22.5 cm between rows prior to sowing. Whereas sowing of sorghum (Cv. JS-20) was done with the help of *desi* plough at a row spacing of 45 cm.

3.2.1.2.4 Irrigation

Adequate irrigation at all the critical physiological stages of wheat was applied. While in sorghum three irrigation in total were given besides rainfall to meet the normal growth.

3.2.1.2.5 Herbicide spraying

All the herbicides were applied at 30 days after sowing (DAS) of wheat, with the help of a knapsack sprayer fitted with flat fan nozzle with a spray volume of 600 l ha^{-1}.

3.2.1.2.6 Manual weeding

No weeds were allowed to grow in weed free treatment in wheat while in sorghum weed free situation was maintained in all plots till harvest by hand weeding.

3.2.1.2.7 Harvesting and threshing

The wheat crop in the net plot area was harvested on April 29, 1997 and on April 25, 1998 using a sickle and left in the field for a week for sundrying. The crop was threshed plotwise with the help of minithresher for recording the grain yield. Harvesting of sorghum was done by cutting the entire plant with the help of sickle.

3.2.1.3 OBSERVATIONS RECORDED

Wheat crop

3.2.1.3.1 Observations on weeds

Weed population count and weed samples for dry matter production were taken to assess the effect of various treatments on weeds growth.

(a) Weed population

An area of 0.50 m^2 was selected randomly for recording species wise weed population count by throwing a metallic quadrate of size 0.5 m x 0.5 m at two places at 30, 60, 90, 120 DAS and at harvest and was expressed on square metre basis (No. m^{-2}). The data thus obtained were transformed ($\sqrt{x + 0.5}$) as wide variations existed among the treatments before statistical analysis.

(b) Weed dry matter

Weeds collected from 0.5 m^2 area were first sundried and then in an electric oven at 70°C till the constant weight was achieved. The total dry weight was recorded at 60, 90, 120 DAS and at harvest and expressed as g m^{-2}.

3.2.1.3.2 Observations on crop

A number of observation on crop were taken at different crop stages during both the years of study.

(a) Plant population: Plant population per metre row length (No. m^{-1}) was recorded from two different rows in each plot at 20 DAS.

(b) Plant height: The height of wheat plant (cm) measured from the base of plant to the tip of the last fully opened leaf was recorded at 30, 60, 90, 120 DAS and at harvest and expressed in centimetre. Plant height at harvest was measured from the base level to the upper portion of the spike. The average of five plants was taken for analysis.

(c) Dry matter production: The samples for dry matter production were taken per metre row length leaving two border rows. These samples were dried under the sun before putting in an oven at 70°C till the constant weight was attained. After complete drying, each sample weight was recorded and expressed as gram per metre row length (g m^{-1}).

(d) Number of tillers : The total number of tillers per metre row length (No. m^{-1}) were recorded at 30, 60, 90 and 120 DAS from two randomly selected rows in each plot leaving border rows. The total number of ear bearing tillers per metre row length were recorded randomly from two places from each plots at harvest as effective tillers. Average of two counts was taken for statistical analysis.

(e) Length of spike: Length from the point of attachment of the lower most primary rachis to the tip of panicle of ten spikes collected randomly from each plot was measured and the average length per spike was calculated (cm).

(f) Grains per earhead: Grains from 10 randomly selected earheads were separated, threshed, cleaned and counted and average was taken.

(g) 1000-grain weight: Grains were drawn randomly from the total produce of each net plot and 1000-grain were counted mechanically by a seed counter and their weight was recorded in gram.

(h) Crop yield: After harvesting, the total biomass produced from each net plot was dried well and then weighed and expressed in q ha^{-1}. Threshing was done by minithresher and the grains were separated, cleaned, dried and then weighed and final grain yield was expressed in q ha^{-1}. The straw yield (q ha^{-1}) was obtained by substracting the grain yield from the total biomass of wheat.

(i) Harvest index (HI): It was expressed as the ratio of grain yield to total biological yield.

$$\text{Harvest index (\%)} = \frac{\text{Economic yield}}{\text{Biological yield}} \times 100$$

3.2.1.4 Chemical analysis

NPK content and uptake by wheat crop: The samples taken for dry matter and grain yield were grinded in a Willey mill and passed through 0.5 mm mesh sieve. Grain and straw samples weighing 0.2 g and 0.5 g each, respectively were used for determination of N, P and K content.

(a) Nitrogen content: Nitrogen content (%) in grain and straw samples of wheat was determined by Nessler's reagent as described by Jackson (1967).

(b) Phosphorus content: Phosphorus content (%) in grain and plant samples was estimated by Vanado molybdophosphoric yellow colour method. The intensity of yellow colour developed was measured at 440 nm wave length using Spectronic-20 (Jackson, 1967).

(c) Potassium content: K content in grain and plant samples was determined by using flame photometer as per method given by Jackson (1967).

(d) N, P and K uptake: NPK uptake by crop straw and grain were calculated by multiplying dry matter with corresponding values of their content and were expressed as kg ha^{-1}.

3.2.1.5 RESIDUAL STUDIES IN FIELD (FIELD BIOASSAY)

3.2.1.5.1 Observations on weed flora before sowing of test crop

Presence or absence of weeds in herbicide treated plots gives the idea about its residual soil activity which influences directly the resurgence of new flushes of weeds and succeeding crops grown in rotation. To see the residual effect of herbicides applied in wheat on *kharif* season weeds if any, population (No. m^{-2}) and weed dry matter (g m^{-2}) of two namely *Trianthema portulacastrum* (santhi) and *Echinochloa colonum* Link (samak) occurring in different intensity were recorded during 1997-98 before sowing of the sorghum crop. In 1996-97, entire field was uniformly infested with all weeds irrespective of dose, herbicide and combinations. Therefore, data were not recorded in the first year of experimentation. Data on population (No. m^{-2}) and dry weight (g m^{-2}) of *T. portulacastrum* were subjected to $\sqrt{x + 0.5}$ transformation. Whereas the data of *E. colonum* were used in original for statistical analysis.

3.2.1.5.2 Observations on test crop

After taking observations on weeds, each experimental plot was prepared individually by power tiller in the same layout. Then after a field bioassay was carried by planting sorghum in the month of July during both the years.

In order to see residual effect alone on growth of sorghum, no weed was allowed to grow in the experimental plots after sowing sorghum crop and following observations with respect to sorghum growth were taken.

(a) Plant population: Plant population per metre row length was recorded from two different rows in each plot at 20, 40 and 80 days after sowing (DAS) and their average was taken for analysis purpose (No. m^{-1}).

(b) Plant height: The plant height from the base level to the tip of the younger leaf of 10 randomly selected plants was measured at 20, 40 and 80 DAS and expressed as plant height in centimetre per plant.

(c) Fresh weight: Plant samples were taken from per metre row length leaving two border rows cutting from the base at 20, 40 and 80 DAS. These samples were weighted immediately for recording their fresh weight (g m^{-1}).

(d) Dry weight: Plant samples collected for fresh weight were dried under sun and then kept in oven at 70°C till the constant weight was achieved. After complete drying, their final weight was recorded and expressed in gram per metre row length (g m^{-1}).

(e) Fodder yield: After harvesting, the total produce from each net plot was weighed immediately and expressed the green fodder yield in q ha^{-1}.

CHEMICAL ANALYSIS

In view to study the effect of residues on fodder quality of sorghum, following parameters were estimated at 40 DAS during 1997-98.

(a) Protein content

The protein content of sorghum plants at 40 DAS was estimated by the conventional micro-Kjeldahl's method (AOAC, 1995).

Reagents

(i) 40% NaOH

(ii) N/100 H_2SO_4

(iii) N/100 NaOH

(iv) Conc. H_2SO_4

Method: One hundred milligrams of dried plant sample was weighted and transferred to 50 ml Kjeldahl's digestion flask. About 1 g of potassium sulphate and 0.1-0.2 g of crystalline copper sulphate was next added followed by 10 ml of concentrated sulphuric acid. The flask was then kept in an inclined position on the burner in the digestion chamber and heated gently till the solution became transparent giving a bluish green colour. After cooling, the contents of the flask was mixed with distilled water, cooled, transferred to a 100 ml volumetric flask and volume was made upto the mark with distilled water. Ten ml of this solution was taken for distillation and distilled after adding 10 ml of 40% NaOH. The liberated ammonia was absorbed in 10 ml of N/100 sulphuric acid containing one or two drops of methyl red indicator. The amount of ammonia absorbed by N/100 sulphuric acid was determined by titrating it with N/100 sodium hydroxide. A blank was also run under similar conditions. The percentage of nitrogen was calculated from N/100 H_2SO_4 used.

1 ml of N/100 H_2SO_4 = 0.00014 g of nitrogen

The protein content was then calculated by multiplying N% by protein factor of 6.25.

(b) Tannin content

Tannin content was estimated as catechin equivalent by Vanillin-hydrochloric acid method of Burns (1971).

Reagents

(i) 8% HCl in methanol

(ii) 4% Vanillin in methanol

(iii) Vanillin: HCl reagent: Prepared by mixing equal volume of solution (i) and (ii) at the time of use.

Method: Two hundred milligrams of dried plant sample was taken in a 50 ml test tube and 25 ml of methanol was added to it. The tubes were fitted with pith corks. The contents of the tubes were shaken occasionally and allowed to stand overnight at 25 to 32°C. One ml of clear supernatant was then pipetted in a test tube and 5 ml of Vanillin-HCl reagent was added to it. The absorbance of brownish colour so produced was measured at 525 nm after 25 minute on a Spectronic 20 colorimeter. A blank containing methanol was also run simultaneously. A standard curve of catechin was prepared simultaneously in order to calculate the amount of tannin content.

***In vitro* dry matter digestibility (IVDMD)**

In vitro dry matter was determined by the method of Tilley and Terry (1963) as modified by Barnes *et al.* (1971).

Reagents

i) Mc Dougall's buffer solution

(a) Solution No. 1: Prepared by dissolving 3.7 g anhydrous Na_2HPO_4 and 9.8 g $NaHCO_3$ in one litre of distilled water at 39°C.

(b) Solution No. 2: This solution was prepared by dissolving 4.7 g NaCl, 5.7 g KCl, 0.4 g $CaCl_2$ and 0.6 g $MgCl_2$ in 100 ml of distilled water.

The buffer solution was prepared by mixing 10 ml of solution No. 2 to one litre of solution No. 1 and CO_2 was allowed to pass slowly through it till pH became 6.8-6.9.

(ii) Pepsin (1:3000 units)

(iii) 6 N NCl

(iv) Inoculant: The rumen fluid for inoculation was obtained from the fistulated young calves maintained on a constant ration. Rumen liquor was removed from the animals with the help of a suction strainer, stored in a thermoflask at 39°C and brought to the laboratory for immediate use. After thorough mixing, the rumen fluid was strained through several layers of fine muslin cloth to remove large particles.

Method: To 250 mg dried plant material, added 20 ml of Mc Dougall's buffer solution in a 50 ml tube fitted with a gas release valve. Then 5 ml of rumen fluid was added to each tube which served as inoculum. Carbon dioxide was passed over the surface of the tube contents for about 2 min. Tubes were stoppered immediately and incubated at 39°C for 48 h. The tubes were swirled gently during incubation period to suspend the substrate. After 48 h, 0.1 g of pepsin and 2 ml of 6 N HCl were added to each tube and mixed thoroughly. The tubes were incubated for an additional 48 h and filtered through tared Whatman No. 4 filter paper using a funnel. The tubes were rinsed four times with hot distilled water (90-100°C). The residue on the filter paper was dried in an oven at 100°C for over night and its weight was taken again. Suitable blanks with buffer solution and rumen fluid were run simultaneously. *In vitro* dry matter digestibility was calculated by substracting the weight of the residue from the original weight of the sample.

3.2.1.6 STATISTICAL ANALYSIS

The data presented in this thesis are mean values. All the observations were statistically analysed by using the statistical methods described under the randomized block design by Panse and Sukhatme (1985). In order to see the significance of treatment effect they were subjected to the statistical analysis by "analysis of variance" technique (Fisher, 1958). The significant treatment effect was judged with the help of 'F' test at 5 per cent level of significance. To judge the difference between means of two treatment effects, the critical difference (C.D.) was worked out by the following formula:

$$C.D. = \sqrt{\frac{2E}{r}} \times t_{5\%}$$

Where,

E	=	The error variance
r	=	The number of replication of the factor for which C.D. is to be calculated
$t_{5\%}$	=	Table value of 't' at 5 per cent level of significance at error degree of freedom

3.2.2 EXPERIMENT-II: Bioefficacy and selectivity of sulfonylurea herbicides against important weeds in wheat and their residual effect on mungbean and sorghum succeeding crops (Pot culture)

This experiment was planned to confirm the results observed in field in connection of efficacy and selectivity of chlorsulfuron, metsulfuron-metyl and metribuzin at different doses against important weed flora of wheat. This experiment was planned for one year (1997-98).

3.2.2.1 Soil analysis

The soil used in the pot culture experiment was brought from the field where no herbicide was used to avoid any possibility of adsorption and persistence of past applied herbicide. The details of analysis of soil are given in Table 2.

3.2.2.2 Pot preparation, sowing, thinning and herbicide application

Earthen pots of 5 kg capacity were used for this experiment. Soil and well rotten farm yard manure were mixed in the ratio of 6:1 by volume after passing it through 2 mm sieve. Pots were watered to settle the soil before sowing. The experiment was conducted in a completely randomized design. Twenty seeds of each weed species were sown in each pot. After emergence, thinning was done and ten plants per pot were maintained. Herbicides were sprayed at 30 DAS with kanpsack sprayer fitted with flat fan nozzle at a pressure of 4.5 kg cm^{-2}. The spraying was done to 10.0 m^2 area using 600 litre of water ha^{-1}. Pots were irrigated at regular intervals.

3.2.2.3 Treatment details

The experiment was laid out in completely randomized block design. Twelve treatments comprising three herbicides namely chlorsulfuron, metsulfuron-methyl and metribuzin at different doses were applied at 30 DAS to each weed species grown in pots (Table 6). Each treatment was replicated three times. Same treatments were also applied on wheat crop to observe the tolerance of wheat crop against applied herbicides.

3.2.2.4 Observations and data analysis

Average plant height (cm) and average number of green leaves per plant were recorded before and after 3 weeks (21 days after herbicide spray) of herbicide spray only in case of wheat, wild oat and canary grass.

Table 6. Details of treatments of experiment-II

Sr.No.	Treatments	Dose ($g\ a.i.\ ha^{-1}$)
1	Untreated (control)	-
2	Chlorsulfuron (CHL.)	5 g ha^{-1}
3	Chlorsulfuron (CHL.)	10 g ha^{-1}
4	Chlorsulfuron (CHL.)	20 g ha^{-1}
5	Chlorsulfuron (CHL.)	40 g ha^{-1}
6	Metsulfuron-methyl (M.M.)	1 g ha^{-1}
7	Metsulfuron-methyl (M.M.)	2 g ha^{-1}
8	Metsulfuron-methyl (M.M.)	4 g ha^{-1}
9	Metribuzin (M)	25 g ha^{-1}
10	Metribuzin (M)	50 g ha^{-1}
11	Metribuzin (M)	100 g ha^{-1}
12	Metribuzin (M)	200 g ha^{-1}

Time of application: All herbicides were applied at 30 days after sowing (DAS)

While the average fresh and dry weight (g plant^{-1}) were recorded for all the weed species including wheat plant after 21 days of herbicide application. The weight of each species (either weed or wheat) recorded immediately after their removal from pot was expressed as their fresh weight (g plant^{-1}). The samples taken for fresh weight were oven dried at 70°C till the constant weight achieved and recorded their dry weight in gram per plant. Per cent mortality was also recorded on a 0 to 100 scale (0 for no control and 100 for complete control) for all weed species and wheat grown in pots. The zero value and 100 value in each weed (or wheat) species were replaced by 0.025 and 99.975, respectively before subjecting to arcsin transformation ($\sin^{-1}\sqrt{x}$) for the statistical analysis of per cent mortality. In some herbicide treatments (e.g. metribuzin) plant height and number of green leaves per plant were taken as 0 (zero) because plants were completely dried after treatment. In order to compare the effect of other herbicide treatments on height and number of green leaves, these 0 values were replaced by 0.5 before subjecting square root transformation ($\sqrt{x+0.5}$).

3.3.2.5 Bioassay studies in pot experiment

Sorghum and mungbean are reported to be sensitive to chlorsulfuron, metsulfuron-methyl and metribuzin. These two crops were grown as test crops in the same earthen pots where herbicides were appiied to wheat and weed species after six months of spraying herbicides. Ten seeds were sown per pot for mungbean and 20 seeds per pot for sorghum. All the observations were taken on these plants as given below. The observations were recorded at 21 DAS.

Observations recorded

Germination percentage, average plant height (cm), number of green leaves per plant, fresh weight per plant and dry weight per plant (g) were recorded at 21 DAS in both the crops.

Germination count of both the test crop were expressed in per cent germination and then subjected to arcsin transformation after replacing 0 and 100 value by 0 + 1/4n and 100 - 1/4n, respectively, n is the number of plants from which observations were made. Leaf area (cm^2) per plant of mungbean was also recorded at the same time on dry weight basis.

Chemical analysis

Protein content, tannin content, *in vitro* dry matter digestibility were estimated in sorghum at 21 DAS and HCN (ppm) at 40 days to see the effect of herbicide residues on palatability of sorghum plants grown in pots.

HCN content

The HCN content was determined by the picric acid method of Hogg and Ahlgren (1942).

Reagents

(i) Alkaline picrate solution : Dissolve 25 g of sodium carbonate and 5 g of picric acid in one litre distilled water.

(ii) Chloroform: The samples of analysis of HCN were taken from the portion of the tiller immediately below the upper most leaf collar. Transferred 0.2 g chopped green plant material to test tube (2.5 cm x 20 cm), then added 3-4 drops of chloroform and suspended a strip of moist

Whatman No. 1 filter paper (15.5 cm x 1.7 cm) saturated with sodium picrate solution. The saturated filter paper strip was held in place with a cork stopper which was used to seal the test tube. The incubation was carried out at room temperature for 24 h. The sodium picrate present on the filter paper was reduced in the presence of HCN. After 24 h, the paper strip was removed and colour was eluted in 10 ml of distilled water. The absorbance of the colour was measured at 515 nm against a reagent blank treated in the same manner as the plant sample. The amount of HCN in ppm on dry weight basis was calculated by calibrating the absorbance with KCM (5-40 ppm) in water as standard (Gilchrist *et al.*, 1967).

CHAPTER - 4

EXPERIMENTAL RESULTS

The data generated from the investigation entitled "Evaluation of sulfonylurea herbicides for weed control in wheat (*Triticum aestivum*)" during 1996-97 and 1997-98 are presented and described here in appropriate tables and figures after having them statistically analysed.

4.1 EXPERIMENT-I: Effect of sulfonylurea herbicides applied alone and in combination with metribuzin on weed control in wheat and their residual effect on growth and quality of sorghum succeeding crop (Field experiment)

WEED STUDIES

4.1.1 WEED FLORA

The experimental field was infested with the following weeds in order of their density.

Table 7. Relative composition of different weed species

Botanical name	Local name	Weed density (%)	
		1996-97	1997-98
Coronopus didymus L.	Pithpapra	70.59	59.43
Chenopodium album L.	Bathu	10.99	04.53
Melilotus indica L.	Senji	07.42	04.53
Phalaris minor Retz.	Kanki (Wild canary grass)	05.37	13.77
Anagallis arvensis L.	Krishan Neel	05.62	12.45
Cirsium arvense (L.) Scop.	Kateli	—	05.28

Infestation of *Cirsium arvense* was observed in the second year experimental field as its infestation was not seen in the first year experimental field.

4.1.1.1 Weed density

Species-wise data and total weed population (No. m^{-2}) at 30, 60, 90, 120 DAS and at harvest are presented in Tables. Before application of herbicides, weed count was taken at 30 DAS in view to observe density (infestation) and distribution of weed flora in the experimental field.

(a) *Coronopus didymus* L.

All the weed control treatments resulted in a significant reduction in the population of *Coronopus didymus* as compared to weedy check in both the years (Table 8). Amongst herbicidal treatments, metribuzin (400 g ha^{-1}) recorded the highest reduction in the population during both the years. However, from 60 days onwards, chlorsulfuron 30 g ha^{-1} and chlorsulfuron + metribuzin (15 + 200 g ha^{-1}) were similar in performance at all the dates.

In sulfonylurea herbicides, chlorsulfuron 30 g ha^{-1} recorded complete control of this weed at 90 DAS onward in both the years. However, metsulfuron 8 g ha^{-1}, metribuzin 200 g ha^{-1}, metsulfuron + metribuzin (2+200 g ha^{-1}) and chlorsulfuron + metribuzin (15 + 100 g ha^{-1}) were similar to chlorsulfuron (30 g ha^{-1}) at harvest during both the years. Metsulfuron + isoproturon (2+500 g ha^{-1}) and metsulfuron (4 g ha^{-1}) gave a poor control of the weed. While isoproturon (1000 g ha^{-1}) and its combination with chlorsulfuron were average in performance.

Table 8. Effect of the treatments on the population of *Coronopus didymus* (No. m^{-2}) at different stages of growth

Treatments	1996-97 (Days after sowing) 30	60	90	120	Harvest	1997-98 (Days after sowing) 30	60	90	120	Harvest
1 Metsulfuron 4g	8.91(79.00)	4.71(21.67)	3.98(15.33)	6.15(37.33)	5.15(26.00)	10.32(106.67)	6.99(48.33)	6.15(37.36)	4.52(20.00)	3.35(12.00)
2 Metsulfuron 8g	8.78(76.67)	2.48(5.67)	2.26(4.67)	1.44(1.67)	1.76(2.67)	10.53(111.00)	2.91(8.00)	1.34(1.33)	1.34(1.33)	0.71(0.00)
3. Metribuzin 200g	8.78(76.67)	1.87(3.00)	1.34(1.33)	0.71(0.00)	0.71(0.00)	9.99(100.00)	2.12(5.33)	1.56(2.00)	1.77(2.67)	0.71(0.00)
4. Metribuzin 400g	9.00(80.67)	1.46(1.67)	0.71(0.00)	0.71(0.00)	0.71(0.00)	9.79(96.00)	1.31(1.33)	0.71(0.00)	0.71(0.00)	0.71(0.00)
5. Chlorsulfuron 15g	8.72(75.67)	2.20(4.33)	2.04(3.67)	1.34(1.33)	0.71(0.00)	10.77(116.00)	2.74(7.00)	2.11(4.00)	0.71(0.00)	0.71(0.00)
6. Chlorsulfuron 30g	9.40(88.00)	1.58(2.00)	0.71(0.00)	0.71(0.00)	0.71(0.00)	10.01(100.00)	1.95(3.33)	0.71(0.00)	0.71(0.00)	0.71(0.00)
7. Metsulfuron+ metribuzin (2+200g)	8.76(76.33)	1.95(3.33)	0.71(0.00)	0.71(0.00)	0.71(0.00)	10.31(106.00)	2.12(5.33)	1.95(3.33)	0.71(0.00)	0.71(0.00)
8. Metsulfuron+ metribuzin (2+100g)	8.98(80.33)	2.79(7.33)	1.56(2.00)	0.71(0.00)	0.71(0.00)	10.11(108.00)	2.97(8.33)	2.67(6.67)	2.27(4.67(	0.71(0.00)
9. Chlorsulfuron+ metribuzin (15+100g)	9.39(88.00)	2.19(4.33)	2.11(4.00)	0.71(0.00)	0.71(0.00)	10.11(102.67)	1.95(3.33)	2.04(3.67)	1.34(1.33)	1.34(1.33)
10. Chlorsulfuron+ metribuzin(15+200g)	9.00(80.67)	1.44(1.67)	0.71(0.00)	0.71(0.00)	0.71(0.00)	9.88(98.67)	1.34(1.33)	1.34(1.33)	1.34(1.33)	0.71(0.00)
11. Isoproturon 1000 g	9.24(85.00)	4.81(22.67)	2.42(5.33)	1.76(2.67)	1.68(2.33)	9.97(100.00)	6.79(45.67)	6.25(38.67)	4.98(24.33)	3.79(14.00)
12. Metsulfuron+isop-roturon(2+500g)	9.34(87.00)	5.76(32.67)	5.93(34.67)	5.81(33.33)	3.58(12.33)	10.16(109.33)	8.57(73.00)	7.43(54.67)	4.81(22.67)	4.30(18.00)
13. Chlorsulfuron+iso-proturon(15+500g)	8.74(76.00)	3.76(13.67)	2.85(7.67)	1.58(2.00)	1.46(1.67)	9.85(96.67)	3.85(14.33)	2.43(5.00)	2.55(6.00)	2.42(5.33)
14. Weedy check	9.61(92.00)	11.33(127.83)	11.63(134.67)	9.75(94.67)	8.01(63.67)	10.27(105.00)	14.75(217.00)	15.06(226.33)	16.96(287.33)	7.34(53.33)
15. Weed free	0.71(0.00)	0.71(0.00)	0.71(0.00)	0.71(0.00)	0.71(0.00)	0.71(0.00)	0.71(0.00)	0.71(0.00)	0.71(0.00)	0.71(0.00)
S.Em(±)	_	0.14	0.12	0.13	0.12	_	0.07	0.13	0.10	0.14
CD at 5%	_	040	0.36	0.38	0.38	_	0.22	0.39	0.31	0.39

Data subjected to $\sqrt{x+0.5}$ transformation. Figures in parentheses are original values.

(b) *Chenopodium album* L.

All treatments except metsulfuron (4 g ha^{-1}) and its tank mixture with isoproturon (2+500 g ha^{-1}) at harvest in 1996-97, caused significant reduction in the population of *Chenopodium album* over weedy check, in both the years at all stages of crop growth (Table 9). Metribuzin (200 and 400 g ha^{-1}), chlorsulfuron (30 g ha^{-1}), chlorsulfuron + metribuzin (15+200 and 15 + 100 g ha^{-1}), chlorsulfuron + isoproturon (15 + 500 g ha^{-1}), metsulfuron (8 g ha^{-1}) and its combination at the lowest dose with metribuzin caused complete control of this weed during both the years. However, chlorsulfuron 15 g ha^{-1} and metsulfuron (4 g ha^{-1}) performed similar to above treatments in the second year of experimentation.

(c) *Melilotus indica* L.

Data presented in Table 10 reveal that the *Melilotus indica* was successfully controlled by all weed control treatments except metsulfuron + isoproturon (2+500 g) in 1997-98. Complete control of this weed at 60 DAS onward was recorded in those plots which were treated with chlorsulfuron (30 g), metsulfuron (8 g), metribuzin (200 and 400 g ha^{-1}) alone and in combination with metsulfuron (2 + 200 g ha^{-1}) and chlorsulfuron (15+ 200 g ha^{-1}). However, at 90 DAS onward all herbicidal treatments except metsulfuron + isoproturon (2 + 500 g ha^{-1}), isoproturon (1000 g ha^{-1}) and metsulfuron (4 g ha^{-1}) were found at par in performance with weed free condition in both the years.

(d) *Phalaris minor* Retz.

Data presented in Table 11 revealed that all weed control treatments except metsulfuron 4 g ha^{-1} at 90 DAS onward and its combination with

Table 9. Effect of the treatments on the population of *Chenopodium album* (No.m^{-2}) at different stages of growth

Treatments	1996-97 (Days after sowing) 30	60	90	120	Harvest	1997-98 (Days after sowing) 30	60	90	120	Harvest
1 Metsulfuron 4g	3.67(13.00)	3.03(8.67)	3.24(10.00)	3.53(12.00)	2.68(6.67)	3.53(12.00)	2.04(3.67)	1.34(1.33)	0.71(0.00)	0.71(0.00)
2 Metsulfuron 8g	3.85(14.33)	1.76(2.67)	1.76(2.67)	1.56(2.00)	0.71(0.00)	3.75(14.00)	0.71(0.00)	0.71(0.00)	0.71(0.00)	0.71(0.00)
3. Metribuzin 200g	3.53(12.00)	0.71(0.00)	0.71(0.00)	0.71(0.00)	0.71(0.00)	3.43(11.33)	0.71(0.00)	0.71(0.00)	0.71(0.00)	0.71(0.00)
4. Metribuzin 400 g	3.67(13.00)	0.71(0.00)	0.71(0.00)	0.71(0.00)	0.71(0.00)	3.61(12.67)	0.71(0.00)	0.71(0.00)	0.71(0.00)	0.71(0.00)
5. Chlorsulfuron 15g	3.75(13.67)	2.42(5.33)	1.77(2.67)	1.34(1.33)	1.34(1.33)	3.12(9.33)	0.71(0.00)	0.71(0.00)	0.71(0.00)	0.71(0.00)
6. Chlorsulfuron 30g	3.49(11.67)	0.71(0.00)	0.71(0.00)	0.71(0.00)	0.71(0.00)	3.43(11.33)	0.71(0.00)	0.71(0.00)	0.71(0.00)	0.71(0.00)
7. Metsulfuron+ metribuzin(2+200g)	3.85(14.33)	0.71(0.00)	0.71(0.00)	0.71(0.00)	0.71(0.00)	3.33(10.67)	0.71(0.00)	0.71(0.00)	0.71(0.00)	0.71(0.00)
8. Metsulfuron+ metribuzin (2+100g)	3.48(11.67)	0.71(0.00)	0.71(0.00)	0.71(0.00)	0.71(0.00)	3.26(10.67)	0.71(0.00)	0.71(0.00)	0.71(0.00)	0.71(0.00)
9. Chlorsulfuron+ metribuzin (15+100g)	3.03(8.67)	0.71(0.00)	0.71(0.00)	0.71(0.00)	0.71(0.00)	3.30(10.67)	0.71(0.00)	0.71(0.00)	0.71(0.00)	0.71(0.00)
10. Chlorsulfuron+me-tribuzin(15+200g)	3.67(13.00)	1.34(1.33)	0.71(0.00)	0.71(0.00)	0.71(0.00)	2.97(8.33)	0.71(0.00)	0.71(0.00)	0.71(0.00)	0.71(0.00)
11. Isoproturon 1000g	3.90(14.67)	2.27(4.67)	2.40(5.33)	2.26(4.67)	1.77(2.67)	3.53(12.00)	2.20(4.33)	2.11(4.00)	1.34(1.33)	1.34(1.33)
12. Metsulfuron+isop-roturon(2+500g)	3.76(13.67)	2.79(7.33)	2.72(7.00)	4.06(16.00)	3.89(14.67)	3.34(10.67)	2.86(7.67)	2.34(5.00)	2.11(4.00)	2.11(4.00)
13. Chlorsulfuron+iso-proturon(15+500g)	3.43(11.33)	1.77(2.67)	1.34(1.33)	0.71(0.00)	0.71(0.00)	3.58(12.33)	1.22(1.00)	0.71(0.00)	0.71(0.00)	0.71(0.00)
14. Weedy check	3.85(14.33)	7.52(56.00)	7.60(57.33)	5.98(35.33)	2.80(7.33)	2.91(8.00)	3.57(12.33)	3.72(13.33)	3.63(12.67)	3.29(10.33)
15. Weed free	0.71(0.00)	0.71(0.00)	0.71(0.00)	0.71(0.00)	0.71(0.00)	0.71(0.00)	0.71(0.00)	0.71(0.00)	0.71(0.00)	0.71(0.00)
S.Em.(±)	_	0.12	0.13	0.10	0.09	_	0.07	0.08	0.07	0.07
CD at 5%	_	0.34	0.38	0.28	0.25	_	0.21	0.23	0.19	0.21

Data subjected to $\sqrt{x+0.5}$ transformation. Figures in parentheses are original values.

Table 10. Effect of the treatments on the population of *Melilotus indica* (No. m^{-2}) at different stages of growth

Treatments	1996-97 (Days after sowing)					1997-98 (Days after sowing)				
	30	60	90	120	Harvest	30	60	90	120	Harvest
1 Metsulfuron 4g	3.29(10.33)	2.67(06.67)	1.77(2.77)	1.46(1.67)	1.34(1.33)	3.16(9.67)	1.93(3.33)	1.34(1.33)	1.00(0.67)	1.00(0.67)
2 Metsulfuron 8g	3.29(10.33)	0.71(00.00)	0.71(0.00)	0.71(0.00)	0.71(0.00)	2.80(7.33)	1.34(1.33)	0.71(0.00)	0.71(0.00)	0.71(0.00)
3. Metribuzin 200g	3.08(09.00)	0.71(00.00)	0.71(0.00)	0.71(0.00)	0.71(0.00)	2.83(8.00)	0.71(0.00)	0.71(0.00)	0.71(0.00)	0.71(0.00)
4. Metribuzin 400g	2.97(08.33)	0.71(00.00)	0.71(0.00)	0.71(0.00)	0.71(0.00)	2.96(9.77)	0.71(0.00)	0.71(0.00)	0.71(0.00)	0.71(0.00)
5. Chlorsulfuron 15g	3.34(10.67)	1.95(03.33)	0.71(0.00)	0.71(0.00)	0.71(0.00)	2.90(8.00)	1.76(2.67)	1.17(1.00)	1.34(1.33)	0.71(0.00)
6. Chlorsulfuron 30g	3.08(09.00)	0.71(00.00)	0.71(0.00)	0.71(0.00)	0.71(0.00)	2.97(8.33)	0.71(0.00)	0.71(0.00)	0.71(0.00)	0.71(0.00)
7. Metsulfuron+ metribuzin (2+200g)	2.97(08.33)	0.71(00.00)	0.71(0.00)	0.71(0.00)	0.71(0.00)	2.72(7.00)	0.71(0.00)	0.71(0.00)	0.71(0.00)	0.71(0.00)
8. Metsulfuron+ metribuzin (2+100g)	2.92(08.00)	1.34(1.33)	0.71(0.00)	0.71(0.00)	0.71(0.00)	2.79(7.33)	1.22(1.00)	0.71(0.00)	0.71(0.00)	0.71(0.00)
9. Chlorsulfuron+ metribuzin (15+100g)	2.86(07.67)	1.34(1.33)	0.71(0.00)	0.71(0.00)	0.71(0.00)	3.13(9.33)	0.71(0.00)	0.71(0.00)	0.71(0.00)	0.71(0.00)
10. Chlorsulfuron metribuzin(15+200g)	2.97(08.33)	0.71(0.00)	0.71(0.00)	0.71(0.00)	0.71(0.00)	3.13(9.33)	0.71(0.00)	0.71(0.00)	0.71(0.00)	0.71(0.00)
11. Isoproturon 1000g	3.29(10.33)	2.79(7.33)	2.11(4.00)	1.95(3.33)	1.34(1.33)	2.92(8.33)	2.32(5.00)	1.77(2.67)	2.67(6.67)	2.55(6.00)
12. Metsulfuron+isop-roturon(2+500g)	3.24(10.00)	4.95(24.00)	3.34(10.67)	2.68(6.67)	2.74(7.00)	3.34(10.67)	2.67(6.67)	3.13(9.33)	3.58(12.33)	3.23(10.00)
13. Chlorsulfuron+iso-proturon(15+500g)	2.97(08.33)	1.22(1.00)	0.71(0.00)	0.71(0.00)	0.71(0.00)	2.93(8.00)	1.34(1.33)	1.17(1.00)	0.71(0.00)	0.71(0.00)
14. Weedy check	3.18(09.67)	3.85(14.33)	5.46(29.33)	3.81(14.00)	3.63(12.67)	2.89(8.00)	3.39(11.00)	3.81(14.00)	3.71(13.30)	3.23(10..00)
15. Weed free	0.71(0.00)	0.71(0.00)	0.71(0.00)	0.71(0.00)	0.71(00.00)	0.71(0.00)	0.71(0.00)	0.71(0.00)	0.71(0.00)	0.71(0.00)
S.Em(±)	–	0.09	0.06	0.07	0.07	–	0.16	0.16	0.10	0.14
CD at 5%	–	0.27	0.17	0.19	0.19	–	0.45	0.45	0.30	0.40

Data subjected to √x+0.5 transformation. Figures in parentheses are original values.

Table 11. Effect of the treatments on the population of *Phalaris minor* (No. m^{-2}) at different stages of growth

Treatments	1996-97 (Days after sowing)					1997-98 (Days after sowing)				
	30	60	90	120	Harvest	30	60	90	120	Harvest
1 Metsulfuron 4g	2.42(5.33)	2.91(8.00)	3.72(13.33)	3.63(12.67)	4.30(18.00)	4.44(19.13)	4.67(21.33)	5.21(26.67)	5.58(30.67)	5.21(26.67)
2 Metsulfuron 8g	2.67(6.67)	1.77(2.67)	1.68(2.33)	1.87(3.00)	1.56(2.00)	4.09(16.33)	3.29(10.33)	2.67(6.67)	2.26(4.67)	1.76(2.67)
3. Metribuzin 200g	2.35(5.00)	1.46(1.67)	1.34(1.33)	1.17(1.00)	0.71(0.00)	4.13(16.67)	3.08(9.00)	2.67(6.67)	1.95(3.33)	1.76(2.67)
4. Metribuzin 400 g	3.08(9.00)	1.05(1.00)	1.17(1.00)	0.71(0.00)	0.71(0.00)	3.97(15.33)	1.34(1.33)	0.71(0.00)	0.71(0.00)	0.71(0.00)
5. Chlorsulfuron 15g	2.85(7.67)	2.26(4.67)	2.91(8.00)	3.29(10.33)	3.63(12.67)	5.00(24.67)	4.00(15.50)	3.23(10.00)	2.91(8.00)	2.42(5.33)
6. Chlorsulfuron 30g	2.68(6.67)	1.46(1.67)	1.34(1.33)	1.00(0.67)	1.08(0.67)	4.74(22.00)	3.17(9.58)	2.55(6.00)	2.11(4.00)	1.76(2.67)
7. Metsulfuron+ metribuzin (2+200g)	2.61(6.33)	1.34(1.33)	1.22(1.00)	1.17(1.00)	0.71(0.00)	4.43(19.33)	3.23(10.00)	2.42(5.33)	2.19(4.33)	1.68(2.23)
8. Metsulfuron+ metribuzin (2+100g)	2.55(6.00)	1.17(1.00)	1.34(1.33)	1.34(1.33)	0.71(0.00)	3.78(14.00)	3.44(11.33)	2.48(5.67)	2.20(4.33)	1.95(3.33)
9. Chlorsulfuron+ metribuzin (15+100g)	2.85(7.67)	1.34(1.33)	1.34(1.33)	1.05(1.00)	0.71(0.00)	4.71(22.00)	3.29(10.33)	2.67(6.67)	2.03(3.67)	1.76(2.67)
10. Chlorsulfuron+ metribuzin(15+200g)	2.42(5.33)	1.05(1.00)	1.05(1.00)	1.17(1.00)	0.71(0.00)	4.58(20.67)	3.08(9.00)	2.61(6.33)	1.95(3.33)	1.95(3.33)
11. Isoproturon 1000g	2.90(8.00)	1.95(3.33)	1.77(2.67)	1.87(3.00)	1.56(2.00)	4.29(18.33)	3.17(9.58)	2.53(5.92)	1.95(3.33)	1.76(2.67)
12. Metsulfuron+isop-roturon(2+500g)	2.35(5.00)	3.13(9.33)	3.13(9.33)	3.44(11.33)	3.66(13.00)	4.13(16.67)	4.38(18.67)	4.57(20.33)	4.48(23.33)	4.22(17.33)
13. Chlorsulfuron+iso-proturon(15+500g)	2.78(7.33)	2.03(3.67)	2.42(5.33)	2.91(8.00)	3.53(12.00)	4.24(17.67)	3.08(9.00)	3.29(10.33)	3.34(10.67)	2.55(6.00)
14. Weedy check	2.74(7.00)	4.18(17.00)	3.53(12.00)	3.63(12.67)	3.97(15.33)	4.92(24.33)	5.98(35.33)	6.20(38.00)	7.13(50.33)	5.98(35.33)
15. Weed free	0.71(0.00)	0.71(0.00)	0.71(0.00)	0.71(0.00)	0.71(0.00)	0.71(0.00)	0.71(0.00)	0.71(0.00)	0.71(0.00)	0.71(0.00)
S.Em(±)	-	0.15	0.12	0.17	0.14	0.23	0.12	0.11	0.10	0.10
CD at 5%	_	044	0.35	0.48	0.41	_	0.36	0.31	0.29	0.31

Data subjected to $\sqrt{x+0.5}$ transformation. Figures in parentheses are original values.

isoproturon at 120 DAS onward in 1996-97, caused significant reduction in the population of canary grass as compared to weedy check during both the years. Among herbicide treatments, metribuzin 400 g ha^{-1} resulted the lowest population of *Phalaris minor* 60 DAS onward during both the years, however, its performance was similar to chlorsulfuron 30 g ha^{-1}, metribuzin 200 g ha^{-1} alone and its combination with metsulfuron (2 + 200 and 2 + 100 g ha^{-1}) and chlorsulfuron (15 + 100 and 15 + 200 g ha^{-1}) on subsequent days of observation in 1996-97. While in 1997-98, metribuzin 400 g ha^{-1} alone proved significantly superior in controlling *P. minor* over rest of the treatments. Metsulfuron (8 g ha^{-1}) and isoproturon (1000 g ha^{-1}) were medium in controlling *P. minor* in both the years. While chlorsulfuron (30 g ha^{-1}), metribuzin (200 g ha^{-1}) and its combination with metsulfuron (2 + 200 and 2 + 100 g ha^{-1}) and chlorsulfuron (15 + 200 and 15 + 100 g ha^{-1}) were better in both the years of experimentation.

Amongst sulfonylurea herbicides, chlorsulfuron 30 g and metsulfuron (8 g ha^{-1}) treatments recorded significantly lower *P. minor* population which were at par with isoproturon (1000 g ha^{-1}), metribuzin (200 g ha^{-1}) and its tank mixtures with metsulfuron (2 + 200 and 2 + 100 g ha^{-1}) and chlorsulfuron (15 + 200 and 15 + 100 g ha^{-1}). While chlorsulfuron (15 g ha^{-1}), metsulfuron (4 g ha^{-1}) and their tank mixtures with isoproturon (500 g ha^{-1}) gave a poor control of this weed. Population of *P. minor* was recorded higher in metsulfuron (4 g ha^{-1}) treated plots 90 DAS onward in 1996-97.

(e) *Anagalis arvensis* L.

All the weed control treatments except metsulfuron + isoproturon at harvest in 1996-97, caused significant reduction in the population of *Anagalis arvensis* as compared to weedy check at all stages during both the years (Table 12). Amongst herbicide treatments, isoproturon (1000 g ha^{-1}), metsulfuron+ isoproturon (2+500 g ha^{-1}) and metsulfuron (4 g ha^{-1}) were comparatively less effective in controlling this weed, in both the years. While other herbicidal treatments provided its complete control at 60 DAS.

(f) *Cirsium arvense* (L.) Scop.

Data presented in Table 13 indicated that herbicide treatments did not exhibit their effects on *Cirsium arvense* at 60 DAS as there was increase in its population under all herbicidal treatments at 60 DAS. However, there was significant reduction in its population at 90 DAS onward in all herbicidal treated plots.

The magnitude of reduction in its population was the highest in metsulfuron (8 g ha^{-1}) treated plots closely followed by metribuzin (200 and 400 g ha^{-1}), chlorsulfuron (30 g ha^{-1}), chlorsulfuron + metribuzin (15 + 200 and 15 + 100 g ha^{-1}), metsulfuron (4 g ha^{-1}) alone and its combination with metribuzin (2 + 200 and 2 + 100 g ha^{-1}). Whereas, chlorsulfuron (15 g ha^{-1}), isoproturon (1000 g ha^{-1}) alone and its tank mixture at lower dose with metsulfuron (2 g ha^{-1}) and chlorsulfuron (15 g ha^{-1}) provided poor control of this weed over rest of the herbicide treatments.

Table 12. Effect of the treatments on the population of *Anagallis arvensis* (No. m^{-2}) at different stages of growth

Treatments	1996-97 (Days after sowing)					1997-98 (Days after sowing)				
	30	60	90	120	Harvest	30	60	90	120	Harvest
1 Metsulfuron 4g	2.91(8.00)	1.95(3.33)	1.77(2.67)	1.77(2.67)	2.11(4.00)	4.57(20.67)	2.59(6.33)	2.20(4.33)	1.68(2.33)	1.76(2.67)
2 Metsulfuron 8g	2.55(6.00)	1.77(2.67)	1.34(1.33)	1.34(1.33)	0.71(0.00)	4.72(22.00)	0.71(0.00)	0.71(0.00)	0.71(0.00)	0.71(0.00)
3. Metribuzin 200g	2.97(8.33)	0.71(0.00)	0.71(0.00)	0.71(0.00)	0.71(0.00)	4.29(18.00)	0.71(0.00)	0.71(0.00)	0.71(0.00)	0.71(0.00)
4. Metribuzin 400g	2.97(8.33)	0.71(0.00)	0.71(0.00)	0.71(0.00)	0.71(0.00)	4.59(20.67)	0.71(0.00)	0.71(0.00)	0.71(0.00)	0.71(0.00)
5. Chlorsulfuron 15g	2.80(7.33)	1.22(1.00)	0.71(0.00)	0.71(0.00)	1.46(1.67)	4.89(23.67)	0.71(0.00)	0.71(0.00)	0.71(0.00)	0.71(0.00)
6. Chlorsulfuron 30g	2.68(6.67)	0.71(0.00)	0.71(0.00)	0.71(0.00)	0.71(0.00)	4.64(21.33)	0.71(0.00)	0.71(0.00)	0.71(0.00)	0.71(0.00)
7. Metsulfuron+ metribuzin (2+200g)	2.55(6.00)	0.71(0.00)	0.71(0.00)	0.71(0.00)	0.71(0.00)	4.51(20.00)	0.71(0.00)	0.71(0.00)	0.71(0.00)	0.71(0.00)
8. Metsulfuron+ metribuzin (2+100g)	2.35(5.00)	0.71(0.00)	1.34(1.33)	0.71(0.00)	0.71(0.00)	4.52(20.00)	0.71(0.00)	0.71(0.00)	0.71(0.00)	0.71(0.00)
9. Chlorsulfuron+ metribuzin (15+100g)	2.42(5.33)	0.71(0.00)	0.71(0.00)	0.71(0.00)	0.71(0.00)	4.30(18.00)	0.71(0.00)	0.71(0.00)	0.71(0.00)	0.71(0.00)
10. Chlorsulfuron+ metribuzin(15+200g)	2.55(6.00)	0.71(0.00)	0.71(0.00)	0.71(0.00)	0.71(0.00)	4.77(22.67)	0.71(0.00)	0.71(0.00)	0.71(0.00)	0.71(0.00)
11. Isoproturon 1000g	2.55(6.00)	2.27(4.67)	1.77(2.67)	1.95(3.33)	2.27(4.67)	4.25(17.67)	3.62(12.67)	3.51(12.00)	3.33(10.67)	3.13(9.33)
12. Metsulfuron+isop-roturon(2+500g)	2.91(8.00)	3.29(10.33)	3.34(10.67)	2.91(8.00)	3.23(10.00)	4.80(23.67)	4.40(19.00)	4.06(16.00)	3.89(14.33)	2.89(8.00)
13. Chlorsulfuron+iso-proturon(15+500g)	2.55(6.00)	1.05(0.67)	0.71(0.00)	1.34(1.33)	0.71(0.00)	4.94(24.00)	0.71(0.00)	0.71(0.00)	0.71(0.00)	0.71(0.00)
14. Weedy check	2.80(7.33)	3.98(15.33)	4.38(18.67)	3.34(10.67)	3.44(11.33)	4.72(22.00)	6.41(40.67)	7.32(53.33)	6.46(41.33)	4.37(18.67)
15. Weed free	0.71(0.00)	0.71(0.00)	0.71(0.00)	0.71(0.00)	0.71(0.00)	0.71(0.00)	0.71(0.00)	0.71(0.00)	0.71(0.00)	0.71(0.00)
S.Em.(±)	–	0.08	0.08	0.09	0.10	–	0.17	0.13	0.13	0.16
CD at 5%	–	0.25	0.22	0.25	0.29	–	0.48	0.37	0.37	0.46

Data subjected to $\sqrt{x+0.5}$ transformation. Figures in parentheses are original values.

Table 13. **Effect of the treatments on the population of *Cirsium arvense* (No. m^{-2}) at different stages of growth**

		1997-98 (Days after sowing)				
	Treatments	30	60	90	120	Harvest
1	Metsulfuron 4g	2.74(7.00)	2.84(7.67)	2.48(5.67)	1.68(2.33)	1.46(1.67)
2	Metsulfuron 8g	2.32(5.00)	2.72(7.00)	1.34(1.33)	1.22(1.00)	1.05(0.67)
3.	Metribuzin 200g	1.87(3.00)	2.67(6.67)	1.86(3.00)	1.58(2.00)	1.46(1.67)
4.	Metribuzin 400 g	1.86(3.00)	2.34(5.00)	1.95(3.33)	1.76(2.67)	1.22(1.00)
5.	Chlorsulfuron 15g	2.20(4.33)	2.74(7.00)	2.67(6.67)	2.86(7.67)	3.08(9.00)
6.	Chlosulfuron 30g	2.09(4.00)	2.65(6.67)	2.11(4.00)	1.68(2.33)	1.56(2.00)
7.	Metsulfuron+metribuzin (2+200g)	2.03(3.67)	2.67(6.67)	1.68(2.33)	1.56(2.00)	1.56(2.00)
8.	Metsulfuron+metribuzin (2+100g)	2.34(5.00)	2.56(6.33)	1.76(2.67)	1.58(2.00)	1.86(3.00)
9.	Chlorsulfuron+metribuzin (15+100g)	1.86(3.00)	2.68(6.67)	1.91(3.17)	1.76(2.67)	1.56(2.00)
10.	Chlorsulfuron+metribuzin (15+200g)	2.11(4.00)	2.80(7.33)	1.77(2.67)	1.22(1.00)	1.68(2.33)
11.	Isoproturon 1000g	2.67(6.67)	2.32(5.00)	2.80(7.33)	3.03(8.67)	2.90(8.00)
12.	Metsulfuron+isoproturon (2+500g)	2.20(4.33)	2.48(5.67)	2.48(5.67)	2.74(7.00)	2.74(7.00)
13.	Chlorsulfuron+isoproturon (15+500g)	2.34(5.00)	2.38(5.67)	2.42(5.33)	2.48(5.67)	2.48(5.67)
14.	Weedy check	3.13(9.33)	2.84(7.67)	3.48(11.67)	3.80(14.00)	3.76(13.67)
15	Weed free	0.71(0.00)	0.71(0.00)	0.71(0.00)	0.71(0.00)	0.71(0.00)
	S.Em(±)	_	0.27	0.12	0.13	0.18
	CD at 5%	_	0.79	.0.35	0.39	0.52

Data subjected to $\sqrt{x+0.5}$ transformation. Figures in parentheses are original values.

(g) Total weed population

Data presented in Table 14 and depicted in Fig. 4 and 5 reveal that total population of weeds per square metre varied significantly due to herbicide treatments compared to weedy check at all the growth stages except at 30 DAS (before herbicide application) in both the seasons.

In herbicide treatments, metribuzin (400 g ha^{-1}) caused significantly the highest reduction in total weed population at all the stages in both the years (Plate 1). However, its performance in first year was found at par with chlorsulfuron (30 g ha^{-1}), metribuzin (200 g ha^{-1}) alone and tank mixture of metribuzin with metsulfuron (2 + 200 and 2 + 100 g ha^{-1}) and chlorsulfuron (15 + 200 and 15 + 100 g ha^{-1}) from 60 DAS onwards, except metsulfuron + metribuzin (2 + 100 g ha^{-1}) and chlorsulfuron + metribuzin (15 + 100 g ha^{-1}) at 60 and 90 DAS. While in 1997-98, chlorsulfuron 30 g ha^{-1}, metsulfuron (8 g ha^{-1}), metribuzin (200 g ha^{-1}) and tank mixture of metribuzin with metsulfuron (except 2 + 100 g ha^{-1} at 60 and 120 DAS) and chlorsulfuron were found significantly superior in reducing total weed count over rest of the treatments.

Minimum reduction in the total weed population was recorded in metsulfuron (4 g ha^{-1}) and metsulfuron + isoproturon (2 + 500 g ha^{-1}) treated plots. However, chlorsulfuron (15 g ha^{-1}), isoproturon (1000 g ha^{-1}) alone and their tank mixture at 15 + 500 g ha^{-1} were comparatively less effective in reducing total weed population (count) in both the years.

4.1.1.2 Dry weight of weeds

Data presented in Table 15 and depicted in Fig. 6 clearly indicate that total dry matter accumulation of complex weed flora decreased

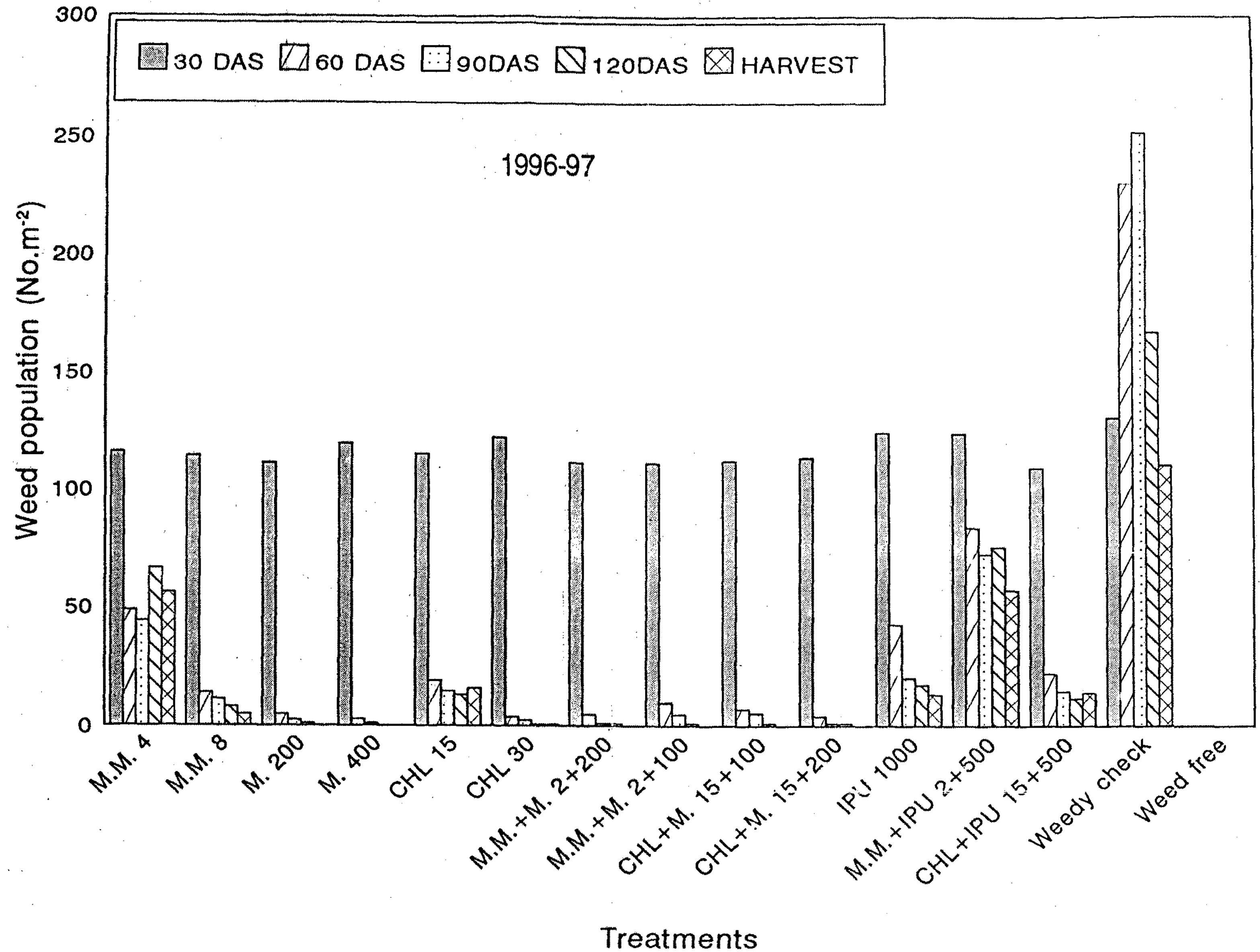


Fig.4 Effect of weed control treatments on total weed population in wheat at different stages of growth

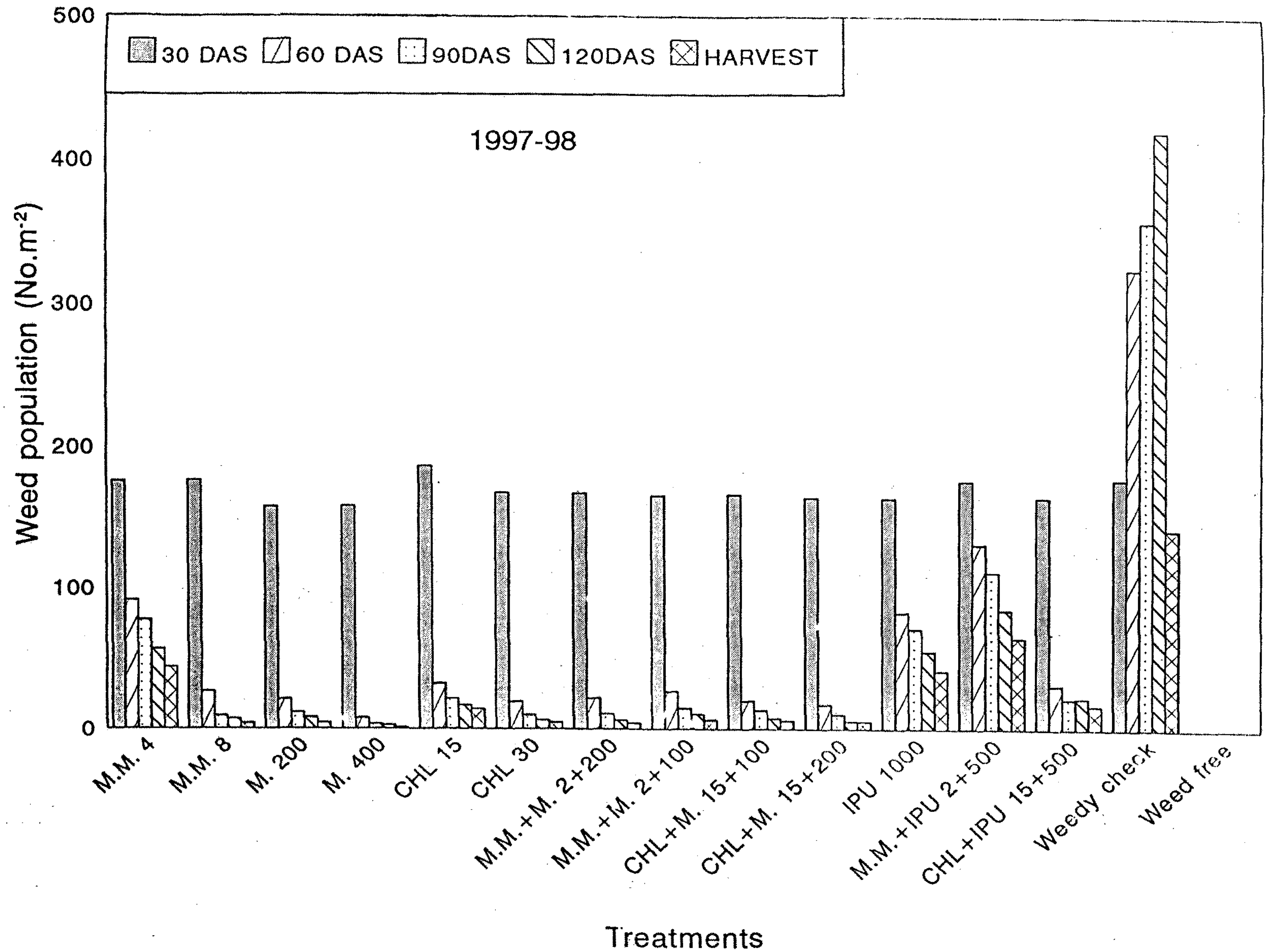


Fig.5 Effect of weed control treatments on total weed population in wheat at different stages of growth

Table 14. Effect of the treatments on total weed population (No. m^{-2}) at different stages of growth

Var HD2329

Treatments	1996-97 (Days after sowing) 30	60	90	120	Harvest	1997-98 (Days after sowing) 30	60	90	120	Harvest
1 Metsulfuron 4g	10.77(115.66)	6.99(48.34)	6.67(44.00)	8.18(66.34)	7.52(56.00)	13.25(175.14)	9.55(90.66)	8.78(76.69)	7.52(56.00)	6.64(43.67)
2 Metsulfuron 8g	10.70(114.00)	3.77(13.68)	3.39(11.00)	2.92(8.00)	2.27(4.67)	13.27(175.66)	5.21(26.67)	3.14(9.33)	2.78(7.22)	2.12(4.00)
3. Metribuzin 200g	10.56(111.00)	2.27(4.67)	1.68(2.33)	1.22(1.00)	0.71(0.00)	12.55(157.00)	4.64(21.00)	3.49(11.67)	2.92(8.00)	2.20(4.34)
4. Metribuzin 400g	10.95(119.33)	1.78(2.67)	1.22(1.00)	0.71(0.00)	0.71(0.00)	12.57(157.44)	2.86(7.67)	1.96(3.33)	1.78(2.67)	1.22_1.00)
5. Chlorsulfuron 15g	10.77(115.01)	4.40(18.80)	3.85(14.34)	3.67(13.00)	4.02(15.67)	13.65(186.00)	5.72(32.17)	4.71(21.67)	4.18(17.00)	3.85(14.33)
6. Chlorsulfuron 30g	11.06(122.00)	2.04(3.67)	1.68(2.33)	1.08(0.67)	1.08(0.67)	12.94(167.00)	4.48(19.58)	3.24(10.00)	2.61(6.33)	2.27(4.67)
7. Metsulfuron+ metribuzin (2+200g)	10.56(111.33)	2.27(4.67)	1.22(1.00)	1.22(1.00)	0.71(0.00)	12.93(166.67)	4.74(22.00)	3.39(10.99)	2.60(6.33)	2.20(4.33)
8. Metsulfuron+ metribuzin (2+100g)	10.56(111.00)	3.19(9.67)	2.27(4.67)	1.22(1.00)	0.71(0.00)	12.86(165.00)	5.24(27.00)	3.94(15.01)	3.39(11.00)	2.68(6.67)
9. Chlorsulfuron+ metribuzin (15+100g)	10.61(112.01)	2.74(7.00)	2.41(5.33)	1.22(1.00)	0.71(0.00)	12.89(165.67)	4.56(20.33)	3.74(13.51)	2.86(7.67)	2.56(6.04)
10. Chlorsulfuron+ metribuzin(15+200g)	10.67(113.33)	2.12(4.00)	1.22(1.00)	1.22(1.00)	0.71(0.00)	12.81(163.67)	4.26(17.67)	3.29(10.34)	2.48(5.66)	2.48(5.67)
11. Isoproturon 1000g	11.16(124.00)	6.57(42.67)	4.52(20.00)	4.18(17.00)	3.67(13.00)	12.79(163.00)	9.10(82.25)	8.43(70.59)	7.45(55.00)	6.47(41.33)
12. Metsulfuron+isop-roturon(2+500g)	11.14(123.67)	9.17(83.67)	8.53(72.33)	8.71(75.33)	7.58(57.00)	13.26(175.34)	11.45(130.68)	10.56(111.0)	9.20(84.16)	8.05(64.33)
13. Chlorsulfuron+iso-proturon(15+500g)	10.46(109.00)	4.70(21.68)	3.85(14.33)	3.44(11.33)	3.76(13.67)	12.81(163.67)	5.64(31.33)	4.71(21.66)	4.78(22.34)	4.18(17.00)
14. Weedy check	11.44(130.33)	15.20(230.33)	15.89(252.00)	12.95(167.33)	10.53(110.33)	13.31(176.67)	18.01(324.00)	18.90(356.66)	20.48(418.96)	11.91(141.33)
15. Weed free	0.71(0.00)	0.71(0.0)	0.71(0.00)	0.71(0.00)	0.71(0.00)	0.71(0.00)	0.71(0.00)	0.71(0.00)	0.71(0.00)	0.71(0.00)
S.Em.(±)	_	0.18	0.16	0.21	0.23		0.15	0.16	0.16	0.17
CD at 5%	_	0.53	0.47	0.60	0.67	_	0.44	0.46	0.47	0.49

Data subjected to √x+0.5 transformation. Figures in parentheses are original values.

Table 15. Effect of the treatments on total weed dry weight (g m^{-2}) at different stages of growth

Treatments	1996-97 (Days after sowing)				1997-98 (Days after sowing)			
	60	90	120	Harvest	60	90	120	Harvest
1. Metsulfuron 4 g	3.45(11.37)	6.23(38.37)	8.73(75.81)	7.54(56.35)	4.33(18.30)	7.65(57.98)	7.86(61.24)	6.99(48.41)
2. Metsulfuron 8g	3.03(8.71)	3.28(10.22)	3.44(11.35)	2.94(8.17)	3.71(13.40)	3.81(14.00)	3.70(13.19)	3.67 (13.00)
3. Metribuzin 200 g	2.16(4.16)	2.83(7.50)	2.58(6.17)	0.71(0.00)	2.47(5.60)	3.51(11.82)	3.75(13.61)	3.54 (12.00)
4. Metribuzin 400g	1.97(3.37)	2.53(5.92)	0.71(0.00)	0.71(0.00)	1.45(1.60)	2.39(5.20)	2.57(6.13)	2.52(5.97)
5. Chlorsulfuron 15g	3.08(9.00)	3.74(13.51)	4.54(20.12)	5.02(24.78)	3.55(12.10)	5.07(25.18)	5.36(28.26)	5.06(25.14)
6. Chlosulfuron 30g	2.21(4.40)	2.55(6.00)	2.43(5.42)	2.18(4.27)	2.82(7.50)	3.73(13.39)	3.67(13.00)	3.40(11.06)
7. Metsulfuron+metribuzin (2+200g)	2.12(4.00)	2.74(7.00)	2.76(7.11)	0.71(0.00)	2.65(6.53)	3.43(11.29)	3.55(12.08)	3.44(11.33)
8. Metsulfuron+metribuzin (2+100g)	2.20(4.33)	2.83(7.50)	2.80(7.33)	0.71(0.00)	2.93(8.12)	3.83(14.15)	3.97(15.28)	3.72(13.33)
9. Chlorsulfuron+metribuzin (15+100g)	2.24(4.52)	2.76(7.11)	2.78(7.25)	0.71(0.00)	2.59(6.21)	3.80(13.97)	4.02(15.66)	3.70(13.19)
10. Chlorsulfuron+metribuzin (15+200g)	2.00(3.50)	2.55(6.00)	2.74(7.00)	0.71(0.00)	2.44(5.45)	3.65(12.80)	3.99(15.52)	3.57(12.28)
11. Isoproturon 1000 g	3.25(9.98)	3.41(11.12)	3.94(15.00)	3.85(14.31)	3.70(13.58)	5.23(26.83)	4.97(24.25)	4.86(23.13)
12. Metsulfuron+isoproturon (2+500g)	4.40(18.95)	6.84(46.31)	8.99(80.32)	7.91(62.00)	4.94(23.95)	7.50(55.76)	7.06(49.39)	6.87(46.74)
13. Chlorsulfuron+isoproturon (15+500g)	2.86(7.71)	3.12(9.21)	3.79(13.95)	3.50(11.72)	3.41(11.12)	5.02(24.67)	4.80(22.53)	4.89(23.43)
14. Weedy check	5.16(26.12)	11.24(125.71)	12.06(145.00)	11.48(131.21)	5.82(33.45)	11.43(130.24)	9.71(109.66)	11.86(140.21)
15 Weed free	0.71(0.00)	0.71(0.00)	0.71(0.00)	0.71(0.00)	0.71(0.00)	0.71(0.00)	0.71(0.00)	0.71(0.00)
S.Em(±)	0.09	0.11	0.18	0.12	0.17	0.14	0.22	0.13
CD at 5%	0.27	0.33	0.51	0.35	0.49	0.40	0.63	0.37

Data subjected to $\sqrt{x+0.5}$ transformation. Figures in parentheses are original values.

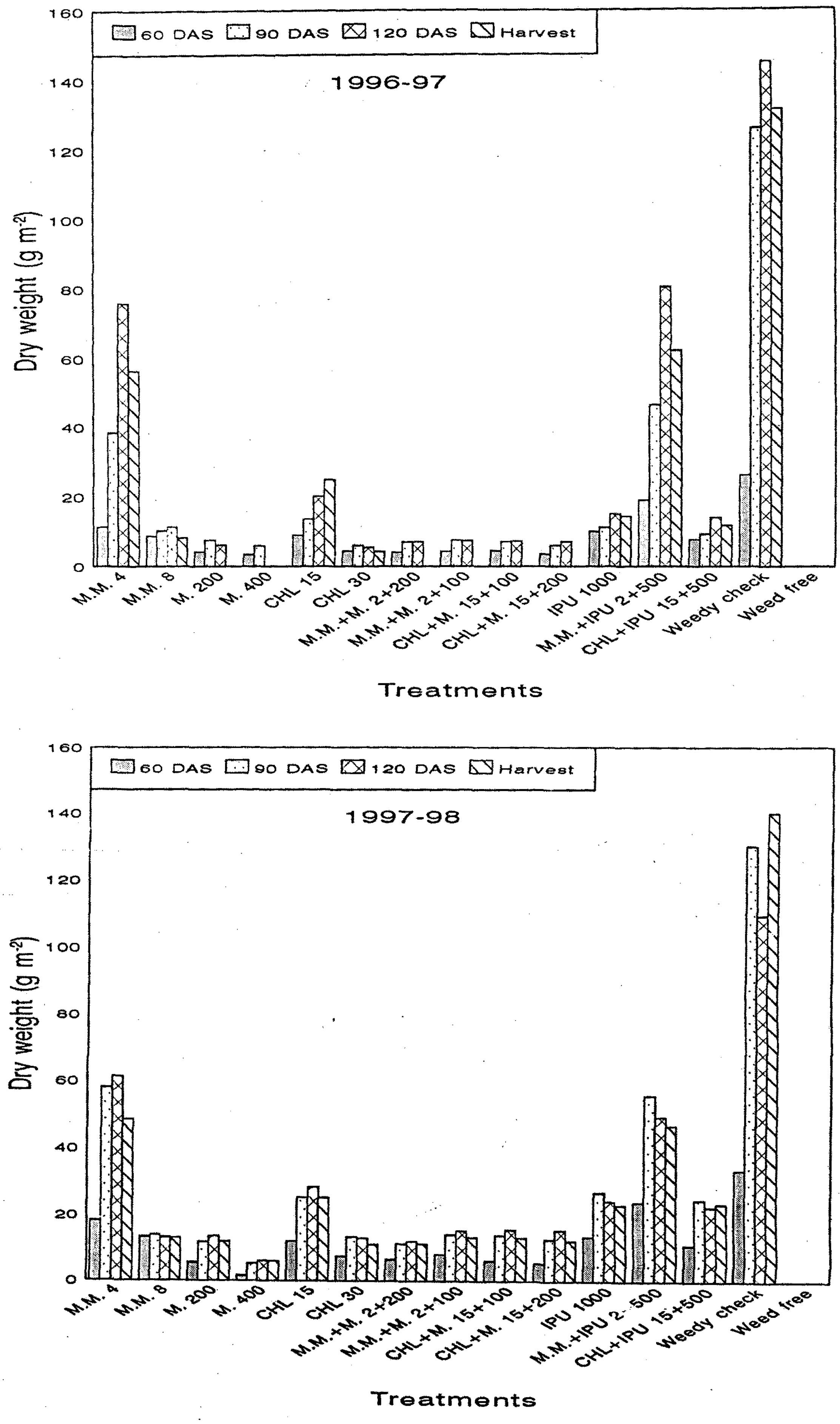


Fig.6 Effect of weed control treatments on total weed dry weight in wheat at different stages of growth

significantly with the application of all the weed control treatments during both the seasons.

Among herbicide treatments, metribuzin (400 g ha^{-1}) caused the highest significant reduction in weed biomass in both the years at 60 DAS. However, it was at par with its lower dose (200 g ha^{-1}), chlorsulfuron (30 g ha^{-1}) and tank mixture of metsulfuron (2 g ha^{-1}) and chlorsulfuron (15 g ha^{-1}) with metribuzin (100 and 200g ha^{-1}) during 1996-97 at 60 DAS. While in 1997-98 metribuzin (200 g), metsulfuron (8 g ha^{-1}), chlorsulfuron (30 g ha^{-1}) and tank mixture of metribuzin with metsulfuron (2 g ha^{-1}) and chlorsulfuron (15 g ha^{-1}) were almost equally effective after 400 g of metribuzin in minimising the total weed dry matter accumulation (Fig. 6).

Isoproturon (1000 g ha^{-1}), chlorsulfuron (15 g ha^{-1}) and chlorsulfuron + isoproturon (15 + 500 g ha^{-1}) were found average whereas metsulfuron (4 g) and metsulfuron + isoproturon (2+500 g) were found to be least effective in reducing the total weed dry matter accumulation in both the years.

4.1.2 STUDIES ON CROP

4.1.2.1 Growth studies

Crop growth was measured in term of plant population, plant height, number of tillers and dry matter accumulation per metre row length and results on these characters are presented in different tables.

(a) Plant population (No. m^{-1})

The data related to germination count $metre^{-1}$ row length of wheat recorded at 20 DAS and are given in Table 16 which reveal that germination

Table 16. **Plant population of wheat (No. m^{-1}) at 20 days after sowing**

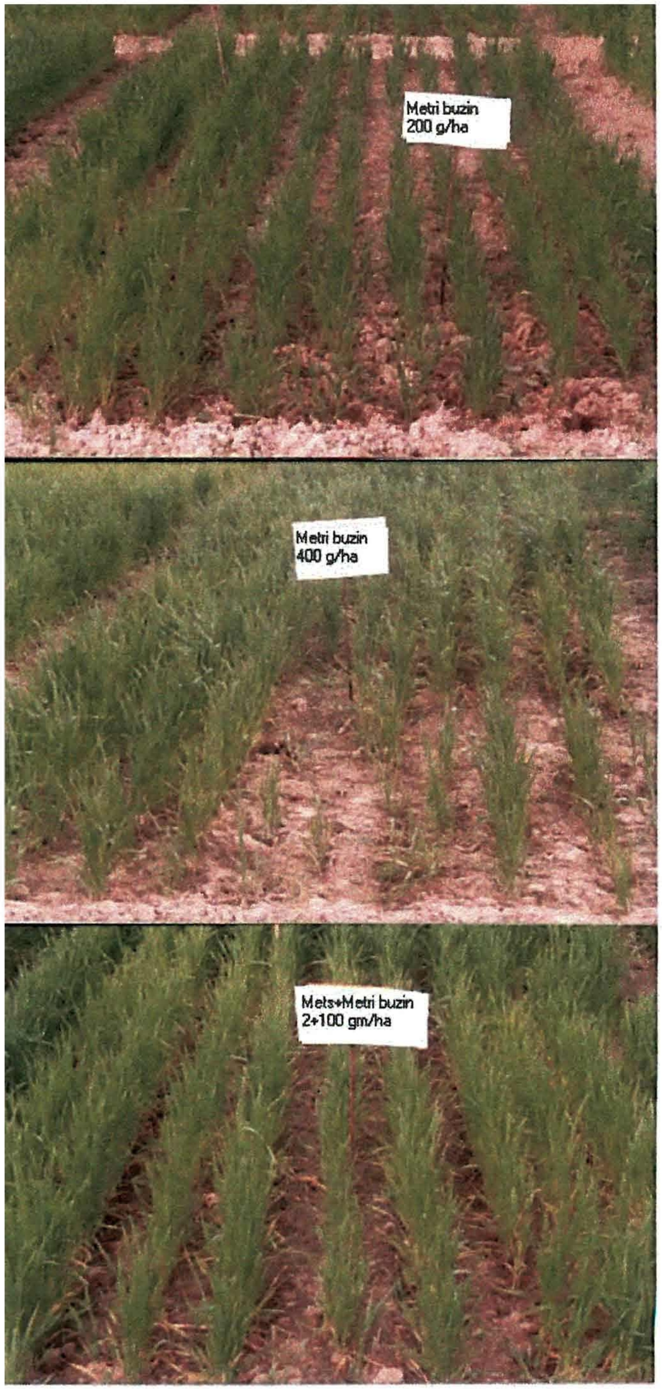
Treatments	1996-97	1997-98
1. Metsulfuron 4g	41.00	44.00
2. Metsulfuron 8g	40.67	43.33
3. Metribuzin 200g	40.00	43.00
4. Metribuzin 400g	41.00	44.00
5. Chlorsulfuron 15g	41.00	43.00
6. Chlorsulfuron 30g	40.67	42.67
7. Metsulfuron + metribuzin (2+200g)	40.67	43.67
8. Metsulfuron + metribuzin (2+100g)	40.67	43.33
9. Chlorsulfuron+metribuzin (15+100g)	40.00	42.67
10. Chlorsulfuron+metribuzin (15+200g)	41.33	43.33
11. Isoproturon 1000 g	41.00	42.33
12. Metsulfuron + isoproturon (2+500g)	41.00	44.00
13. Chlorsulfuron+isoproturon (15+500g)	41.67	42.67
14. Weedy check	40.00	42.33
15. Weed free	41.33	44.67
S.Em.(±)	1.55	4.90
CD at 5%	NS	NS

of crop was uniform in entire experimental field before applying weed control treatments during both the years.

(b) Plant height (cm)

Weed control treatments significantly influenced the plant height of wheat at all stages of observation during both the years except at 60 DAS in 1996-97. The pertinent data are presented in Table 17. The tallest plants were recorded in weed free plots (89.84 and 97.15 cm) which differed significantly to weedy check and all doses of metribuzin alone and in combination with metsulfuron (2 g ha^{-1}) at all stages in both the years.

Amongst herbicidal treatments, chlorsulfuron at 30 g ha^{-1} exhibited the highest increase in plant height (Plate 2) during both the years which, however, did not differ significantly with other treatments including season long weed infested plot (weedy check). No herbicide treatment could bring significant increase in plant height over weedy check in both the years. However, the herbicide treatments like metribuzin at 200 and 400 g ha^{-1} alone and its combination with metsulfuron (2 + 100 and 2 + 200 g ha^{-1}) recorded comparatively lower plant height as compared to weedy check in both the years, however, the difference was significant only during 1997-98. Therefore, plant had minimum height in metribuzin (400 g ha^{-1}) treated plots in both the seasons (Plate 1). Initial crop growth in term of plant height was comparatively better during second year of experimentation.



A

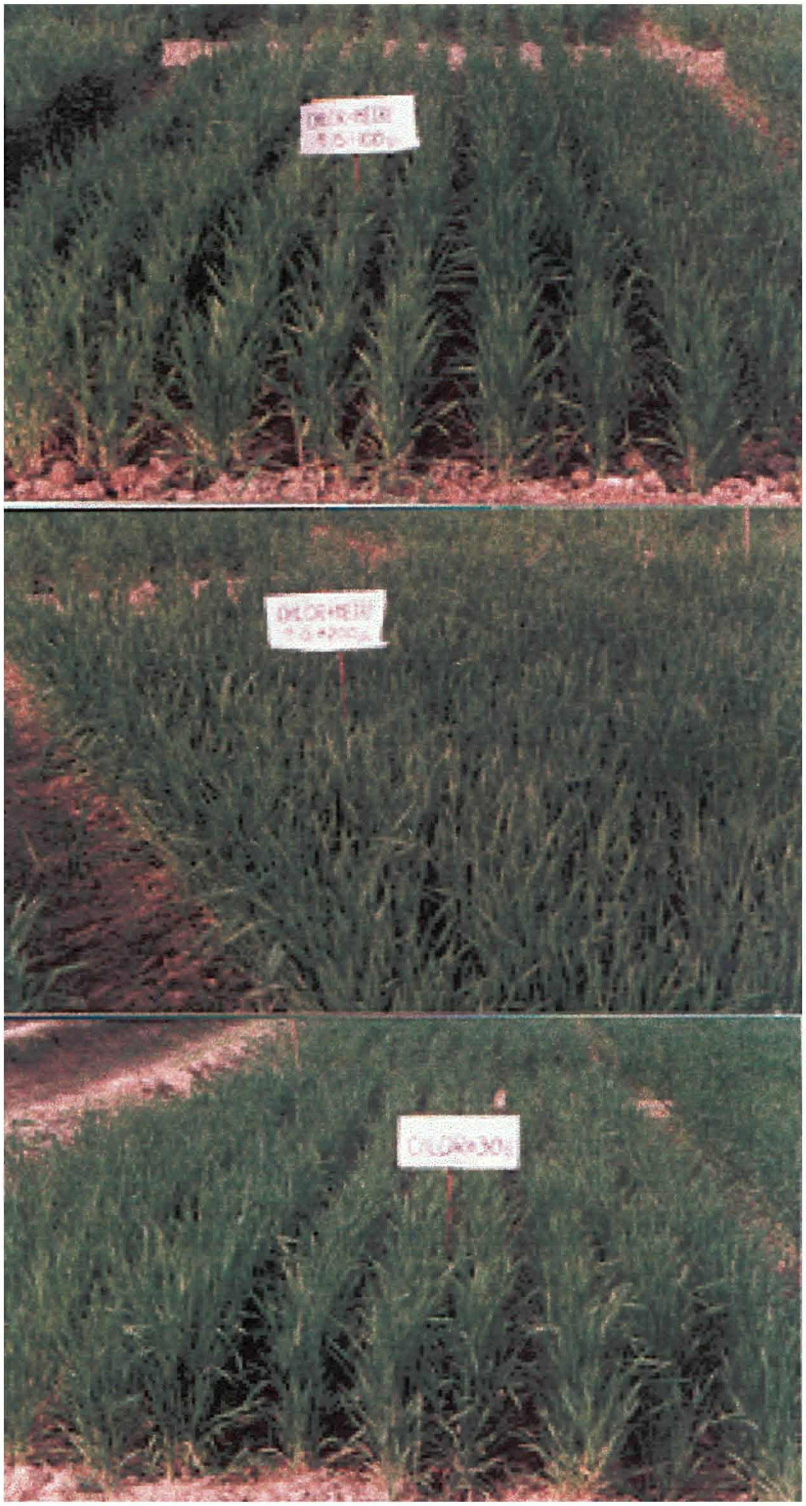
B

C

Plate 1 Studies on the effect of Metri buzin alone ('A' and 'B') and in combination with metsulfron ('C') on wheat growth

Table 17. **Effect of treatments on plant height (cm) of wheat at different stages of growth**

Treatments	1996-97 (Days after sowing)					1997-98 (Days after sowing)				
	30	60	90	120	Harvest	30	60	90	120	Harvest
1. Metsulfuron 4g	13.51	32.81	64.13	85.75	88.15	20.80	43.80	77.27	94.20	95.60
2. Metsulfuron 8g	13.71	31.22	63.48	84.84	87.21	21.07	43.00	76.93	93.89	94.96
3. Metribuzin 200g	13.60	30.18	61.00	82.11	84.78	20.60	38.67	70.60	89.47	90.21
4. Metribuzin 400g	13.25	29.97	60.78	82.66	84.31	20.53	37.87	68.33	88.33	90.00
5. Chlorsulfuron 15g	14.00	32.50	64.71	85.67	87.41	21.00	42.53	78.00	94.40	95.20
6. Chlorsulfuron 30g	13.95	32.37	65.32	85.80	88.65	20.73	43.87	80.13	94.87	95.77
7 Metsulfuron + metribuzin (2+200g)	13.61	31.15	60.39	82.59	85.78	20.60	38.20	70.40	89.17	90.27
8. Metsulfuron + metribuzin (2+100g)	14.05	32.79	60.16	83.40	86.21	20.80	38.40	71.87	89.67	90.20
9. Chlorsulfuron+metribuzin (15+100g)	12.97	31.85	63.68	85.20	88.55	20.73	42.93	78.73	94.31	95.60
10. Chlorsulfuron+metribuzin (15+200g)	13.11	32.13	63.87	85.70	88.22	20.80	42.80	79.97	94.87	95.00
11. Isoproturon 1000 g	13.55	32.84	63.71	84.98	88.20	21.67	43.00	78.80	93.27	94.86
12. Metsulfuron +isoproturon (2+500g)	13.24	31.33	63.38	84.15	87.84	20.86	41.47	76.88	93.31	94.90
13. Chlorsulfuron+isoproturon (15+500g)	13.24	32.56	63.23	85.12	87.75	20.80	42.80	78.87	94.73	95.2114.
14. Weedy check	13.52	30.19	62.23	84.43	86.00	21.00	38.20	76.00	91.17	93.46
15. Weed free	14.57	32.78	65.44	86.97	89.84	21.20	43.96	81.10	96.07	97.15
S.Em.(±)	1.15	1.94	0.78	0.76	0.92	1.64	1.50	1.48	1.52	1.25
CD at 5%	NS	NS	2.26	2.19	2.65	NS	4.37	4.25	4.40	3.62



Chl+Metri
(15+100)

A

Chl+Metri
(15+200)

B

Chlorsulfuron
30 g

C

Plate 2. Studies on the effect of chlorsulfuron alone (C) and in combination with metribuzin (A) and (B) on wheat growth

(b) Dry matter accumulation (g m^{-1})

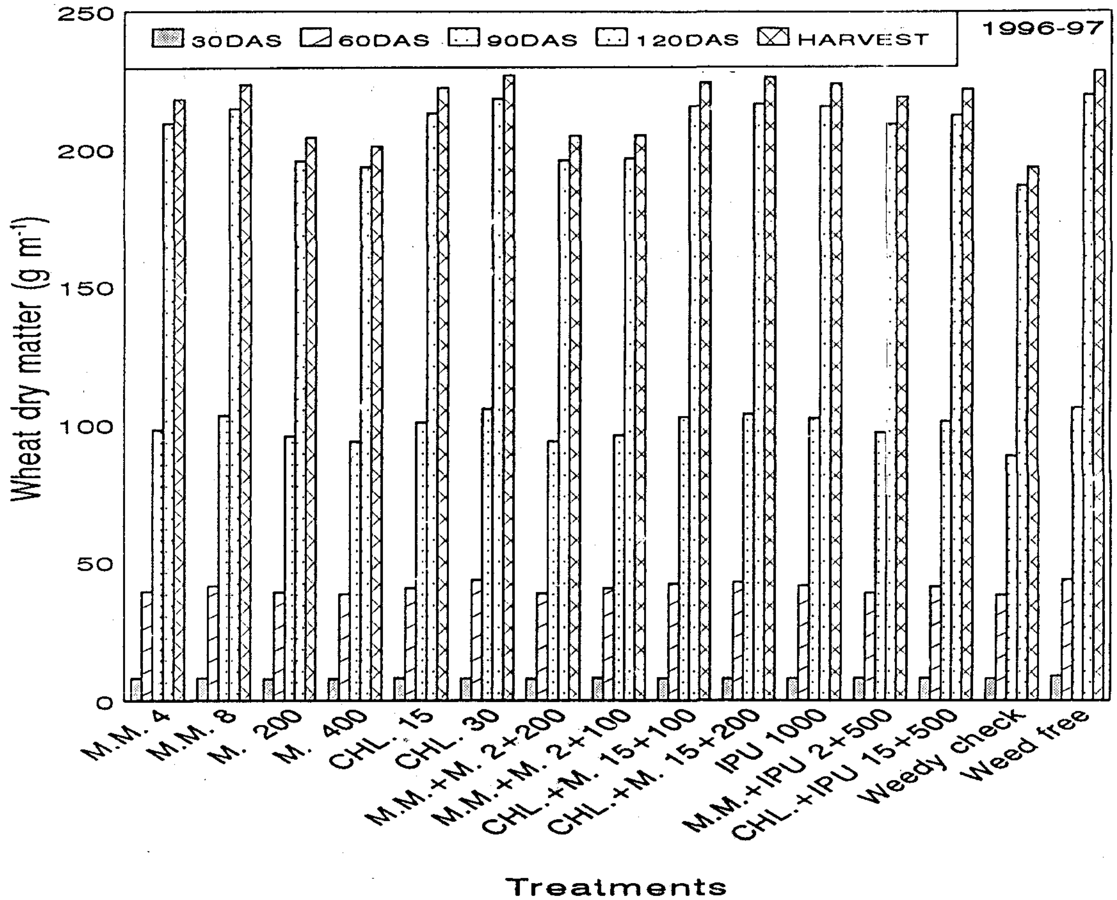
The data on dry matter accumulation per metre row length presented in Table 18 and Fig. 7 revealed that it increased with the advancement of crop age and maximum increase was recorded at 90 and 120 DAS in both the years. However, dry matter production was relatively higher in 1997-98.

There were no significant difference in accumulation of crop dry weight upto 30 DAS during both the years. While at subsequent stages there was reduction in the dry matter accumulation by wheat to the extent of 15.31 and 14.24 per cent at harvest over weedy check in 1996-97 and 1997-98, respectively.

Maximum dry matter accumulation was recorded in weed free plots at all stages during both the years which differed significantly from all treatments except chlorsulfuron (30 g ha^{-1}), isoproturon (1000 g ha^{-1}), metsulfuron (8 g ha^{-1}) and tank mixture of chlorsulfuron and metribuzin during both consecutive *rabi* seasons (Plate 2).

Amongst herbicidal treatments, 30 g of chlorsulfuron provided significantly higher dry matter production but the difference with its tank mixture with metribuzin (15 + 200 and 15 + 100 g ha^{-1}) and individual application of metsulfuron (8 g ha^{-1}) and isoproturon (1000 g ha^{-1}) was, however, non-significant. Application of chlorsulfuron and metsulfuron alone at lower doses and tank mixture with isoproturon (500 g ha^{-1}) produced similar effect on dry matter production in both the years.

Metribuzin (400 g ha^{-1}) caused the highest reduction in dry matter accumulation among herbicidal treatments during both the years of study



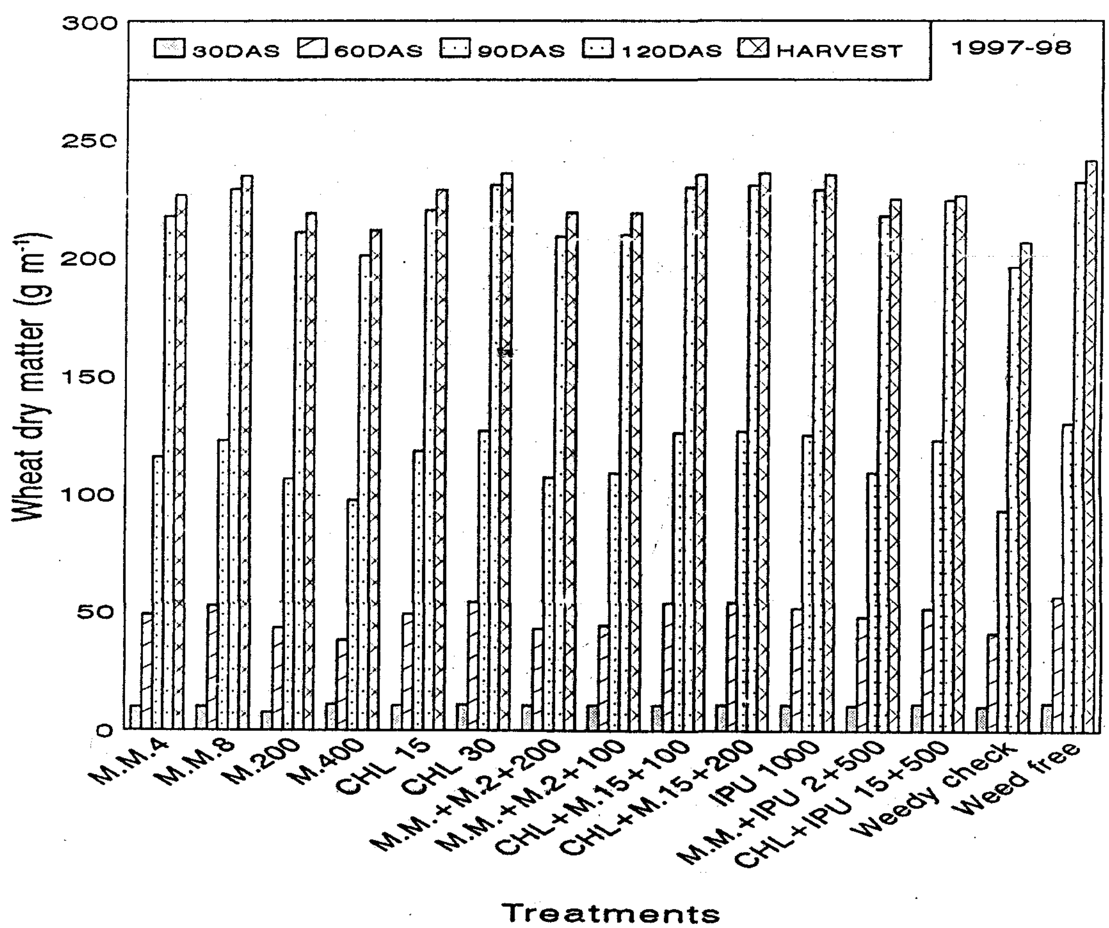


Fig.7 Effect of weed control treatments on dry matter production of wheat at different stages of growth

Table 18 . **Effect of treatments on dry matter production (g m^{-1}) of wheat at different stages of growth**

Treatments	1996-97 (Days after sowing)					1997-98 (Days after sowing)				
	30	60	90	120	Harvest	30	60	90	120	Harvest
1. Metsulfuron 4g	8.15	39.29	98.20	209.23	217.91	10.15	49.00	115.73	217.34	226.25
2. Metsulfuron 8g	8.31	41.26	103.33	214.44	223.15	10.31	52.71	122.85	228.91	234.33
3. Metribuzin 200g	7.89	38.91	95.67	195.38	204.00	7.88	43.33	106.41	210.69	218.61
4. Metribuzin 400g	7.92	38.30	93.65	193.17	200.61	11.25	37.96	97.33	200.78	211.43
5. Chlorsulfuron 15g	8.11	40.51	100.60	212.59	221.84	10.72	49.11	118.44	220.01	228.59
6. Chlorsulfuron 30g	8.05	43.39	105.57	217.81	226.34	11.17	54.19	127.00	230.62	235.55
7. Metsulfuron + metribuzin (2+200 g)	7.93	38.41	93.81	195.31	204.29	10.89	43.00	107.17	208.92	218.95
8. Metsulfuron + metribuzin (2+100g)	8.13	40.51	95.96	196.12	204.47	10.95	44.25	108.95	209.54	218.82
9. Chlorsulfuron+metribuzin (15+100g)	8.03	41.91	102.45	214.93	223.39	11.00	53.92	126.18	229.60	234.84
10. Chlorsulfuron+metribuzin (15+200g)	7.88	42.52	103.58	215.63	225.42	11.20	54.07	126.81	230.27	235.38
11. Isoproturon 1000 g	7.95	41.37	102.09	214.75	223.11	11.15	51.73	125.33	228.46	234.81
13. Metsulfuron +isoproturon (2+500g)	8.10	38.62	96.87	208.39	218.18	10.90	48.00	109.24	217.54	224.50
13.Chlorsulfuron+isoproturon (15+500g)	8.13	40.98	100.97	211.45	220.88	11.65	51.52	123.19	223.97	226.01
14. Weedy check	7.96	38.00	88.53	185.88	192.67	10.55	41.22	92.97	196.10	206.44
15. Weed free	8.96	43.50	105.93	218.78	227.51	12.00	56.59	130.27	231.66	240.73
S.Em.(±)	0.63	0.78	1.47	1.52	1.69	2.13	1.69	2.59	1.54	2.24
CD at 5%	NS	2.26	4.25	4.41	4.88	NS	4.88	7.51	4.47	6.50

except its lower dose (200 g ha^{-1}) and tank mixture with metsulfuron in 1996-97 (Plate 1).

(c) Number of tillers (No. m^{-1})

The difference in the number of tillers per running metre row length amongst the experimental plots at 30 DAS (before the imposition of herbicide treatments) was not significant in both the years (Table 19). In general, number of tillers were relatively lower in the first year of experimentation. The number of tillers m^{-1} row length at various stages of crop growth were significantly affected by different weed control treatments.

Amongst treatments, weed free condition produced significantly higher number of tillers at all stages during both the years, which was at par with chlorsulfuron (30 g ha^{-1}), metsulfuron (8 g ha^{-1}) alone and combined application of chlorsulfuron + metribuzin (15 + 100 and 15 + 200 g ha^{-1}). Application of chlorsulfuron at 30 g ha^{-1} recorded significantly higher number of tillers amongst herbicidal treatments in both the years, which was closely followed by metsulfuron (8 g ha^{-1}), isoproturon (1000 g ha^{-1}) and combined application of chlorsulfuron + metribuzin (15 + 100 g and 15 + 200 g ha^{-1}) (Plate 2).

In herbicide treatments, metribuzin at 400 g ha^{-1} registered minimum increase in number of tillers as compared to weedy check in both the years. However, this treatment (400 g ha^{-1} metribuzin) was on par with its lower dose (200 g ha^{-1}) and combined application of metsulfuron + metribuzin (2 + 100 g and 2 + 200 g ha^{-1}) in 1996-97 but in 1997-98 differed significantly.

Table 19. **Effect of treatments on number of tillers (No. m^{-1}) of wheat at different stages of growth**

Treatments	1996-97 (Days after sowing)				1997-98 (Days after sowing)			
	30	60	90	120	30	60	90	120
1. Metsulfuron 4g	46.33	71.33	81.67	84.67	55.00	83.33	89.00	91.00
2. Metsulfuron 8g	47.39	76.67	86.67	90.00	52.33	87.67	94.00	97.00
3. Metribuzin 200g	46.33	70.33	77.00	79.00	50.00	80.00	85.00	88.33
4. Metribuzin 400g	45.33	67.00	74.33	77.67	51.00	72.67	80.00	83.00
5. Chlorsulfuron 15g	46.67	72.00	81.33	83.33	49.67	84.67	88.00	93.00
6. Chlorsulfuron 30g	45.00	78.67	87.67	90.67	49.33	89.33	95.00	98.67
7. Metsulfuron + metribuzin (2+200g)	45.33	70.67	74.67	79.33	49.67	80.33	85.00	87.67
8. Metsulfuron + metribuzin (2+100g)	46.00	71.00	75.00	80.33	50.67	81.00	85.33	88.00
9. Chlorsulfuron+metribuzin (15+100g)	45.33	77.67	86.67	89.33	51.00	88.67	93.33	97.00
10. Chlorsulfuron+metribuzin (15+200g)	45.67	78.33	87.00	89.00	50.00	89.00	93.67	97.33
11. Isoproturon 1000 g	46.33	74.33	83.67	86.67	49.67	85.33	91.33	94.67
14. Metsulfuron +isoproturon (2+500g)	45.33	70.00	77.00	79.00	49.93	78.00	84.67	86.33
13. Chlorsulfuron+isoproturon (15+500g)	44.67	73.67	81.67	83.00	50.27	85.00	90.00	92.00
14. Weedy check	46.00	66.33	70.00	72.00	46.67	74.67	78.67	81.00
15. Weed free	46.67	80.00	89.33	93.67	50.67	90.67	96.33	99.00
S.Em.(±)	2.14	1.83	1.43	1.75	3.02	1.34	1.36	1.62
CD at 5%	NS	5.30	4.11	5.06	NS	3.90	3.94	4.58

4.1.2.2 Yield and yield attributes

Data on various yield attributing characters viz., effective tillers per metre row length, length of earhead (cm), number of grains per earhead (spike), test weight (g) as influenced by different weed control treatments were recorded and presented in Table 20.

(a) Number of effective tillers

Number of effective tillers per metre row length of wheat crop increased significantly with the application of different weed control treatments. Season long weed free condition recorded significantly higher number of effective tillers (earbearing) in both the years, which was similar to chlorsulfuron (30 g ha^{-1}), metsulfuron (8 g ha^{-1}) and chlorsulfuron + metribuzin (15 + 100 g and 15 + 200 g ha^{-1}) treated plots.

In herbicide treatments, chlorsulfuron (30 g ha^{-1}) recorded significantly higher number of effective tillers in both the years which was closely followed by metsulfuron (8 g ha^{-1}), isoproturon (1000 g ha^{-1}) and combined application of chlorsulfuron + metribuzin (15 + 100 and 15 + 200 g ha^{-1}). Application of metribuzin at 400 g ha^{-1} registered minimum increase in number of effective tillers as compared to season long weedy condition in both the seasons (Table 20). However, the difference with its lower dose (200 g ha^{-1}) and tank mixed application of metsulfuron + metribuzin (2 + 100 g and 2 + 200 g ha^{-1}) was non-significant in 1996-97.

(b) Length of earhead

Application of all weed control treatments except chlorsulfuron (15 g ha^{-1}), metsulfuron (4 g ha^{-1}) and metsulfuron + isoproturon (2+500 g ha^{-1}) in

Table 20. *Effect of treatments on yield attributes of wheat crop*

Treatments	Effective tillers (m^{-1})		Length of earhead (cm)		Grains per ear head		Test weight (g)	
	1996-97	1997-98	1996-97	1997-98	1996-97	1997-98	1996-97	1997-98
1. Metsulfuron 4g	80.33	87.67	8.30	9.10	40.76	43.87	39.80	37.94
2. Metsulfuron 8g	86.67	94.00	8.50	9.20	43.60	45.80	40.26	38.92
3. Metribuzin 200g	74.00	81.00	8.50	8.80	41.93	43.49	41.93	38.24
4. Metribuzin 400g	73.00	77.67	8.80	9.10	43.00	44.00	42.00	40.00
5. Chlorsulfuron 15g	79.33	90.00	8.30	9.20	41.60	43.66	39.65	38.22
6. Chlorsulfuron 30g	88.00	96.00	8.90	9.40	44.23	47.26	41.96	39.17
7. Metsulfuron + metribuzin (2+200g)	74.00	82.00	8.50	8.70	40.66	43.40	39.72	38.67
8. Metsulfuron + metribuzin (2+100g)	74.33	83.00	8.50	8.90	41.46	43.23	39.86	38.43
9. Chlorsulfuron+metribuzin (15+100g)	86.67	95.00	8.90	9.40	43.93	46.83	42.00	39.77
10. Chlorsulfuron+metribuzin (15+200g)	87.00	95.67	8.80	9.50	44.00	47.00	42.10	39.93
11. Isoproturon 1000 g	85.67	92.00	8.70	9.30	43.83	46.49	41.95	39.10
12. Metsulfuron +isoproturon (2+500g)	72.00	80.00	8.10	8.90	41.00	43.37	39.26	37.19
13. Chlorsulfuron+isoproturon (15+500g)	78.67	87.00	8.60	9.20	42.63	44.20	41.30	38.23
14. Weedy check	66.67	74.00	7.90	8.40	38.43	40.00	39.98	36.67
15. Weed free	90.00	96.67	9.00	9.70	45.16	48.00	42.00	40.88
S.Em.(±)	2.12	1.09	0.14	0.14	0.57	1.15	1.78	0.63
CD at 5%	6.14	3.16	0.42	0.40	1.64	3.33	NS	1.83

1996-97 and metsulfuron + metribuzin (2 + 200 g ha^{-1}) in 1997-98 recorded significantly longer earhead as compared to weedy check in both the years (Table 20). The highest length of earhead was recorded in weed free plot which, however, was non-significant with chlorsulfuron (30 g ha^{-1}), chlorsulfuron + metribuzin (15 + 100 and 15 + 200 g ha^{-1}), metribuzin (400 g ha^{-1}), isoproturon (1000 g ha^{-1}) and chlorsulfuron + isoproturon (15 + 500 g ha^{-1}) treated plots during both the years except metribuzin (400 g ha^{-1}) and chlorsulfuron + isoproturon (15 + 500 g ha^{-1}) in 1997-98.

Amongst herbicide treatments, chlorsulfuron (30 g ha^{-1}) and tank mixture of chlorsulfuron + metribuzin (15 + 200 g ha^{-1}) recorded the maximum increase in the length of earhead in 1996-97 and 1997-98, respectively over weedy check. Season long uninhibited growth of weeds, however, recorded the shortest earhead in both the years.

(c) Grains per earhead

All weed control treatments except metsulfuron + metribuzin (2+100 g ha^{-1}) in 1997-98, brought about significant increase in the number of grains per earhead over weedy check during both the years (Table 20).

Weed free treatment recorded the highest (45.16 and 48.00) number of grains per earhead which, however, was found at par with chlorsulfuron (30 g ha^{-1}), isoproturon (1000 g ha^{-1}), chlorsulfuron + metribuzin (15 + 100 g and 15 + 200 g ha^{-1}) and metsulfuron (8 g ha^{-1}) in both the years except metsulfuron (8 g ha^{-1}) treatment in first year of experimentation.

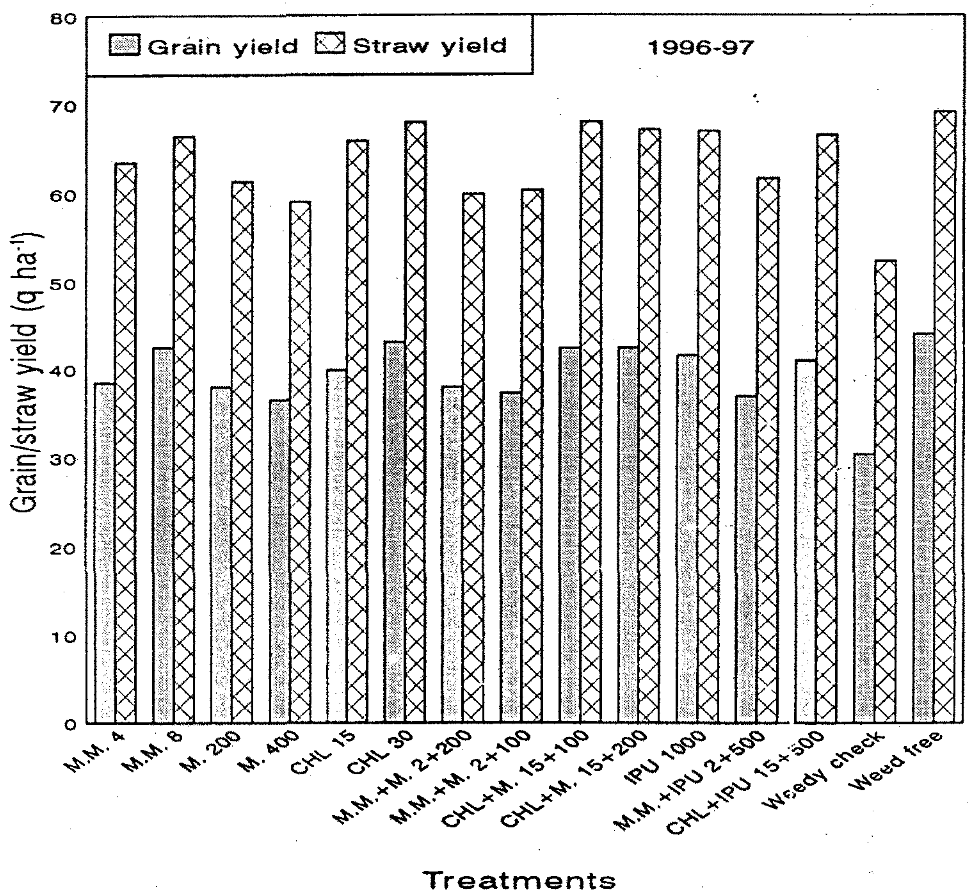
In herbicide treatments, chlorsulfuron at 30 g ha^{-1} obtained the maximum number of grains per earhead which was closely followed by isoproturon (1000 g ha^{-1}), metsulfuron (8 g ha^{-1}), chlorsulfuron + metribuzin (15 + 100 and 15 + 200 g ha^{-1}), chlorsulfuron + isoproturon (15+500 g ha^{-1}) and metribuzin at 400 g ha^{-1} in both the years of experimentation.

(d) Test weight (1000-grain weight)

Effect of weed control treatments on test weight turned out to be nonsignificant during 1996-97. However, in 1997-98, test weight was significantly affected due to the influence of various herbicidal treatments applied. During 1997-98, weed free treatment recorded the maximum test weight (40.88 g) which differed significantly from all treatments except chlorsulfuron at 30 g ha^{-1}, isoproturon 1000 g ha^{-1} and tank mixture of chlorsulfuron + metribuzin (15 + 100 g and 15 + 200 g ha^{-1}). Among herbicidal treatments, tank mixture of chlorsulfuron + metribuzin at 15 + 200 g ha^{-1} had significantly higher test weight (39.93 g) but its difference with other treatments except metsulfuron 4 g ha^{-1} and metsulfuron + isoproturon (2+500 g ha^{-1}) was nonsignificant during the second year of study. Test weight was comparatively more in the second year of investigation (Table 20).

(e) Grain yield

Grain yield (q ha^{-1}) of wheat was significantly influenced by weed control treatment in both the years (Table 21). However, the grain yield was comparatively higher in 1997-98 than that of 1996-97. But the efficacy of all weed control treatments was almost similar in both the years. Significantly higher increase in grain yield was recorded in season long weed free plot (44.0 and 50.00 q ha^{-1}) (Fig. 8) which was statistically on par



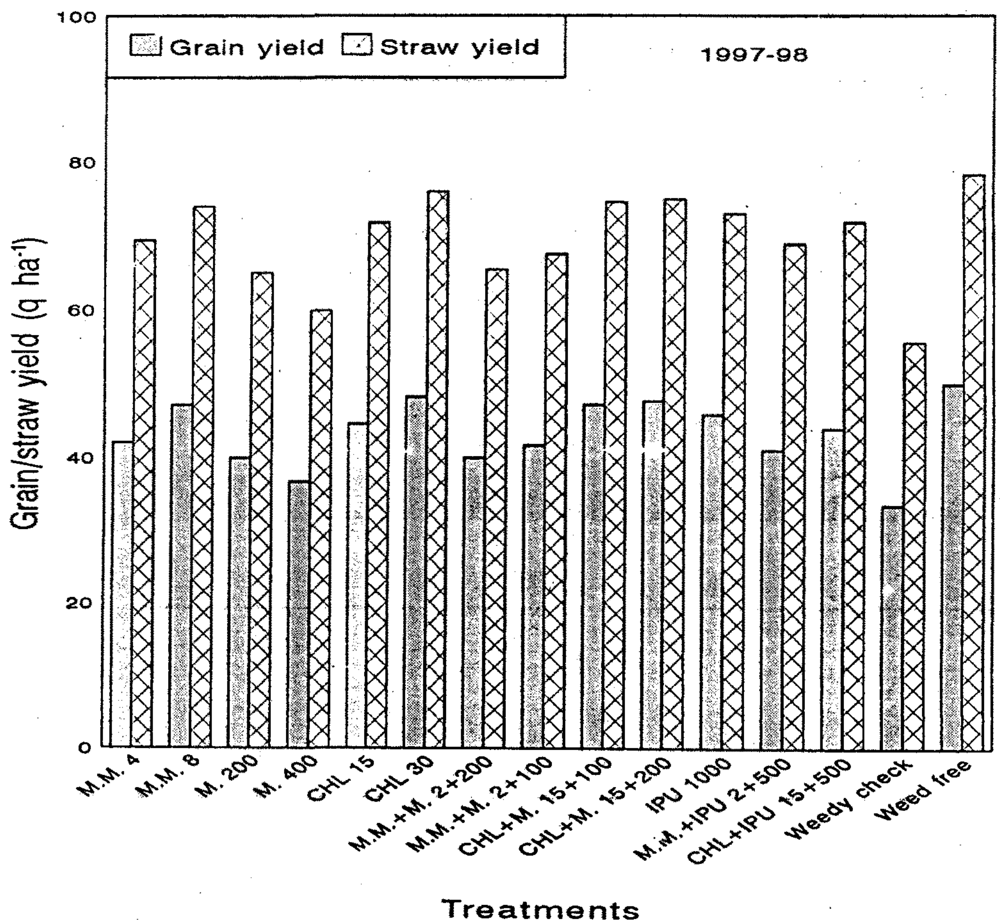


Fig.8 Effect of weed control treatments on grain and straw yield of wheat

Table 21 . Effect of treatments on grain and straw yield (q ha^{-1}) and harvest index (%) of wheat

Treatments	Grain yield		Straw yield		Harvest index	
	1996-97	1997-98	1996-97	1997-98	1996-97	1997-98
1. Metsulfuron 4g	38.48	42.04	63.43	69.26	37.75	37.76
2. Metsulfuron 8g	42.50	47.11	66.36	73.85	38.48	38.94
3. Metribuzin 200g	38.00	39.87	61.28	64.88	38.28	38.06
4. Metribuzin 400g	36.52	36.59	59.00	59.86	38.25	37.94
5. Chlorsulfuron 15g	39.87	44.55	65.83	71.68	37.72	38.33
6. Chlorsulfuron 30g	43.11	48.20	67.90	75.92	38.83	38.94
7. Metsulfuron + metribuzin (2+200g)	37.98	39.95	59.83	65.32	38.83	37.89
8. Metsulfuron + metribuzin (2+100g)	37.28	41.59	60.25	67.44	37.56	38.13
9. Chlorsulfuron+metribuzin (15+100g)	42.38	47.17	67.87	74.51	38.44	38.76
10. Chlorsulfuron+metribuzin (15+200g)	42.43	47.70	67.00	74.88	38.83	38.92
11. Isoproturon 1000 g	41.53	45.87	66.85	72.95	38.32	38.61
12. Metsulfuron +isoproturon (2+500g)	36.92	41.00	61.58	68.80	37.50	37.34
13. Chlorsulfuron+isoproturon (15+500g)	40.95	44.00	66.41	71.81	38.15	37.98
14. Weedy check	30.37	33.44	52.28	55.66	36.73	37.53
15. Weed free	44.00	50.00	69.00	78.17	38.94	39.01
S.Em.(±)	0.56	1.04	0.89	1.27	0.44	0.54
CD at 5%	1.62	3.00	2.58	3.67	1.29	NS

with chlorsulfuron at 30 g ha^{-1}, metsulfuron 8 g ha^{-1} and combined application of chlorsulfuron + metribuzin (15 + 100 g and 15 + 200 g ha^{-1}) during both the years.

Application of chlorsulfuron at 30 g ha^{-1} produced the highest grain yield (43.11 and 48.20 q ha^{-1}) amongst herbicidal treatments during both the seasons, however, its effect in increasing grain yield was at par with metsulfuron 8 g ha^{-1}, isoproturon 1000 g ha^{-1} and tank mixture of chlorsulfuron + metribuzin (15 + 100 and 15 + 200 g ha^{-1}) (Plate 2). While application of metribuzin at 400 g ha^{-1} resulted the lesser increase in grain yield of wheat amongst herbicidal treatments over weedy check during both the years (Plate 1). However, the difference with the grain yield recorded in metribuzin 200 g ha^{-1} and metsulfuron+ metribuzin (2 + 100 and 2 + 200 g ha^{-1}) treated plots was found significant during second year of the study.

(f) Straw yield

The application of weed control treatments significantly enhanced the straw yield of wheat in both the years (Table 21). In general, straw yield in each treatment was comparatively higher in the second year of investigation. The maximum straw yield of 69.00 and 78.17 q ha^{-1} was recorded in weed free plots in respective years of experimentation (Fig. 8). However, its difference in straw yield was non-significant with chlorsulfuron 30 g ha^{-1}, chlorsulfuron + metribuzin (15 + 100 and 15 + 200 g ha^{-1}), isoproturon 1000 g ha^{-1} and metsulfuron 8 g ha^{-1} in both the years except latter two treatments in 1997-98.

Application of 30 g of chlorsulfuron resulted in the highest gain in straw yield and varied significantly with rest of the treatments except its tank mixture with metribuzin (15 + 100 and 15 + 200 g ha^{-1}), isoproturon 1000 g ha^{-1}, metsulfuron 8 g ha^{-1}, chlorsulfuron + isoproturon (15 + 500 g ha^{-1}) and chlorsulfuron 15 g ha^{-1} in both the seasons except two latter treatments in 1997-98.

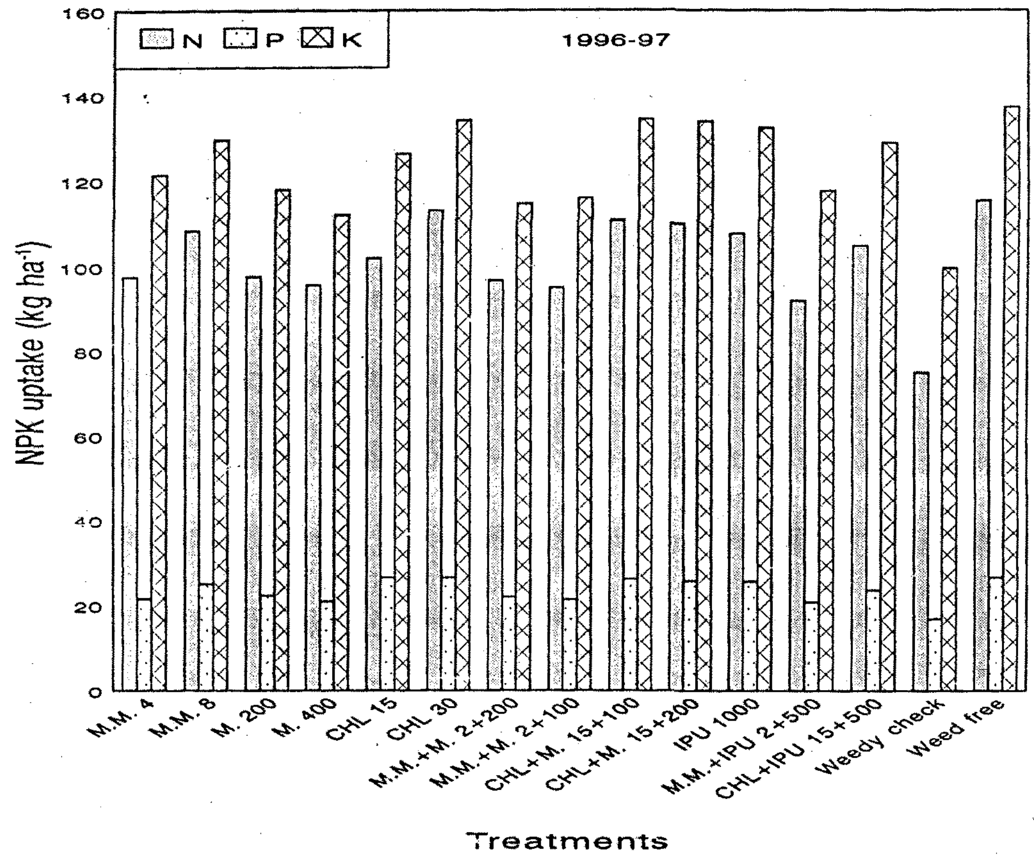
(g) Harvest index

Harvest index was not uniformly affected by various weed control treatments in both the years (Table 21). However, it was significantly affected due to application of different weed control measures in 1996-97, whereas in 1997-98 it remained unaffected.

Maximum and minimum increase in harvest index was recorded in weed free and unweeded plot, respectively in both the years. All herbicide treatments except metsulfuron + metribuzin (2 + 100 g ha^{-1}) and metsulfuron + isoproturon (2+ 500 g ha^{-1}) recorded significantly higher harvest index in 1996-97 over season long weedy check.

4.1.2.3 Nutrient studies

The data presented in Table 22, 23, 24 and depicted in Fig. 9 indicate that application of herbicides had no marked effect on NPK content in grain and straw over weedy check during both the years. However, their uptake by grain, straw and total uptake were significantly enhanced except P uptake by straw during both the years of experimentation. Total N and K uptake were comparatively higher during second year of experimentation.



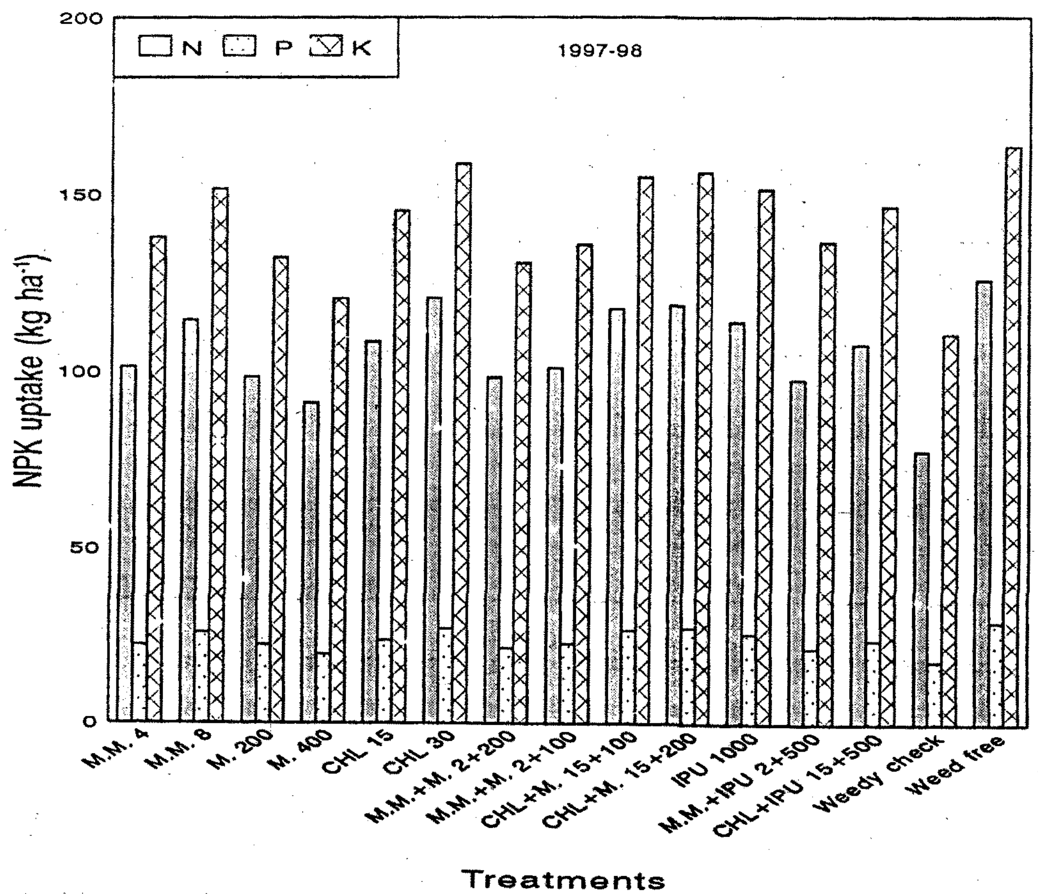


Fig.9 Effect of weed control treatments on total NPK uptake by wheat crop

(a) Nitrogen uptake (kg ha^{-1})

All weed control treatments except metsulfuron + isoproturon (2+500 g ha^{-1}) and metribuzin (400 g ha^{-1}) in 1997-98 recorded significant increase in N-uptake in grain as well as straw (Table 22). Weed free condition resulted in the highest N-uptake in grain (80.10 and 88.50 kg ha^{-1}) and straw (35.19 and 37.56 kg ha^{-1})during both the years. However, the difference was nonsignificant with other treatments except metribuzin 200 g ha^{-1}, metsulfuron + metribuzin (2+ 200 g ha^{-1}), metsulfuron 4 g ha^{-1} in 1997-98 and metsulfuron + isoproturon (2+500 g ha^{-1}), metribuzin 400 g ha^{-1}, metsulfuron + metribuzin (2+ 100 g ha^{-1}) in both the years.

As regards herbicide treatments, 30 g ha^{-1} of chlorsulfuron resulted the highest N-uptake in grain and straw during both the years. However, its difference with isoproturon 1000 g ha^{-1}, metsulfuron 8 g ha^{-1} and its lower dose alone i.e. chlorsulfuron 15 g ha^{-1} and incombination with metribuzin (100 and 200 g ha^{-1}) and isoproturon (500 g ha^{-1}) was non-significant in both the seasons. Similar performance of all weed control treatments was noticed with respect to total uptake of N in both the years.

(b) Phosphorus uptake (kg ha^{-1})

Weed control treatments did not bring significant variation in P content of grain and straw and P uptake of straw in both the years (Table 23; Fig. 9). However, its accumulation in grain increased significantly over weedy check.

Weed free condition promoted the highest P uptake in grain (21.98 and 23.56 kg ha^{-1}) which was closely followed by chlorsulfuron 30 g ha^{-1},

Table 22. Effect of treatments on nitrogen content and its uptake by wheat

Treatments	Nitrogen content (%)				Nitrogen uptake (kg ha^{-1})				Total uptake (kg ha^{-1})	
	Grain		Straw		Grain		Straw		1996-97	1997-98
	1996-97	1997-98	1996-97	1997-98	1996-97	1997-98	1996-97	1997-98		
1. Metsulfuron 4g	1.74	1.69	0.48	0.44	67.12	70.99	30.44	30.48	97.70	101.44
2. Metsulfuron 8g	1.79	1.71	0.49	0.46	75.90	80.56	32.51	33.97	108.41	114.53
3. Metribuzin 200g	1.80	1.74	0.48	0.45	68.35	69.37	29.41	29.17	97.76	98.55
4. Metribuzin 400g	1.81	1.74	0.50	0.46	66.12	63.66	29.49	27.53	95.63	91.18
5. Chlorsulfuron 15g	1.76	1.71	0.47	0.45	71.10	76.21	30.94	32.29	102.05	108.49
6. Chlorsulfuron 30g	1.82	1.75	0.51	0.48	78.47	84.42	34.65	36.44	113.12	120.86
7 Metsulfuron + metribuzin (2+200g)	1.80	1.73	0.48	0.45	68.02	69.09	28.73	29.43	96.75	98.52
8. Metsulfuron + metribuzin (2+100g)	1.79	1.72	0.47	0.44	66.73	71.34	28.32	29.71	95.05	101.05
9. Chlorsulfuron+metribuzin (15+100g)	1.80	1.74	0.51	0.48	76.23	82.04	34.61	35.76	110.84	117.80
10.Chlorsulfuron+metribuzin (15+200g)	1.82	1.75	0.49	0.47	77.24	83.65	32.84	35.18	110.07	118.83
11. Isoproturon 1000 g	1.79	1.74	0.50	0.47	74.34	79.81	33.38	34.26	107.72	114.07
13. Metsulfuron +isoproturon (2+500g)	1.72	1.68	0.46	0.42	63.50	68.88	28.33	28.90	91.82	97.78
13.Chlorsulfuron+isoproturon (15+500g)	1.78	1.72	0.48	0.45	72.97	75.55	31.88	32.28	104.85	107.83
14. Weedy check	1.71	1.66	0.44	0.44	51.95	55.49	22.98	22.27	74.93	77.76
15. Weed free	1.82	1.77	0.51	0.48	80.10	88.50	35.19	37.56	115.29	126.07
S.Em.(±)	0.08	0.07	0.02	0.02	4.52	4.62	1.98	1.85	5.13	4.23
CD at 5%	NS	NS	NS	NS	13.10	13.39	5.74	5.37	14.86	12.25

Table 23. **Effect of treatments on phosphorus content and its uptake by wheat**

Treatments	P-content (%)				P-uptake (kg ha^{-1})				Total uptake (kg ha^{-1})	
	Grain		Straw		Grain		Straw			
	1996-97	1997-98	1996-97	1997-98	1996-97	1997-98	1996-97	1997-98	1996-97	1997-98
1. Metsulfuron 4g	0.46	0.42	0.06	0.07	17.72	17.64	4.00	4.72	21.71	22.36
2. Metsulfuron 8g	0.49	0.44	0.07	0.07	20.78	20.73	4.38	5.34	25.16	26.07
3. Metribuzin 200g	0.48	0.44	0.07	0.08	18.26	17.55	4.13	4.87	22.39	22.43
4. Metribuzin 400g	0.47	0.42	0.06	0.07	17.24	15.36	3.83	4.32	21.07	19.68
5. Chlorsulfuron 15g	0.47	0.42	0.06	0.07	18.73	18.70	4.20	5.08	26.59	23.78
6. Chlorsulfuron 30g	0.51	0.45	0.07	0.08	21.98	21.70	4.61	5.69	26.59	27.39
7. Metsulfuron + metribuzin (2+200g)	0.48	0.42	0.06	0.07	18.23	16.80	3.80	4.71	22.12	21.50
8. Metsulfuron + metribuzin (2+100g)	0.47	0.43	0.07	0.07	17.47	17.88	3.97	4.93	21.44	22.81
9. Chlorsulfuron+metribuzin (15+100g)	0.51	0.45	0.07	0.08	21.60	21.22	4.62	5.59	26.22	26.80
10. Chlorsulfuron+metribuzin (15+200g)	0.50	0.46	0.07	0.08	21.22	21.94	4.62	5.60	25.84	27.53
11. Isoproturon 1000 g	0.51	0.45	0.07	0.06	21.17	20.63	4.55	5.21	25.72	25.85
12. Metsulfuron +isoproturon (2+500g)	0.46	0.41	0.06	0.08	16.98	16.81	3.88	4.75	20.87	21.56
13. Chlorsulfuron+isoproturon (15+500g)	0.47	0.43	0.06	0.07	19.27	18.90	4.34	5.17	23.61	24.07
14. Weedy check	0.45	0.41	0.06	0.07	13.70	13.75	3.25	3.79	16.94	17.88
15. Weed free	0.50	0.47	0.07	0.08	21.98	23.56	4.68	5.86	26.66	29.42
S.Em.(±)	0.03	0.01	0.01	0.01	1.04	0.98	0.58	0.47	1.60	1.30
CD at 5%	NS	NS	NS	NS	3.00	2.64	NS	NS	4.63	3.76

chlorsulfuron + metribuzin (15 – 100 and 15 + 200 g ha^{-1}), metsulfuron 8 g ha^{-1} isoproturon 1000 g ha^{-1} and chlorsulfuron + isoproturon (15 + 500 g ha^{-1}) in both the years except latter three treatments in second year.

Application of chlorsulfuron at 30 g ha^{-1} resulted in the maximum P uptake in grain in both the years but did not vary significantly with its tank mixture at lower dose with metribuzin (15 + 100 and 15 + 200 g ha^{-1}) and application of metsulfuron alone (8 g ha^{-1}) and isoproturon 1000 g ha^{-1}. But the application of metribuzin at 400 g ha^{-1} in 1997-98 did not cause significant increase in P-uptake in grain as compared to unweeded control. Variation in weed control treatments effected marked increase in total P-uptake in both the years. Of the weed control treatments, season long weed free condition resulted in the highest total P-uptake in both the years, however, it remained statistically at par with all other treatments except metribuzin 400 g ha^{-1}, metsulfuron 4 g ha^{-1} alone and its combination with metribuzin (100 g ha^{-1}) and isoproturon (500 g ha^{-1}) separately during 1996-97. Whereas in 1997-98, weed free treatment was at par with metsulfuron 8 g ha^{-1}, isoproturon 1000 g ha^{-1} and chlorsulfuron 30 g ha^{-1} alone and its tank mixture at lower dose with metribuzin (15 + 100 and 15 + 200 g ha^{-1}) and isoproturon (15 + 500 g ha^{-1}). Among the herbicide treatments, chlorsulfuron at 30 g ha^{-1} and chlorsulfuron + metribuzin (15 + 200 g ha^{-1}) remained at par with each other and recorded significantly higher total P-uptake by wheat in 1996-97 and 1997-98, respectively.

(c) Potassium uptake (kg ha^{-1})

The data pertaining to the influence of different weed control treatments on K content and its uptake in grain and straw and on total uptake are presented in Table 24 and exhibited in Fig. 9. The difference in potassium content of grain and straw amongst different weed control treatments was found non-significant. But the difference in its uptake in both grain and straw and in total was found highly significant. Maximum uptake of potassium in grain (19.78 and 24.48 kg ha^{-1}), straw (117.29 and 139.16 kg ha^{-1}) and total uptake (137.08 and 163.65 kg ha^{-1}) were recorded under weed free situation which was closely followed by metsulfuron 8 g ha^{-1}, isoproturon 1000 g ha^{-1} and chlorsulfuron at 30 g ha^{-1} alone and its tank mixture at lower dose with metribuzin. However, it differed significantly with metribuzin 400 g, metsulfuron + metribuzin (2 + 200 and 2 + 100 g ha^{-1}) and metsulfuron + isoproturon (2 + 500 g ha^{-1}) in K uptake in grain during both the years. Whereas the lowest uptake of K was recorded in weedy check in both grain and straw in both the years which, however, was found statistically similar to metsulfuron + metribuzin (2 + 200 and 2 + 100 g ha^{-1}), metsulfuron + isoproturon (2+500 g ha^{-1}) and metribuzin at 200 and 400 g ha^{-1}.

Total K uptake was significantly higher under all the herbicidal treatment in both the years. However, uptake of K by both grain and straw and variation in their values amongst various weed control treatment was comparatively larger during second year of experimentation.

4.1.2.4 Residual effect on kharif season weeds

Weed population (No. m^{-2}) and dry weight (g m^{-2})

(a) *Trianthema portulacastrum* L.

All the herbicide treatments applied either alone or incombination with others in wheat crop except metsulfuron 4 g ha^{-1} and metribuzin 200

Table 24. Effect of treatments on potassium content and its uptake by wheat

Treatments	K- content (%)				K-uptake (kg ha^{-1})				Total uptake (kg ha^{-1})	
	Grain		Straw		Grain		Straw			
	1996-97	1997-98	1996-97	1997-98	1996-97	1997-98	1996-97	1997-98	1996-97	1997-98
1. Metsulfuron 4g	0.42	0.43	1.66	1.73	16.16	18.13	105.20	119.84	121.45	137.96
2. Metsulfuron 8g	0.43	0.46	1.68	1.76	18.23	21.67	111.50	129.98	129.73	151.65
3. Metribuzin 200g	0.43	0.47	1.66	1.75	16.33	18.74	101.74	113.55	118.07	132.29
4. Metribuzin 400g	0.42	0.45	1.64	1.74	15.34	16.49	96.76	104.17	112.10	120.66
5. Chlorsulfuron 15g	0.43	0.47	1.66	1.74	17.17	20.94	100.27	124.50	126.44	145.39
6. Chlorsulfuron 30g	0.45	0.49	1.69	1.78	19.40	23.62	114.73	135.13	134.13	158.74
7. Metsulfuron + metribuzin (2+200g)	0.42	0.44	1.65	1.73	15.95	17.68	98.52	113.01	114.67	130.68
8. Metsulfuron + metribuzin (2+100g)	0.43	0.45	1.66	1.74	16.01	18.68	100.02	117.27	116.03	135.95
9. Chlorsulfuron+metribuzin (15+100g)	0.45	0.48	1.70	1.77	19.06	23.11	115.37	131.84	134.43	154.94
10. Chlorsulfuron+metribuzin (15+200g)	0.44	0.48	1.69	1.78	18.64	22.85	115.20	133.35	133.84	156.26
11. Isoproturon 1000 g	0.44	0.48	1.70	1.78	18.25	21.56	114.30	129.89	132.37	151.45
12. Metsulfuron +isoproturon (2+500g)	0.42	0.44	1.66	1.73	15.51	17.67	102.10	119.03	117.61	136.70
13. Chlorsulfuron+isoproturon (15+500g)	0.43	0.44	1.67	1.76	17.64	19.77	110.87	126.90	128.84	146.67
14. Weedy check	0.42	0.43	1.66	1.73	12.80	14.37	96.70	96.32	99.50	110.69
15. Weed free	0.45	0.47	1.70	1.78	19.78	24.48	117.29	139.16	137.08	163.65
S.Em.(±)	0.02	0.02	0.04	0.04	1.28	1.26	2.80	4.24	2.97	4.23
CD at 5%	NS	NS	NS	NS	3.71	3.64	8.12	12.28	8.59	12.25

g ha^{-1} significantly affected the population of *Trianthema portulacastrum* as compared to untreated plots (Table 25). However, its dry weight was significantly lower in all the herbicide treated plots. No specific trend of their residual effect on population and dry weight was recorded in respect of all the treatments. No single plant of this weed was found in 30 g chlorsulfuron treated plot (Plate 3). While the second lowest value of its count and dry weight was obtained in 400 g ha^{-1} metribuzin treated plot. The treatments involving combination recorded higher and lower decrease in the population and dry weight of *Trianthema portulacastrum*, respectively as compared to their individual application irrespective of dose and herbicide.

(b) *Echinochloa colonum* (L.) Link (Jungle rice)

All herbicide treated plots except metsulfuron 4 g ha^{-1} recorded lower population of this weed as compared to untreated plots (Table 25). However, the dry weight of *E. colonum* was significantly lower in all herbicide treated plots.

Amongst herbicide treated plots chlorsulfuron 30 g ha^{-1} and metribuzin 400 g ha^{-1} treated plots recorded significantly higher reduction in its population and dry weight as compared to untreated plots (Plate 3). The treatments involving combined application of chlorsulfuron + metribuzin (15 + 100 g and 15 + 200 g ha^{-1}), chlorsulfuron + isoproturon (15 + 500 g ha^{-1}) and metsulfuron + metribuzin (2+ 100 and 2+ 200 g ha^{-1}) recorded higher reduction in population and dry weight of *Echinochloa colonum* as compared to their individual application. The highest

Table 25. Residual effect of herbicide treatments applied in wheat on *Kharif* season weeds during 1998

Treatments	*Trianthema portulacastrum**		*Echinochloa colonum*	
	Weed population (No. m^{-2})	Weed dry weight (g m^{-2})	Weed population (No. m^{-2})	Weed dry weight (g m^{-2})
1. Metsulfuron 4g	19.14 (368.00)	9.69 (93.80)	340.00	40.40
2. Metsulfuron 8g	17.29(300.00)	8.68 (74.92)	288.00	39.48
3. Metribuzin 200g	20.18 (408.00)	12.78 (163.00)	248.00	49.76
4. Metribuzin 400g	6.30 (40.00)	4.82 (23.36)	51.00	28.96
5. Chlorsulfuron 15g	15.86 (252.00)	9.25 (85.32)	168.00	43.36
6. Chlorsulfuron 30g	0.71 (0.00)	0.71 (0.00)	40.00	25.04
7. Metsulfuron+metribuzin (2+200g)	17.06 (296.00)	12.27 (150.28)	138.00	28.28
8. Metsulfuron+metribuzin (2+100g)	15.71 (248.00)	11.27 (126.92)	128.00	28.52
9. Chlorsulfuron+metribuzin (15+100g)	11.32 (128.00)	8.80 (77.20)	150.00	40.40
10.Chlorsulfuron+metribuzin (15+200g)	10.01 (100.00)	10.43 (108.28)	120.00	35.24
11. Isoproturon 1000 g	9.34 (88.00)	8.07 (64.88)	168.00	43.68
12. Metsulfuron+isoproturon (2+500g)	16.98 (288.00)	11.64 (135.00)	184.00	76.96
13. Chlorsulfuron+isoproturon (15+500g)	13.25 (176.00)	10.85 (117.64)	116.00	38.68
14. Weedy check	20.46 (420.00)	14.14 (200.00)	300.00	93.24
15. Weed free	19.70 (390.00)	13.83 (191.00)	310.00	98.76
S.Em.(±)	0.80	0.32	4.86	1.86
CD at 5%	2.32	0.92	14.08	5.39

*Data subjected to $\sqrt{x+0.5}$ transformation as there was zero value in one treatment.
Figures in parentheses are original values

Metri
400 g

Chlorsulfuron
30 g

B

Weed free
(untreated)

C

Plate 3. Studies on the residual effect of herbicides applied in wheat crop on <u>Trianthema portulacastrum</u> and <u>Echinochloa colonum</u> in <u>kharif</u> season (1997-98)

population and the highest dry weight of *E. colonum* amongst herbicide treated plots were recorded in metsulfuron 4 g ha^{-1} and metsulfuron + isoproturon (2 + 500 g ha^{-1}), respectively.

Besides the above two weeds, experimental plots were heavily and uniformly infested with *Cyperus rotundus* (data not given) irrespective of the dose, herbicide and combination (Plate 3).

4.1.2.5 Residual effect of herbicides applied in wheat on sorghum

(a) Growth studies

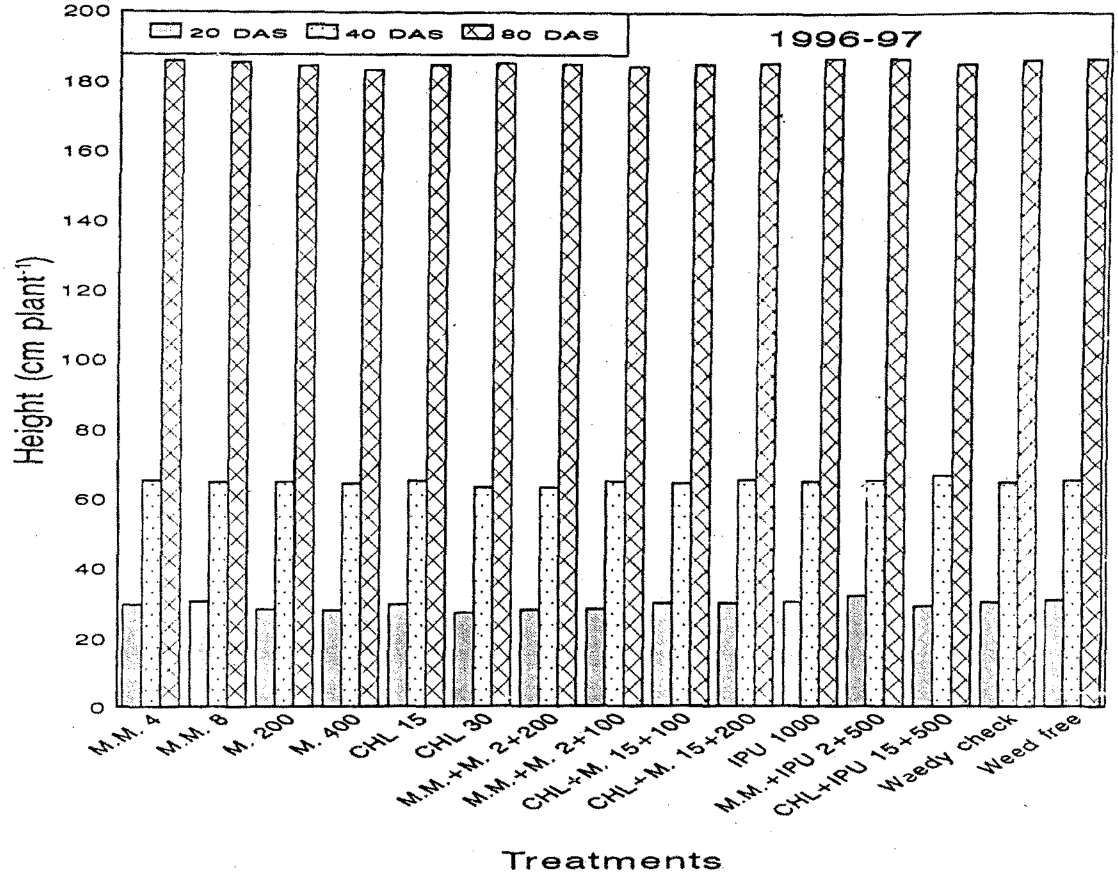
Following growth parameters of sorghum grown after wheat at different growth stages were recorded to study the effect of residues of herbicides applied in wheat.

(i) Plant stand (No.m^{-1})

Data presented in Table 26 illustrate that the residues of herbicides applied in wheat did not affect emergence of sorghum at all stages of observation during both the years (Plate 4). However, plant stand was comparatively more in first year of experimentation.

(ii) Plant height (cm)

Data presented in Table 27 and Fig. 10 indicate that height of sorghum plants during 1996-97 was not affected due to herbicidal treatments applied in wheat. However, in 1997-98 plant height was significantly effected at all stages except 20 DAS. Sorghum plants were comparatively taller in first year than that of second year at 40 and 80 DAS.



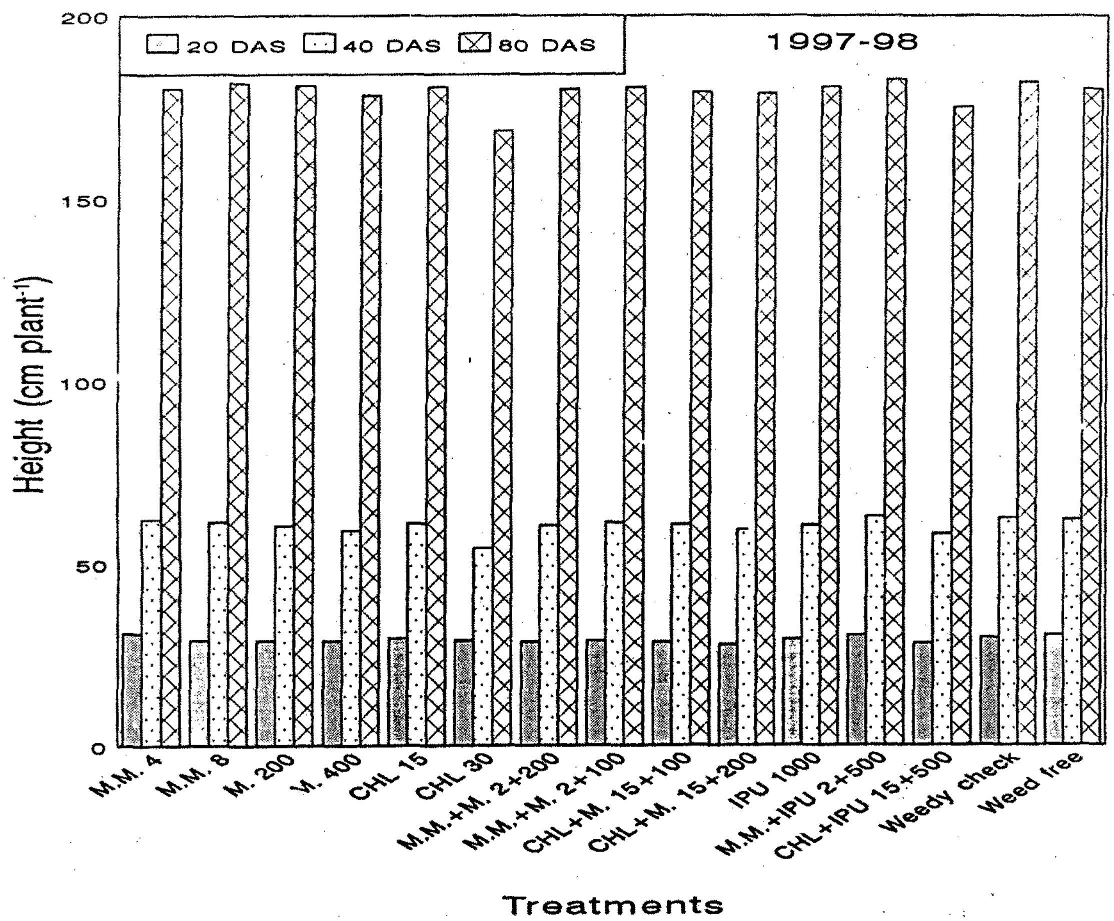


Fig.10 Effect of different herbicide residues on height of sorghum plant (Field bioassay study)

Table 26. Effect of herbicide residues on plant stand of sorghum (No. m^{-1})

Treatments	1996-97 (Days after sowing)			1997-98 (Days after sowing)		
	20	40	80	20	40	80
1. Metsulfuron 4g	125.67	135.00	108.00	115.00	127.00	95.33
2. Metsulfuron 8g	124.00	134.00	107.67	117.67	126.67	94.67
3. Metribuzin 200g	125.33	134.67	107.00	114.00	128.00	94.00
4. Metribuzin 400g	125.00	133.67	107.67	113.67	125.33	92.67
5. Chlorsulfuron 15g	124.33	135.33	108.33	113.33	127.67	94.33
6. Chlorsulfuron 30g	124.67	133.67	108.67	112.00	124.67	91.67
7. Metsulfuron+metribuzin (2+200g)	124.67	133.00	107.67	113.00	127.00	93.00
8. Metsulfuron+metribuzin (2+100g)	124.67	134.33	107.33	113.00	126.67	93.67
9. Chlorsulfuron+metribuzin (15+100g)	125.00	133.67	107.67	114.00	126.33	93.00
10. Chlorsulfuron+metribuzin (15+200g)	125.00	134.00	107.33	114.00	127.33	94.00
11. Isoproturon 1000 g	126.00	134.67	108.00	116.33	126.00	94.33
12. Metsulfuron +isoproturon (2+500g)	126.33	135.33	108.33	115.33	125.67	94.67
13. Chlorsulfuron+ isoproturon (15+500g)	124.67	134.67	107.67	114.67	126.33	94.33
14. Weedy check	126.33	135.00	108.67	115.00	128.00	93.00
15. Weed free	125.67	135.67	107.33	115.33	127.33	95.33
S.Em.(±)	3.98	3.46	3.72	3.47	3.10	3.37
CD at 5%	NS	NS	NS	NS	NS	NS

Table 27. Effect of herbicide residues on height of sorghum plant (cm)

Treatments	1996-97 (Days after sowing)			1997-98 (Days after sowing)		
	20	40	80	20	40	80
1. Metsulfuron 4g	29.60	65.32	185.81	30.93	62.27	180.13
2. Metsulfuron 8g	30.47	64.73	185.44	28.92	61.58	181.60
3. Metribuzin 200g	28.23	64.87	184.39	28.83	60.40	180.86
4. Metribuzin 400g	27.92	64.35	183.21	28.81	59.10	178.12
5. Chlorsulfuron 15g	29.46	65.17	184.69	29.48	61.07	180.47
6. Chlorsulfuron 30g	27.01	63.11	185.11	28.85	54.27	168.40
7. Metsulfuron+metribuzin (2+200g)	27.95	64.83	184.91	28.53	60.55	179.80
8. Metsulfuron+metribuzin (2+100g)	28.13	64.35	184.38	28.76	61.20	180.40
9. Chlorsulfuron+metribuzin (15+100g)	29.88	65.32	185.05	28.33	60.73	178.95
10. Chlorsulfuron+metribuzin (15+200g)	29.91	64.95	185.45	27.55	59.27	178.73
11. Isoproturon 1000 g	30.18	65.23	186.87	29.15	60.47	180.48
12. Metsulfuron +isoproturon (2+500g)	31.87	66.81	186.81	30.28	62.78	182.53
13. Chlorsulfuron+ isoproturon (15+500g)	29.11	64.97	185.23	27.98	58.07	174.86
14. Weedy check	30.21	65.58	186.41	29.51	62.49	181.83
15. Weed free	30.82	65.71	186.84	30.21	61.98	179.92
S.Em.(±)	2.97	8.97	4.44	1.85	1.43	2.51
CD at 5%	NS	NS	NS	NS	4.15	7.26

(A)

(B)

(C)

Plate 4. Studies on residual effect of herbicides (metribuzin 400 g (A) and chlorsulfuron 30 g (B) applied in wheat on the growth of sorghum succeeding crop

Significantly lowest height of sorghum plant (54.27 and 168.40 cm) was recorded at 40 and 80 DAS in those plots wherein chlorsulfuron 30 g ha^{-1} applied in wheat (Plate 4) and found at par with chlorsulfuron + isoproturon (15 + 500 g ha^{-1}). But the difference in height amongst other treatments was at par.

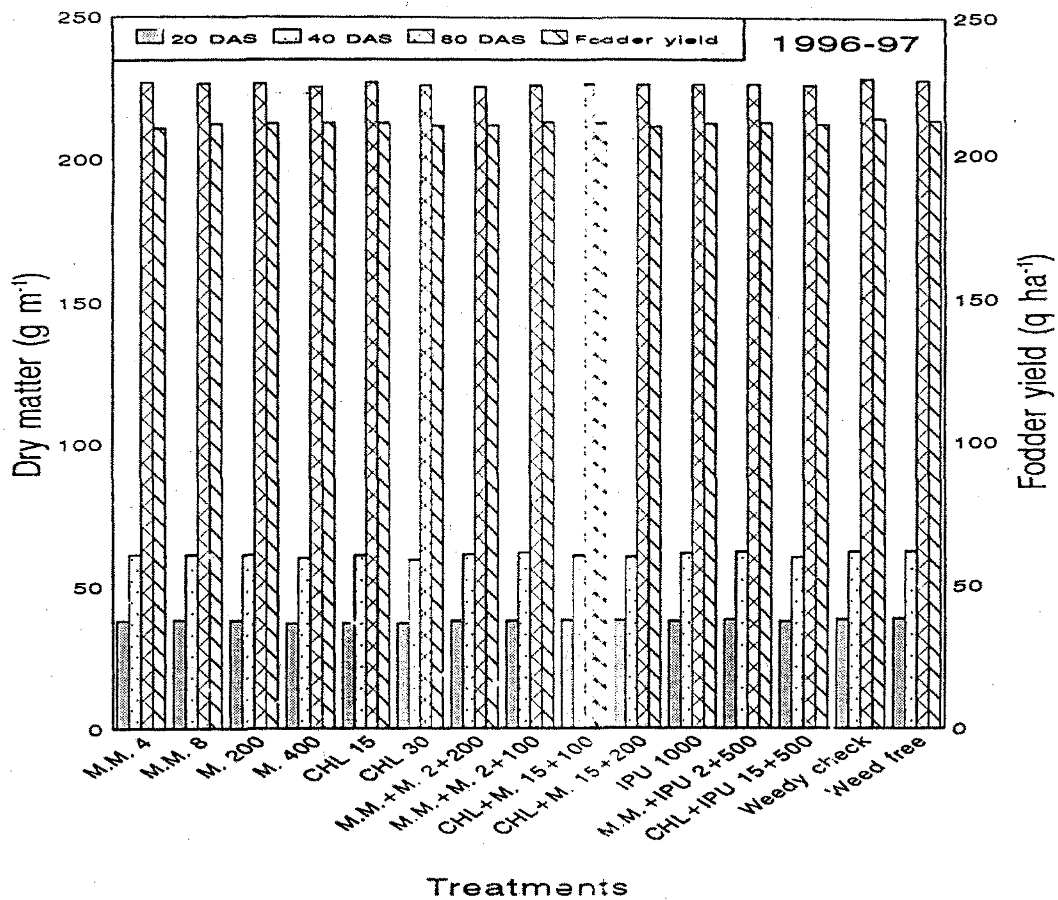
(iii) Average fresh weight (g m^{-1})

The data pertaining to average fresh weight per metre row length presented in Table 28 revealed that the application of herbicidal treatments in wheat crop did not have any significant effect on fresh weight accumulation of sorghum except at 40 and 80 DAS in 1997-98. Fresh weight was comparatively more in 1996-97 than 1997-98. The lowest fresh weight of sorghum (174.21 g m^{-1}) (40 DAS) was recorded in those plots where chlorsulfuron was applied at 30 g ha^{-1} at both 40 and 80 DAS (Plate 4). However, its difference with fresh weight obtained in plots treated with metribuzin 400 g ha^{-1} (178.00 g) and chlorsulfuron + isoproturon (15 + 500 g ha^{-1}) (178.01 g) was non-significant

(iv) Average dry matter accumulation (g m^{-1})

Data presented in Table 29 and depicted in Fig. 11 show that there was no significant effect of herbicidal treatments applied in wheat on dry matter accumulation of sorghum in both the years except at 40 and 80 DAS in 1997-98. In general dry matter accumulation decreased with increase in dosage of herbicides.

The lowest dry matter accumulation of sorghum (46.93 g at 40 DAS and 210.81 g at 80 DAS) was recorded in those plots where



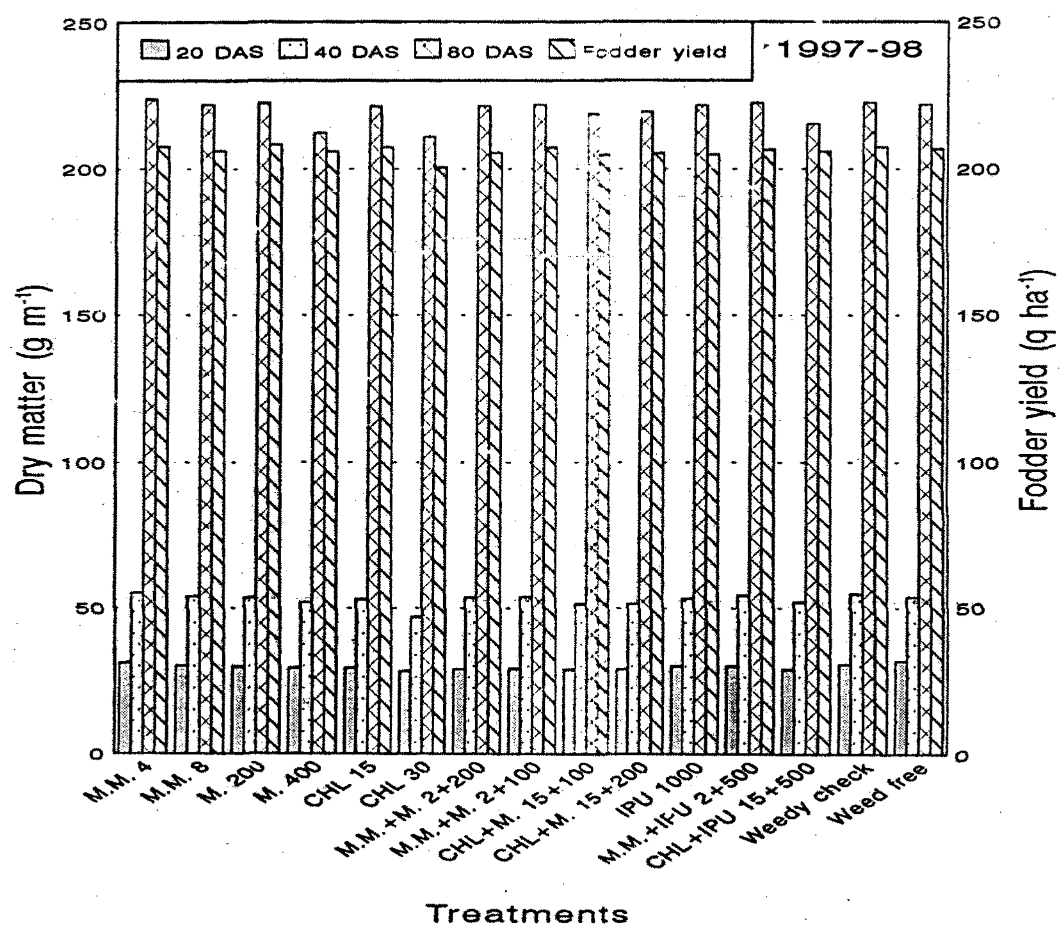


Fig. 11 Effect of different herbicide residues on dry matter production and fodder yield of sorghum (Field bioassay study)

Table 28. Effect of herbicide residues on fresh weight of sorghum plants (g m^{-1})

Treatments	1996-97 (Days after sowing)			1997-98 (Days after sowing)		
	20	40	80	20	40	80
1. Metsulfuron 4g	65.11	192.84	993.73	62.31	183.29	975.48
2. Metsulfuron 8g	65.17	192.93	993.22	61.97	182.26	972.08
3. Metribuzin 200g	64.95	192.52	993.10	60.81	180.67	973.43
4. Metribuzin 400g	64.15	191.22	991.73	60.17	178.00	967.04
5. Chlorsulfuron 15g	64.34	192.63	993.51	60.85	182.56	973.74
6. Chlorsulfuron 30g	64.12	190.76	990.24	60.02	174.21	963.33
7. Metsulfuron+metribuzin (2+200g)	64.19	192.97	991.95	60.98	180.34	972.39
8. Metsulfuron+metribuzin (2+100g)	64.21	193.00	992.33	61.28	180.78	973.21
9. Chlorsulfuron+metribuzin (15+100g)	65.02	192.38	992.10	59.12	179.00	971.57
10. Chlorsulfuron+metribuzin (15+200g)	64.98	192.61	991.89	60.22	179.71	971.68
11. Isoproturon 1000 g	64.87	191.33	992.35	61.26	180.08	972.16
12. Metsulfuron +isoproturon (2+500g)	65.77	193.00	992.26	62.01	182.43	975.75
13. Chlorsulfuron+ isoproturon (15+500g)	65.10	192.39	991.98	61.84	178.01	968.21
14. Weedy check	66.51	193.83	993.50	62.00	182.79	975.13
15. Weed free	66.00	193.62	992.88	61.11	181.87	973.27
S.Em.(±)	1.99	2.48	2.67	3.95	1.49	1.78
CD at 5%	NS	NS	NS	NS	4.31	5.15

Table 29. Effect of herbicide residues on dry matter production (g m^{-1}) and fodder yield (q ha^{-1}) of sorghum

Treatments	1996-97 (Days after sowing)			1997-98 (Days after sowing)			Fodder yield (q ha^{-1})	
	20	40	80	20	40	80	1996-97	1997-98
1. Metsulfuron 4g	37.93	61.22	226.63	31.31	55.13	223.72	210.44	207.73
2. Metsulfuron 8g	38.21	61.01	226.25	30.28	54.01	221.71	211.91	206.13
3. Metribuzin 200g	37.98	61.01	226.14	29.98	53.55	222.35	211.87	208.28
4. Metribuzin 400g	37.02	59.88	224.82	29.51	51.86	212.21	211.95	205.89
5. Chlorsulfuron 15g	37.11	60.81	226.50	29.46	52.87	221.13	211.82	207.32
6. Chlorsulfuron 30g	36.97	59.12	225.23	28.42	46.93	210.81	210.74	200.48
7. Metsulfuron + metribuzin (2+200g)	37.78	61.12	224.74	29.11	53.58	221.28	210.77	205.43
8. Metsulfuron + metribuzin (2+100g)	37.81	61.66	225.15	29.18	53.72	221.79	211.83	207.26
9. Chlorsulfuron+metribuzin (15+100g)	38.05	60.65	225.67	29.00	51.28	218.68	211.31	204.73
10. Chlorsulfuron+metribuzin (15+200g)	37.94	60.13	225.36	29.10	51.43	219.35	210.05	205.32
11. Isoproturon 1000 g	37.55	61.27	225.52	30.12	53.24	221.46	211.16	204.89
12. Metsulfuron +isoproturon (2+500g)	38.12	61.78	225.48	30.15	54.30	222.39	211.37	206.53
13. Chlorsulfuron+isoproturon (15+500g)	37.59	60.02	225.10	28.98	52.01	215.19	210.75	205.95
14. Weedy check	38.31	61.94	227.55	30.73	54.79	222.51	212.85	207.34
15. Weed free	38.55	61.98	226.97	31.89	53.73	221.71	211.92	206.77
S.Em.(±)	1.43	1.22	2.20	1.78	1.36	1.59	3.11	1.35
CD at 5%	NS	NS	NS	NS	3.94	4.61	NS	NS

chlorsulfuron was applied in wheat crop during 1997-98. However, it was at par with metribuzin 400 g ha^{-1} (112.21 g) and chlorsulfuron + isoproturon (215.19 g) at 80 DAS (Plate 4).

(v) Fodder yield (q ha^{-1})

The data presented in Table 29 and Fig. 11 indicated that there was no significant difference in fodder yield due to herbicidal treatments applied in wheat crop during both the years. However, the magnitude of difference in fodder yield was comparatively higher during second year of experimentation due to herbicidal treatments. The highest fodder yield (208.28 q ha^{-1}) was obtained in plots where metribuzin was applied at 200 g ha^{-1} in second year of investigation.

(b) Fodder quality

Data on protein content, tannin content and IVDMD of forage sorghum at 40 DAS as affected by weed control treatments applied in wheat in 1997-98 are presented in Table 30 and shown in Fig. 12.

(i) Protein content (%)

Protein content of sorghum was not affected by different weed control treatments applied in wheat crop.

(ii) Tannin content (%)

Unlike protein, tannin content of sorghum varied significantly due to the residues of herbicides applied in wheat. However, there is no specific trend obtained amongst the treatments but some idea about variation in tannin content with respect to herbicides residues can be drawn from the data obtained indicating an increase in tannin content with increase in

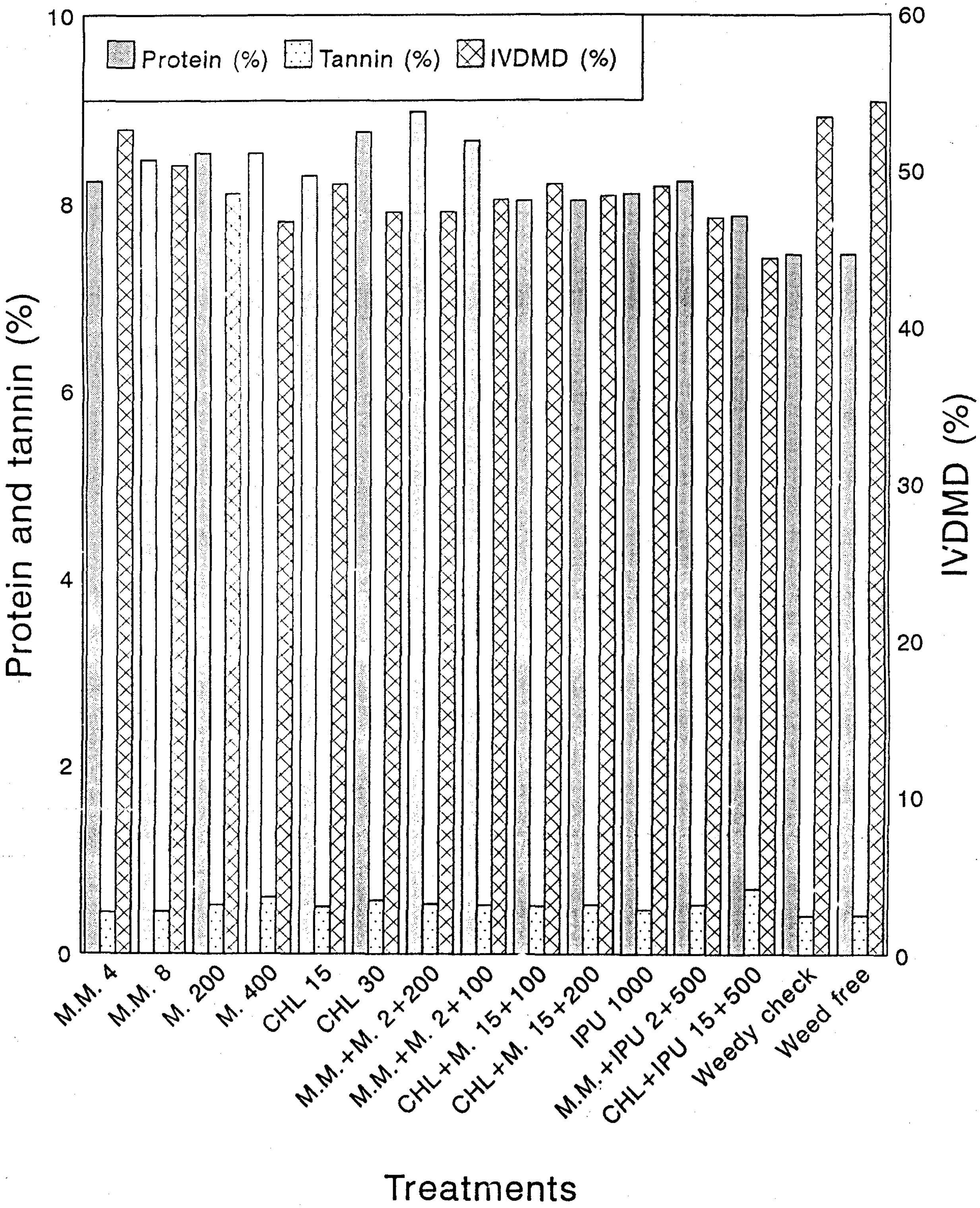


Fig. 12 Effect of different herbicide residues applied in wheat on protein, tannin and IVDMD of sorghum crop grown after wheat (Field bioassay study)

Table 30. Effect of herbicide residues applied in wheat on protein (%), tannin (%) and IVDMD (%) of sorghum plants grown after wheat crop

Treatments	Protein (%)	Tannin (%)	IVDMD (%)
1. Metsulfuron 4g	8.23	0.44	52.70
2. Metsulfuron 8g	8.46	0.45	50.40
3. Metribuzin 200g	8.53	0.52	48.60
4. Metribuzin 400g	8.53	0.60	46.80
5. Chlorsulfuron 15g	8.29	0.50	49.20
6. Chlorsulfuron 30g	8.75	0.57	47.40
7. Metsulfuron + metribuzin (2+200g)	8.97	0.53	47.40
8. Metsulfuron + metribuzin (2+100g)	8.66	0.52	48.20
9. Chlorsulfuron+metribuzin (15+100g)	8.02	0.51	49.20
10. Chlorsulfuron+metribuzin (15+200g)	8.02	0.52	48.40
11. Isoproturon 1000 g	8.09	0.47	49.00
12. Metsulfuron + isoproturon (2+500g)	8.22	0.52	47.00
13. Chlorsulfuron+isoproturon (15+500g)	7.85	0.69	44.40
14. Weedy check	7.44	0.41	53.40
15. Weed free	7.44	0.41	54.40
S.Em.(±)	0.47	0.01	1.18
CD at 5%	NS	0.04	3.43

dosage of particular herbicide. The lowest tannin content (0.41%) was recorded in untreated plots (weedy check and weed free in wheat crop) closely followed by metsulfuron application at 4 and 8 g ha^{-1}. While the highest tannin accumulation (0.69%) was observed in chlorsulfuron + isoproturon (15 + 500 g ha^{-1}) treated plots (Table 30). Metribuzin 400 g ha^{-1} and chlorsulfuron 30 g ha^{-1} treated plots also caused a significant higher accumulation of tannin content in sorghum plants sown after wheat harvest. Results depicted in Fig. 12 indicate that the combined application of respective herbicides in wheat resulted in to higher tannin accumulation in sorghum as compared to their application alone.

(iii) *In vitro* dry matter digestibility (IVDMD)

Digestibility of sorghum plants sown after wheat harvest was significantly affected due to the residues of herbicides applied in wheat crop (Table 30). The highest percentage of IVDMD (53.40 and 54.40%) was accumulated in untreated plots (weedy check and weed free) closely followed by metsulfuron treated plots at 4 g ha^{-1}, whereas the lowest digestibility (44.40%) was recorded in those plots where chlorsulfuron + isoproturon (15 + 500 g ha^{-1}) was applied in wheat crop (Fig. 12). However, the variation in digestibility with metribuzin (400 g ha^{-1}), metsulfuron + isoproturon (2 + 500 g ha^{-1}), chlorsulfuron (30 g ha^{-1}) and metsulfuron + metribuzin (2+200 g ha^{-1}) treated plots was non-significant.

Results depicted in Fig. 12 reveal that there is negative correlation between tannin and IVDMD in sorghum in respect of treatments applied in wheat crop for weed control.

4.2 EXPERIMENT- II: Bio-efficacy and selectivity of sulfonylurea herbicides against important weeds in wheat and their residual effect on mungbean and sorghum succeeding crops (Pot culture study)

4.2.1 *Triticum aestivum* L.

All the herbicides under test were also sprayed on wheat plant (cv. HD 2329) in order to see their toxicity on wheat crop. Metribuzin was proved to be highly toxic to wheat crop causing 95-100 per cent mortality (Plate 5-A) at all the doses except the lowest dose (25 g ha^{-1}) where 86.66 per cent mortality was recorded within seven days of its application (Fig. 13). Significantly the lowest fresh weight and dry matter accumulation were recorded in metribuzin treated pots (Table 31). Whereas the other herbicide treatments were found at par with untreated pots (control) for all the observations recorded.

4.2.2 *Avena ludoviciana* Dur.

Ninety eight to 100 per cent mortality of wild oat was recorded in metribuzin treated pots (Table 32 and Fig. 13), while in other treatments no mortality was found even at their highest dose. Metribuzin (all doses) and chlorsulfuron at 40 g ha^{-1} caused significant reduction in plant height, number of green leaves, fresh weight and dry weight per plant. All the plants of wild oat dried in metribuzin treated pots within a period of 10-15 days after its application (Plate 5-B). Thus, the values for plant height and number of green leaves per plant were taken as zero before subjecting to square root transformation for statistical analysis. Weight recorded immediate after the collection of plant samples from pots are presented as

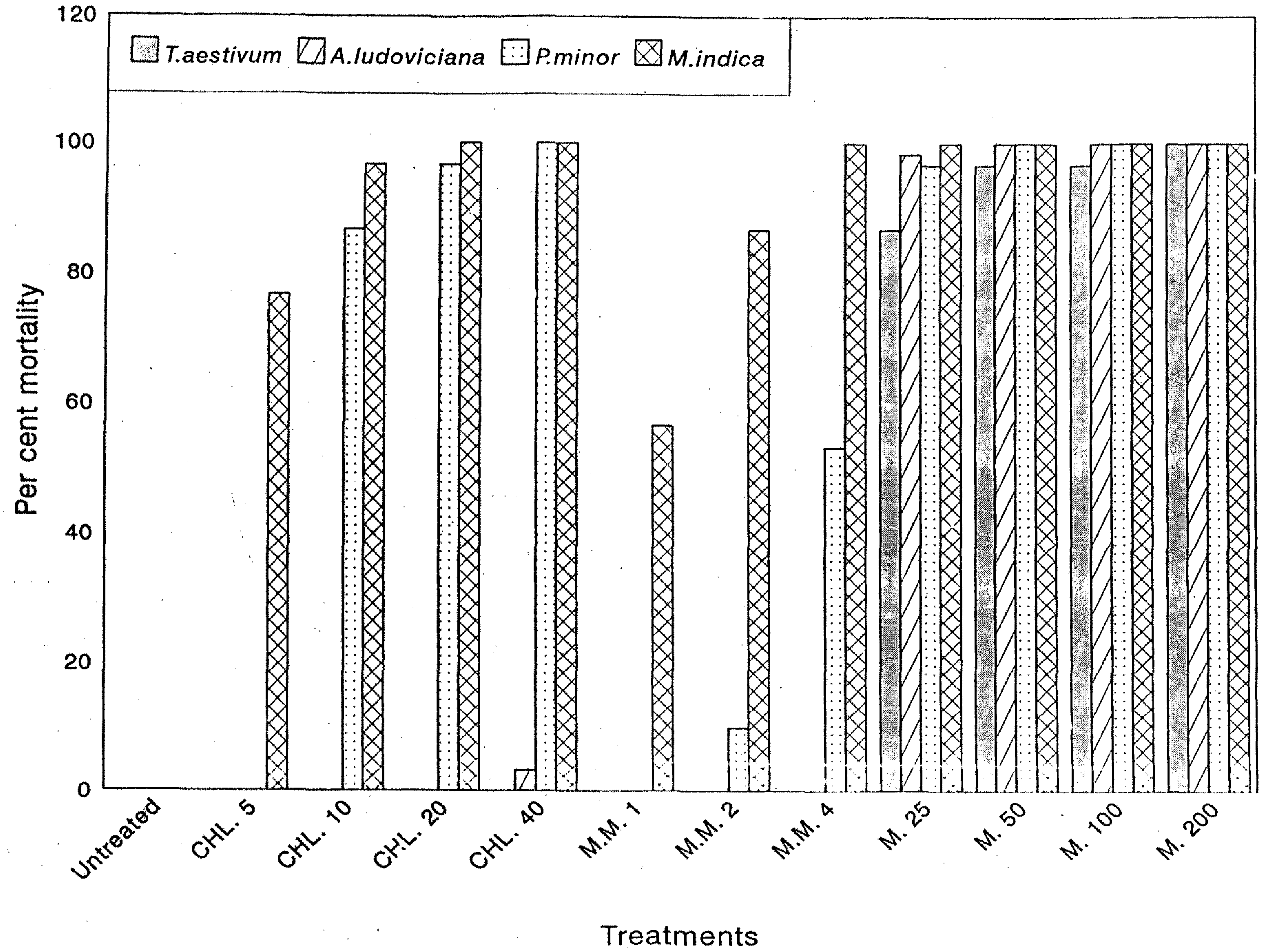
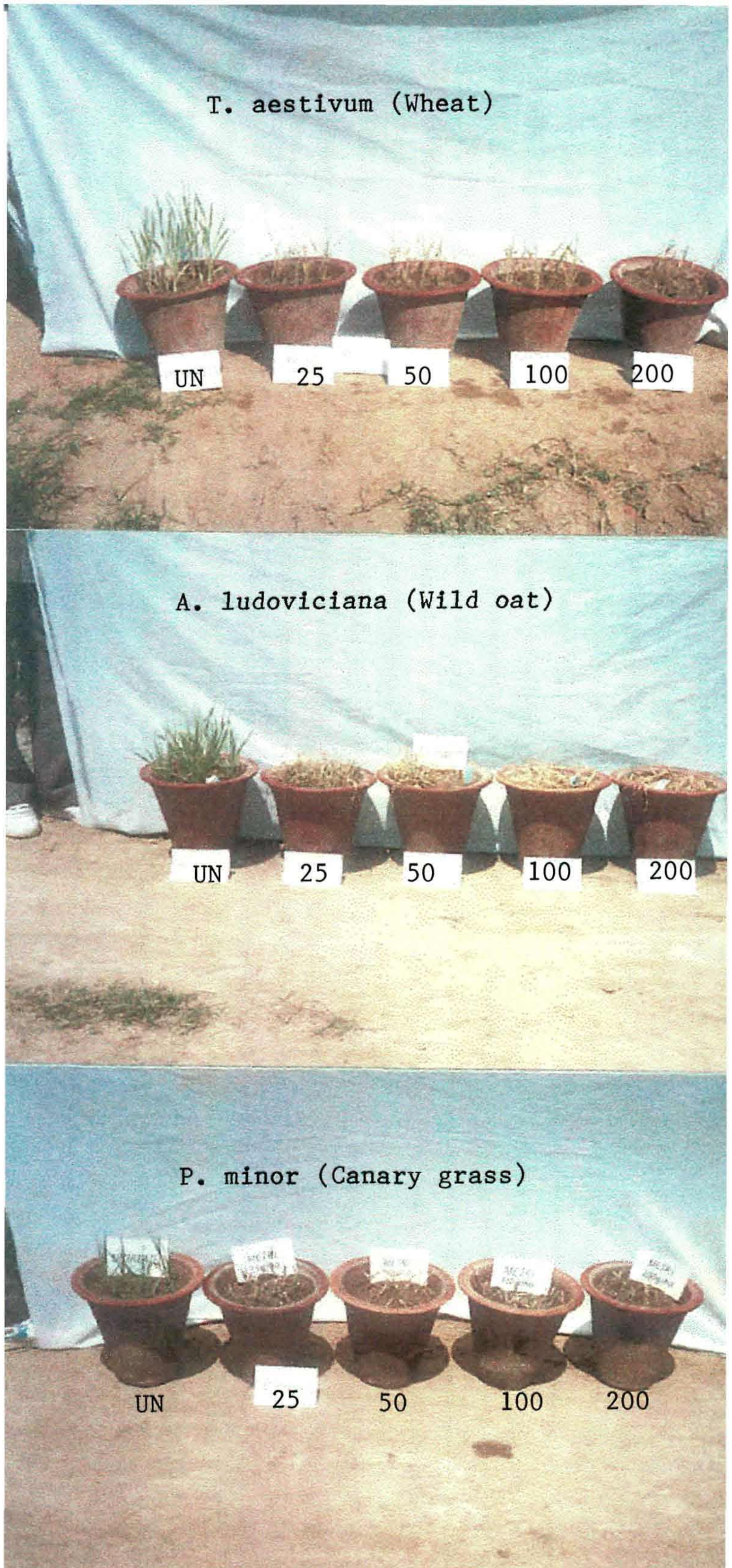


Fig.13 Effect of herbicide treatments on wheat and different weed species (pot culture study)



(A)

(B)

(C)

Plate 5. Studies on the effect of metribuzin on the growth of wheat (A), wild oat (B) and wild canary grass (C)

Table 31. Effect of different herbicides on growth of wheat (*Triticum aestivum* L.) (Pot culture study)

Treatments	Before herbicide spray		21 days after herbicide spray				
	Plant height (cm)	No. of green leaves (No. plant^{-1})	% mortality*	Plant height (cm) +	No. of green leaves (No. plant^{-1})+	Fresh weight (g plant^{-1})	Dry weight (g plant^{-1})
1. Control (untreated)	17.80	4.30	0.91 (0.00)	5.68 (31.75)	1.79 (2.70)	2.850	1.640
2. Chlorsulfuron 5 g ha^{-1}	17.20	4.10	0.91 (0.00)	5.70 (32.00)	1.76 (2.60)	2.770	1.610
3. Chlorsulfuron 10 g ha^{-1}	17.95	3.90	0.91 (0.00)	5.55 (30.34)	1.76 (2.61)	2.820	1.590
4. Chlorsulfuron 20 g ha^{-1}	17.21	4.20	0.91 (0.00)	5.57 (30.45)	1.72 (2.46)	2.813	1.620
5. Chlorsulfuron 40 g ha^{-1}	17.50	3.80	0.91 (0.00)	5.56 (30.35)	1.73 (2.48)	2.800	1.620
6. Metsulfuron 1 g ha^{-1}	17.10	3.60	0.91 (0.00)	5.56 (30.37)	1.77 (2.63)	2.820	1.600
7. Metsulfuron 2 g ha^{-1}	17.21	3.80	0.91 (0.00)	5.55 (30.30)	1.74 (2.54)	2.830	1.580
3. Metsulfuron 4 g ha^{-1}	18.10	4.20	0.91 (0.00)	5.55 (30.32)	1.76 (2.59)	2.807	1.610
9. Metribuzin 25 g ha^{-1}	17.22	4.22	68.86 (86.66)	0.71 (0.00)	0.71 (0.00)	0.240	0.230
10. Metribuzin 50 g ha^{-1}	17.67	3.90	83.25 (96.66)	0.71 (0.00)	0.71 (0.00)	0.270	0.270
11. Metribuzin 100 g ha^{-1}	17.40	4.13	83.25 (96.66)	0.71 (0.00)	0.71 (0.00)	0.240	0.210
12. Metribuzin 200 g ha^{-1}	17.90	3.92	89.09 (100.00)	0.71 (0.00)	0.71 (0.00)	0.220	0.190
S.Em (±)	1.76	0.84	2.51	0.041	0.018	0.032	0.037
CD at 1%	NS	NS	9.93	0.162	0.071	0.127	0.146

* Data subjected to arc sine transformation before statistical analysis

+ Data subjected to $\sqrt{X+0.5}$ transformation.

Figures in parentheses are original values

Table 32. Effect of different herbicides on growth of *Avena ludoviciana* Dur.

Treatments	Before herbicide spray		21 days after herbicide spray				
	Plant height (cm)	No. of green leaves (No. plant^{-1})	% mortality*	Plant height (cm) +	No. of green leaves (No. plant^{-1})+	Fresh weight (g plant^{-1})	Dry weight (g plant^{-1})
1. Control (untreated)	14.01	10.70	0.91 (0.00)	6.47 (41.41)	2.39 (5.20)	3.675	1.618
2. Chlorsulfuron 5 g ha^{-1}	13.80	10.35	0.91 (0.00)	6.38 (40.16)	2.36 (5.05)	3.624	1.602
3. Chlorsulfuron 10 g ha^{-1}	13.85	10.33	0.91 (0.00)	6.46 (41.25)	2.38 (5.15)	3.678	1.615
4. Chlorsulfuron 20 g ha^{-1}	13.50	10.41	0.91 (0.00)	6.45 (41.20)	2.30 (4.80)	3.612	1.590
5. Chlorsulfuron 40 g ha^{-1}	13.92	11.01	6.75 (3.33)	5.20 (26.25)	2.24 (4.50)	3.569	1.562
6. Metsulfuron 1 g ha^{-1}	13.25	10.92	0.91 (0.00)	6.39 (40.30)	2.38 (5.17)	3.626	1.625
7. Metsulfuron 2 g ha^{-1}	13.55	10.58	0.91 (0.00)	6.40 (40.32)	2.37 (5.12)	3.611	1.620
8. Metsulfuron 4 g ha^{-1}	13.65	10.32	0.91 (0.00)	6.41 (40.55)	2.36 (5.05)	3.585	1.617
9. Metribuzin 25 g ha^{-1}	13.51	11.05	85.09 (98.33)	0.71 (0.00)	0.71 (0.00)	0.349	0.263
10. Metribuzin 50 g ha^{-1}	14.05	10.92	89.09 (100.00)	0.71 (0.00)	0.71 (0.00)	0.302	0.246
11. Metribuzin 100 g ha^{-1}	13.60	10.87	89.09 (100.00)	0.71 (0.00)	0.71 (0.00)	0.284	0.260
12. Metribuzin 200 g ha^{-1}	13.94	11.00	89.09 (100.00)	0.71 (0.00)	0.71 (0.00)	0.250	0.226
S.Em (±)	0.78	1.02	2.04	0.026	0.01	0.026	0.01
CD at 1%	NS	NS	8.09	0.103	0.04	0.103	0.04

* Data subjected to arc sine transformation before statistical analysis

+ Data subjected to $\sqrt{X+0.5}$ transformation.

Figures in parentheses are original values

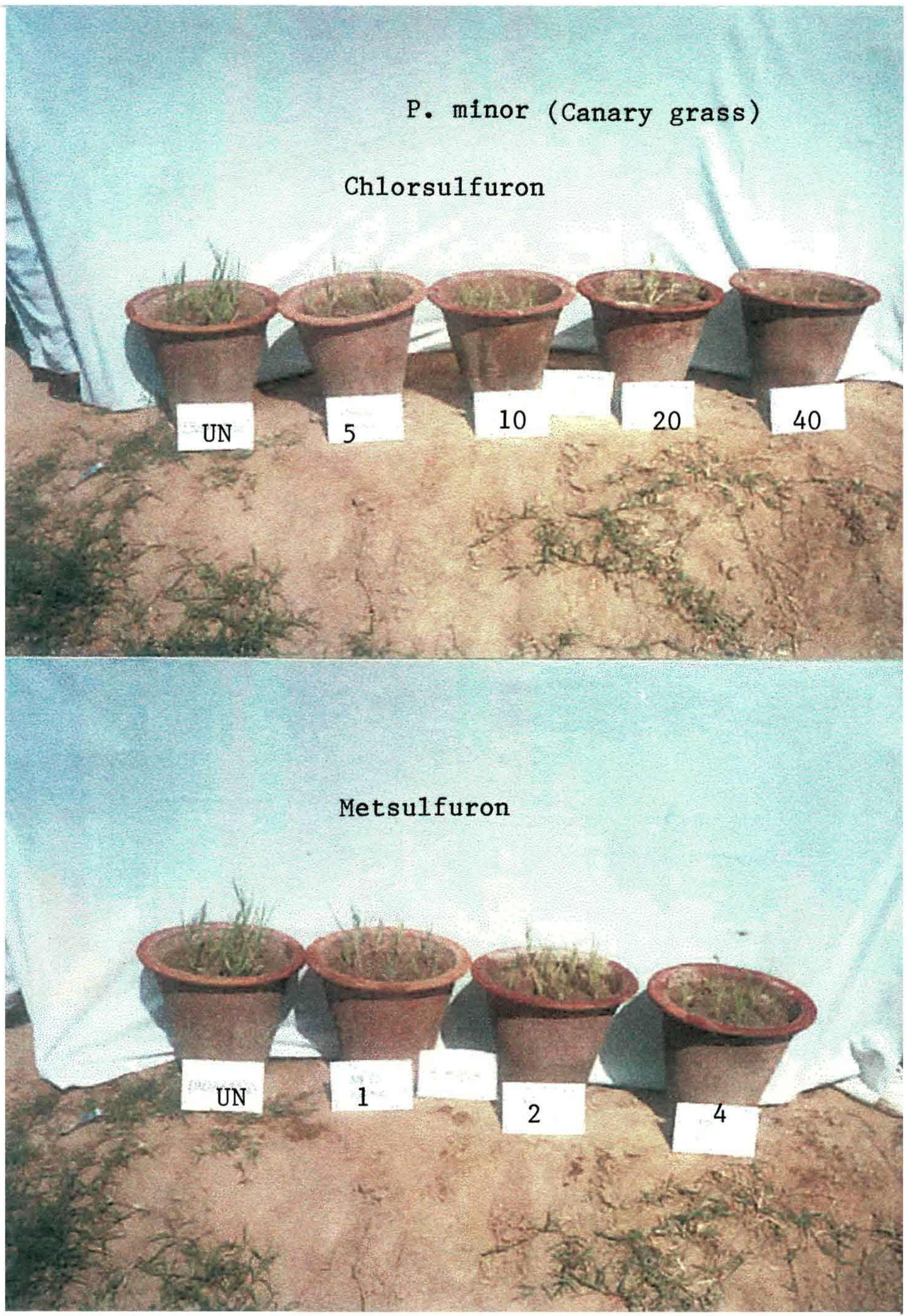
average fresh weight per plant in each observation. However, the difference between rest of the treatments for all recorded observations was non-significant and were statistically similar to untreated pots.

4.2.3 *Phalaris minor* Retz.

The data relating to the effect of different herbicides on the mortality and growth of *P. minor* are presented in Table 33. All the herbicides significantly increased the mortality rate of *P. minor* with increase in the dose. Cent per cent mortality was recorded in 50,100 and 200 g of metribuzin and in 40 g of chlorsulfuron treated pots (Fig. 13; Plate 5-C). However, the difference in per cent mortality between 20 g of chlorsulfuron and the lowest dose of metribuzin (25 g ha^{-1}) was found nonsignificant. The lowest dose of chlorsulfuron (5 g ha^{-1}) and metsulfuron (1 g ha^{-1}) did not cause any mortality of *P. minor.* The application of 10 g of chlorsulfuron and 2 and 4 g ha^{-1} of metsulfuron recorded 86.60 per cent and 10 and 53.33 per cent mortality of *P. minor,* respectively (Plate 6). Significant reduction in growth parameters was recorded due to all herbicides application except 5 g of chlorsulfuron as compared to untreated pot. While minimum reduction in plant height, fresh and dry weight of *P. minor* was recorded at the lowest dose of metsulfuron followed by its higher dose and 5 g of chlorsulfuron as well. The response of all the doses of metribuzin was almost identical.

4.2.4 *Melilotus indica* L.

The data pertaining to the effect of different herbicides on *M. indica* is shown in Table 34. It can be observed that there was a significant



(A)

(B)

Plate 6. Studies on the effect of sulfonylurea herbicides on wild canary grass (P. minor Retz.)

Table 33 . **Effect of different herbicides on growth of *Phalaris minor* Retz.**

Treatments	Before herbicide spray		21 days after herbicide spray				
	Plant height (cm)	No. of green leaves (No. plant^{-1})	% mortality*	Plant height (cm) +	No. of green leaves (No. plant^{-1})+	Fresh weight (g plant^{-1})	Dry weight (g plant^{-1})
1. Control (untreated)	10.80	4.10	0.91 (0.00)	4.61 (20.75)	1.64 (2.20)	0.428	0.220
2. Chlorsulfuron 5 g ha^{-1}	10.93	3.70	0.91 (0.00)	3.75 (13.53)	1.64 (2.20)	0.228	0.129
3. Chlorsulfuron 10 g ha^{-1}	10.75	3.60	68.86 (86.66)	3.42 (11.22)	0.71 (0.00)	0.185	0.098
4. Chlorsulfuron 20 g ha^{-1}	10.59	3.60	83.25 (96.66)	0.71 (0.00)	0.71 (0.00)	0.170	0.081
5. Chlorsulfuron 40 g ha^{-1}	10.28	3.80	89.09 (100.00)	0.71 (0.00)	0.71 (0.00)	0.111	0.052
6. Metsulfuron 1 g ha^{-1}	10.37	3.90	0.91(0.00)	4.10 (16.33)	1.38 (1.40)	0.344	0.185
7. Metsulfuron 2 g ha^{-1}	11.02	3.80	18.43 (10.00)	3.81 (14.00)	1.30 (1.20)	0.248	0.086
8. Metsulfuron 4 g ha^{-1}	10.92	3.90	46.92 (53.33)	3.39(11.00)	0.88 (0.30)	0.237	0.072
9. Metribuzin 25 g ha^{-1}	10.39	3.70	83.25 (96.66)	0.71 (0.00)	0.71 (0.00)	0.063	0.034
10. Metribuzin 50 g ha^{-1}	10.91	4.67	89.09 (100.00)	0.71 (0.00)	0.71 (0.00)	0.043	0.028
11. Metribuzin 100 g ha^{-1}	11.02	4.03	89.09 (100.00)	0.71 (0.00)	0.71 (0.00)	0.040	0.027
12. Metribuzin 200 g ha^{-1}	11.00	3.80	89.09 (100.00)	0.71 (0.00)	0.71 (0.00)	0.038	0.027
S.Em (±)	1.13	0.58	2.57	0.018	0.052	0.02	0.01
CD at 1%	NS	NS	10.17	0.071	0.206	0.078	0.039

* Data subjected to arc sine transformation before statistical analysis
+ Data subjected to $\sqrt{X+0.5}$ transformation.
Figures in parentheses are original values

Table 34. **Effect of different herbicides on growth of *Melilotus indica* L.**

Treatments	Before herbicide spray		21 days after herbicide spray		
	Plant height (cm)	No. of green leaves (No. plant^{-1})	% mortality*	Fresh weight (g plant^{-1})	Dry weight (g plant^{-1})
1. Control (untreated)	5.50	4.30	0.91 (0.00)	0.326	0.100
2. Chlorsulfuron 5 g ha^{-1}	5.00	4.00	61.22 (76.66)	0.056	0.029
3. Chlorsulfuron 10 g ha^{-1}	5.00	4.22	83.25 (96.66)	0.047	0.020
4. Chlorsulfuron 20 g ha^{-1}	5.10	4.71	89.09 (100.00)	0.044	0.021
5. Chlorsulfuron 40 g ha^{-1}	5.09	3.60	89.09 (100.00)	0.037	0.016
6. Metsulfuron 1 g ha^{-1}	5.00	4.67	48.85 (56.66)	0.083	0.051
7. Metsulfuron 2 g ha^{-1}	5.06	4.22	68.86 (86.66)	0.063	0.038
8. Metsulfuron 4 g ha^{-1}	5.11	4.57	89.09 (100.00)	0.044	0.024
9. Metribuzin 25 g ha^{-1}	5.38	4.75	89.09 (100.00)	0.028	0.024
10. Metribuzin 50 g ha^{-1}	5.28	4.33	89.09 (100.00)	0.026	0.021
11. Metribuzin 100 g ha^{-1}	5.28	4.33	89.09 (100.00)	0.023	0.020
12. Metribuzin 200 g ha^{-1}	5.55	4.77	89.09 (100.00)	0.021	0.020
S.Em (±)	0.69	0.72	2.04	0.032	0.01
CD at 1%	NS	NS	8.08	0.127	0.039

* Data subjected to arc sine transformation before statistical analysis
Figures in parentheses are original values

increase in mortality and reduction in all growth parameters due to weed control treatments.

Hundred per cent mortality of this weed was observed under metribuzin (at all doses), metsulfuron (4 g ha^{-1}) and chlorsulfuron (20 and 40 g ha^{-1}) treated pots (Plate 7) which were also at par with 10 g of chlorsulfuron. The lowest per cent mortality (56.66) was noted at the lowest dose of metsulfuron which was significantly lower than that recorded in 5 g of chlorsulfuron and 2 g of metsulfuron treated pots (Fig. 13). Maximum reduction in fresh and dry weight (g $plant^{-1}$) was found in metribuzin treated pots followed by chlorsulfuron. Whereas the minimum reduction was noticed in 1 and 2 g of metsulfuron treated pots.

4.2.5 *Coronopus didymus* L., *Chenopodium album* L. and *Anagallis arvensis* L.

All the herbicide treatments except chlorsulfuron (5 g ha^{-1}) and metsulfuron (1 g ha^{-1}), caused 100 per cent mortality of all these three weeds (Table 35 and Fig. 14). Significant reduction in fresh weight and dry weight of these weeds was noticed in all herbicide treatments except with the lowest dose of both the sulfonylurea herbicides applied for *Coronopus didymus* and *Anagallis arvensis*.

4.2.6 Residual effect of herbicides on mungbean and sorghum

Mungbean and sorghum are mainly grown for grain and fodder purpose in India after wheat harvest. New group of herbicides like sulfonylurea are being applied for weed control in wheat whose residual effects are reported on succeeding crops in other countries. But very little information about their residual effects on growth and quality of

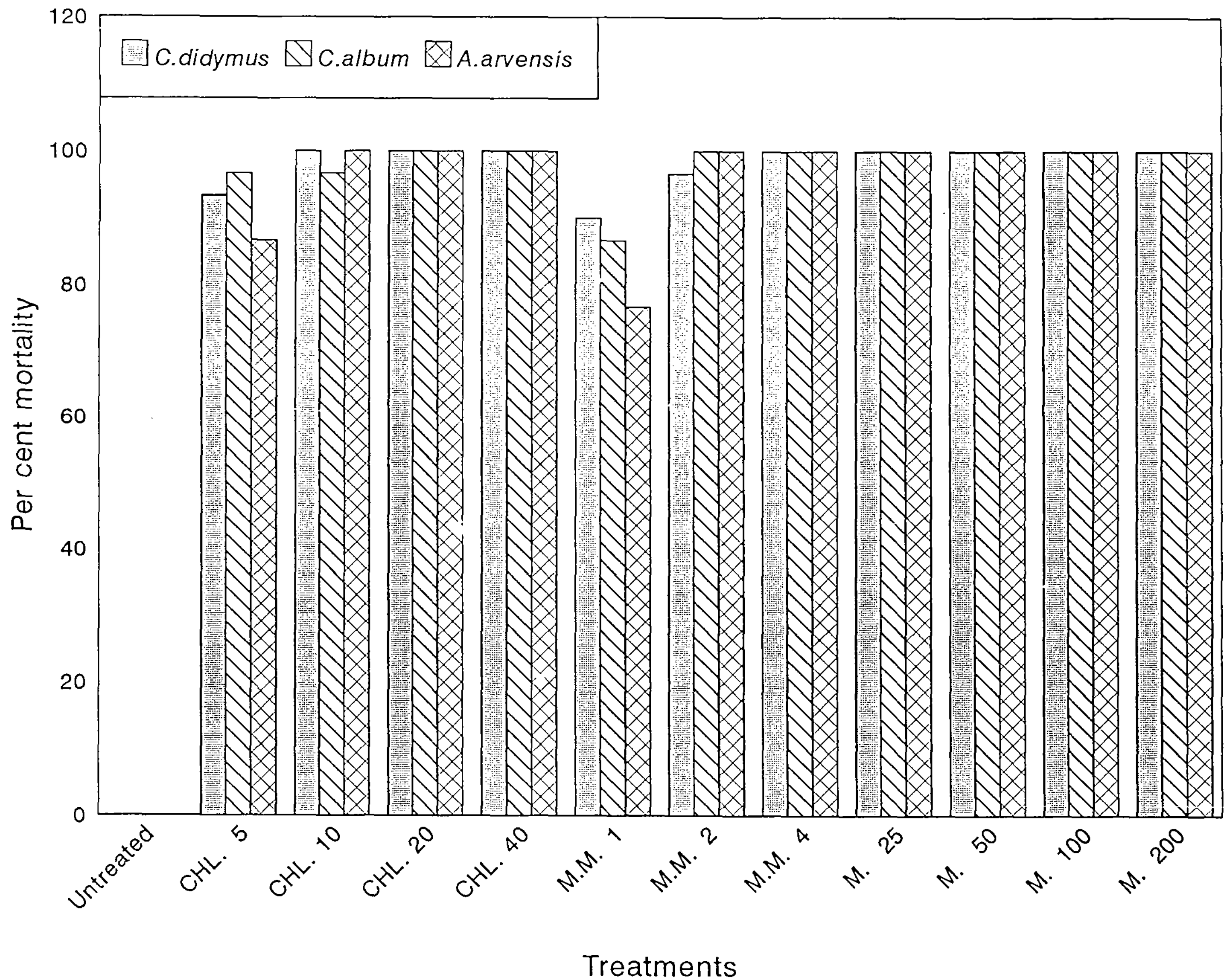
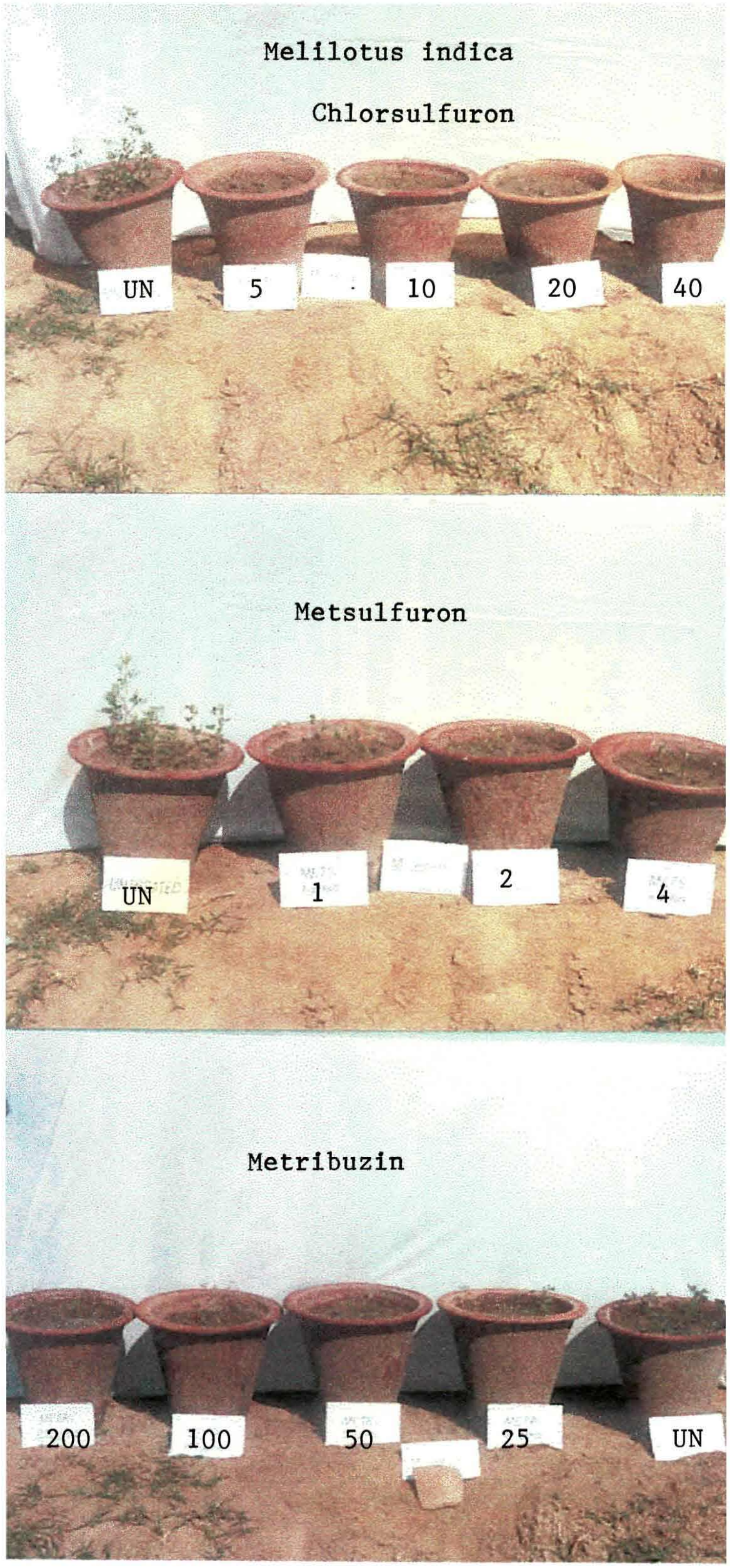


Fig.14 Effect of herbicide treatments on different weed speices (pot culture study)



(A)

(B)

(C)

Plate 7. Studies on the effect of chlorsulfuron (A), metsulfuron (B) and metribuzin (C) on Melilotus indica

Table 35. **Effect of different herbicides on growth of *Coronopus didymus* L., *Chenopodium album* L. and *Anagallis arvensis* L.**

Treatments	*Coronopus didymus*			*Chenopodium album*			*Anagallis arvensis*		
	% mortality*	Fresh weight (g plant^{-1})	Dry weight (g plant^{-1})	% mortality*	Fresh weight (g plant^{-1})	Dry weight (g plant^{-1})	% mortality*	Fresh weight (g plant^{-1})	Dry weight (g plant^{-1})
1. Control (untreated)	0.91 (0.00)	0.148	0.097	0.91 (0.00)	0.934	0.318	0.91 (0.00)	0.077	0.056
2. Chlorsulfuron 5 g ha^{-1}	77.41 (93.33)	0.098	0.071	83.25 (96.66)	0.170	0.136	68.86 (86.66)	0.044	0.023
3. Chlorsulfuron 10 g ha^{-1}	89.09 (100.00)	0.081	0.060	83.25 (96.66)	0.160	0.130	89.09 (100.00)	0.026	0.010
4. Chlorsulfuron 20 g ha^{-1}	89.09 (100.00)	0.063	0.052	89.09(100.00)	0.112	0.078	89.09 (100.00)	0.021	0.009
5. Chlorsulfuron 40 g ha^{-1}	89.09 (100.00)	0.061	0.049	89.09 (100.00)	0.103	0.072	89.09 (100.00)	0.017	0.007
6. Metsulfuron 1 g ha^{-1}	74.70 (96.66)	0.112	0.084	68.86 (86.66)	0.201	0.159	61.22 (76.66)	0.041	0.022
7. Metsulfuron 2 g ha^{-1}	83.25 (100.00)	0.079	0.057	89.09 (100.00)	0.073	0.063	89.09 (100.00)	0.023	0.015
8. Metsulfuron 4 g ha^{-1}	89.09 (100.00)	0.070	0.062	89.09 (100.00)	0.033	0.023	89.09 (100.00)	0.015	0.008
9. Metribuzin 25 g ha^{-1}	89.09 (100.00)	0.035	0.024	89.09 (100.00)	0.064	0.039	89.09 (100.00)	0.011	0.004
10.Metribuzin 50 g ha^{-1}	89.09 (100.00)	0.027	0.020	89.09 (100.00)	0.019	0.017	89.09 (100.00)	0.010	0.004
11.Metribuzin 100 g ha^{-1}	89.09 (100.00)	0.025	0.015	89.09(100.00)	0.012	0.011	89.09 (100.00)	0.010	0.003
12.Metribuzin 200 g ha^{-1}	89.09 (100.00)	0.025	0.009	89.09 (100.00)	0.011	0.008	89.09 (100.00)	0.010	0.003
S.Em (±)	3.24	0.01	0.01	2.51	0.01	0.01	1.01	0.01	0.01
CD at 1%	12.80	0.04	0.04	9.93	0.04	0.04	4.00	0.04	0.04

* Data subjected to arc sine transformation before statistical analysis
Figures in parentheses are original values

succeeding crops particularly grown for fodder is known under Indian condition. In the above context, the present investigation was undertaken in the same pots wherein herbicides were applied on different major weed species of wheat crop to investigate the injurious effect of sulfonylurea herbicides soil residues on these two rotational crop. These crops were sown about six month after the herbicide application.

Data relating to the residual effects of herbicide residues on growth of mungbean and sorghum are presented in Table 36 and 37 and exhibited in Fig. 15 and 16.

(a) Mungbean

(i) Germination (%)

Residual effect of all herbicide treatments except 1 g ha^{-1} of metsulfuron caused significant reduction in the per cent germination of the test crop. The lowest germination percentage was recorded in chlorsulfuron treated pots at 20 and 40 g ha^{-1} closely followed by the highest dose of metribuzin (Fig. 15; Plate 8-A). However, the next lowest germination percentage was also recorded in 10 g chlorsulfuron treated pots which did not vary significantly with other herbicide treated pots, except 1 and 2 g of metsulfuron and 25 g of metribuzin (Table 36).

(ii) Plant height (cm)

Plant height was significantly decreased under all the treatments except with 1 g of metsulfuron over untreated plants. The maximum reduction in plant height was noted in 40 g of chlorsulfuron treated pots, which was closely followed by its subsequent lower dose (Table 36).

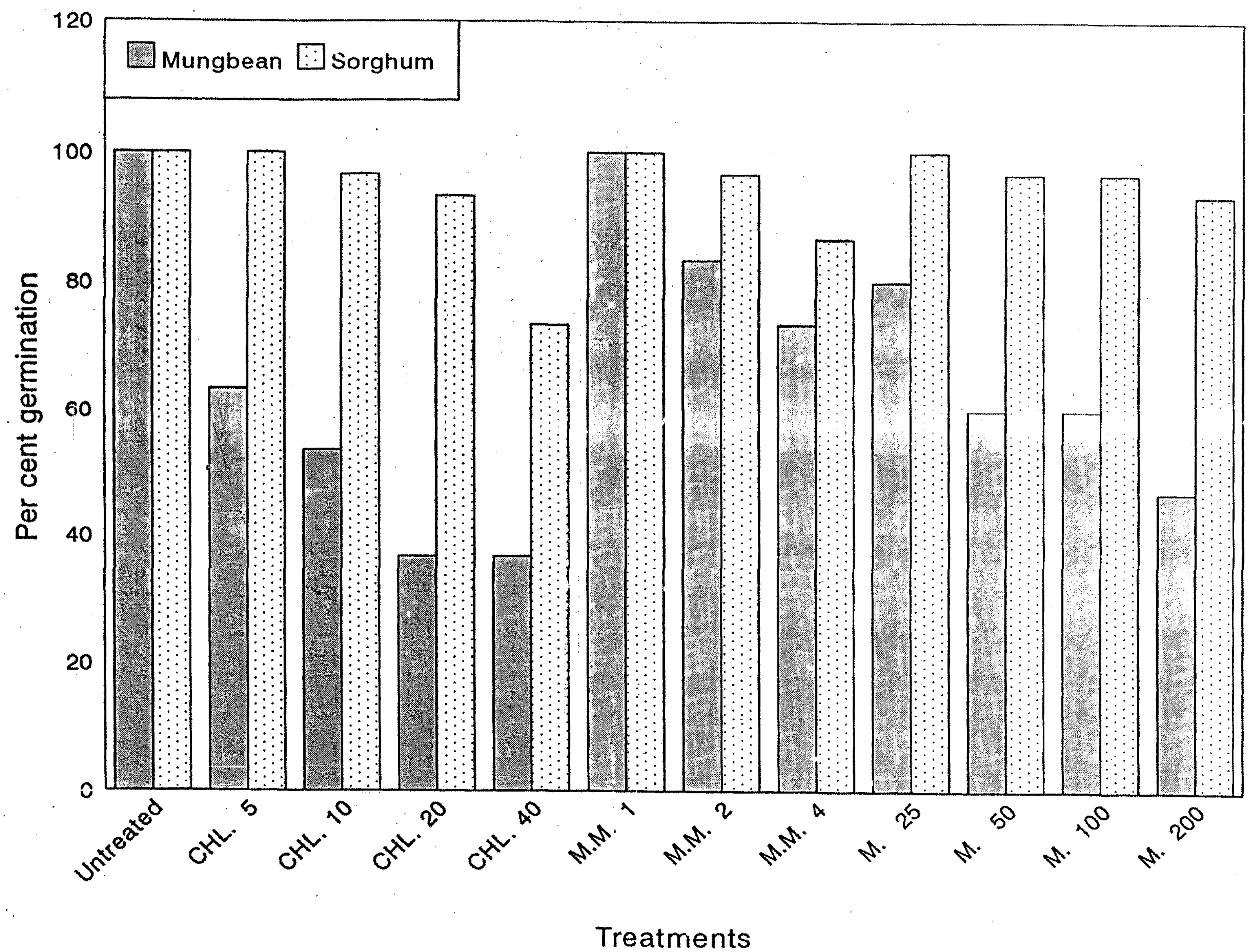


Fig.15 Effect of different herbicide residues on the per cent germination of mungbean and sorghum (Pot culture bioassay study)

(A)

(B)

(C)

Plate 8. Studies on the residual effect of chlorsulfuron (A), metsulfuron (B) and metribuzin (C) on the growth of mungbean (pot culture bioassay study)

Table 36. Residual effect of different herbicides on growth of mungbean succeeding crop (Pot culture bioassay study)

Treatments	Germination* (%)	Plant height (cm)	No. of green leaves (No. plant^{-1})	Leaf area (cm^2 plant^{-1})	Fresh weight (g plant^{-1})	Dry weight (g plant^{-1})
1. Control (untreated)	89.09 (100.00)	11.24	6.50	49.74	0.971	0.190
2. Chlorsulfuron 5 g ha^{-1}	52.78 (63.33)	7.10	4.40	25.41	0.523	0.099
3. Chlorsulfuron 10 g ha^{-1}	46.92 (53.33)	6.17	1.83	11.65	0.244	0.051
4. Chlorsulfuron 20 g ha^{-1}	37.22 (36.66)	5.57	1.88	11.90	0.241	0.051
5. Chlorsulfuron 40 g ha^{-1}	37.22 (36.66)	5.44	1.44	11.22	0.207	0.042
6. Metsulfuron 1 g ha^{-1}	89.09 (100.0)	11.10	6.11	45.13	0.804	0.148
7. Metsulfuron 2 g ha^{-1}	66.14 (83.33)	10.36	5.63	42.35	0.719	0.136
8. Metsulfuron 4 g ha^{-1}	59.00 (73.33)	8.42	5.83	38.97	0.697	0.133
9. Metribuzin 25 g ha^{-1}	63.43 (80.00)	8.33	5.17	31.34	0.528	0.118
10. Metribuzin 50 g ha^{-1}	50.85 (60.00)	8.33	5.14	29.31	0.505	0.114
11. Metribuzin 100 g ha^{-1}	50.77 (60.00)	7.38	5.00	27.75	0.464	0.110
12. Metribuzin 200 g ha^{-1}	43.08 (46.66)	7.10	5.00	26.91	0.458	0.109
S.Em ±	1.90	0.04	0.13	0.71	0.03	0.01
CD at 1%	7.51	0.16	0.53	2.79	0.11	0.04

* Data subjected to arc sine transformation before statistical analysis
Figures in parentheses are original values

Magnitude of reduction in plant height was significantly higher in chlorsulfuron treated pots than metribuzin and metsulfuron. Minimum reduction in height was noticed in metsulfuron treated pots. Similar effect was also observed on the bearing of number of green leaves per plant of mungbean.

(iii) Leaf area (cm^2 plant^{-1})

Leaf area per plant of mungbean was significantly affected by the persistence action of all herbicides used in pot culture study. The lowest leaf area was measured in chlorsulfuron treated pots, however, the difference in reduction of leaf area under 10 to 40 g chlorsulfuron treated pots was non-significant (Table 36). While residue of metsulfuron (1-4 g ha^{-1}) caused minimum reduction in leaf area among various doses of chlorsulfuron and metribuzin (Plate 8-B).

(iv) Fresh and dry weight (g plant^{-1})

There was significant reduction in fresh as well as dry weight of mungbean at all the doses of herbicides used in this study (Table 36). Maximum reduction in fresh and dry weight of mungbean was obtained in chlorsulfuron (40 g ha^{-1}) treated pots which were at par with its lower doses (10 and 20 g ha^{-1}). While the least reduction in fresh and dry weight compared to untreated pots was noticed at 1 g of metsulfuron (Plate 8-B), which was found at par with its higher doses.

(b) Sorghum

(i) Germination (%)

Germination of sorghum was significantly affected due to the residues of sulfonylurea herbicides at their highest dose (Table 37).

Table 37 . Residual effect of different herbicides on growth and quality of sorghum succeeding crop (Pot culture bioassay study)

Treatment	Germination* (%)	Plant height (cm)	No. of green leaves (No. plant^{-1})	Fresh weight (g plant^{-1})	Dry weight (g plant^{-1})	Protein content (%)	Tannin content (%)	IVDMD (%)	HCN (ppm) at 40 DAS
1. Control (untreated)	89.37 (100.00)	46.40	2.60	2.184	0.871	14.480	0.46	55.90	89.00
2. Chlorsulfuron 5 g ha^{-1}	89.37 (100.00)	37.60	2.60	1.233	0.352	12.10	0.56	52.20	87.00
3. Chlorsulfuron 10 g ha^{-1}	83.44 (96.66)	38.20	2.30	1.211	0.311	11.57	0.57	50.30	72.33
4. Chlorsulfuron 20 g ha^{-1}	77.50 (93.33)	33.60	2.40	0.952	0.246	10.79	0.60	49.60	55.67
5. Chlorsulfuron 40 g ha^{-1}	59.21 (73.33)	22.40	2.00	0.483	0.083	6.31	0.69	47.40	48.00
6. Metsulfuron 1 g ha^{-1}	89.37 (100.00)	37.20	2.40	1.215	0.335	12.25	0.73	46.20	67.00
7. Metsulfuron 2 g ha^{-1}	83.44 (96.66)	33.70	2.30	0.982	0.264	10.87	0.77	46.00	55.00
8. Metsulfuron 4 g ha^{-1}	68.86 (86.66)	27.30	1.90	0.587	0.150	6.34	0.81	41.60	53.00
9. Metribuzin 25 g ha^{-1}	89.37 (100.00)	34.20	2.60	1.015	0.287	10.28	0.64	48.07	38.00
10. Metribuzin 50 g ha^{-1}	83.44(96.66)	34.50	2.50	0.991	0.285	10.35	0.65	48.00	37.33
11. Metribuzin 100 g ha^{-1}	83.44 (96.66)	32.70	2.50	0.982	0.266	7.88	0.67	47.67	33.00
12. Metribuzin 200 g ha^{-1}	77.50 (93.33)	23.90	2.20	0.569	0.133	5.38	0.69	47.00	32.00
S.Em ±	3.65	0.52	0.08	0.01	0.02	0.43	0.01	0.74	3.14
CD at 1%	14.45	2.05	0.30	0.04	0.06	1.70	0.05	2.94	12.40

* Data subjected tc arc sine transformation before statistical analysis
Figures in parentheses are original values

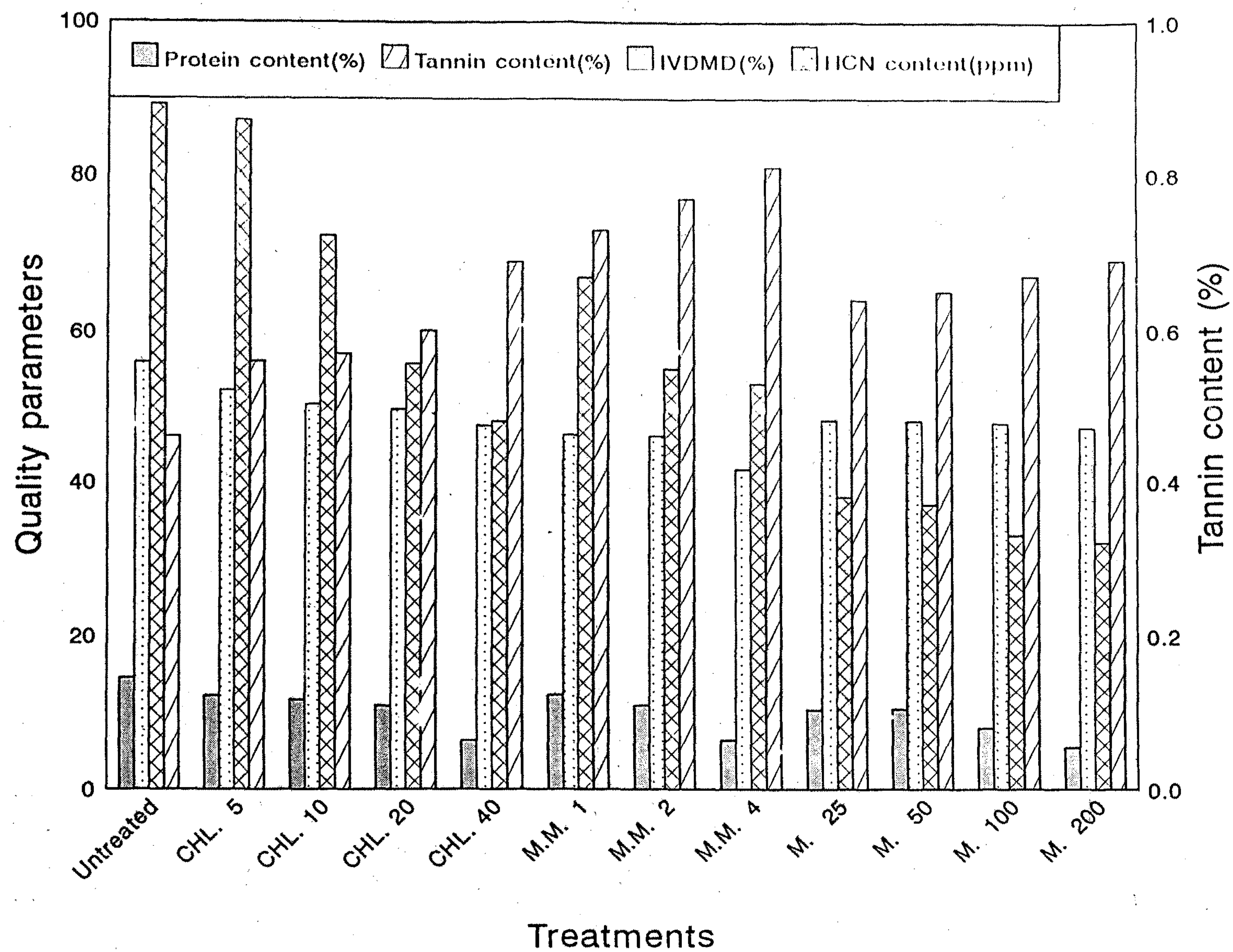
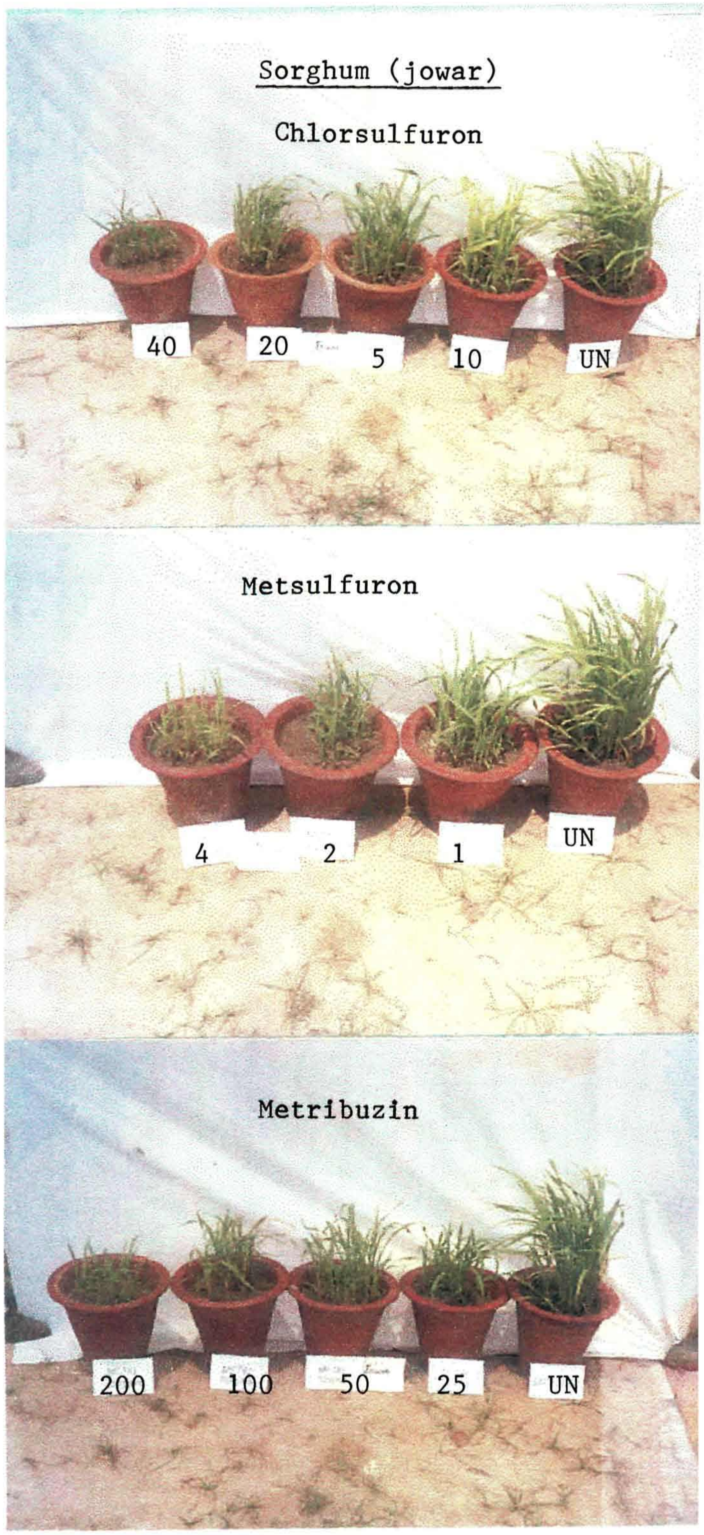


Fig.16 Effect of different herbicide residues on the quality parameters of sorghum (pot culture bioassay study)



(A)

(B)

(C)

Plate 9. Studies on the residual effect of chlorsulfuron (A), metsulfuron (B) and metribuzin (C) on the growth of sorghum (Pot culture bioassay study)

Residues of chlorsulfuron (40 g ha^{-1}) caused the highest reduction in germination (26.67%) which however differed significantly from rest of the treatments except with 4 g of metsulfuron (13.39%) (Fig. 15; Plae 9-A). Sorghum germination was not affected due to the residues of chlorsulfuron (5 g ha^{-1}), metsulfuron (1 g ha^{-1}) and metribuzin (25 g ha^{-1}) and were not significantly different with rest of the pots except chlorsulfuron (40 g ha^{-1}) and metsulfuron (4 g ha^{-1}) treated pots. Difference in per cent germination amongst the various doses of metribuzin and untreated pots was non-significant (Table 37).

(ii) Plant height (cm)

Plant height of sorghum was significantly reduced at all the doses of chlorsulfuron, metsulfuron and metribuzin (Table 37). However, the residues of chlorsulfuron(40 g ha^{-1}) caused the highest decrease in plant height and was closely followed by metribuzin (200 g ha^{-1}) (Plate 9-A). The minimum reduction in plant height was noted in chlorsulfuron (10 g ha^{-1}) which was at par with 5 g chlorsulfuron and 1 g metsulfuron treatments. However, the difference in plant height within metribuzin (25 to 100 g), metsulfuron (2 g) and chlorsulfuron (20 g) was not found significant.

(iii) Number of leaves (No. $plant^{-1}$)

Number of green leaves per plant were significantly reduced by the herbicidal residues persisted at their highest doses. However, the difference in number of leaves per plant between all herbicidal treatments except their highest dose and untreated (control) were found non-significant (Table 37).

(iv) **Fresh and dry weight (g plant^{-1})**

Fresh and dry weight of sorghum were significantly influenced by the herbicide residues. Increased reduction in both the values was observed with increase in dose of herbicides. Residues of 40 g of chlorsulfuron caused significant reduction in both fresh and dry weight of sorghum plant among all the doses of chlorsulfuron (Table 37). However, the next highest reduction was recorded at the highest dose of metsulfuron (4 g ha^{-1}) and metribuzin (200 g ha^{-1}). While the minimum reduction in fresh and dry weight was observed under the influence of lower dose of chlorsulfuron (5 g and 10 g ha^{-1}) and metsulfuron (1 g ha^{-1}). The differences among metribuzin (25, 50 and 100 g ha^{-1}), metsulfuron (2 g ha^{-1}) and chlorsulfuron (20 g ha^{-1}) was not found significant.

(v) **Effect of herbicide residues on sorghum quality**

Effect of herbicides residues on protein, tannin, HCN content that content and *in vitro* dry matter digestibility of sorghum plants were estimated considering their importance for the assessment of the quality and palatability of a fodder. Data relating to quality parameters are presented in Table 37 and depicted in Fig. 16.

Protein content (%): Protein content in sorghum was significantly reduced due to the residual effect of all three herbicides and decreased with corresponding increase in the doses of chlorsulfuron, metsulfuron and metribuzin. However, the highest reduction in protein content was recorded with metribuzin residues at 200 g ha^{-1} which was on par with the highest dose of metsulfuron and chlorsulfuron (Table 37). Minimum reduction in protein content as compared to untreated plants was noticed in 1 g metsulfuron treated pots which, however, was found at par with 5, 10 and 20 g ha^{-1} of chlorsulfuron and 2 g of metsulfuron (Fig. 16). Variation in the value of protein content of sorghum grown in metribuzin (at 25 and 50 g ha^{-1}), metsulfuron (2 g ha^{-1}) and chlorsulfuron (10 g and 20 g ha^{-1}) treated pots were statistically non-significant.

Tannin content (%): Tannin content of sorghum plants grown in herbicide treated pots was significantly increased as compared to the untreated plants. It was found to be increased with an increase in the doses of all herbicides. The maximum increase in tannin content was noticed with metsulfuron residues (0.73 to 0.84%) (Table 37 and Fig. 16) which were closely followed by the chlorsulfuron(40 g ha^{-1}) and metribuzin (200 g ha^{-1}). However, the difference in tannin content among various doses of metribuzin and 40 g of chlorsulfuron was found non-significant. While the minimum increase in tannin content was obtained with the lowest dose of chlorsulfuron (0.56%) and was closely followed by its higher doses except 40 g ha^{-1}.

***In vitro* dry matter digestibility** (%): It was significantly reduced under the influence of the herbicide residues. Amongst various treatments, the lowest digestibility (41.65) was obtained with the influence of the residues of 4 g metsulfuron (Table 37). Whereas, the highest digestibility (52.2%) was obtained under the residual effect of 5 g of chlorsulfuron in various herbicidal treatments closely followed by its higher doses (10 and 20 g ha^{-1}) (Fig. 16). However, *in vitro* dry matter digestibility in the range of 46-48 per cent was obtained in metsulfuron (1-2 g), chlorsulfuron (40 g ha^{-1}) and metribuzin (25 g to 200 g ha^{-1}) treated pots.

HCN content (ppm): HCN content in sorghum plants at 40 DAS was significantly affected due to herbicide residues. Significant decrease in HCN content was observed with increasing levels of all the herbicides except with 5 g of chlorsulfuron. The minimum HCN content was recorded in metribuzin treated pots as compared to other treatments (Fig. 16). The highest HCN content (89 ppm) was observed in untreated plants of sorghum which, however, found statistically similar with the lowest dose of chlorsulfuron (5 g ha^{-1}) (Table 37).

CHAPTER - 5

DISCUSSION

Continuous use of a same herbicide for 10-15 years in monoculture is generally known to result weed shift and development of resistance in weeds against that particular herbicide. The first case of herbicide resistance was reported in *Phalaris minor* against isoproturon in recent past in Haryana particularly in areas where rice-wheat cropping system was continuously followed for 10-15 years (Malik and Singh, 1993). As a result of it, efficacy of isoproturon has come down and crop failure is now being reported.

Under this situation it was imperative to look for new alternative herbicides having different mechanism of action which is effective in controlling both grassy and broad leaved weeds and also selective to wheat and subsequent crops grown in rotation. This investigation was carried out (for two years 1996-97 and 1997-98) to evaluate the efficacy of chlorsulfuron and metsulfuron-methyl (or metsulfuron) new chemicals of sulfonylurea group of herbicides alone and as tank mixture with metribuzin and isoproturon for controlling complex weed flora and their residual effect on growth and quality of succeeding crop of sorghum grown in rotation.

5.1 EXPERIMENT-1: Effect of sulfonylurea herbicides applied alone and in combination with metribuzin on weed control in wheat and their residual effect on growth and quality of sorghum succeeding crop (Field experiment)

5.1.1 STUDIES ON WEEDS

Behaviour of weeds as influenced by the treatments was studied in term of weed population (No.m^{-2}) and dry matter accumulation ($g\ m^{-2}$))at different stages of crop growth. The dominant weed flora in the wheat experiment comprised of *Phalaris minor, Coronopus didymus, Chenopodium album, Melilotus indica* and *Anagallis arvensis* in both the years. Infestation of *Cirsium arvense* was observed only during second year of experimentation. Infestation of all weeds was comparatively higher in second year. This might be due to higher and uniform distribution of rainfall in 1997-98 which could have favoured weeds growth. Besides this, delay in sowing of wheat in 1996-97 by 20 days might have resulted in poor weed growth (Table 7). Significant reduction in weed population and dry matter accumulation due to delay in sowing of wheat has also been reported by Singh *et al.* (1997). Population of all weeds was significantly reduced due to herbicidal treatments as compared to weedy check at all stages of observation in both the years (Fig. 4 and 5). However the variation in weed count and dry matter accumulation amongst the herbicidal treatments was statistically significant. But the reduction in the population of *Cirsium arvense* was not affected equally by all herbicidal treatments. Metsulfuron (4 and 8 g ha^{-1}), chlorsulfuron (30 g ha^{-1}), metribuzin (200 and 400 g ha^{-1}) and their tank mixture were very effective in controlling *C. arvense* than rest of the treatments. This was due to the fact that these are broad-leaved weed killers. Similar findings were also reported by Pandey and Singh (1994) at New Delhi and by Walia *et al.* (1997) at Ludhiana.

Amongst herbicide treatments metsulfuron (8 g ha^{-1}), chlorsulfuron (30 g ha^{-1}), metribuzin (200 and 400 g ha^{-1}) alone and combined application of metsulfuron (metsulfuron-methyl) (2g ha^{-1}) and chlorsulfuron (15 g ha^{-1}) with metribuzin (100 and 200 g ha^{-1}) separately proved the best combinations for the control of mixed weed flora including *Phalaris minor* at 60 DAS onward in both the years (Table 14). Almost similar decreasing trend was also observed in accumulating weed dry matter (Table 15 and Fig. 6) in the respective treatments in both the years. Similar results were also reported by Singh *et al.* (1999) and Bazoobandi (2001) at different locations. This may be due the fact that metribuzin itself is well known to affect the growth of *P. minor* and broad-leaved weeds in wheat.

Chlorsulfuron (30g ha^{-1}) and metsulfuron (8 g ha^{-1}) which are known as broad-leaved weed killers were also found very effective against *P. minor* (Table 11) and were comparable to weed free and metribuzin applied alone and in combination with metsulfuron (2g ha^{-1}) and chlorsulfuron (15g ha^{-1}). This might be due to the fact that chlorsulfuron and metsulfuron are quite effective at higher doses against annual broad-leaved weeds and annual grassy weeds in wheat as reported by Vicari *et al.* (1994). Similar findings were also reported by Singh *et al.* (1997) at Jabalpur and Singh and Malik (1992) at Hisar. Bradford *et al.* (1989) and Mitra and Ghosh (1992) also reported the effectiveness of metsulfuron-methyl (Algrip 20 WP) against grassy weeds in rice crop. The lower dose. i. e. metsulfuron (4g ha^{-1}) and chlorsulfuron 15g ha^{-1} were effective against broad-leaved weeds but were not effective enough to cause a reasonable level of control of *Phalaris minor* in this present investigation (Table 11). Isoproturon at 1000 g ha^{-1} was not effective against *Coronopus didymus, Melilotus indica, Anagallis arvensis and Cirsium arvense* (in 1997-98) in both the years. The acceptable control of broad-leaved weeds except *C. album* with isoproturon was also not obtained by Panwar *et al.* (1996). This might be an account of reduced efficiency of isoproturon on the population of broad -leaved weeds. Application of tank mixture of metsulfuron (2g ha^{-1}) and isoproturon (500 g ha^{-1}) could not control broad-leaved weeds and also *Phalaris minor* because of their lower doses. Similar reports were also given by Panwar *et al.* (1996) at H.A.U. Hisar. The tank mixture of chlorsulfuron (15 g ha^{-1}) and isoproturon (500g ha^{-1}) provided selective control of broad-leaved weeds except *C. arvense* but it failed to provide desirable reduction in the density and dry weight of *P. minor* during both the years of experiments. Similar observations were also recorded by Dixit and Bhan (1997) at Jabalpur. Observation of weed population (No.m^{-2}) species-wise and their total dry weight at 90-120 DAS (third sampling) showed increase in the population of *Phalaris minor, Coronopus didymus* and *C. album* in first year due to new flushes of these weeds. It may be due to low residual effect and persistence of all herbicides in soil in 1996-97. However new flushes could not compete with well established wheat crop.

5.1.2 STUDIES ON CROP

5.1.2.1 Crop growth

The overall growth of wheat plants measured in terms of plant height (cm), dry matter accumulation (g m^{-1}) and number of tillers per running metre row length was comparatively less during the first year of experimentation. This was due to late sowing of wheat and prolonged cloudy weather at the time of sowing in 1996-97. Similar finding with late sowing of wheat was also reported by Singh *et al.* (1997). Observation at 60 DAS showed that application of metribuzin at 200 g ha^{-1} and 400 g ha^{-1} alone and in combination with metsulfuron (2 g ha^{-1}) resulted in stunting of wheat plant growth compared to other herbicidal treatments (Plate 1). Higher the dose of metribuzin application, shorter was the wheat plant height and it did not recover till harvest. Hence significant difference was observed amongst treatments at 60 DAS onward for each growth parameters in both years except for plant height at 60 DAS in first year.

This may be due to mechanism of action of metribuzin which interferes in cell division, elongation, coleoptile growth and development in early stages of growth. Besides above, metribuzin injury to wheat plant might be due to rainfall in both the years (received in the 2nd week after its application; Table 1) which leached the herbicides in to the root zone of wheat and contributed to crop injury (Wicks *et al.*, 1987)

Phytotoxicity of metribuzin remained visible upto 70 to 90 DAS on wheat plants, which however recovered slightly but its residual effect on wheat plants remained till harvest during both the years, as reflected by significant reduction in number of tillers, dry matter accumulation and yield attributing characters as compared to other herbicidal treatments (Tables 18, 19 and 20) in both years despite complete weed control (Plate 1 and Fig. 7). Similar findings were also accorded by Shaw and Wesley (1992) where wheat injury with 0.28 kg metribuzin was found sufficient to reduce wheat yield despite good weed control of both grassy and broad-leaved weeds. Phytotoxicity due to post emergence application of metribuzin at 210g ha^{-1} on wheat plant was also reported by Singh *et al* (1999). Higher crop injury and lower number of tillers per metre row length due to metribuzin application (400 g ha^{-1}) were also reported by Balyan *et al.*(1997).

Combined application of chlorsulfuron + metribuzin (15+100 and 15+200 g ha^{-1}) did not show any phytotoxicity (Plate 2) on wheat plant however it was highly effective on *Phalaris minor* and other broad leaved weeds and found statistically similar to other metribuzin treated plots particularly for weed control (Table 11). This might be due to the antagonistic effect of chlorsulfuron on metribuzin toxicity to wheat plant but not to present weed flora Chlorsulfuron (15 g ha^{-1}) applied with metribuzin reduced wheat injury caused by metribuzin. This effect may result from chlorsulfuron induced reduction of metribuzin uptake by wheat plant or chlorsulfuron may stimulate the rate of metribuzin metabolism in wheat. Similar results have also been documented by Colby (1967) and Anderson (1986) who reported the occurrence of antagonism between metribuzin and chlorsulfuron and found reduced metribuzin toxicity in wheat plant compared to metribuzin applied alone.

Gillespie and Nalewaja (1989) also reported the antagonistic effect of chlorsulfuron to triallate toxicity to wheat. Similarily application of chlorsulfuron to triallate did not reduce triallate toxicity to wild oat and other broad-leaved weeds in their studies as we observed no reduction in metribuzin toxicity to *Phalaris minor* and broad leaved weeds due to antagonism of chlorsulfuron. As a result of antagonism, the tank mixture of chlorsulfuron +metribuzin (15+100 and 15+200g ha^{-1}) became selective to wheat crop and effective against *Phalaris minor* and broad-leaved weeds thereby resulting in significant increase in all growth parameters viz., plant height, dry matter production, number of tiller and effective tiller as compared to season long weedy check.

Maximum and the minimum increase in plant height was found in season long weed free situation (89.84 and 97.15 cm) and in metribuzin treated plot (84.31 and 90.00 cm) except chlorsulfuron + metribuzin (15+100 and 15+200 g ha^{-1}) in both the years, respectively. No herbicidal treatment could bring significant increase in plant height as compared to season long weed infestation (Table 7). Metribuzin toxicity on wheat plants seemed more during second year as reflected by higher decrease in plant height over weedy check.

Higher dry matter production was recorded in the plots under weed free treatment (240.73 g m^{-1} in 1997-98) however, it was statistically at par with the application of metsulfuron 8 g ha^{-1} (234.33 g), isoproturon 1000g ha^{-1}(234.81g), chlorsulfuron 30 g ha^{-1} (235.55g), and chlorsulfuron + metribuzin (15+100 and 15+200 g ha^{-1}) (235.38 g) (Fig. 7). This was because of better control of *Phalaris. minor* and broad-leaved weeds offering minimum weed-crop competition than other herbicidal treatments (Fig. 4, 5). Dry matter production in 400 g metribuzin treated plots increased gradually as compared to weedy check at later stages in both the years. However the increase in dry matter production in 400g metribuzin treated plots was found significant during 1996-97. This might be due to reduced phytotoxicity of metribuzin at 400g ha^{-1} with the advancement of crop age during later stages of crop growth. No significant gain in dry matter production in 400g metribuzin treated plots in 1997-98 despite complete weed control might be due to prolonged metribuzin (400 g ha^{-1}) phytotoxicity in second year of the investigation.

Growth of wheat plant in term of total number of tillers and effective tillers was relatively better in the second year of experimentation. This might be due to timely sowing of wheat crop which could have given enough time for development of wheat plant. Number of tillers and effective tillers, the major yield component were found to vary significantly owing to weed control treatment in both the years. Significantly higher number of tillers and effective tillers (Table 19, 20) per metre row length were recorded in the plots under weed free treatment in both the years. This was because of better crop growth owing to reduced weed-crop competition for nutrients, light, space and moisture in season long weed free plots. Number of tillers and effective tillers had been significantly more in plots treated with chlorsulfuron 30 g ha^{-1}, metsulfuron 8 g ha^{-1}, isoproturon 1000 g ha^{-1} alone and the tank mixture of chlorsulfuron + metribuzin (15+100 and 15+200 gha^{-1}) amongst herbicide treatments during both the years. This might be due to better control of both grassy and broad-leaved weeds and therefore less weed-crop competition compared to their lower doses alone and in combination with different herbicides. These results are in close conformity with the results reported by Singh *et al.* (1997) at Jabalpur. Metribuzin at 400 g ha^{-1} recorded significantly lower number of tiller (73.00 and 83.00) and effective tiller (73.00 and 77.67) among herbicidal treatments in both the years (Table 19, 20). This might be due to metribuzin phytotoxicity observed in all metribuzin treated plots except chlorsulfuron + metribuzin in both the seasons (Plate 1 and 2).

The phytotoxicity that reduced dry matter accumulation by wheat also resulted in lower number of tillers and effective tillers despite negligible weed-crop competition in both the years. Similar findings were also reported by Balyan (1999) where 10-15% reduction in tillering was observed with metribuzin at 400 g ha^{-1}. Reduction in wheat crop density due to metribuzin phytotoxicity was also reported by Singh *et al* (1999).

5.1.2.2 Yield attributes and yield

Effect of weed control treatments on number of effective tillers (No.m^{-1}), major yield contributing character have already been discussed under the effect on growth.

Length of earhead and number of grains per earhead are dominant genetic feature or trait of plant described by breeder. But being the resultant of crop growth, they were significantly higher in weed free plots (9.0-9.7cm and 45.16-48.00) due to no weed competition. Significant improvement in all yield attributes including test weight (except in 1996-97) (Table 20) was obtained with the application of all herbicides probably because of lower weed population and dry weight. Relatively higher increase in yield attributes was recorded in chlorsulfuron 30g ha^{-1}, chlorsulfuron + metribuzin (15+100 and 15+200g ha^{-1}), metsulfuron 8g ha^{-1} and metribuzin 400g ha^{-1} treated plots amongst herbicidal treatments in both the years. This could be attributed to their significant effect on both *P. minor* and broad-leaved weeds in comparision to the other herbicides. The results are in accordance with the findings of Singh *et al.* (1997) and Walia *et al.* (1997). Application of metribuzin at 400g ha^{-1} did not effect earhead length, number of grains per earhead and test weight inspite of high phytotoxcity at early stages in both the years. This probably might be due the reduced phytotoxicity of metribuzin with the advancement of the crop age and maximum availability of moisture, nutrients, light and space due to less competition within the established crop plant per running metre row length as reflected by reduced tillering and high mortality by 400 g of metribuzin than other herbicide treated plots. The lowest values of all the yield attributing character were obtained under season long weedy condition. This was due to the fact that wheat plants in weedy check were under competitive stress for all resources and thereby produce smallest earhead (7.9 cm), fewer grains per earhead (38.43) and lower test weight (36.67 g). Similar observation were also recorded by Dixit and Bhan (1997) and Singh and Bajpai (1992).

Grain yield is the resultant of above mentioned attributes. Therefore, maximum expression of yield attributes viz. Effective tillers, earhead length, grains number per earhead and test weight due to reduced crop-weed competition in weed free plot resulted the highest increase in grain yield by 30.98 per cent and 33.12 per cent in 1996-97 and 1997-98 respectively over season long weed infestation (Table 21 and Fig. 8) In general grain yield was comparatively lower in 1996-97 than 1997-98. This was due to late sowing of wheat wherein the period required for ear and grain development was not sufficient and the increased temperature during the month of April coincided with the grain development leading to forced maturity of the crop. Similar findings have also been reported by Singh *et al.* (1997). Besides the above fact, higher and frequent rainfall received during March and April might have also effected the development and maturity of grain during first year of experimentation (Fig. 1).

All herbicide treatments significantly increased the grain and straw yield (Table 21) over weedy check during both the season. However the application of chlorsulfuron 30 g ha^{-1}, metsulfuron 8 g ha^{-1}, and chorsulfuron + metribuzin (15+100 and 15+200 g ha^{-1}) were comparable to weed free plot in term of higher grain and straw yield in both the years (Fig. 8). The better performance of these treatments in term of grain yield could be attributed to better expression of their yield attributes due to reduction in crop - weed competition. This could be attributed to their selectivity to crop and significant effects on *Phalaris minor* and broad-leaved weeds. Balyan and Malik (2000) recorded more or less similar yields to weed free yields with the application of chlorsulfuron 25 and 30 g ha^{-1} and metsulfuron 4 and 6 g ha^{-1}.

Kurchania *et al.* (2000) also reported the poor efficacy of metsulfuron 4 g ha^{-1} against *P. minor.* The minimum increase of 13.97 per cent and 6.3 per cent grain yield was recorded in 400 g metribuzin treated plot amongst herbicidal treatments despite complete weed control in 1996-97 and 1997-98, respectively. This was mainly due to metribuzin phytotoxicity to wheat (Plate 1) which expressed in term of minimum increase in crop dry matter accumulation and in number of effective tillers during both the years of experimentation. However, the magnitude of yield reduction due to metribuzin toxicity was comparatively higher in second year. This was due to lower mean temperature (during 1997-98) following its application which might have restricted its degradation (breakdown) resulting in its longer persistence in the top soil and immediate phytotoxicity (Fig. 2). Lower degradation rates in the cooler condition of the winter months following post-emergence application of herbicides are reported by Anderson and Humburg (1987). Rapid detoxification of herbicides under the effect of high mean temperature was also reported by Yadav *et al* (1995) at Hisar. Lower grain yield in metribuzin 200gha^{-1} and tank mix application of metsulfuron + metribuzin (2+100 g and 2+200 g ha^{-1}) despite having high efficacy against all weeds was due to phytotoxic effect of metribuzin as reflected by the lower increase in crop dry matter accumulation and number of effective tillers per metre row length. Dry matter accumulation in straw followed almost similar trend to those obtained in grain yield under different weed control treatments in both the years and therefore followed the same result and the same justification may hold true.

The highest -harvest index and the lowest H I were recorded in weed free and weedy check plot in both the years. However the proportion of grain and straw production was almost similar in all treatments irrespective of doses, herbicides and tank mixture in both the years of experimentation.

5.1.2.3 Nutrient uptake by crop

All the weed control measures except metribuzin 400 gha^{-1} and metsulfron + isoproturon (2+500 g ha^{-1}) significantly increased the uptake of NPK by crop than weedy check (Table 22-24). However the per cent contents of these nutrients in the wheat plant were not significantly influenced by different weed control treatments in both the years. Maximum nutrient uptake by crop was registered in weed free plot showing 38.32, 39.25 and 32.36 per cent increase in N, P. and K uptake over unweeded plot.

Application of chlorsulfuron 30 g ha^{-1}, chlorsulfuron + metribuzin (15+100 and 15+200 g ha^{-1}), metsulfuron 8 g ha^{-1} and isoproturon 1000 g ha^{-1} were comparable to weed free condition and resulted in higher uptake of nutrients by crop than rest of the herbicide treatments (Fig. 9). This was due to the fact that weed control treatments controlled the weeds effectively and consequently made more nutrients available to wheat and enhanced nutrient concentration and the yield and thereby higher uptake of nutrients. Similar findings have been reported by Singh and Malik (1992). Higher NPK uptake by crop in hand weeded or herbicide treated plot also reported by Pandey *et al.* (2000). This was due to reduced depletion of nutrients by weeds and concomitant increase in the absorption and translocation of higher concentration of these nutrients to different wheat plant parts for enhanced photosynthetic efficiency. Metribuzin at 400 g ha^{-1} also resulted in lower increase in P uptake by crop due to its phytotoxic effect which resulted in less plant biomass (Fig. 9).

5.1.2.4 Residual effect of herbicides on *kharif* season weeds

Growth of *Trianthema portulacastrum* and *E. colonum* in term of their population and dry weight was significantly reduced due to the herbicide treatments given in wheat crop (Table 25). No single plant of *Trianthema portulacastrum* was found in entire 30 g chlorsulfuron treated plot (Plate 3). The lowest population (40 m^{-2}) and dry weight (25.04 g m^{-2}) of *E. colonum* was also recorded in the same plot. This might be due to the residual activity of the applied herbicides which increased with increasing rate of application. Chlorsulfuron residues were detected by Vicari *et al.* (1994) even after 15 months of its application at 30 g a i ha^{-1}. However, no residues was detected by the maize bioassay at 15 g a. i.ha^{-1} and 8 g a i. ha^{-1}, of chlorsulfron and metsulfuron, respectively. The treatments involving combination recorded the higher reduction in population and dry weight of both the weeds than their application alone (Table 25). This might be due to synergistic response of herbicide interaction in combined application. All the experimental plots were uniformly infested with the population of *Cyperus rotundus* irrespective of dose, herbicide and combination which reflected that *C. rotundus* was not at all affected by the herbicide residues (Plate 3).

5.1.2.5 Residual effect of herbicides on sorghum crop (Field bioassay)

(a) Growth studies

Sorghom plant population (No. m^{-1}) was not affected due to herbicide treatments applied in the wheat crop in both the years of experimentation. (Plate 4). This might be due to the fact that chlorsulfuron and metsulfuron being anionic, weakly adsorbed to soil and leached through the soil in to deeper layer due to high rainfall received before and after the sowing of sorghum crop (during July - August). As a result sorghum plant population remained unaffected in both the seasons. Similar findings were also reported by Peterson and Arnold (1985). Plant population of sorghum was comparatively higher in the 1996-97 than 1997-98. This was due to better rainfall received during July and August, 1996-97 (Fig. 1).

Height of sorghum plant (cm) was significantly affected by herbicides residues at 40 and 80 DAS in the 1997-98 (Fig. 10). Height of sorghum plant grown in plots treated with 30 g of chlorsulfuron was significantly lower than the rest of the plots (Plate 4). However, the difference in the value of plant height amongst treated and nontreated plot was found non-significant. At later stages of crop growth (40 and 80 DAS), roots of sorghum plant might have come in contact of herbicide residues accumulated in deeper soil layer and thereby resulting in stunted growth (Plate 4). Effect of residues of chlorsulfuron or other herbicides even at their highest dose was not evident on the growth of sorghum crop in 1996-97. In general the persistence, behaviour and the residual phytotoxicity to sensitive rotational crops of the most soil applied herbicides in the soil is greatly determined or controlled by temperature, soil pH and soil moisture (Palm *et al.*, 1980). Because degradation rate of herbicides is more under higher mean temperature and thereby resulting in lower persistence. In 1996-97, the mean temperature in 2-3 weeks following herbicide treatment was comparatively higher than 1997-98 which might have resulted in rapid dissipation of the chemicals in initial period during 1996-97 than in 1997-98. Similar findings were also reported by Eleftherohorinos and Syka (1989) and Yadav *et al.* (1997).

Chlorsulfuron and metsulfuron are the new members of the sulfonylurea group of herbicides and closely related chemically but their persistence behaviour may be slightly different under the same environmental conditions (Vicari *et al.*, 1994). In the present metsulfuron 8 g ha^{-1} did not affect the plant height and other growth parameters of sorghum grown after wheat harvest. This might be due its lower level of residual soil bioactivity compared to chlorsulfuron (30 g ha^{-1}). Similarly, Vicari *et al.* (1994) also detected no residues of metsulfuron 8 g ha^{-1} and chlorsulfuron 15 g ha^{-1} in maize bioassay. Metsulfuron may be confined to surface layer which being microbiologically active, may help in its faster degradation than the chlorsulfuron moved in to deeper layer up to (30-50 cm). Residues of these herbicides once moved in deeper layer are known to unavailable to micro organism but available for uptake by rotational crops in deeper layer of soils (Walker *et al.*, 1989).

Fresh and dry weight of sorghum plant per metre row length (g m^{-1}) were significantly lower at 40 and 80 DAS in those plots where 30 g and

400 g of chlorsulfuron and metribuzin were applied respectively in the wheat in 1997-98 (Fig.11). While in 1996-97, no significant difference recorded in their values compared to untreated. The similar justification as described in respect of plant height holds true for this reduction also. This was relatively due to higher residual bioactivity of chlorsulfuron (30 g ha^{-1}) and metribuzin (400 g ha^{-1}) at higher rate than first year of the experimentation. Reduction in fresh weight of maize, sunflower, sugarbeet and onion due to the residual activity of chlorsulfuron and metsulfuron was reported by Brewster and Appleby (1983), Eleftherohorinos and Syka (1989) and Yadav *et al.* (1995).

The reduction in the fodder yield was not significant in both the years in any of the herbicide treatments given to wheat crop. However the lowest yield of fodder was noted under the influence of 30 g of chlorsulfuron (Table 29).

(b) Quality (Fodder)

Residues of the herbicides affecting the growth of sensitive rotational crops would certainly influence their quality directly or indirectly. Because the quality produce of any field crop is totally the resultant of its growth maintained in the entire season. Residues of chlorsulfuron (30 g ha^{-1}) and metribuzin (400 g ha^{-1}) affected the growth of sorghum in term of plant height, fresh and dry weight. Therefore their effects on the major component of fodder quality viz, protein content, tannin content and *in vitro* dry matter digestibility were expected in second year of experimentation.

Protein content was not significantly influenced due to the residues of applied herbicides (Table 30). However, the lowest value of protein content was noted in untreated plots. But increase in tannin content was significantly more in herbicide treated plots as compared to untreated plots (Fig. 12). The highest value of tannin content was recorded in those plots where tank mix of chlorsulfuron + isoproturon (15+500 g ha^{-1}) was applied. Chhlorsulfuron (30 g ha^{-1}) and metribuzin (400 g ha^{-1}) also recorded significant increase in tannin content of their sorghum plants (Fig. 12). The plots treated with combination registered higher accumulation of tannin content than those treated with individual herbicide. This might be due to their additve response which enhanced the accumulation of tannin content than their individual application.

Digestibility of the sorghum dry matter was significantly reduced due to the residual bioactivity of all herbicides applied in wheat. This was due to the fact that dry matter digestibility is inversely related with tannin content of that particular dry matter. Tannin form non-foaming complexes with proteins and there by decrease the palatability of forages due to astringency (Jones *et al.*, 1970) As the tannin content of the dry matter increased, the digestibility of that particular dry matter decreased automatically (Fig. 12). Arora and Luthra (1974) observed that with each unit increase of tannin, the digestibiluity is reduced by 6.36 per cent. The dry matter of the highest and the lowest digestibility was obtained in untreated (weed free and weedy check maintained in wheat crop) and chlorsulfuron + isoproturon (15 + 500 g ha^{-1}) treated plot, respectively (Fig. 12).

5.2 EXPERIMENT-II : Bio-efficacy and selectivity of sulfonylurea herbicides against important weeds in wheat and their residual effect on mungbean and sorghum succeeding crops (Pot culture study)

5.2.1 *Triticum aestivum*

Metribuzin was found phytotoxic to wheat plant (Plate 5-A) at all the doses applied and caused 86 to 100 per cent mortality (Fig. 13) with in a period of a week of its application. Fresh and dry weight were significantly reduced to the extent of 92.28 and 88.14 per cent, respectively in 200 g metribuzin treated pot (Plate 5). Phytotoxicity of metribuzin to wheat plant have already been reported by several researchers at different location in India and abroad (Balyan *et al.*, 1997 ; Balyan, 1999 and Singh *et al.*, 1999)). Chlorsulfuron and metsulfuron did not affect growth of wheat plant irrespective of the doses.

5.2.2 *Avena ludoviciana* Dur.

Ninety-eight to hundred per cent mortality of wild oat (Fig. 13) was recorded with the application of metribuzin at 25 to 200 g ha^{-1} and thereby resulting in the lowest fresh (0.250 g) and dry weight (0.226 g) (Plate 5-B). Similar findings were also documented by Balyan (1999) where 75 to 98 per cent mortality of *Avena ludoviciana* was obtained with the application of metribuzin at 200 g ha^{-1}. Chlorsulfuron at 40 g ha^{-1} also brought significant reduction in all growth parameters of wild oat. However, 3.33 per cent mortality of the wild oat was recorded with the chlorsulfuron application.

5.2.3 *Phalaris minor* Retz.

Growth of *P. minor* was drastically reduced with the application of all the herbicides (Fig. 13). However, 100 per cent mortality of *Phalaris minor* was obtained with 50 to 200 g of metribuzin and 40 of chlorsulfuron application which were closely followed by 20 g of chlorsulfuron (96.66%) and 25 g of metribuzin (96.66%) resulting equal mortality (96.66%) (Plate 5-A and 6). The higher efficacy of metribuzin on *P. minor* was also reported Balyan (1999) and Singh *et al.* (1999) in field from 140 to 420 g ha^{-1}. Application of chlorsulfuron at 10 g ha^{-1} caused 86.66 per cent mortality of *P.minor* which was 43 per cent higher than that obtained by the higher dose of metsulfuron (4 g ha^{-1}). The highest reduction in fresh (0.038 g) and dry weight (0.027g) of *P.minor* was noted in metribuzin treated pots which was followed by 40 g of chlorsulfuron. Singh *et al.* (1997) also reported that 20g of chlorsulfuron controlled *P.minor* by 87.5 per cent at Jabalppur. Metsulfuron also at 1 and 2g brought significant reduction in height (4.42-6.75 cm), number of leaves (0.80-1.0), fresh (0.084-0.180 g) and dry weight (0.035-0.134 g) of *P.minor* compared to untreated plant (Plate 6). However its performance in controlling *P. minor* was inferior to metribuzin and chlorsulfuron. Kurchania *et al.* (2000) also reported the poor efficacy of metsulfuron at 4 g ha^{-1} against *P. minor* at Jabalpur in field condition.

5.2.4 *Melilotus indica* L.

All the herbicide treatments caused significantly higher mortality of *M.indica* as compared to untreated pots (Fig. 13 and Plate 7). However 100 per cent mortality of this weed was recorded at all the doses of metribuzin 4 g of metsulfuron and at 20 and 40g of chlorsulfurin. Blackshaw (1994), Panwar *et al.* (1996)and Walia *et al.* (1997), reported the higher efficacy of metsulfuron (4 g ha^{-1})and chlorsulfuron (15 g ha^{-1}) against *M.indica*.

5.2.5 *Coronopus didymus, Chenopodium album* and *Anagallis arvensis*

All the herbicide treatments except the lowest dose of chlorsulfuron (5 g ha^{-1}) and metsulfuron (1g ha^{-1}) caused 100 per cent mortality of all three broad leaved weeds (Fig. 14). Similar trend in reduction in their fresh and dry weight was observed under the influence of all three herbicides (Table 35). However, the magnitude of reduction in fresh and dry weight of these three weeds was comparatively higher in metribuzin applied pots. Similar findings were also reported by Panwar *et al.* (1996).

5.2.6 Residual effect on mungbean grown in herbicide treated pots

Per cent germination of munbean seeded six month after herbicide application was significantly reduced due to the residual phytotoxicity of all three herbicides (Table 36; Fig. 15). Highest (63.34) and the lowest (16.67%) reduction in per cent genmination was recerded in chlorsulfuron (40 and 20 g ha^{-1}) and metsulfuron (2 and 1 gha^{-1}) respectively (Plate 8). Germination percentage was decreased with corresponding increase in the doses of the herbicide. The residues of metribuzin at 200 g ha^{-1} brought about 53.34 per cent reduction in germination of mungbean. Growth of mungbean plant in term of height (cm plant^{-1}), number of green leaves (No.plant^{-1}), leaf area (cm^2 plant^{-1}), fresh and dry weight (g plant^{-1}) was significantly less under the influence of the residues in all three herbicides (Table 36). This was due to the inhibition of Acetolactate synthase activity which decreased production of branched chain aminoacids and leaf extension in sensitive crops (Ray, 1989). Reduction in fresh and dry weight of mungbean seedling due to residues of tribenuron methy was also reported by Punia *et al.* (1996) at Hisar. However, the magnitude of reduction in the growth parameters of mungbean plant was significantly higher due to the residues of 40g of chlorsulfuron followed by the residues of 200 g ha^{-1} metribuzin and 4 g ha^{-1} of metsulfuron.

5.2.7 Residual effect on sorghum

Germination of sorghum was singificantly lower due to the residual bioactivity of sulfonylurea herbicides particularly at their highest dose applied (Table 37; Fig. 15). The extent of reduction in per cent germination was higher in chlorsulfuron 40 g (26.67%) than in metsulfuron 4 g g ha^{-1} (13.34%) (Fig. 15). But increase in height, fresh and dry weight was significantly affected due to the residual phytotoxicity of all three herbicides (Plate 9-A). Reduction in all growth parameters was increased with corresponding increase in the rate of the herbicide applied. However the poorest growth of sorghum plant in term of height, fresh and dry weight was observed in 40 g chlorsulfuron treated pots (Plate 9). Reduction in fresh and dry weight of snap bean and corn due to residues of chlorsulfuron (35g ha^{-1}) was also recorded by Brewster and Appleby (1983) and Peterson and Arnold (1985).

Protein content in sorghum plants was significantly less in herbicide treated pots which further decreased with increase in the rate of the herbicide application, whereas a opposite trend in tannin content was observed which was significantly more in the herbicide treated pots (Fig. 16). Dry matter digestibility was significantly lower in herbicide treated pots and decreased with corresponding increase in the rate of herbicide application. Reasons for this has already been explained earlier in field experiment with regard to qualities. Accumulation of tannin content was significantly higher in metsulfuron treated pots than rest of the herbicides (Fig. 16).

HCN content known for deciding the suitability of a fodder to feed animals at early stages of growth, was also affected by the herbicide treatments. HCN content was significantly lower in all the herbicide treated pots except 5g of chlorsulfuron (Fig. 16). The role of these herbicides in reducing HCN content in sorghum plants is still to be confirmed as HCN content is also known to be influenced by abiotic factors such as temperature, water stress , irrigation, low light intensity, plant age, nitrogen and phosphorus fertilization in the field at the time of its estimation (Pederson *et al.*,1996 and Stochmal and Oleszek, 1997).

CHAPTER - 6

SUMMARY AND CONCLUSION

The investigation "Evaluation of sulfonylurea herbicides for weed control in wheat (*Triticum aestivum*)" was undertaken during the *rabi* season of 1996-97 and 1997-98 at Agronomy Farm of Chaudhary Charan Singh. Haryana Agricultural University, Hisar. The salient findings of the investigation are depicted hereunder:

EXPERIMENT-I: Effect of sulfonylurea herbicides applied alone and in combination with metribuzin on weed control in wheat and their residual effect on growth and quality of sorghum succeeding crop (Field experiment)

1. Application of chlorsulfuron at 15 g ha^{-1} and metsulfuron at 4 g ha^{-1} controlled all the broad-leaved weeds effectively but not *Phalaris minor.*

2. Application of metsulfuron - methyl at 4 g or 8 g ha^{-1} found very effective in controlling *Cirsium arvense* than rest of the treatments.

3. Application of the higher dose of sulfonylurea herbicides (chlorsulfuron 30 g and metsulfuron-methyl at 8 g ha^{-1}) resulted significant reduction in the density and dry weight of both broad-leaved and grassy weeds (*P. minor*) in both the years.

4. Application of metribuzin at 200 and 400 g ha^{-1} resulted complete control of composite weed flora comprising *Phalaris minor, Cirsium arvense, Coronopus didymus, Chenopodium album, Melilotus indica, Anagallis arvensis* except *Convolvulus arvensis.*

5. Tank mixture of sulfonylurea herbicides with metribuzin recorded broad spectrum control of weeds except *Convolvulus arvensis.*

6. Isoproturon at 1000 g ha^{-1} provided satisfactory control of *P. minor* but not of broad-leaved weeds.

7. The highest value of wheat dry matter production, number of tillers, effective tillers, earhead length, number of grains per earhead, 1000 -grain weight, grain and straw yield was recorded in season long weed free environment.

8. Season long weed free environment and application of chlorsulfuron 30 g ha^{-1} , metsulfuron-methyl 8 g ha^{-1} and tank mixture of chlorsulfuron + metribuzin (15+100 and 15+200 g ha^{-1}) were equally effective in increasing all growth parameters of wheat crop.

9. Application of metribuzin (200 g and 400 g ha^{-1}) alone and in combination with metsulfuron-methyl (2 g ha^{-1}) was phytotoxic to wheat crop upto 80-90 DAS and resulted considerable reduction in wheat growth.

10. Uncontrolled weeds caused 30.97 and 33.12 per cent reduction in the grain yield of wheat during 1996-97 and 1997-98, respectively.

11. Weeds depleted 35.01 - 38.32, 36.49, 39.23 and 27.41-32.36 per cent N, P and K respectively, when allowed to grow with the crop uninterrupted.

12. Fodder yield (q ha^{-1}) and protein content (%) of sorghum were not significantly affected due to the residues of herbicides.

13. Tannin content (%) of sorghum plant on the contrary was significantly higher whereas *in vitro* dry matter digestibility (%) was significantly lower in the herbicide treated plots than untreated plots.

EXPERIMENT -II : Bio-efficacy and selectivity of sulfonylurea herbicides against important weeds in wheat and their residual effect on mungbean and sorghum succeeding crops (Pot culture study)

1. Metribuzin was phytotoxic to wheat plant at all the rates of application and caused 96 to 100 percent mortality within 5-6 days of its application.

2. Application of chlorsulfuron and metsulfuron did not influence the growth of wheat plant irrespective of their doses applied.

3. Ninety eight to hundred per cent mortality of wild oat was recorded with the application of metribuzin at 25 to 200 g ha^{-1}.

4. No mortality of wild oat was recorded with the application of sulfonylurea herbicides, but chlorsulfuron at 40 g ha^{-1} brought significant reduction in its growth.

5. Application of metribuzin at 50,100 and 200 g ha^{-1} and chlorsulfuron at 40 g ha^{-1} caused 100 per cent mortality of *P. minor* but metsulfuron caused 54 per cent mortality at 4 g ha^{-1}.

6. Application of metribuzin (25 to 200 g ha^{-1}), chlorsulfuron (40 and 20 g ha^{-1}) and metsulfuron (4 g ha^{-1}) caused 100 per cent mortality of *Melilotus indica, Coronopus didymus, Chenopodium album* and *Anagallis arvensis* as compared to untreated pots.

Pot bioassay study - Mungbean

7. Per cent germination of mungbean was significantly reduced due to the residual phytotoxicity of chlorsulfuron (40 and 20 g ha^{-1}), metsulfuron (2 and 1 g ha^{-1}) and metribuzin (200 g ha^{-1}).

8. Reduction in growth of mungbean in terms of height, leaf number (green), fresh and dry weight was increased with corresponding increase in the dose of the herbicide.

Pot bioassay study: Sorghum

9. Per cent germination of sorghum was significantly lower due to the residual bioactivity of sulfonylurea herbicides particularly at their highest dose applied.

10. Height, fresh and dry weight of sorghum plant were significantly affected due to the residual phytotoxicity of all three herbicides.

11. Protein content (%), HCN content (ppm) and *in vitro* dry matter digestibility (%) of sorghum plant were reduced whereas tannin content (%) increased significantly in all three herbicides.

Conclusion

Application of chlorsulfuron at 30 g ha^{-1}, metsulfuron-methyl 8 g ha^{-1} and tank mix of chlorsulfuron + metribuzin (15 + 100 and 15 + 200 g ha^{-1}) found very effective against mixed weed flora and were similar to weed free environment in producing grain yield in both years of the study. Application of chlorsulfuron (15 g ha^{-1}) and metsulfuron (4 g ha^{-1}) at lower dose was also effective against broad leaved weeds. Single and mixture application of metribuzin with metsulfuron (2 g ha^{-1}) was phytotoxic to wheat crop.

Growth of sorghum plants was affected due to the residues of 30 g of chlorsulfuron in 1997-98. Fodder yield of sorghum was not affected during both the years. Metribuzin resulted in complete control of complex weed flora including wild oat, vis-a-vis remained phytotoxic to wheat. Application of chlorsulfuron and metsulfuron was found very effective against all broad-leaved weeds. Chlorsulfuron at higher dose also caused 100 per cent mortality of *Phalaris minor* in pot culture study.

Germination and growth of mungbean and sorghum was significantly reduced due to the residual activity of all the herbicides in pot culture study which confirmed their sensitivity to residues applied herbicides. Protein content (%), dry matter digestibility (%) and HCN content (ppm) were significantly lower in herbicide treated pots, whereas tannin content (%) increased with increase in rate of herbicide application.

Future line of work

Efficacy of sulfonylurea herbicides against grassy weeds needs to be evaluated by further experimentation under largely infested field at other locations. Residual effect of chlorsulfuron at 30 g ha^{-1} on growth of sorghum plant at 40 and 80 DAS observed in second year needs further experimentation to quantify its residues levels and their effects on succeeding crops at different doses by G.L.C. technique under different temperature and rainfall conditions. Variation observed in protein content (%) tannin content (%), dry matter digestibility (%) and HCN content (ppm) of sorghum plant due to the effect of herbicide residues in field as well as in pot culture study are further required to be confirmed by further exprimentation on the residual effects of these herbicides on different succeeding crops especially corn and forage crops at different location in India.

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ABSTRACT

a)	Title of Dissertation	:	Evaluation of sulfonylurea herbicides for weed control in wheat (*Triticum aestivum*)
b)	Full name of degree holder	:	Rajvir Sharma
c)	Title of degree	:	Doctor of Philosophy
d)	Name and Address of Major Advisor	:	Dr. S.S. Pahuja Professor (Agronomy) Department of Agronomy CCS HAU, Hisar-125 004
e)	Degree awarding University/Institute	:	CCS Haryana Agricultural University Hisar-125 004 (Haryana), India
f)	Year of award of degree	:	2001
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i)	Number of words in the Abstract	:	Approx. 200

Field and pot experiments were conducted during 1996-97 and 1997-98 at the Agronomy Research Farm of Chaudhary Charan Singh Haryana Agricultural University, Hisar to evaluate the efficacy of sulfonylurea herbicides alone and in combination with other herbicides for controlling weeds in wheat and their residual effects on the sorghum crop in field as well as in pots. Season long crop-weed competition reduced the grain yield by 30.97 - 33.12 per cent as compared to weed free environment. All the weed control treatments resulted in significant increase in grain yield over weedy check owing to lesser crop-weed competition in both the years. Application of chlorsulfuron at 30 g ha^{-1}, metsulfuron 8 g ha^{-1} and combined application of chlorsulfuron and metribuzin at 15 + 100 g ha^{-1} and 15 + 200 g ha^{-1} resulted in complete control of composite weed flora, thereby yielded as good as weed free environment. Metribuzin alone at 200 and 400 g ha^{-1} and in combination with metsulfuron at 2 g ha^{-1} was phytotoxic to wheat plants in field as well as in pot experiment. Growth of sorghum grown after wheat was significantly affected due to the residues of chlorsulfuron 30 g ha^{-1} followed by metribuzin 400 g ha^{-1} in both the conditions. Tannin content (%) and *in vitro* dry matter digestibility of sorghum plants were found to be significantly affected in the herbicide treated plots in both field as well as in pot culture study.

Major Advisor

Signature of Degree Holder

Head of the Department